The epidemiology of frailty and its association with disability and quality of life among rural community-dwelling older adults in Kegalle district of Sri Lanka

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THESIS

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DECLARATION OF AUTHORSHIP

I, Dhammika Deepani Siriwardhana, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: ----------

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ABSTRACT

Background and aim: Frailty is an important age related medical condition that predicts numerous adverse health outcomes. Many low-and middle-income countries (LMICs) are ageing rapidly but we know little about the epidemiology of frailty in these countries. This thesis describes the epidemiology of frailty and its association with disability and quality of life among rural community-dwelling older adults in Kegalle district of Sri Lanka.

Methods: Part A) A systematic review and meta-analysis on prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs. Part B) A population-based cross-sectional study conducted in 2016 to i) estimate the prevalence of frailty, ii) describe factors associated with frailty, and iii) evaluate the association of frailty with disability and quality of life among rural community-dwelling older adults in Kegalle district. A three stage probability sampling was used to recruit 746 older adults aged ≥60 years. Frailty was assessed using the Fried phenotype.

Results: Part A) Limited evidence was found on the prevalence of frailty in low-income and lower middle-income countries. The random-effects pooled prevalence of frailty and pre-frailty in community-dwelling older adults in LMICs was 17.4% (95% CI: 14.4%, 20.7%) and 49.3% (95% CI: 46.4%, 52.2%) respectively. Part B) The prevalence of frailty and pre-frailty among rural community-dwelling older adults aged ≥60 years in Kegalle district of Sri Lanka was estimated as 15.2% (95% CI: 12.3%, 18.6%) and 48.5% (95% CI: 43.8%, 53.2%) respectively. The

prevalence of limitations in instrumental activities of daily living (≥1 IADL) assessed with Lawton IADL scale was high (84.4%) in frail older adults. The prevalence of basic activities of daily living (≥1 BADL) assessed with Barthel index was 38.7% in frail older adults. Being frail lowered the odds of having no IADL limitations and was associated with a four times higher count of IADL limitations compared with non-frail counterparts. Frailty was associated with a small but significant lower quality of life in this rural Sri Lankan population.

Conclusions: The prevalence of frailty appears higher in rural community-dwelling older adults in Sri Lanka compared with upper middle-income and high-income countries with a significant impact on IADL limitations but with lower than anticipated impact on BADL limitations and quality of life.

IMPACT STATEMENT

Frailty is a clinically recognisable state that may explain the heterogeneity of health status among older adults with the same chronological age. Frail older adults are at a higher risk of developing adverse health outcomes and are high users of health and social care services. Though the majority of the world's older population is currently living and continues to grow in low-and middle-income countries (LMICs), research is scarce on frailty in these settings. My PhD aimed to broaden the understanding of the scale of the problem (frailty) in LMICs with special emphasis on Sri Lanka.

I conducted the first comprehensive systematic review and meta-analysis synthesising research on prevalence of frailty in LMICs. I found limited evidence on frailty from LMICs. The burden of frailty appears higher in upper middle-income countries compared with high-income countries. I published this in BMJ Open in 2018 and it has 25 citations already. I have presented this work in two conferences: 48th Asia Pacific Academic Consortium for Public Health (APACPH) Conference, Tokyo, Japan (2016) and International Federation on Ageing (IFA) 14th Global Conference, Toronto, Canada (2018). I received young oral presentation award for this work at 48th APACPH conference.

I conducted the first population-based cross-sectional study (community survey) to estimate the prevalence of frailty and explore the sociodemographic, health-related, and lifestyle factors associated with frailty in a large representative sample of rural community-dwelling older adults in Kegalle district of Sri Lanka.

The prevalence of frailty was higher among rural Sri Lankan older adults compared with upper middle-income and high-income countries. Nearly half of the older adults aged ≥80 years were frail in my sample. By 2041, one out of every four will be an older adult in Sri Lanka. These findings highlight the anticipated higher burden of frailty associated with this rapid demographic shift in Sri Lanka. I have recently published my prevalence study in BMJ Open (2019) and presented these findings at 50th Asia Pacific Academic Consortium for Public Health Conference, Malaysia, 2018.

No previous studies have investigated the association between frailty and disability and frailty and quality of life in the South-East Asia region. My findings indicate a substantial impact of frailty on day-to-day activities required to live independently in the community: e.g. cooking, shopping, etc., however, the impact on personal self-care activities was small. Frailty was associated with small but significant reduction of quality of life among rural Sri Lankan older adults. The mostly affected domains were related to physical health. I published these findings in Quality of Life Research (2019) and presented at International Alliance of Research Universities (IARU) Ageing, Longevity and Health Conference, Duke-NUS medical School in Singapore (2018).

I performed additional methodological work to increase the robustness of my findings. There was no validated instrument in Sri Lanka to assess IADL limitations. I therefore translated and cross-culturally adapted Lawton IADL scale from English to Sinhala and tested its reliability and validity alongside the community survey

and published this in PLOS ONE (2018). So far three researchers from University of Malaysia Sarawak and University of Colombo, Sri Lanka have requested permission to use the scale in their research studies.

THESIS PUBLICATIONS

Four peer-reviewed journal papers have been published based on the work undertaken in this thesis. They are based on work presented in Chapter 3, Chapter 4, Chapter 5, Chapter 6, and Chapter 8. One manuscript is being prepared for publication at present based on the results presented in Chapter 7.

1. Siriwardhana DD, Hardoon S, Rait G, Weerasinghe MC, Walters KR. Prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries: a systematic review and meta-analysis. BMJ Open. 2018;8(3).

2. Siriwardhana DD, Walters K, Rait G, Bazo-Alvarez JC, Weerasinghe MC. Cross-cultural adaptation and psychometric evaluation of the Sinhala version of Lawton Instrumental Activities of Daily Living Scale. PLoS ONE. 2018;13(6):e0199820.

3. Siriwardhana DD, Weerasinghe MC, Rait G, Falcaro M, Scholes S, Walters KR. Prevalence of frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka: a population-based cross-sectional study. BMJ Open. 2019;9(1):bmjopen-2018-026314.

4. Siriwardhana DD, Weerasinghe MC, Rait G, Scholes S, Walters KR. The association between frailty and quality of life among rural community-dwelling older adults in Kegalle district of Sri Lanka: a cross-sectional study. Quality of Life Research. 2019;28(8):2057-2068.

Furthermore, I presented my work at four international conferences: three oral presentations and one poster presentation (please see below).

2016	Oral	'Prevalence of frailty and pre-frailty in low-and middle-income countries: A systematic review and meta-analysis'; 48th Asia Pacific Academic Consortium of Public Health Conference (APACPH) conference, Tokyo, Japan.
2018	Oral	'Burden of Frailty Syndrome in Low-and Middle-Income Countries: A Systematic Review and Meta-Analysis'; International Federation on Ageing (IFA) 14th Global Conference on Ageing, Toronto, Canada.
2018	Oral	'The Epidemiology of Frailty among Community-Dwelling Older Adults in Rural Sri Lanka'; 50th Asia Pacific Academic Consortium of Public Health Conference (APACPH), Kota Kinabalu Sabah, Malaysia.
2018	Poster	'The Association Between Frailty and Quality of Life Among Community-Dwelling Older Adults in Rural Sri Lanka'; 2018 International Alliance of Research Universities (IARU) Ageing, Longevity and Health Scientific and Graduate Student Conference, Centre for Ageing Research and Education, Duke-NUS medical School, Singapore.

FREQUENTLY USED ABBREVIATIONS

BADL	Basic Activities of Daily Living
B-FIT	Brief Frailty Instrument for Tanzania
BMI	Body Mass Index
CES-D scale	Center for Epidemiologic Studies-Depression scale
CFA	Confirmatory Factor Analysis
CHS	Cardiovascular Health Study
CGA	Comprehensive Geriatric Assessment
DNA	deoxyribonucleic acid
EFA	Exploratory Factor Analysis
EFS	Edmonton Frail Scale
ELSA	English Longitudinal Study of Ageing
FI	Frailty Index
FI-CGA	Frailty Index based on Comprehensive Geriatric Assessment
FRAIL scale	Fatigue, Resistance, Ambulation, Illness, Loss of weight scale
GDP	Gross Domestic Product
GDS	Geriatric Depression Scale
GFI	Groningen Frailty Indicator
GNI	Gross National Index

HDI	Human Development Index
HIC	High-Income Countries
HR	Hazard Ratio
HRQoL	Health-Related Quality of Life
IADL	Instrumental Activities of Daily Living
ICC	Intraclass correlation
IPAQ	International Physical Activity Questionnaire
IQR	Interquartile range
IRR	Inter-rater reliability
LMICs	Low-and Middle-Income Countries
MoCA	Montreal Cognitive Assessment
MOH areas	Medical Officer of Health areas
NCDs	Noncommunicable diseases
OPQOL	Older People's Quality of Life Questionnaire
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
OR	Odds Ratio
PPS	Probability Proportional to Size
PSU	Primary Sampling Units
QoL	Quality of Life

RCTs	Randomized Controlled Trials
RR	Rate Ratio
RRR	Relative Risk Ratio
SD	Standard Deviation
SE	Standard Error
SOF frailty index	Study of Osteoporotic Fracture index
SPSS	Statistical Package for the Social Sciences
SRS	Simple Random Sampling
SSU	Secondary Sampling Unit
TFI	Tilburg Frailty Indicator
UK	United Kingdom
USA	United States of America
WHO	World Health Organization
ZIP	Zero-Inflated Poisson
95% CI	95% Confidence Interval

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Chapter 1: Introduction

1.1 Chapter overview

In this chapter, I provide a comprehensive overview about the topic of this thesis: 'frailty'. First, I discuss the public health impact of population ageing worldwide. Second, I describe the conceptualisation of frailty followed by the biological and physiological basis of ageing and frailty. Next, I provide a detailed description of frailty measurements and the public health importance of frailty. Finally, I conclude this chapter by discussing recent research on interventions for frailty.

1.2 Background

1.2.1 Global public health impact of population ageing

Population ageing is a universal phenomenon affecting all countries in the world at different rates.[1] People in general are living longer lives than ever before[1]; but increasing longevity does not necessarily translate into increasing healthy life expectancy. Cognitive and physical functions decline as people age. The ongoing demographic transition is associated with an epidemiological transition which describes the changing patterns of mortality, life expectancy, and cause of death.[2] There is an increase of age-related noncommunicable diseases (NCDs)/chronic conditions and other complex health issues of older age such as frailty, urinary incontinence, falls, and delirium among older populations.[3, 4] Today, primarily because of continued public health efforts, together with social and welfare policies, and medical advancements, many people live longer lives despite having accumulated health problems over the life course. Thus, ageing commonly leads to complex health needs, including both medical and social care needs. However, the levels of economic and human development, and the levels of health and social care provision vary globally and even within the same region, making the situation more challenging.[4]

1.2.2 Conceptualising frailty

Historically the term 'frail' was often used to describe an older adult who appears weak and vulnerable.[3] Chronological age is a well-established risk factor that determines the health and survival of people. However, not every older adult has multiple health issues. Individuals of the same chronological age can be drastically different to each other in terms of their health status.[5] Frailty is a concept that may explain this heterogeneity of health status among older adults of the same chronological age.[6] To date, no consensus exists over a gold-standard definition for frailty.[7] The reasons for this include: a relatively new research concept and field of research introduced around 2001 and a rapidly accumulating body of work since then, complex aetiology, difficulty distinguishing the concept of frailty from other aspects such as ageing and disability.[8]

However, following a Delphi methods based consensus-building effort in 2011, there was a common agreement on a conceptual framework for frailty.[7] The experts agreed that frailty is a multidimensional syndrome characterised by loss of resilience, decreased reserves across multiple bodily systems and diminishing resistance to stressors, e.g. poor recovery from acute stressors such as a urinary tract infection or a non-injurious fall. Moreover, they identified frailty and disability as distinct entities.[7] Over the past two decades, two main approaches/models: (i) biological driven frailty and, (ii) deficit driven frailty have been extensively used in the literature to conceptualise frailty.[3] In addition, some

researchers have conceptualised frailty as a multidimensional concept including multiple domains such as physical, psychological, and social.[9]

1.2.2.1 Biological driven frailty

The biological driven approach views frailty as an age-related clinical syndrome caused by cumulative decline of physiological reserves across multiple body systems and that manifest during periods of stress.[10] The Fried phenotype is the most commonly used model to elucidate this approach. It is underpinned by a biological construct[10], hence, it is often referred to as physical frailty, the most commonly used conceptualisation[11]. The Fried phenotype is based on a theoretical 'cycle of frailty' that hypothesises that it is a cycle of decline in energy, nutrition, and skeletal muscles triggered by ageing, diseases, medications, and environmental stressors, which drives the development of frailty. Five phenotypic components (shrinking (unintentional weight loss), poor endurance and energy, weakness, slowness, and low physical activity) were used to operationalise this hypothesis. This model was proposed by Fried and colleagues in 2001 from a secondary analysis of a prospective cohort study: Cardiovascular Health Study (CHS).[10] They further hypothesised frailty, comorbidity, and disability as distinct entities (although they often overlap with each other) and investigated their hypotheses using the CHS cohort.[10]

According to their findings, frailty and comorbidity (defined as two or more of the following nine diseases: myocardial infarction, angina, congestive heart failure, claudication, arthritis, cancer, diabetes, hypertension, and chronic obstructive

pulmonary disease) was present in 46.2% of the population; frailty and disability (defined as the presence of limitation in at least one basic activity of daily living (BADL)) was present in 5.7%; and the combination of frailty, comorbidity and disability was present in 21.5% of the study cohort. Frailty was present without comorbidity or disability in 26.6% of the study group. This finding provides support for frailty as an independent concept, distinct from comorbidity and disability though they are related.[10] Therefore, generally comorbidity is regarded as a precursor to frailty while disability is recognised as an adverse outcome of frailty in this conceptualisation.

1.2.2.2 Deficit driven frailty

The deficit driven approach is the second widely used conceptualisation of frailty. The cumulative deficit model underpins an accumulation of related and unrelated biological, health, functional, cognitive, and social deficits. This approach perceives frailty as an age-associated nonspecific state of vulnerability which reflects multisystem physiological change. However, according to this conceptualisation, physiological changes do not always occur due to disease conditions and that is the reason for some oldest-old adults becoming frail without having life threatening disease conditions.[12] The deficit driven frailty model considers disability and comorbidity as integral components of frailty rather than as related separate entities, although they can be caused by frailty.[6] It is also of note that the deficit accumulation model was not constructed with an underlying biological theory or potential aetiology. According to its originators,

this conceptualisation does not oppose the idea of a physical frailty syndrome, instead, people who are classified as frail in the syndromic approach will have a higher number of deficits compared with their counterparts who do not.[6] This model was proposed in 2001 by Rockwood and colleagues as part of the Canadian Study of Healthy Aging and Frailty Index (FI) was used to operationalise this conceptualisation.[13]

1.2.3 The biological and physiological basis of ageing and frailty

Ageing is characterised by progressive loss of anatomic and physiological integrity across multiple organs and systems[3], as a consequence of cumulative molecular and cellular changes occurring over the lifetime. Nine tentative biological hallmarks were proposed in 2013 to explain the ageing process.[14] These included: (i) genomic instability, (ii) telomere attrition, (iii) epigenetic alterations, (iv) loss of proteostasis, (v) deregulated nutrient sensing, (vi) mitochondrial dysfunction, (vii) cellular senescence, (viii) stem cell exhaustion, and (ix) altered intercellular communication.[14]

Ageing predisposes to frailty but not all older adults are frail, implying heterogeneity of ageing. Hence, 'normal ageing' can be differentiated from frailty.[15] With advanced age, there is a gradual loss of physiological reserves and homeostatic mechanisms.[3] With frailty, this decline is believed to be accelerated and repair mechanisms fail to maintain system homeostasis (the process of regulating conditions in the body in order to maintain a steady internal environment). Consequently, frailty reduces older adults' ability to cope with day-

to-day minor stressors, e.g. acute infections, falls, etc. indicating that available functional reserves are inadequate for a complete recovery.[15] Evidence is emerging to explain the interconnections between (i) ageing-related molecular and cellular changes, (ii) disease states, and (iii) dysregulation of multiple physiological systems and homeostatic pathways that probably lead to the development of frailty.[16, 17]

1.2.3.1 Ageing related molecular and cellular changes

At a molecular level, (i) genomic instability (e.g. accumulation of genetic damage as a result of failing deoxyribonucleic acid (DNA) repair and other specific mechanisms of maintaining genomic stability[14]); (ii) increasing number of epigenetic alterations (e.g. alterations in DNA methylation patterns, post-translational modifications to histones, etc.)[14]; and (iii) telomere attrition (shortening the length of the telomere)[14] are likely to cause age-related alterations in gene expression that prompt physiological changes.[14] At a cellular level, protein quality control is essential for cellular homeostasis and cellular functioning. (iv) The progressive loss of protein homeostasis with ageing accumulated cellular debris, impairs an efficient response to stress.[14] (v) Cumulative damage to mitochondria and mitochondrial DNA (mitochondrial dysfunction) occurs with ageing in all cells and thereby reduces the energy production and increases the production of harmful reactive oxygen species that cause oxidative stress.[14] This has a huge impact on energy metabolism and chronic inflammation. Ageing affects the renewal ability of both stem cells and their

microenvironment (niche). Stem cells are the main source that enable cells to repair and regenerate damaged tissues and organs.[18] Therefore, (vi) stem cell exhaustion leads to declining regenerative tissue repair, and has a significant impact on immune function. Cellular senescence is a dynamic process driven by genetic and epigenetic changes that stops the division of cells and undergoes distinctive phenotypic alterations.[19] With ageing, senescent cell populations arise and (vii) cellular senescence contributes to the overall decline of tissue regenerative capacity, growth arrest of stem cells and disruption of local stem cell niche. Likewise presence of accumulated senescent cells at sites of age-related pathologies are likely to promote inflammation through proinflammatory growth factors and cytokines they secrete.[19] Many of the aforementioned biological mechanisms are interrelated and lifelong accumulation of damage at molecular and cellular level leads to gradual physiological decline accompanied with ageing.

1.2.3.2 Chronic disease conditions

Multi-system changes are observed with both chronic diseases and frailty.[17] The causal relationship between chronic diseases and frailty is still unclear, but it is thought that there are shared underlying biological mechanisms between some chronic diseases and frailty such as chronic activation of inflammatory and coagulation pathways.[20, 21] Previous research shows that a number of chronic disease conditions including: cardiovascular diseases[22, 23], chronic heart failure[24], chronic obstructive pulmonary disease[25], depression[26], diabetes mellitus[27, 28], and hypertension[29] coexist with frailty. Thus, the presence of these chronic disease

conditions is likely to chronically activate the following physiological systems: the innate immune system, the hypothalamic-pituitary-adrenal (HPA) axis, and the sympathetic nervous system that would have a destructive impact on many organs, tissues, and stem cells that hamper their replenishment.[17] However, frailty can also occur in the absence of chronic diseases.[12, 30]

1.2.3.3 Dysregulation of multiple physiological systems and homeostatic pathways

The precise level of cellular damage required to cause impaired organ physiology is unknown.[31] Nevertheless, redundancy in many organ systems leads to the depletion of physiological reserve that compensates for age and disease related changes.[31] Frailty has been shown to be associated with depletion of physiological reserves in brain[32], skeletal muscle[33, 34], endocrine[35], immune[36], respiratory[37], cardiovascular[23], renal[38], and haematological and clotting systems[21, 39]. (i) Altered energy metabolism: fasting glucose and insulin levels[40]; (ii) lower levels of anabolic hormones: insulin-like growth factor, dehydroepiandrosterone sulphate[41, 42]; (iii) activated innate immune system: elevated inflammatory markers (proinlammatory cytokine interleukin-6 and C-reactive protein)[36] and modifications to the clotting process (factor VIII, Didimers)[21]; (iv) activated HPA axis: increased cortisol levels[43], low testosterone[44]; (v) activated sympathetic nervous system: lack of heart rate variability[45], and low 25(OH) Vitamin D[46] provide evidence for dysregulated stress response systems that are important for the development of frailty. Moreover, these physiological systems are likely to

activate each other.[17] With frailty, physiological decline is accelerated and is accumulated across multiple inter-related physiological systems. Evidence indicates that the presence of abnormalities in three or more systems was a stronger predictor of frailty than an individual abnormal system.[47] Consequently, frailty is seen as a disorder of several interrelated physiological systems that are responsible for healthy adaptation to stressors.[31, 48]

1.2.4 Operationalising frailty

A plethora of instruments to measure frailty have been developed in recent years.[49] However, no gold-standard measurement tool is available at present for clinicians, researchers or policy makers to operationalise the concept of frailty.[3, 8] During a consensus building effort held in 2011 (mentioned previously), no agreement was reached about an overall operational definition for frailty.[7] Instead, experts emphasized the need for conducting additional research on clinical and laboratory biomarkers of frailty prior to achieving an operational definition.[7] A separate consensus conference with a wide range of experts convened in 2012, recognised and agreed on the distinction between the physical definition of frailty and the broader definition of frailty which includes multiple domains.[50] This group of experts agreed on four key points in relation to the assessment of physical frailty. They were: (i) that frailty is an important medical syndrome with multiple causes; (ii) it can be potentially prevented or treated with specific modalities; (iii) there are simple, rapid validated screening tests that can be used by physicians (e.g. FRAIL scale, frailty phenotype, Clinical Frailty Scale,

Gérontopôle Frailty Screening Tool); and (iv) that all adults aged over 70 years should be screened.[50]

The difficulty of achieving an agreement over a single frailty instrument is due to a number of reasons: (i) having multiple theoretical definitions, for instance the nature of the frailty concept (e.g. unidimensional or multidimensional); (ii) breadth of measures available such as single item physical performance tests, rapid screening questionnaires, and indexes; (iii) lack of data on clinimetric or psychometric properties of these instruments such as reliability and agreement, validity, floor and ceiling effects, responsiveness, and interpretability; and (iv) type of scoring and frailty classification used, e.g. dichotomous, ordinal, and continuous.[51] In addition, a lack of explicit attention to the purpose and the context of the frailty instrument to be used is also viewed as a cause for the inconclusive consensus building efforts.[11]

Table 1.1 (page 47) summarises the findings of 12 reviews published since 2011 that aimed to describe frailty instruments used for screening or for frailty identification with community-dwelling older adults. Ten of these reviews were included in a systematic review of reviews published in 2018.[52] Authors of this review had restricted their search to include studies published between January 2010 and December 2016 claiming that there was an influx of research on this aspect in those six years.[52] The specific objectives of these reviews were to: catalogue all existing frailty instruments generally[49, 53] used for different purposes and contexts[11]; review instruments or markers used for frailty screening in

primary care settings[54, 55]; assess the psychometric properties of all available frailty instruments[51, 56, 57] and instruments used in low-and middle-income countries (LMICs)[58]; appraise diagnostic test accuracy of simple frailty instruments[59, 60]; and to determine the best frailty instrument to be used in research and in clinical practice based on Clegg et al's (2013) four criteria[31] for frailty classification[8]. These were as follows: (i) to accurately identify frailty, (ii) reliably predict adverse clinical outcomes, (iii) respond to potential therapies for patients, and (iv) be supported by a biological causative theory.

Table 1.1 Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Sternberg et al, 2011[53]	Systematic review From 1997 to 2009	To systematically review the literature on clinical definitions, screening tools, and severity measures of frailty used with community-dwelling older adults.	The most common components used to identify frailty were physical functioning, mobility, and cognition. Limitations in instrumental activities of daily living (IADL) and basic activities of daily living (BADL) were included as components of frailty more frequently in early years while gait speed and cognition have been commonly used more recently. The choice of the most suitable frailty instrument is dependent on the need or objective of the study.	None
de Vries et al, 2011[51]	Systematic review From inception of the databases to 23 February 2010	To assess the clinimetric properties[61] of frailty instruments and identify best available instrument to evaluate outcome measures in clinical practice and for observational and experimental research.	20 frailty instruments were identified. A comprehensive overview was given on the multidimensional nature (physical, psychological, and social domains) and type of scoring system used (dichotomous, ordinal, and continuous scale) in the frailty instruments. A substantial number of instruments have only covered the physical aspects of frailty. Half of the instruments did not contain items pertaining to the psychological domain.	Frailty index (FI)

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
de Vries et al, 2011[51] cont.			Most instruments have used a dichotomous scoring system (i.e. either frail or not frail). Frailty instruments have often been developed and validated as prognostic instruments and not as outcome measures.	
Pijpers et al, 2012[59]	Systematic review From inception of the databases to December 2010	To describe the currently available frailty scoring systems and their predictive values in the general population.	Current screening instruments for frailty are not sensitive enough for screening and for diagnosing frailty. However, there is no gold-standard frailty test to compare screening and diagnostic instruments with.	None
Bouillon et al, 2013[56]	Systematic review From 1948 to May 2011	To provide an overview of measures of frailty (including psychometric properties) used in population-based studies.	27 frailty instruments were identified, of them 19 were developed in population-based samples, seven among hospitalised patients, and one without specifications.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Bouillon et al, 2013[56] cont.			Half of the instruments reviewed had incorporated disability or comorbidity items into the instruments. Half of the instruments were created in USA (14) followed by Canada (5), The Netherlands (3), and Italy (2) and one each in Australia, France, and Sweden. Frailty index and Fried phenotype were the two instruments widely tested for validity but not for reliability. Fried phenotype was the most evaluated and widely used instrument.	
Pialoux et al, 2012[54]	Systematic review From inception of the databases to 25 June 2011	To review the literature on validated screening instruments for frailty in primary healthcare settings.	10 instruments were identified for screening for frailty in primary healthcare. The psychometric properties of two instruments: Tilburg Frailty Indicator (TFI), Survey of Health Ageing and Retirement in Europe Frailty Instrument (SHARE-FI) compared with Comprehensive Geriatric Assessment (CGA) appeared to be potentially suitable.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Buckinx et al, 2015[49]	Review Not mentioned	To review the recent literature on the definition of frailty, the burden of frailty, and the challenges for public health.	The other operational concepts of frailty are on a spectrum between two main approaches of frailty, namely the biological syndrome and the deficit model. 10 frequently cited validated measures of frailty were identified in the literature.	None
Clegg et al, 2015[60]	Systematic review From 1990 to October 2013	To investigate the diagnostic test accuracy of simple frailty instruments to use with community-dwelling older adults.	Review identified seven simple frailty tests/instruments: gait speed, PRISMA-7 questionnaire, timed-up-and-go test, self-rated health, general practitioner assessment, polypharmacy, and Groningen Frailty Indicator (GFI). Slow gait speed, PRISMA-7 questionnaire, timed-up-and-go test demonstrate high sensitivities (few false- negative results) and moderate specificities (moderate levels of false-positive results) that limit their diagnostic test accuracy. Thus these instruments cannot be used as accurate single tests.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Buta et al, 2016[11]	Review From inception of the databases to December 2013	To comprehensively catalogue frailty instruments in the research literature and systematically categorise the different purposes and contexts of their use.	67 frailty instruments were identified, 9 of which were highly cited. Over half of the highly cited instruments included measures of comorbidity and disability. Fried phenotype was the most cited and used frailty instrument in the literature followed by the frailty index. Frailty instruments were frequently used as risk assessment tools followed by use for the investigation of the aetiology of frailty. Use of frailty measurements for clinical decision-making and as an interventional target found to be limited. The most common assessment context was observational cohort studies of community-dwelling older adults. This review recommended to select frailty instruments based on the intended purpose, theoretical basis, validity, and feasibility.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Gray et al, 2016[58]	Systematic review From inception of the databases to 30 June 2014	To systematically review the frailty screening tools used in low-and middle-income countries (LMICs).	Studies were conducted in 22 LMICs (9 in Asia, 7 in South or Central America, 4 in Africa and 2 in Europe). Brazil, Mexico, and China provided data for 60 of 70 studies (85.7%). Of 70 studies reviewed, 60 studies were community-based, six were hospital-based and four were nursing home-based. Twenty eight studies (40.0%) included people living in rural locations. Correspondingly 36, 20, and eight studies had used Fried phenotype, frailty index and Edmonton Frail Scale (EFS). EFS was the best validated instrument with content and construct validity, reliability, and agreement: all of the aforementioned psychometric properties found to be acceptable in two studies from Brazil. None of the frailty assessment tools used has been fully validated to use in LMICs. Therefore, further validation of frailty assessment tools is required from LMICs.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Sutton et al, 2016[57]	Systematic review From inception of the databases to 30 March 2015	To identify multi-component frailty assessment tools that were specifically developed to assess frailty in older adults aged ≥60 years and evaluate the reliability and validity of these tools.	A large number of (38) multi-component frailty assessment tools were identified in 73 studies. However, the range and quality of the psychometric properties of these instruments are limited. Groningen Frailty Indicator followed by Tilburg Frailty Indicator (TFI) were the most frequently tested instruments for psychometric properties. Only TFI (acceptable evidence for 4 measurement domains out of 9) and Frailty Index based on Comprehensive Geriatric Assessment (FI-CGA) (acceptable evidence for 3 measurement domains out of 9) had reliability and validity testing results within parameters of fair to excellent quality. At present, TFI has the most robust evidence-based support for its reliability and validity in assessing frailty. The psychometric properties of all multi-component frailty assessment tools require an in-depth evaluation.	None

Table 1.1 continued. Summarising the findings of systematic reviews/reviews on frailty instruments

Authors and year	Type of review and search period	Objective of the review	Main findings	Best frailty instrument/s proposed
Dent et al, 2016[8]	Review From January 2009 to July 2015	To determine the best frailty measurement instrument in research and in clinical practice according to Clegg et al's (2013) criteria[31] for frailty measurement.	29 different frailty measurements were identified. The majority of studies have used frailty measurement as a prognostic tool. To date, Fried phenotype and frailty index are the two most commonly used frailty measurements that appear to be the most robust tools for researchers and clinicians.	Fried phenotype Frailty index
Lee et al, 2017[55]	Systematic review From 1966 to March 2016	To systematically review markers for frailty or risk tools that have been validated in ambulatory care settings.	There is a lack of psychometrically sound and clinically useful frailty markers.	None

Overall, research on frailty instruments has increased greatly over the past two decades. As demonstrated in the findings of the systematic reviews evaluating the psychometric properties of instruments set out in Table 1.1 (page 47), the quality of the existing frailty instruments varies widely.

Some researchers have identified the best available frailty instrument/s in the literature according to their review objectives.[8, 51] Fried phenotype derived from the biological approach and the frailty index derived from the deficit accumulation approach have been the most extensively used frailty assessment methods to date by researchers and by clinicians.[11, 56] One review has claimed that these two instruments appeared to be the most robust frailty assessment tools for use by clinicians and researchers at present[8] according to Clegg et al's (2013) criteria[31] for frailty measurement. There has been a growing interest in frailty in LMICs recently, and the majority of the studies to date have used the Fried phenotype as their assessment method.[58] None of the frailty instruments used thus far have been fully validated for use in LMICs.[58] To date, the Edmonton Frail Scale is the best validated instrument found from LMICs.[58] The content and construct validity, reliability and agreement was found to be acceptable in two studies conducted in Brazil.[62, 63]

The prevalence of frailty varies considerably in the same study population-based on the frailty instrument used.[64-67] Table 1.2 (page 57) presents the characteristics of 14 frequently cited frailty instruments in the literature.[8, 49] Of these, I describe

the Fried phenotype and the original Frailty Index (FI) and its subsequent modifications in detail in the next section.

Table 1.2 Characteristics of the commonly used frailty instruments in the literature

Frailty instrument	Country of origin	Number of items	Description	Frailty classification	Context used
Fried phenotype[10]	USA	5	Shrinking, poor endurance and energy, weakness, slowness, and low physical activity	Frailty≥3 items Pre-frail=1-2 item Non-frail =0 items	Clinical and population level screening
Frailty index[6, 13]	Canada	30+	A list of health, functional, cognitive, and social deficits. Frailty index is calculated as the number of deficits the participant has, divided by the total number of deficits considered. FI score ranges from 0 (no deficits) to 1 (all deficits).	Suggested frailty cut-off>0.25	Clinical and population level screening
Frailty index derived from comprehensive geriatric assessment (FI-CGA)[68, 69]	Canada	14 (Originally)[68] 52 (Later)[69]	**Impairment index comprised of 10 domains** (cognition, emotion, communication, mobility, balance, bladder function, bowel function, nutrition, IADL and BADL, and social resources) **and Comorbidity index** (Cumulative Illness Rating Scale) FI-CGA score ranges from 0-1.	Suggested frailty cut-off>0.25	Clinical
Clinical Frailty Scale[13, 70]	Canada	1	A brief clinician assessment using visual and written chart for frailty with nine graded pictures. 1=very fit, 9=terminally ill.	Severely frail (score 7-8) Mild to moderately frail (score 5-6) Non-frail (score 1-4)	Clinical

Table 1.2 continued. Characteristics of the commonly used frailty instruments in the literature

Frailty instrument	Country of origin	Number of items	Description	Frailty classification	Context used
Gérontopôle Frailty Screening Tool[71]	France	8	The first six questions evaluate the individual's status (living alone, involuntary weight loss, fatigue, mobility difficulties, memory problems, and gait speed). The last two questions are about clinical judgement of frailty status of the individual (Do you think your patient is frail?; If yes, is your patient willing to be assessed for his/her frailty status at a future frailty clinic?)	Based on clinical judgement of the general practitioner	Clinical
Study of Osteoporotic Fractures (SOF) frailty index[72]	USA	3	Weight loss (intentional/unintentional, >5.0% in the last year), exhaustion (self-reported), and low mobility (inability to perform chair rise five times)	Frailty≥2 items Pre-frail=1 item Non-frail =0 items	Clinical and population level screening
Fatigue, Resistance, Ambulation, Illness, Loss of Weight scale (FRAIL scale)[73]	USA	5	Fatigue (self-reported), resistance (self-reported difficulty walking up 10 steps alone without resting and walking aids), ambulation (self-reported difficulty of walking several hundred yards alone without aids), illness (five or more illness out of 11 illnesses), and loss of weight (self-reported, >5.0% in the last year)	Frailty≥3 items Pre-frail=1-2 items Non-frail =0 items	Clinical and population level screening

Table 1.2 continued. Characteristics of the commonly used frailty instruments in the literature

Frailty instrument	Country of origin	Number of items	Description	Frailty classification	Context used
Edmonton Frail Scale (EFS)[74]	Canada	9	Cognition (clock drawing), general health status (number of hospital admissions in the last year), functional independence (help needed with number of IADL activities), social support, medication use (≥5 regular medications), nutrition (recent weight loss), mood (often feel sad or depressed), continence (urinary incontinence), and functional performance (timed up-and-go test) EFS score ranges from 0-17.	Severe frailty (score 12-17) Moderate frailty (score 10-11) Mild frailty (score 8-9) Vulnerable (score 6-7) Non-frail (score 0-5)	Clinical and population level screening
SHARE frailty instrument (SHARE-FI)[75]	Ireland	5	Fatigue, loss of appetite, grip strength, functional difficulties, and physical activity	Frailty≥3 items Pre-frail=1-2 items Non-frail =0 items	Clinical and population level screening
PRISMA-7[76]	Canada	7	Self-reported dichotomous components: older than 85 years, male, having health problems which limit activities, support of another person is needed, having health problems required to stay at home, social support, and use of a cane/walker/wheelchair PRISMA-7 score ranges from 0-7.	Frail (scores≥3)	Population-level screening

Table 1.2 continued. Characteristics of the commonly used frailty instruments in the literature

Frailty instrument	Country of origin	Number of items	Description	Frailty classification	Context used
Groningen Frailty Indicator (GFI)[77]	The Netherlands	15	Self-reported dichotomous questions in four domains: **physical** (independence in shopping, walking, dressing, toileting, physical fitness, vision, hearing, weight loss, and polypharmacy), **cognitive** (memory issues), **psychological** (feeling down hearted or sad, feeling nervous or anxious), **social** (emptiness, missing others, and feeling abandoned) GFI score ranges from 0 (not frail)-15 (very frail).	Frail (scores≥4)	Population-level screening
Tilburg Frailty Indicator (TFI)[78]	The Netherlands	15	Self-reported questions in three domains: **physical** (physical health, weight loss, difficulty in walking, balance, hearing, vision, gripping, and tiredness), **psychological** (memory, feeling down, anxiety, and coping), **social** (living alone, social isolation, and social support) TFI score ranges from 0-15.	Frail (scores≥5)	Population-level screening

Table 1.2 continued. Characteristics of the commonly used frailty instruments in the literature

Frailty instrument	Country of origin	Number of items	Description	Frailty classification	Context used
Sherbrooke Postal Questionnaire (SPQ)[79]	Canada	6	Self-reported questions with dichotomous answers; living alone, taking ≥3 medications daily, use of a cane/walker/wheelchair, eyesight, hearing, and memory problems SPQ score ranges from 0-6.	Frail (scores≥2)	Population-level screening
Kihon Check-List (KCL)[80]	Japan	25	25 items in a self-administered questionnaire: instrumental (3 items) and social (4 items) activities of daily living, physical functions (5 items), nutritional status (2 items), oral functions (3 items), cognitive function (3 items), and depressive mood (5 items) KCL is calculated as the number of deficits the participant has, divided by the number of deficits considered (25).	Suggested cut-off>0.25	Population-level screening

1.2.4.1 Fried phenotype

As mentioned in Section 1.2.2.1 (page 38), the Fried phenotype is based on a theoretical 'cycle of frailty' that hypothesises a cycle of decline in energy, nutrition, and skeletal muscles triggered by ageing, diseases, medications, and environmental stressors, which drives the development of frailty. The Fried phenotype and the concept of physical frailty originated in USA.[10] The Fried phenotype is comprised of five components: (i) shrinking, (ii) poor endurance and energy, (iii) weakness, (iv) slowness, and (v) low physical activity. The corresponding methods used to operationalise each component in the original study (CHS)[10] were: (i) shrinking: unintentional weight loss of 4.5 kg or more in the last year, (ii) poor endurance and energy: self-reported exhaustion as identified by two questions from the Center for Epidemiologic Studies Depression Scale, (iii) weakness: being in the lowest quintile of grip strength after adjusting to sex and body mass index (BMI) quartiles, (iv) slowness: being in the lowest quintile of walking speed after adjusting for sex and standing height, and (v) low physical activity: being in the lowest quintile of weekly kilocalories expenditure adjusted for sex assessed using the short version of the Minnesota Leisure Time Activity questionnaire. For each individual, a score of 0-5 is generated based on cut-off points for frailty for each component. Zero means none of the components are present while five means the presence of all five components. In the original study (as well as in the subsequent research) co-occurrence of at least three of the five components was considered as 'frail', presence of one to two components was

considered as ‘pre-frail’ and ‘robust’/‘non-frail’ if none of the components were present.[10]

Researchers have frequently modified the methods used to operationalise these components (usually based on the availability of data) and it has been shown that these modifications substantially affect the magnitude of subsequent frailty prevalence estimates, even when used with the same study sample.[81] Areas where modifications have been noted are: (i) number of phenotypic components used, (ii) how phenotypic components were operationalised, (iii) which cut-off points were used for performance based measures such as grip strength and gait speed, (iv) how frailty status for each component was identified, (v) how missing data of frailty components were handled (sum of available items or imputations (i.e. assumed frail) for missing data), (vi) how the total frailty score was computed and (vii) how persons were classified accordingly (e.g. use of a two-level classification of frail and non-frail compared with original three-level classification), and (viii) inclusion and exclusion criteria used to define the study population (for example including those in residential care settings or not, or those with dementia).[81]

The Fried phenotype has been validated in large epidemiological studies.[10, 82, 83] It predicts recurrent falls, nursing home admission, developing IADL and BADL limitations, overnight hospitalisation, emergency room visits, and mortality independently from multiple potential confounding factors.[10, 82, 84] However, the Fried phenotype was not developed for use in routine care. Scoring in clinical

settings is difficult for three components: weakness (low grip strength), slowness (low gait speed), and low physical activity, as population values are required.[85] It is time consuming and has been criticised for non-inclusion of psychosocial components of frailty[8] (e.g. cognition, mood, social support, and living arrangement), as well as sensory impairments (e.g. vision and hearing). Moreover, no biological markers are included in the Fried phenotype.[15]

1.2.4.2 Frailty index (FI)

In contrast to the phenotype model, using the cumulative deficit model, the multidimensional nature of frailty has been operationalised as an accumulation of related and unrelated biological, health, functional, cognitive, and social deficits in the form of a frailty index. A range of items are included in the frailty index[6] as 'deficits': symptoms (e.g. changes in sleep, low mood, memory complaints); signs (e.g. tremor, decreased peripheral pulses); diseases (e.g. diabetes mellitus, heart diseases); abnormal laboratory measurements (e.g. calcium, creatinine, urea); social factors (e.g. living alone); and disabilities (limitations in instrumental and basic activities of daily living).[6] However, these deficits vary across a range of severity, from items associated with risk of death (e.g. heart failure) to items which cause discomfort (e.g. constipation).[6] An individual's frailty index score is computed as the proportion of deficits present at a given chronological age.[86] If an individual has more deficits, they have a higher likelihood of being frail. The frailty index score is continuous and ranges from 0 to 1. A score of 0 is given if there are no deficits, and a score of 1 is given if all deficits included within the

index are present. The upper limit of frailty index is believed to be around 0.67 and higher scores do not generally occur.[87] There is no consensus on a cut-off for frailty and values between 0.2 and 0.25 are often used.[58, 88] However, these values have been not validated as there is no gold-standard frailty instrument for comparison, and the sensitivity and specificity of these values are also not established. Concurrent and predictive validity of the frailty index have been assessed with multiple datasets.[56] Several studies have found that the frailty index has a higher predictive ability of adverse clinical events (e.g. all-cause mortality, admission to a residential care facility, move from low-level care to high-level care within residential care, functional decline over hospitalisation, and long length of hospital stay) compared with other frailty assessment methods with both hospitalised and community-dwelling older adults.[89-91] It has also been suggested that the FI can be used as a population indicator of healthy ageing and can be used when evaluating the performance of health and social care delivery and policies.[85] If collecting original data, the index can be time consuming to calculate and is not suitable to use in clinical settings.[8, 85] However, 'electronic' versions have been developed (the eFI) in the UK which use routinely collected data from healthcare records to automatically generate a version of the FI without any extra work by clinicians.[92] Similar work has been done with Canadian primary care electronic medical records recently and indicates the possibility of using eFI as a case-finding instrument.[93] However, using FI in low resource settings is challenging where medical histories of older adults are not readily available in digital form.

In addition, deriving the frailty index using the more routinely used Comprehensive Geriatric Assessment (CGA)[94] has been undertaken. The CGA is the global standard assessment for older adults in clinical practice. It is a multidimensional assessment and a treatment plan, and regular review is delivered by a multidisciplinary team.[95] CGA is therefore viewed as the gold-standard for the care of people with frailty.[95] However, it is a time and resource intensive specialist approach.[96] Although the CGA has not been specifically designed to measure and classify participants as frail and non-frail, evidence is emerging that the clinically obtained CGA results were highly correlated with the original FI[97] and were predictive of death and of the need for institutional care.[13, 68] Thus, the frailty index derived from the CGA (FI-CGA) is considered as a valid, reliable, and sensible clinical measure of frailty that can be used for risk stratification.[68] Based on these research findings, Clegg and colleagues[31] have suggested the CGA as the current gold-standard instrument to detect frailty.[31] This suggestion has been further endorsed by some researchers in the field claiming that the CGA is the current criterion standard for frailty identification and management.[93]

All the frequently used frailty instruments included in Table 1.2 (page 57) have been developed in high-income countries (HICs). Most of the tools have been based on either the biologically based syndromic approach or the deficit accumulation approach.[17] There is an increasing trend towards developing multidimensional tools, but the best instrument to measure frailty remains

debatable among experts in the field. Similarly, the choice of the components to be included in the frailty assessments is not conclusive.[49] However, there is an increasing recognition that none of these existing frailty instruments are sufficient for all purposes: clinical practice, risk assessment, biological and epidemiological research, intervention development, and outcome assessment.[50] Hence, there is a tendency to recommend gold-standard frailty measurement tools for each purpose.[11]

1.2.5 Public health importance of frailty

Frailty has emerged as a major global health concern linked with ageing populations worldwide that has significant medical, public health, and social implications for patient outcomes as well as health and social care services utilisation.[50] Recently frailty has been described as the most problematic expression of population ageing[31] and is increasingly recognised as a hallmark geriatric syndrome from which other geriatric syndromes such as delirium and falls may develop.[3] Frailty is triggered by a complex multifactorial aetiology.[98] In addition to the biological and physiological changes associated with ageing and frailty, lifestyle and environmental stressors also contribute to the pathogenesis of frailty.[98]

1.2.5.1 Adverse outcomes of frailty

Frailty is a strong independent predictor of numerous adverse health outcomes such as all-cause mortality[99, 100], cognitive impairment[101], delirium[102], disability

(i.e. limitations in instrumental activities of daily living and basic activities of daily living) [103], recurrent falls[104], hospitalisation[105], emergency room visits[84], and low quality of life[106] among both community-dwelling and institutionalised older adults. The results of an extensive review and meta-analysis of prospective studies which included 31 articles on 13 negative health outcomes with 158,764 participants revealed that frailty significantly increased the risk of developing several negative health outcomes.[107] According to the findings of this meta-analysis (pre)frailty increased the risk of mortality [OR 2.3 (1.8, 3.1); HR/RR 1.8 (1.7, 2.0)], hospitalisation [OR 1.8 (1.5, 2.2); HR/RR 1.2 (1.1, 1.3)], institutionalisation [OR 1.7 (1.0, 2.8); HR/RR 1.7 (1.5, 1.8)], BADL limitations [OR 2.1 (1.7, 2.4); HR/RR 1.6 (1.5, 1.8)], and IADL limitations [OR 2.5 (2.1, 3.1)].[107]

1.2.5.2 Health and social care costs

Frailty and its adverse outcomes contribute to the increasing demand on health and social care systems globally. This will have various implications for individuals, families, governments, and society. Healthcare costs have been found to be attributable more to frailty and to comorbidity than to age.[108] Several studies have reported increased total healthcare costs among frail older adults[109-111] and in particular increased costs for outpatient care[110], hospitalisation and skilled nursing facility stay[110], inpatient care[111], and for informal nursing care[111]. Some of these findings remained significant even after adjusting for multimorbidity and functional limitations.[110] Limited evidence is available on family caregiver burden

and physical frailty, however, existing studies reported negative associations with caregiving frail older adults including anxiety and depression.[112]

1.2.5.3 Screening for frailty

Routine screening for frailty has been encouraged in international consensus guidance in order to optimally manage individuals with physical frailty.[50] For instance, optimising medication for frail older adults could help to reduce harm and minimise inappropriate hospital admissions.[113] Frailty screening is increasingly used as a guide for clinical decision-making and has been used as a risk stratification tool in predicting adverse patient outcomes: increased mortality, morbidity, and healthcare consumption across a number of medical and surgical subspecialties.[114, 115] These subspecialties include oncology[116], cardiology[116-118], and patients with chronic kidney disease[119], geriatric trauma patients[120], intensive care patients[121], general, vascular, and hip surgical patients[116].

1.2.5.4 Frailty trajectories

The actual level of frailty at a certain time point can be placed on a continuum between not frail to severely frail.[9] Older adults can make dynamic transitions across frailty statuses in both directions. Pre-frail older adults have more than twice the risk of becoming frail compared with non-frail.[10] According to pooled results of a recent meta-analysis, over a 3.9 years mean follow up time, approximately 10.0% of older adults improved their frailty status while 40.0%

worsened and half remained the same.[122] Hence frailty may be potentially a reversible risk condition.[123] Evidence suggests that pre-frail/moderately frail individuals may better respond to interventions and have a greater chance to improve compared with those who are already frail.[124, 125] There is therefore a need for better management and to slow down the trajectories towards further deterioration of health and functional status in order to improve quality of life in later years.

1.2.6 Interventions for frailty

Since frailty is a progressive condition on a spectrum[15], early detection (through screening for example) is potentially important in order to take preventive measures and reduce its severity by delaying or slowing its progression.[126] Over the past decade, an increasing number of studies have examined the effectiveness of various types of interventions for preventing the progression of pre-frailty and frailty in older adults.[127, 128]

Two previous systematic reviews which included randomized controlled trials (RCTs) published in 2014[129] and 2015[130] provided some evidence for the benefit of physical exercise interventions in frail older adults. Compared with control interventions, exercise showed significant improvement in gait speed and Short Physical Performance Battery in the frail older adults. However, results were inconclusive for endurance outcomes, balance, and functional status.[129] Another review suggested that multi-component exercise programmes would promote global function of frail older adults.[130] However, both reviews concluded that

uncertainty remains about the optimal exercise programme.[129, 130] A systematic review published in 2018 has collated information on a broad range of 21 RCTs of clinical interventions tested predominantly with community-dwelling older adults, published in 2001-2015.[127] This review demonstrated mixed results regarding the effectiveness of frailty interventions. Physical exercise interventions were generally effective in reducing or reversing frailty but only where classes or groups interventions were used.[127] Another systematic review published in 2019 which included 47 studies explored primary care interventions for frailty[128], and suggested that a combination of strength exercises and protein supplementation are the most effective and easiest to implement interventions to delay or reverse frailty.[128]

It is essential to highlight some limitations of both the systematic reviews and a number of studies included within them. Three of the four reviews discussed above were limited to studies published in English language only[127, 128, 130]; hence, might have missed the studies published in other languages. Studies were highly heterogeneous in terms of intervention characteristics and outcome measurements, therefore meta-analyses were not possible in many instances. Some studies have provided lack of or unclear information on participant blinding to treatment allocation and on the study instruments they used.[127] Disagreement on frailty definition also limits the comparability and generalisability of findings into different clinical and economic contexts. Furthermore, evidence is scarce on the cost-effectiveness of these interventions.[127] Almost all these interventional

studies have been conducted in HICs and therefore they lack evidence from LMICs directly relevant to Sri Lanka.

Chapter 2: Thesis rationale and objectives

2.1 Chapter overview

In this chapter, I present the rationale and objectives of my PhD. First, I describe population ageing in low-and middle-income countries (LMICs) with a particular emphasis on Asia, and the importance of having a complete catalogue of research on the epidemiology of frailty in LMICs. Second, I provide a brief introduction about Sri Lanka and the causes, dynamics, and current situation of population ageing in the country. Subsequently, I describe one potentially relevant study on the epidemiology of frailty from Sri Lanka. This is followed by a rationale for evaluating the association of frailty with disability and with quality of life in Sri Lanka. Finally, I outline the two main parts of my PhD: Part A) a systematic review and meta-analysis on prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs, and Part B) a population-based cross-sectional study, along with their objectives.

2.2 Thesis rationale

2.2.1 Population ageing and prevalence of frailty in low-and middle-income countries (LMICs) and in Asia

Table 2.1 (below) presents the percentage of population aged ≥60 years living in the world and by income classification, and distribution of the world's total older population by income groups for the year 2015, and according to population projections for 2030 and 2050.[1] By 2030 and 2050 middle-income countries will have aged considerably and they will be the home for the majority of the older adults in the world. These countries are mostly located in Asia and in Latin America and the Caribbean regions.[1]

Table 2.1 Percentage of population aged ≥60 years in the world and according to income classification and distribution of the total population (aged ≥60 years) of the world by income classification

Income groups	**Percentage in each income group**			**Distribution of world's total older population across income groups (%)**		
	2015	**2030**	**2050**	**2015**	**2030**	**2050**
World	12.3	16.5	21.5	100.0	100.0	100.0
High-income	22.1	27.7	31.9	34.4	29.2	23.1
Upper middle-income	13.4	21.2	30.5	35.5	38.9	38.3
Lower middle-income	8.1	11.2	16.5	26.4	28.1	33.1
Low-income	5.2	5.8	8.3	3.7	3.9	5.5

Data source: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Ageing 2015 (ST/ESA/SER.A/390).

Similarly, Table 2.2 (below) presents the percentage of population aged ≥60 years living in each region and distribution of the world's total older population by region for the year 2015 and according to population projections for 2030 and 2050.[1] Asia is already home to more than half of the world's older population and the percentage of the population aged ≥60 years is expected to rise to 60.2% by 2030.[1]

Table 2.2 Percentage of population aged ≥60 years in the world and according to geographic region and distribution of the total population (aged ≥60 years) of the world by geographic region

Region	**Percentage in each region**			**Distribution of world's total older population across regions (%)**		
	2015	**2030**	**2050**	**2015**	**2030**	**2050**
World	12.3	16.5	21.5	100.0	100.0	100.0
Africa	5.4	6.3	8.9	7.2	7.5	10.5
Asia	11.6	17.2	24.6	56.4	60.2	61.8
Europe	23.9	29.6	34.2	19.6	15.5	11.6
Latin America and the Caribbean	11.2	16.8	25.5	7.9	8.6	9.6
Oceania	16.5	20.2	23.3	0.7	0.7	0.6
Northern America	20.8	26.4	28.3	8.3	7.5	5.9

Data source: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Ageing 2015 (ST/ESA/SER.A/390).

Asia is the earth's largest and most populous continent. The United Nations (UN) has divided Asia into four sub regions namely, Eastern Asia (five countries), Central Asia (five countries), Southern Asia (nine countries), South-Eastern Asia (11 countries), and Western Asia (18 countries) including 48 countries in total when mainland China and its special administrative regions are considered as a single country.[131] Except Japan, Hong Kong Special Administrative Region (SAR), Singapore, South Korea, and Taiwan, the majority of Asian countries are emerging economies. Declining fertility levels, marked improvements in infant mortality, increasing life expectancy, and migration of the working populations (thereby leaving older parents in their home countries) are the driving determinants influencing the structural change in the ageing population in Asia.[3]

However, not all Asian countries are ageing at the same rate. Most of the high-income Asian countries (Hong Kong SAR, Japan, Singapore, and South Korea) have been experiencing ageing populations in parallel with advanced Western economies.[3] The fastest growth will continue in East Asia followed by some countries in South-East Asia.[3] These varying ageing profiles, along with the different levels of economic development, mean that each country is required to react to this immediate challenge in their own way considering the country's unique cultures and traditions.[3] However, many health and social challenges associated with population ageing have not received due consideration in many LMICs included within Asia.

Frailty is one such age-related vulnerability. The prevalence of frailty has been widely studied in Western high-income countries.[132, 133] In contrast, a narrative review of frailty in LMICs (developing countries) published in 2015 (search was conducted from 1990 to January 2014) found limited studies (14 studies); all of which were from middle-income countries and none from low-income countries. Furthermore, this review suggested that frailty occurs more frequently in LMICs.[132] Understanding the magnitude and patterns of frailty in these rapidly ageing populations in LMIC settings is worthwhile in order to evaluate the current and future health, social, and economic consequences associated with frailty and take necessary steps to provide care for those who are frail and to prevent or reduce the incidence of frailty among their growing older populations.

2.2.2 Sri Lankan context

2.2.2.1 Economic profile and healthcare system of Sri Lanka

Sri Lanka has a population of about 21 million[134] and is a lower middle-income country with a gross national income (GNI) per capita US$ 3850[135] and a high Human Development Index (HDI) of 0.770[136] as per the statistics of the year 2017. Lower middle-income economies are those with GNI per capita between US$ 996 and US$ 3895. In 2017 Sri Lanka was at the top end close to entering the category of higher middle-income economies.[137]

The Government led health delivery system in Sri Lanka has contributed to significant achievements such as higher life expectancy and good health outcomes

e.g. reduction in maternal mortality, reduction in child mortality, better control of communicable diseases, elimination of malaria, poliomyelitis, Filariasis, and the control of vaccine preventable diseases. Sri Lanka is known for its effective health service delivery at reasonable cost when compared with countries with comparable health outcomes where the investment on health in terms of percentage Gross Domestic Product (GDP) is relatively high.[138] In 2016, the Sri Lankan government contribution for health was 1.6% of GDP.[138]

2.2.2.2 Sri Lanka: a member state of World Health Organization (WHO) South-East Asia region

With reference to health-related initiatives, Sri Lanka is classified under the World Health Organization (WHO) South-East Asia region which includes 11 countries (Bangladesh, Bhutan, Democratic People's Republic of Korea (DPR Korea), India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Leste); home to a quarter of the world's population[139] (Figure 2.1, page 79). According to recent statistics, Thailand, Sri Lanka, and DPR Korea have the highest proportion of older persons (those aged ≥60 years), among the 11 member states that belong to WHO South-East Asia region.[1] Table 2.3 (page 80) presents key economic, demographic, and human development indicators of countries belonging to the WHO South-East Asia region.

Figure 2.1 Countries belonging to WHO South-East Asia region

Note: Map was created with mapchart.net©

Table 2.3 Key economic, demographic, and human development indicators of countries belonging to the WHO South-East Asia region

Country	Income classification 2017 (GNI per capita US$)[135]	Total population 2015 (thousands)[131]	Median age 2015[131]	Fertility rate 2010-2015[1]	Life expectancy at birth (years)[1]		% aged ≥60 2015[1]	% aged ≥60 2030[1]	Expected years of schooling 2017[136]	Mean years of schooling 2017[136]	Human Development Index (HDI) in 2017[136]
					Males	Females					
Bangladesh	Lower-middle 1470	161,201	25.6	2.2	69.9	72.3	7.0	11.5	11.4	5.8	0.608 (Medium)
Bhutan	Lower-middle 2660	787	26.3	2.1	68.6	69.1	7.4	11.6	12.3	3.1	0.612 (Medium)
DPR Korea	Not available	25,244	34.0	2.0	66.3	73.3	12.5	19.4	12.0	Not available	Not available
India	Lower-middle 1800	1,309,054	26.7	2.5	66.1	68.9	8.9	12.5	12.3	6.4	0.640 (Medium)
Indonesia	Lower-middle 3540	258,162	28.0	2.5	66.6	70.7	8.2	13.2	12.8	8.0	0.694 (Medium)
Maldives	Upper-middle 9760	418	27.9	2.2	75.4	77.4	6.8	11.7	12.6	6.3	0.717 (High)
Myanmar	Lower-middle 1210	52 404	27.7	2.3	63.6	67.7	8.9	13.2	10.0	4.9	0.578 (Medium)
Nepal	Low 800	28,656	23.2	2.3	67.6	70.5	8.6	10.8	12.2	4.9	0.574 (Medium)
Sri Lanka	Lower-middle 3850	20,714	32.3	2.1	71.2	78.0	13.9	21.0	13.9	10.9	0.770 (High)
Thailand	Upper-middle 5950	68,658	37.8	1.5	70.8	77.6	15.8	26.9	14.7	7.6	0.755 (High)
Timor-Leste	Lower-middle 1790	1,241	17.4	5.9	66.1	69.5	7.2	6.8	12.8	4.5	0.625 (Medium)

2.2.2.3 Population ageing in Sri Lanka

Sri Lanka's ageing population is a positive result of decades-long investment in education and in healthcare systems since the country's independence in 1948. Life expectancy at birth for males and females was 43.3 and 41.6 years respectively in 1946[140] while it has gradually increased up to 71 and 78 years respectively in 2015[1]. Increasing life expectancy and decreasing fertility rates have mainly contributed to the increasing proportion of older adults in the total population and this trend is expected to continue. As a result, Sri Lanka has become one of the fastest growing ageing populations in South-East Asia.[141] According to census data, the proportion of the population aged ≥60 years was 6.6% in 1981. It only took 31 years to double this figure to 12.4% in 2012.[140] It is expected that in two more decades (by 2041), one quarter of the population will be aged ≥60 years in Sri Lanka.[142] In contrast, population ageing in many high-income countries has happened gradually allowing them to tackle the consequences of this with continuing economic and social development. For instance, France took 115 years to double its proportion of population aged ≥65 years from 7.0% to 14.0%, followed by 85 years in Sweden.[143] Therefore, the same demographic transition that occurred in Western countries over at least one century is happening in two or three decades in many Asian countries.[3]

Currently the ageing of the Sri Lankan population is occurring at a lower level of economic development; economic growth during the last two decades has fluctuated and has been in a downward trend for the last five years.[144] This has

potential serious economic, health, and social repercussions at the individual, family and societal levels in near future. Hence, the multiple challenges associated with population ageing warrant immediate attention and response of many sectors and stakeholders in Sri Lanka.

2.2.2.4 Healthcare services for older adults

All Sri Lankan citizens have access to a publicly funded standard healthcare system. The institutions which provide curative care have been classified into three levels as primary, secondary, and tertiary primarily based on the available facilities. Primary medical care units only provide outpatient care, and divisional hospitals mainly provide inpatient and outpatient care with non-specialist doctors and allied staff. However, there are some divisional hospitals which provide specialist care conducted by visiting consultants through outreach clinics. Secondary (Base hospitals and District General hospitals) and tertiary (Provincial General hospitals and Teaching hospitals) care institutions provide both non-specialised and specialised care including main and sub specialties (some institutions only).[145, 146] However, geriatric medicine is not a sub specialty offered by Sri Lankan hospitals at present.

Public health services at field level are provided through health units commonly known as Medical Officer of Health (MOH) areas.[147] There are 341 MOH areas in Sri Lanka and the average population for a MOH area is approximately 60,000. Each MOH area is headed by a medical officer and supported by field staff. Each member of the supporting staff: Public Health Nursing Sister, Public Health

Inspectors, Supervising Public Health Midwife, and Public Health Midwives is also responsible for a subdivided area of an MOH. The main services provided through MOH areas include maternal and child health, screening for noncommunicable diseases, school health inspections, implementation of the Food Act, monitoring water quality and sanitation, and health promotion activities.[147]

To date, there are no specific health services provided for older adults or those with frailty. The majority of older adults are treated in the standard public curative care system. However, most of the patients treated in these specialist health services (e.g. cancer care, eye care, cardiology, etc.) are older adults.[145] Similarly no public health services are available for older adults at field level. Therefore, the health problems of older adults are likely to be under-recognised in our health system.[148] Likewise, many of the health issues in older age have been under researched and there is a paucity of epidemiological data.[148]

2.2.2.5 Social care services for older adults

The enactment of 'Protection of the Rights of Elders Act'[149] in 2000 led to the establishment of the National Council for Elders, a National Secretariat for Elders, a National Fund for Elders, and a Maintenance Board for Elders. The National Council of Elders represents the social, health, finance, voluntary, and non-government sectors and promotes and protects the welfare and rights of older adults in Sri Lanka.[145] Subsequently in 2006, the National Charter for Senior Citizens and National Policy for Senior Citizens Sri Lanka were formed.[150]

The activities conducted by the National Council for Elders include conducting island- wide awareness programmes for legal empowerment of older adults and to create general awareness of the challenges of population ageing, conducting pre-retirement seminars for public sector employees on a healthy and active life, provision of financial assistance for setting up day-care centres for older adults, training for the carers of older adults, provision of well-trained home care workers for a charge (for a fee), providing a 24- hour online psychological counselling service and weekly counselling sessions, a free legal advice service, a financial assistance programme for older adults who do not have any income, support for income generating activities, provision of eye lenses and assistive devices for older adults with disabilities, issuing special identity cards for older adults to get preferential treatment when obtaining public services from hospitals, post-offices, banks, and other public institutions, and published standards for homes for the aged.[151] However, some of these services are not very well known to the public. Also, each divisional secretariat area has an officer working on social services overseeing elderly care related matters. However, thus far, caring for older adults in Sri Lanka remains a prime responsibility of the family members- mainly children.

2.2.3 The epidemiology of frailty in Sri Lanka

I found only one potentially relevant study on the epidemiology of frailty from Sri Lanka[152] before commencement of my PhD. This study was conducted in 1989 and had used the older conceptualisation of frailty as a more indistinct concept that overlapped with disability.[152] The findings are therefore not directly comparable to other more recent methods as described in Section 1.2.4 in Chapter 1 (page 44) earlier. However, the prevalence of 'functional frailty' among older adults measured with limitations in IADL, BADL, physical strength items, and emotional limitations in Sri Lanka was reported as 19.9% in this study.[152] When designing this PhD during 2015 to 2016, other than the aforementioned study, there was no research available in Sri Lanka on frailty employing one of the two main approaches used to conceptualise frailty (Section 1.2.2, page 37) or a commonly agreed conceptual definition of frailty[50]. Understanding the epidemiology of frailty (prevalence and factors associated with frailty) in Sri Lanka is therefore an absolute need in the context of country's rapidly ageing population.

2.2.4 The association of frailty with disability in Sri Lanka

Disability is an adverse outcome of frailty according to the Fried conceptualisation of frailty.[107] The International Classification of Functioning, Disability and Health defines disability as difficulties faced in any or all three areas of functioning: impairments (problems in body function and structure), activity limitations (difficulties an individual has in executing activities), and participation restrictions (problems an individual may experience in involvement of life situations).[153] Frailty has been conceptualised as a distinct concept from disability[50] although they often overlap with each other.[30] Many people with frailty also have disability.[154] Similarly there are many people with a long term disability who do not have frailty.[154] Frailty is also recognised as a cause of incident and worsening disability in community-dwelling older adults.[10, 107]

There were few studies in the literature estimating the prevalence of disability in depth (e.g. prevalence of specific IADL and BADL limitations) among frail, pre-frail, and non-frail community-dwelling older adults. These studies were from Canada, England, and Egypt[155-157] and to the best of my knowledge, there are no studies estimating the prevalence of frailty and disability simultaneously and investigating the association between frailty and disability in Sri Lanka or WHO South-East Asia. The development of disability is a complex process that involves biological and disease conditions that are integrated into the social and environmental context.[158] Thus, the strength of the association between frailty and disability could be influenced by these context specific factors such as education level,

socioeconomic status, ethnicity, lifestyle factors, and cultural context that shapes all the aforementioned factors. Given this heterogeneity, it is not possible to extrapolate the findings from one region or country to other settings. In this context, understanding the association between frailty and disability among Sri Lankan community-dwelling older adults is important. In addition, this will provide better understanding of the IADL and BADL limitations prevalent amongst this population and help to understand to some extent potential caregiver burden in older populations in WHO South-East Asia.

2.2.5 The association of frailty with quality of life in Sri Lanka

Frailty has been shown to increase the risk of several detrimental health outcomes.[107] These poor outcomes along with physical, psychological, and social risk factors associated with frailty[159] could have negative impacts on the quality of life (QoL) of older adults. Alternatively, experiencing poor QoL for long periods could also lead to frailty.[160] Therefore, there could be a bidirectional association between frailty and QoL. Besides, QoL is particularly important in the context of frailty as it is associated with several adverse outcomes and many interventions are being tested currently to prevent or slow down the progression of frailty.

A systematic review and meta-analysis has demonstrated a consistent inverse association between frailty, pre-frailty, and health-related quality of life (HRQoL).[106] However, these studies have been limited to high-income countries such as Italy[161], Taiwan[162, 163], and USA[164]. I found only one study from upper middle-income countries (Mexico)[165] and no studies were found from low-income or lower middle- income countries. The concepts of QoL and HRQoL are often used interchangeably.[166] However, QoL is a broad multidimensional construct[167] whereas HRQoL focuses more on the aspects of quality of life that are influenced by one's health status directly, excluding non-health dimensions such as home and neighbourhoods, and financial circumstances. It is widely accepted that the construct of QoL is strongly influenced by culture.[168] Hence, cross-cultural differences of quality of life may exist. Therefore, QoL measures inform the needs

of populations, resource allocation, and development of new policies in different social and cultural contexts.[169]

Sri Lanka is a multi-ethnic, multi-cultural, and multi-faith country which has a deeply rooted culture of caring for older adults predominantly shaped by Buddhist principles and values. The majority of older Sri Lankan adults are supported within extended family networks.[170] However, along with the urbanisation, migration, and changing family structure, these cultural norms are gradually changing.[171] Furthermore, Sri Lanka's noncommunicable disease burden is rising along with a rapidly ageing population.[142, 172] The prevalence of depression among older adults in Sri Lanka is reported to be higher relative to other Asian countries like China, Japan, South Korea, Malaysia, and Taiwan.[173] Hence, these context-specific micro, meso, and macro level factors could be positively or negatively contributing to the QoL of frail older adults. Two recent studies from Sri Lanka reported moderate levels of QoL[174] and poor levels of HRQoL[175] among community-dwelling older adults. To date, no studies have examined the association between frailty and QoL in WHO South-East Asia region and in low income or lower middle-income countries more generally. Understanding the association between frailty and QoL will inform policy on service delivery to meet the needs of frail older adults in order to improve QoL.

2.2.6 Summary

It is clear that population-based epidemiological studies are scarce, and there is limited research on the different aspects of frailty in the Sri Lankan older population as well as in low-income and middle-income Asian populations in general. This PhD has important public health implications as this is the first attempt towards understanding the epidemiology of frailty and associated adverse health outcomes in Sri Lanka.

2.3 Thesis objectives

This PhD thesis is comprised of two main parts. The overall and specific objectives of each part are stated below.

2.3.1 Part A: a systematic review and meta-analysis

To conduct a systematic review and meta-analysis on prevalence of frailty and pre-frailty among community-dwelling older adults in low-and middle-income countries (LMICs).

The specific objectives in Part A include;

i. To systematically review the research conducted on prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs.

ii. To estimate the pooled prevalence of frailty and pre-frailty in community-dwelling older adults in LMICs.

iii. To estimate the pooled prevalence of frailty and pre-frailty in LMICs by frailty assessment method, geographic region, sex, age, and 'age-and sex'.

iv. To compare the pooled prevalence of frailty and pre-frailty in middle-income countries with high-income countries.

2.3.2 Part B: a population-based cross-sectional study

To describe the epidemiology of frailty and its association with disability and quality of life among rural community-dwelling older adults in Kegalle district of Sri Lanka.

The specific objectives of Part B include; with a representative sample of rural community-dwelling older adults in Kegalle district of Sri Lanka:

i. To describe the epidemiology of frailty

ii. To evaluate the cross-sectional association of frailty with disability

iii. To evaluate the cross-sectional association of frailty with total and domain-specific quality of life

Despite increasing research on different aspects of frailty, evidence gaps still remain. Frailty research is disproportionately concentrated in high-income countries and it is an extremely under researched area in the rest of the world where the majority of the world's population live. Therefore, it is crucial to understand the epidemiology of frailty in different parts of the world in order to develop and implement efficient and effective context specific interventions for the prevention and management of frailty.

Chapter 3: Systematic review and meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in low-and middle-income countries (LMICs)

3.1 Chapter overview

This chapter presents an introduction, methodology, and findings of the systematic review and meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs, and a discussion including a summary of the main findings and presents review's findings relating to existing literature. This work has been published as a peer-reviewed journal article by Siriwardhana et al in BMJ Open journal in 2018.[176]

3.2 Introduction

A systematic review conducted in 2012 reported that the prevalence of frailty among community-dwelling older adults living in high-income countries (HICs) ranged from 4.0% to 59.1% using different frailty assessment methods.[133] The majority of the studies were from North America (n=11) followed by Europe (n=7), Oceania (n=2), and Asia (n=1).[133] The overall weighted prevalence of frailty in this review was 10.7% and pre-frailty was 41.6%.[133] A cross-country survey conducted in 10 European countries using the Fried phenotype reported an overall prevalence of frailty and pre-frailty as 17.0% and 42.3% respectively; between country differences in frailty prevalence were observed; the highest and lowest prevalences were reported from Spain (27.3%) and Switzerland (5.8%) respectively.[177] A higher prevalence of frailty was observed in Southern European countries within this study (Spain, Italy, France, and Greece). A meta-analysis comprised of studies conducted in Japan (n=5) reported relatively lower pooled prevalence of frailty and pre-frailty estimates using the Fried phenotype (7.4% and 48.1% respectively).[178] In contrast to the systematic review conducted in HICs and the European multi-country survey mentioned above, studies included in the Japanese review reported a narrower range in prevalence from 4.6% to 9.5%.[178] It is also of note that the aforementioned three studies were based on community-dwelling older adults aged ≥65 years.

These cross-country differences in frailty prevalence could be partially explained by differences in socioeconomic contexts. A cross-sectional analysis of the

Women's Health and Aging Studies reported increased odds of frailty for those of low socioeconomic status even after adjusting for age, ethnicity, chronic disease, insurance status, and smoking status.[179] Similarly, there is some suggestion of a socioeconomic gradient in frailty between HICs in Europe; one study including 15 European countries reported a lower mean frailty index in North and Western Europe compared to lower income countries in Southern and Eastern Europe.[180] It has also been found that the survival of frail older adults was higher in countries with a higher relative income within Europe.[180] It is possible that the prevalence of frailty in low-and middle-income countries (LMICs) is higher than HICs, given a steeper gradient in income. Alternatively the prevalence may be lower in older adults living in LMICs with reduced average life expectancies as prevalence of frailty increases with age.[133] A narrative review published in 2015 on frailty in low- and middle-income (developing) countries found limited availability of studies and suggested that frailty occurs more frequently in developing countries.[132] However, no studies were available when designing the present systematic review collating all the epidemiological findings available from LMICs to describe the burden of frailty in these countries. This is important to inform healthcare planning in these countries in the context of world-wide population ageing.

3.3 Objectives

The overall and specific objectives addressed in this chapter are as follows:

Overall objective

To conduct a systematic review and meta-analysis on prevalence of frailty and pre-frailty among community-dwelling older adults in low-and middle-income countries (LMICs).

Specific objectives

i. To systematically review the research conducted on prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs.

ii. To estimate the pooled prevalence of frailty and pre-frailty in community-dwelling older adults in LMICs.

iii. To estimate the pooled prevalence of frailty and pre-frailty in LMICs by frailty assessment method, geographic region, sex, age, and 'age-and sex'.

iv. To compare the pooled prevalence of frailty and pre-frailty in middle-income countries with high-income countries.

3.4 Methodology

The review protocol was registered in PROSPERO (International prospective register of systematic reviews: number CRD42016036083). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed when reporting the present review.[181]

3.4.1 Search Strategy for identifying relevant studies

A four step search strategy was conducted. Initially a scoping search was performed in MEDLINE using OvidSP interface and CINAHL to identify potential key words used in titles, abstracts, and subject headings to index the articles. At the second step a comprehensive structured search was performed in six electronic bibliographic databases. MEDLINE, EMBASE, and AMED databases using OvidSP interface, Web of Science Core Collection, CINAHL Plus databases, and WHO Global Health Library were searched from their inception to 12 September 2017. Two concepts: 'frailty' and 'LMICs' were used to develop the electronic search strategy. The example LMIC filters developed by Cochrane organisation in 2012 were used with slight modifications.[182] The World Bank country classification issued on 1 July 2017[183] which is based on 2016 economic data was used to identify the countries that switched from LMICs to HICs in 2017 or vice versa. Studies in these countries were included only if the country belonged to the low-and middle-income category during the time of data collection. The electronic search strategy was first developed for MEDLINE and then adapted accordingly for other databases with the support of a specialist

librarian. The electronic search strategy used for MEDLINE database is attached in Appendix 1 (page 403). In the third stage, reference lists of the selected articles were scanned to identify additional articles that were not recognised in step two. At the fourth step, citation searches were performed in the Web of Science. The search was limited to full-text articles as study quality assessment requires a detailed description of the study methodology. No language restriction was imposed on the search.

3.4.2 Eligibility criteria

3.4.2.1 Condition studied

The condition studied was frailty assessed by any frailty assessment method developed following the introduction of biological and deficit driven approaches of frailty.

3.4.2.2 Study population

The review was restricted to studies recruiting community-dwelling older adults aged ≥60 years living in the LMICs. This age cut-off is in line with the UN definition of older populations.[184] Studies with institutionalised or hospitalised older adults, nursing home residents, outpatients of primary or secondary care clinics, or older adults belonging to specific disease groups (e.g. chronic kidney disease, type II diabetes, and osteoarthritis), and specific populations (e.g. navy veterans) were excluded.

3.4.2.3 Types of studies included

Cross-sectional studies conducted to assess the prevalence and associated factors of frailty, prospective follow-up studies that have baseline prevalence of frailty, and cross-sectional studies conducted to explore the association of frailty with some other health variable(s) or disease(s) (e.g. haemoglobin level and cardio vascular risk factors) were included in the present review.

3.4.3 Study selection

All the identified citations were exported into EndNote X8 and duplicates were removed. The auto-deduplication function and hand searching were used to remove the duplicates. In the first stage, the title and abstract of the citations were screened against inclusion and exclusion criteria to identify potentially eligible citations. In the second stage, full-texts of potentially eligible articles were retrieved. Two reviewers independently reviewed the full-text articles to identify the articles meeting eligibility criteria (myself and a senior research fellow (SH)). If multiple studies were available from the same cohort, the study with the largest sample and most information was included in the review. Disagreement between the reviewers was resolved through discussions and consulting other supervisors in the supervisory panel (KW, GR, and MCW).

3.4.4 Assessment of methodological quality of the studies

Selected articles were subjected to a quality assessment. Methodological rigour of the articles was assessed using eight criteria proposed by Loney et al[185] for the

critical appraisal of prevalence literature. It includes: (i) studying a random sample or whole population; (ii) use of an unbiased sampling frame (i. e. census); (iii) having an adequate sample size (>300 subjects); (iv) use of standard measures; (v) outcomes measured by unbiased assessors; (vi) having an adequate response rate (70.0%), and description of those who refused to participate; (vii) reporting confidence intervals, and subgroup analysis; and (viii) description of study participants. Criteria (vi) and (vii) are comprised of two sub-criteria. Hence, 0.5 was allocated to each sub-criterion. Other criteria were weighted equally giving one point and the maximum total was eight points. If a study achieved three criteria or less (low study quality) it was excluded from the review.

3.4.5 Data extraction

Data from the studies were extracted using a piloted electronic data extraction form developed in Microsoft Excel 2013. Extracted data included information on study background (authors and year of publication, data source, study setting, and study period); characteristics of the population (percentage of females in the study sample, mean age, age range, and number of frail and pre-frail participants in the total sample and by age-and-sex); study methodology (study design, effective sample, sampling technique, and frailty assessment method); and study strengths and limitations. I (primary reviewer) assessed the study quality of all selected articles and extracted data from all the articles that passed the methodological quality assessment. The second reviewer (SH) assessed the study quality of a random 10.0% of articles and extracted data from a random 10.0% of

articles eligible to be included in the review. Discrepancies were checked across both reviewers. Corresponding authors of the studies were contacted requesting additional data required for subgroup analysis.

3.4.6 Data synthesis and statistical analyses

Inter-rater agreement between the reviewers during the study selection process was assessed using the Cohen's Kappa coefficient.[186] The PRISMA study flow diagram was used to visualise each stage of the study selection process. Results of the study quality assessment were summarised in a table and described using range, mean, and the standard deviation (SD). The results of the systematic review were presented in tabular format and narratively synthesised. All statistical analyses were performed in Stata version 14 (StataCorp, College Station, Texas, USA).

3.4.6.1 Meta-analysis of prevalence of frailty and pre-frailty

A random-effects meta-analysis with 95% confidence interval (95% CI) was performed to calculate the pooled prevalence of frailty and pre-frailty. A random-effects model was chosen as there is variation in the true prevalence from one study to another. Besides this there was considerable heterogeneity of the study characteristics including recruitment age, frailty assessment method, frailty cut-offs, and geography. When a study had used multiple assessment methods for frailty, the prevalence presented using the Fried phenotype was used for the meta-analysis as it was the most commonly used frailty assessment method in the

literature.[81] The analysis was performed on Freeman-Tukey double arcsine transformed proportions to stabilise the variance.[187] Results were presented using forest plots. The main meta-analysis and subgroup analysis excluded three studies, two studies with minimum recruitment age of ≥80 years and another study with minimum recruitment age ≥90 years (due to their expected higher prevalence rates for frailty). The findings from these studies were reported separately.

Cochran's Q statistic was used to assess heterogeneity between the studies. $p<0.05$ was considered as evidence of heterogeneity. The I^2 statistic was further used to quantify the magnitude of the heterogeneity. I^2 values of 25.0%, 50.0%, and 75.0% were considered as being of low, moderate, and high heterogeneity respectively.[188] Funnel plots were used to visually inspect the existence of reporting biases and/or between study heterogeneity. In the absence of biases and/or between study heterogeneity, funnel plots typically resemble a symmetrical inverted funnel shape.[189] However, this eye ball test is subjective. Hence, I used Egger's weighted regression test to measure the degree of funnel plot asymmetry. The null hypothesis for Egger's test is that symmetry exists in the funnel plot.[190, 191]

3.4.6.2 Subgroup analyses

The prevalence of frailty status is dependent on the frailty assessment method used. Cross-country studies have also reported differences of frailty prevalence estimates within the same geographic region.[177, 180] The prevalence of frailty is

typically higher among females compared with males, and increases with advancing age.[133] Socioeconomic status and a country's income level are also typically associated with frailty status.[179, 180] Thus, performing a series of subgroup analyses according to these characteristics was decided a priori.

The frailty assessment methods considered in the subgroup analysis were: (i) Fried phenotype with five components where weakness and slowness were assessed objectively using grip strength and gait speed respectively, (ii) Fried phenotype with five components where weakness and slowness were assessed using self-reported questions (subjective), (iii) Fried phenotype with four components, (iv) Edmonton Frail Scale (EFS), (v) Frailty Index, and (vi) FRAIL scale. If the same cohort of participants had been assessed using different frailty assessment methods, that information was used in this subgroup analysis. Studies that used different frailty assessment methods to those mentioned above were excluded from the subgroup analysis as they could not be grouped into a particular category (e.g. Study of Osteoporotic Fractures (SOF) frailty index, Cuban frailty criteria, and Brief Frailty instrument for Tanzania (B-FIT)). Subgroup analysis by geographic region: Latin America and the Caribbean, and Asia was also performed. Two studies, one from Russia and the other from Tanzania, were excluded from the analysis as they do not belong to the aforementioned geographic regions. Further subgroup analyses were performed using the following grouping variables: sex, age group (60-64, 65-69, 70-74, 75-79, 80-84, and ≥85 years) and 'age-and sex'. This analysis was limited to studies which had

employed the Fried phenotype with five components where weakness and slowness were assessed using objective tests. A two sample proportion test was used to compare the prevalence of frailty and pre-frailty by sex.

3.4.6.3 Comparison of the pooled prevalence of frailty and pre-frailty of middle-income countries with HICs

For this analysis published data from a systematic review on prevalence of frailty which includes HICs only was used.[133] Of the included studies, 14 had used the Fried phenotype frailty assessment method. The random-effects pooled prevalence of frailty and pre-frailty was calculated only with the studies that had used the Fried phenotype-weakness and slowness assessed using objective tests (10 studies [10, 84, 192-199]). The minimum recruitment age of the participants included in this review was 65 years. For a fair comparison with HIC studies, random-effects pooled prevalence of frailty and pre-frailty was estimated only with the studies of minimum recruitment age 65 years that had used the same assessment method in the present review (13 studies). Except for one study from India (lower middle-income country) all the other studies were from upper middle-income countries. Therefore, the random-effects pooled prevalence of frailty and pre-frailty was calculated both including and excluding the Indian study from the analysis. A two-sample proportion test was performed to compare the prevalence rates of HICs and middle-income countries.

3.4.6.4 Meta-regression

Random-effects univariable and multivariable meta-regression were performed to identify the potential sources of heterogeneity: demographic, geographical, and methodological differences between the studies.[200] Three studies which used SOF frailty index, Cuban frailty criteria, and B-FIT were excluded from the analysis. The following explanatory variables were included in the models: mean age; percentage of females in the study sample; study quality assessment score; World Bank region classification (Latin America and the Caribbean, East Asia and Pacific, Europe and Central Asia, and South Asia); and frailty assessment method (Fried phenotype with five components where weakness and slowness assessed objectively using grip strength and gait speed respectively, Fried phenotype with five components where weakness and slowness assessed using self-reported questions (subjective), Fried phenotype assessed with only with four of the five components, Edmonton Frail Scale (EFS), and frailty index). All the variables were included in the multivariable model irrespective of their significance (p value) in the univariable analysis.

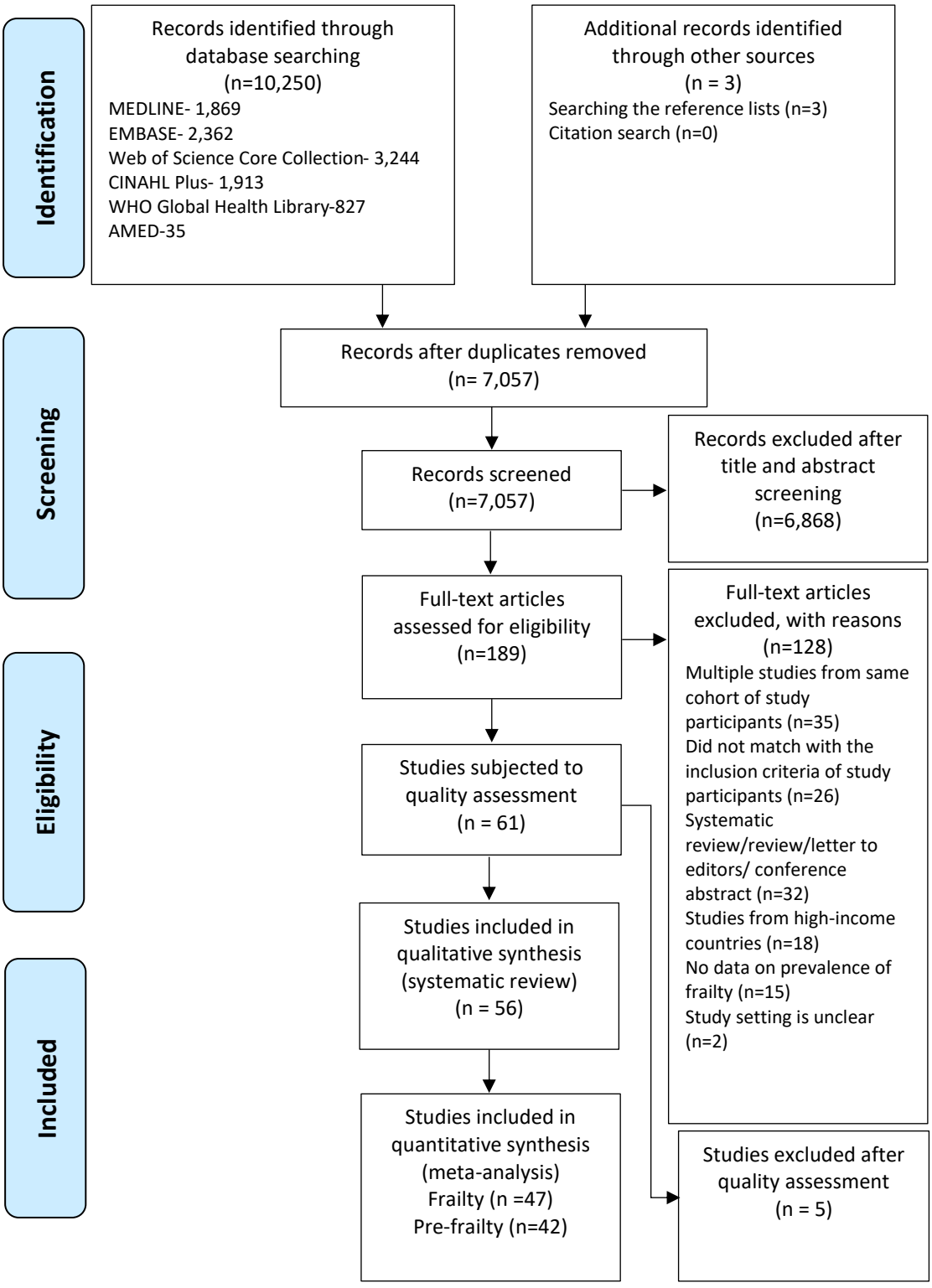
3.5 Results

3.5.1 Results of the systematic review

3.5.1.1 Study selection

The search yielded 10,253 records, with 7,057 records left after removing duplicates. Fifty six studies meeting all eligibility criteria were included in the present systematic review (Figure 3.1, page 107). 47 and 42 studies were included in the meta-analysis of frailty and pre-frailty respectively. The agreement between the two raters at the study selection stage was high with a kappa value of 0.84 (95% CI: 0.72, 0.90).

Figure 3.1 PRISMA flow diagram for study selection



Note: Figure was taken from a published paper by Siriwardhana et al[176].

3.5.1.2 Study quality assessment

The study quality assessment score of the studies included in the review ranged from 3.5 to 7.5, with a mean (SD) score of 6.0 (1.1). Quality assessment results of the studies are presented in Appendix 2 (page 406).

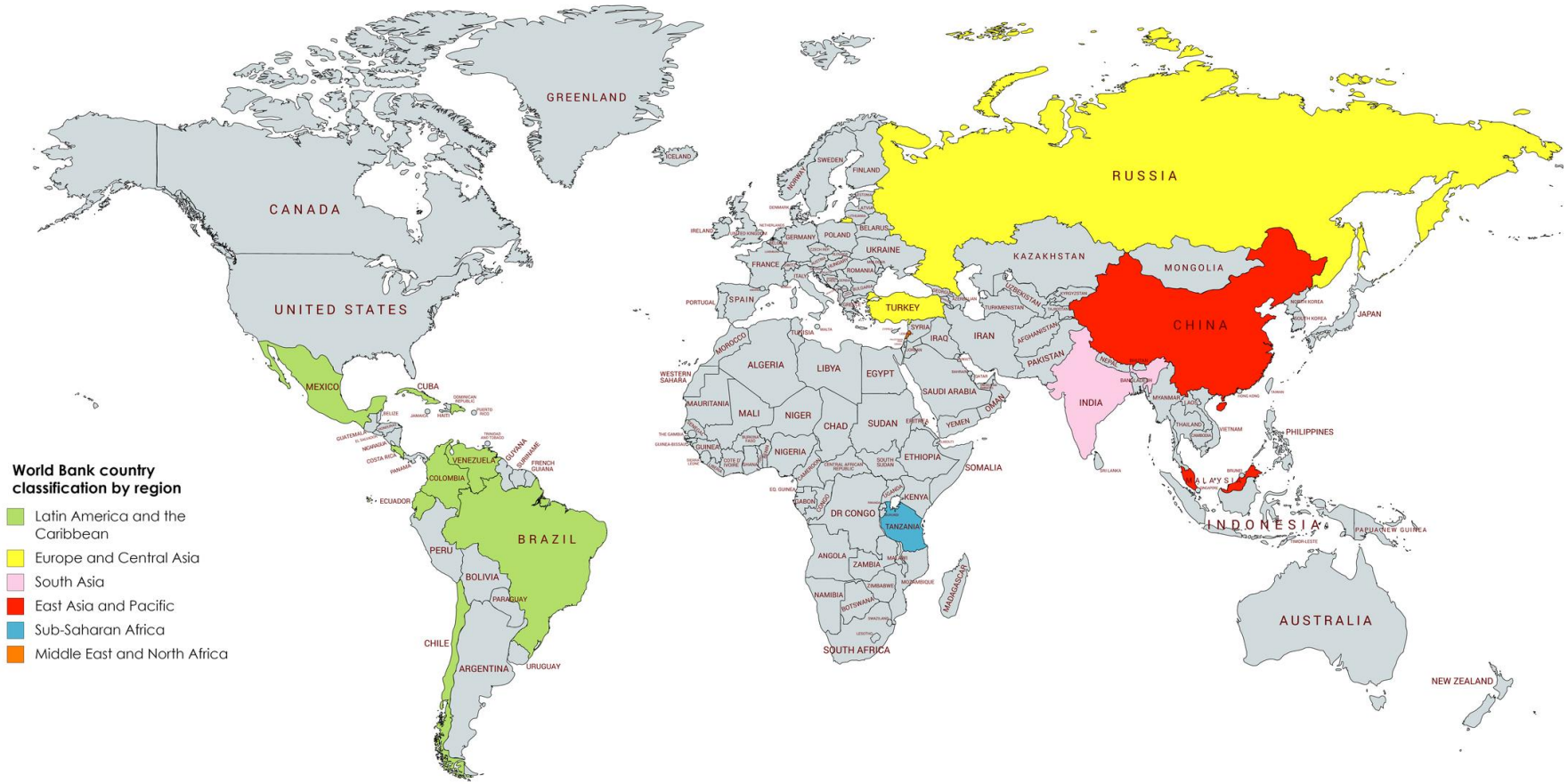
3.5.1.3 Study characteristics

The characteristics of studies included in the systematic review (n=56) are described in the table in Appendix 3 (page 409). The oldest research study was published in 2008. Fifty studies have been published between 2012 and 2017. The majority of the studies were from the Latin America and the Caribbean region, predominantly from Brazil (Table 3.1, page 109). Geographical distribution of the studies included the present systematic review according to World Bank country classification by region is visualised in a world map in Figure 3.2 (page 110).

Table 3.1 Geographic distribution of the studies included in the present systematic review according to World Bank country classification by region

World Bank country classification	Country	Number of studies
Latin America and the Caribbean		
	Brazil	24
	Mexico	9
	Colombia	3
	Costa-Rica	1
	Cuba	1
	Ecuador	1
	Multi-country study (Barbados, Brazil, Chile, Cuba, and Mexico)	1
East Asia and Pacific		
	China	8
	Malaysia	2
Europe and Central Asia		
	Russian Federation	1
	Turkey	1
Middle East and North Africa		
	Lebanon	1
South Asia		
	India	1
Sub-Saharan Africa		
	Tanzania	1
Multi-country study		
	Cuba, Dominican Republic, Mexico, Peru, Venezuela, China, and India	1

Figure 3.2 Geographic distribution of the studies included in the present systematic review according to World Bank country classification by region



Note: Map was created with mapchart.net©

Most of the studies had used data from large population-based cross-sectional or longitudinal studies on ageing. The most commonly used studies were Network Studies on the Frailty of Elderly Brazilians (REDE FIBRA): a multi-centre study encompassing 17 Brazilian cities with different human development levels; Health, Wellbeing and Ageing (SABE): a multi-centre cross-sectional study conducted in seven Latin American and Caribbean cities; Mexican Health and Aging Study (MHAS): Mexican study of Nutritional and Psychosocial Markers of Frailty; Study on Aging and Dementia in Mexico (SADEM); Chinese Longitudinal Health and Longevity Study (CLHLS). The present review has also included the results of different waves of SABE (Sao Paulo, Brazil) and MHAS.

Five studies did not mention the sampling technique used to select the study participants. Two studies used non-probability sampling where all the other studies used probability sampling or census. Two studies were based on nationally representative samples from Mexico and China. The sample size of the studies varied (range 54 to 12,373) and the minimum recruitment age of the study participants varied from 60 to 90 years. The minimum age at recruitment of the study participants was 60 years in 30 studies, 65 years in 19 studies, 70 years in 4 studies, 80 years in 2 studies, and 90 years in one study. Fifty two studies reported the percentage of females in the study samples and this varied from 48.1% to 100.0%, with more than half of participants being females in all except three studies. Of 56 studies, 42 reported the mean age of the participants, which ranged

from 68.2 to 77.2 years. This excludes three studies with minimum recruitment age ≥80 years (two studies) and ≥90 years (one study).

Studies used various frailty assessment methods. The Fried phenotype was the most extensively used method. However, researchers had operationalised the Fried phenotype differently. Three broad categories were identified based on the number of phenotypic components used and measures used to operationalise those components. Thirty studies used Fried phenotype with five components-weakness and slowness assessed using objective tests. Three studies used Fried phenotype with five components-weakness and slowness assessed using self-reported questions (subjective), and another two studies used Fried phenotype assessed with only with four of the five components. The other assessment methods included the Edmonton Frail Scale (EFS) (n=6), Frailty Index (n=6), Brief Frailty Instrument for Tanzania: B-FIT (n=1), Cuban frailty criteria (n=1), five physical tests (n=1), FRAIL scale (n=1), and SOF frailty index (n=1). Four used multiple assessment methods. For more details please refer to table in Appendix 3 (page 409).

3.5.1.4 Prevalence of frailty and pre-frailty

Irrespective of the frailty assessment method, the prevalence of frailty varied from 3.9% in China (Fried phenotype with five components-weakness and slowness assessed using objective tests) to 51.4% in Cuba (Cuban frailty criteria). The prevalence of pre-frailty ranged from 13.4% in Tanzania (B-FIT) to 71.6% in Brazil (Fried phenotype with five components-weakness and slowness measured

objectively) for the studies with minimum recruitment age 60 years, 65 years, and 70 years. A study with participants aged ≥80 years did not report a cut-off value for the frailty index to define frail participants. Instead, the authors reported six levels based on the value of the frailty index and the percentage of participants belonging to each level. The other study with participants aged ≥80 years reported 14.8% and 63.8% of participants as frail and pre-frail respectively using Fried phenotype with five components-weakness and slowness assessed using objective tests. There was one study with participants aged ≥90 years, reporting 61.8% participants as frail using the frailty index (the % of pre-frail was not reported). When restricting to the studies that used Fried phenotype with five components-weakness and slowness assessed objectively, the prevalence of frailty varied from 3.9% in China to 26.0% in India. The prevalence of pre-frailty varied from 40.7% to 71.6% in Brazil. Please refer to table in Appendix 3 (page 409) for more information.

3.5.2 Results of the meta-analysis

3.5.2.1 Study characteristics

Descriptions of studies included in the meta-analysis are presented in Table 3.2 (page 115). Of 56 studies included in the systematic review, 47 were included in the meta-analysis. The majority of the studies were from the Latin America and Caribbean region (n=32) followed by East Asia and Pacific (n=8), Europe and Central Asia (n=2), and one study each from the Middle-East and North Africa, South Asia, and Sub-Saharan Africa. Only one study was from a low-income country (Tanzania). Two prevalence estimates were available from a lower middle-income country (India). All the other studies were from upper middle-income countries. The minimum study recruitment age was 60, 65, and 70 years in 25, 18, and 4 studies respectively. Four studies did not mention the sampling technique used to select the study participants. Two studies used non-probability sampling whilst all the other studies used probability sampling or census. Twenty eight studies used Fried phenotype with five components-weakness and slowness assessed using objective tests. Three studies used Fried phenotype with five components-weakness and slowness assessed using self-reported questions (subjective) and another three studies with Fried phenotype only with four components. Other frailty assessment methods used by the studies include EFS (n=6), frailty index (n=3), B-FIT (n=1), Cuban frailty criteria (n=1), and SOF frailty index (n=1).

Table 3.2 Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Tribess et al, 2012[201]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	622	19.9	49.8
Júnior et al, 2014[202]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	286	23.8	58.7
Pegorari et al, 2014[203]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	958	12.8	54.5
Santos et al, 2015[204]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	136	16.9	61.8
Closs et al, 2016[205]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	521	21.5	51.1
Mello et al, 2017[206]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	137	12.4	61.3
de Albuquerque Sousa et al, 2012[207]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	391	17.1	60.1
dos Santos Amaral et al, 2013[208]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	295	18.6	55.3
Moreira et al, 2013[209]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	754	9.5	47.5

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Neri et al, 2013[210] (Belem)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	720	10.8	48.2
Neri et al, 2013[210] (Parnaiba)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	431	9.7	55.5
Neri et al, 2013[210] (Campina Grande)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	395	8.9	51.4
Neri et al, 2013[210] (Pocos de Caldas)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	388	9.3	53.4
Neri et al, 2013[210] (Ermelino Matarazzo)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	384	8.1	54.9
Neri et al, 2013[210] (Campinas)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	898	7.7	52.2
Neri et al, 2013[210] (Ivoti)	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	197	8.6	47.7
Vieira et al, 2013[211]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	601	8.7	46.3
Ricci et al, 2014[212]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	761	9.7	48.0

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Silveira et al, 2015[213]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	54	11.1	46.2
Calado et al, 2016[214]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	385	9.1	49.6
Augusti et al, 2017[215]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	306	21.5	71.6
Ferriolli et al, 2017[216] **(Recife)**	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	556	12.1	66.9
Ferriolli et al, 2017[216] **(Juiz de Fora)**	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	412	15.5	63.1
Ferriolli et al, 2017[216] **(Fortaleza)**	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype*	481	10.4	63.6
Ocampo-Chaparro et al, 2013[217]	Colombia	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	314	12.7	71.3
Curcio et al, 2014[218]	Colombia	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	1,878	12.2	53.0
Samper-Ternent et al, 2016[219]	Colombia	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	1,442	9.4	52.4

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Sánchez-García et al, 2017[220]	Mexico	Latin America and the Caribbean	Upper middle income	≥ 60	Fried phenotype*	1,252	11.2	50.3
Moreno-Tamayo et al, 2017[221]	Mexico	Latin America and the Caribbean	Upper middle income	≥ 70	Fried phenotype*	657	11.9	51.9
Chen et al, 2015[222]	China	East Asia and Pacific	Upper middle income	≥ 60	Fried phenotype*	604	12.7	56.5
Wu et al, 2017[223]	China	East Asia and Pacific	Upper middle income	≥ 60	Fried phenotype*	5,290	6.3	51.3
Dong et al, 2017[224]	China	East Asia and Pacific	Upper middle income	≥ 60	Fried phenotype*	1,188	3.9	45.9
Wang et al, 2015[225]	China	East Asia and Pacific	Upper middle income	≥ 65	Fried phenotype*	316	14.2	49.1
Badrasawi et al, 2017[226]	Malaysia	East Asia and Pacific	Upper middle income	≥ 60	Fried phenotype*	473	8.9	61.7
Kashikar et al, 2016[227]	India	South Asia	Lower middle income	≥ 65	Fried phenotype*	250	26.0	63.6
Gurina et al, 2011[65]	Russia	Europe and Central Asia	Upper middle income	≥ 65	Fried phenotype*	611	21.1	63.0

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Alvarado et al, 2008[228] (SABE wave 1)	Barbados	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1,446	26.7	54.4
Alvarado et al, 2008[228] (SABE wave 1)	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1,879	40.6	48.8
Alvarado et al, 2008[228] (SABE wave 1)	Chile	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1,220	42.6	51.4
Alvarado et al, 2008[228] (SABE wave 1)	Cuba	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1,726	39.0	51.6
Alvarado et al, 2008[228] (SABE wave 1)	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1,063	39.5	49.0
Aguilar-Navarro et al, 2015[229] (MHAS wave 1)	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	5,644	37.2	51.3
Avila-Funes et al, 2016[230]	Mexico	Latin America and the Caribbean	Upper middle income	≥70	Fried phenotype†	927	14.1	37.3
Sanchez-Garcia et al, 2014[231]	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype‡	1,933	15.7	33.3

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Akin et al, 2015[66] (KEHES)	Turkey	Europe and Central Asia	Upper middle income	≥60	Fried phenotype‡	848	27.8	34.8
Zhu et al, 2016[232]	China	East Asia and Pacific	Upper middle income	≥ 70	Fried phenotype‡	1,478	12.0	42.9
Jotheeswaran et al, 2015[67]	China (Urban)	East Asia and Pacific	Upper middle income	≥ 65	Fried phenotype‡	989	7.8	-
Jotheeswaran et al, 2015[67]	China (Rural)	East Asia and Pacific	Upper middle income	≥ 65	Fried phenotype‡	1,002	8.7	-
Jotheeswaran et al, 2015[67]	Cuba (Urban)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	2,637	21.0	-
Jotheeswaran et al, 2015[67]	Dominican Republic (Urban)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	1,706	34.6	-
Jotheeswaran et al, 2015[67]	India (Urban)	South Asia	Lower middle income	≥ 65	Fried phenotype‡	748	11.4	-
Jotheeswaran et al, 2015[67]	Mexico (Urban)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	909	10.1	-
Jotheeswaran et al, 2015[67]	Mexico (Rural)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	933	8.5	-

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Jotheeswaran et al, 2015[67]	Peru (Urban)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	1,245	25.9	-
Jotheeswaran et al, 2015[67]	Peru (Rural)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	507	17.2	-
Jotheeswaran et al, 2015[67]	Venezuela (Urban)	Latin America and the Caribbean	Upper middle income	≥ 65	Fried phenotype‡	1,697	11.0	-
Fhon et al, 2012[233]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	240	39.2	24.6
Agreli et al, 2013[234]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	103	30.1	22.3
Duarte et al, 2013[235]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	166	39.2	21.7
Del Brutto et al, 2016[236]	Ecuador	Latin America and the Caribbean	Upper middle income	≥60	EFS	298	31.2	22.0
Fabricio-Wehbe et al, 2009[62]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	EFS	137	31.4	20.4
Carneiro et al, 2016[237]	Brazil	Latin America and the Caribbean	Upper middle income	≥ 65	EFS	511	41.3	-

Table 3.2 continued. Characteristics of the studies included in the meta-analysis of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Pre-frailty
Woo et al, 2015[238]	China (urban)	East Asia and Pacific	Upper middle income	≥ 65	Frailty Index	6,320	17.0	-
Woo et al, 2015[238]	China (rural)	East Asia and Pacific	Upper middle income	≥ 65	Frailty Index	978	5.2	-
Sathasivam et al, 2015[239]	Malaysia	East Asia and Pacific	Upper middle income	≥ 60	Frailty Index	789	5.7	67.7
Perez-Zepeda et al, 2016[240]	Mexico	Latin America and the Caribbean	Upper middle income	≥ 60	Frailty index	7,108	45.2	-
Galban et al, 2009[241]	Cuba	Latin America and the Caribbean	Upper middle income	≥ 60	Cuban frailty criteria	541	51.4	-
Boulos et al, 2016[242]	Lebanon	Middle East and North Africa	Upper middle income	≥ 65	SOF frailty index	1,120	36.4	30.4
Gray et al, 2017[243]	Tanzania	Sub-Saharan Africa	Low income	≥70	B-FIT	941	4.6	13.4

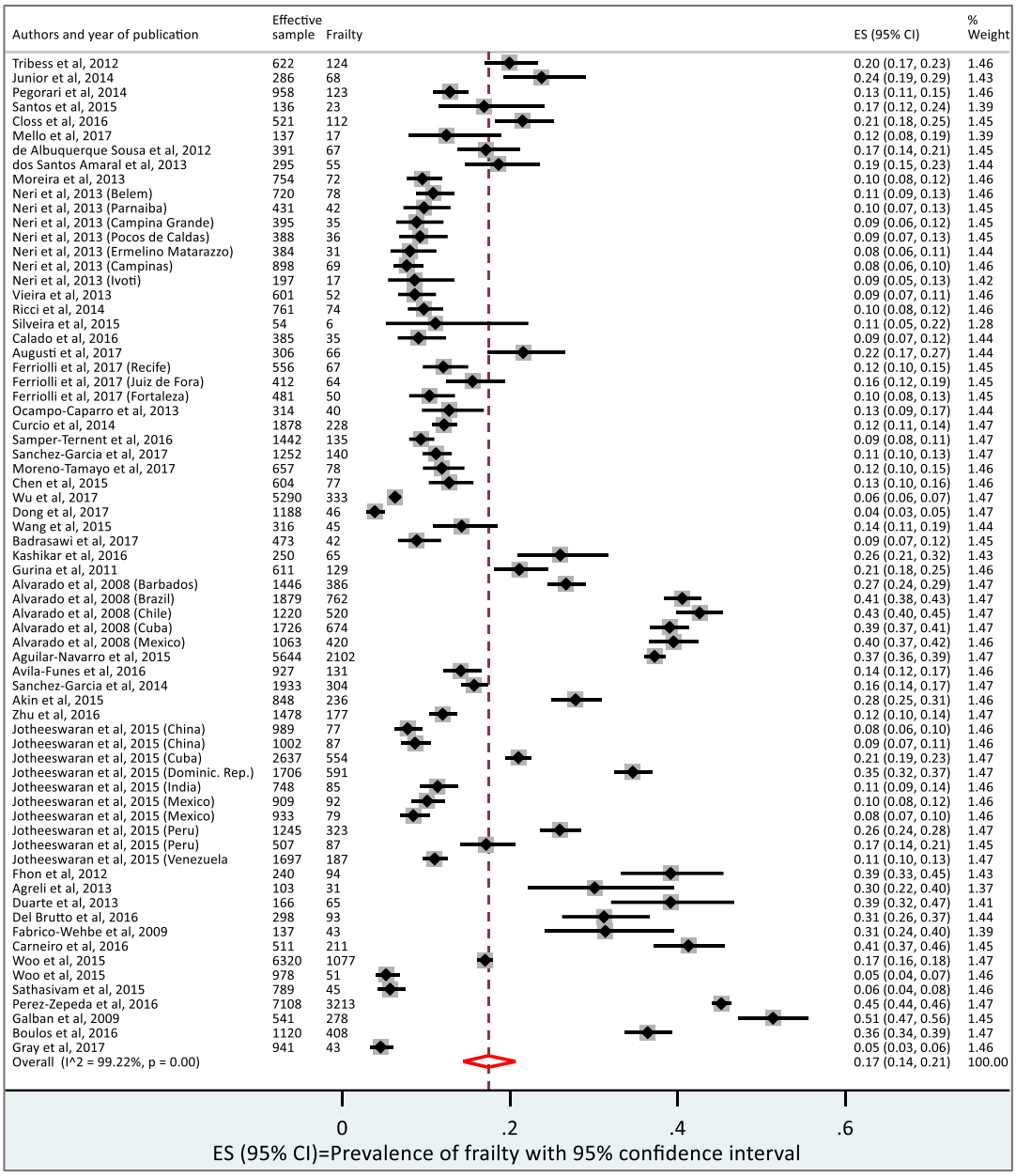
*Fried phenotype with five components-weakness and slowness assessed using objective tests.
†Fried phenotype with five components-weakness and slowness assessed using self-reported questions (subjective).
‡Fried phenotype with four components.
B-FIT-Brief Frailty Instrument for Tanzania; EFS-Edmonton Frail Scale; SOF frailty index-Study of Osteoporotic Fractures frailty index
KEHES-Kayseri Elderly Health Study; MHAS-Mexican Health and Aging Study; SABE-Health, Wellbeing and Ageing Study
Note: Table was taken from a published paper by Siriwardhana et al[176].

3.5.2.2 Pooled prevalence of frailty and pre-frailty

Frailty

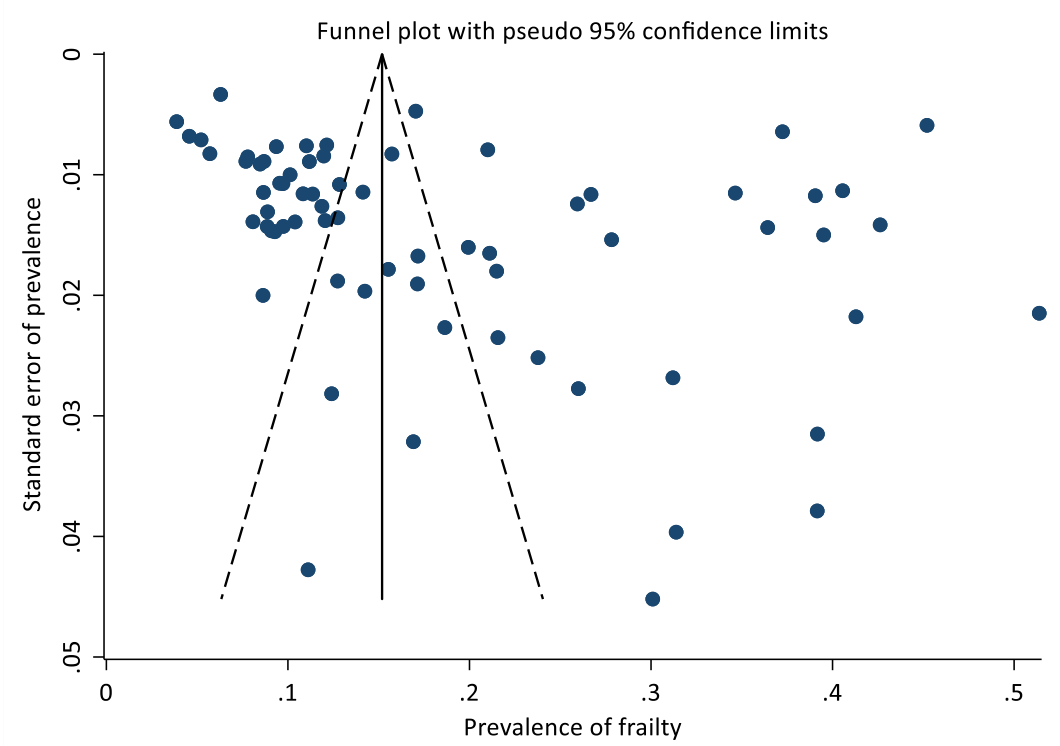
Sixty nine prevalence estimates (47 studies), corresponding to a total of 75,133 community-dwelling older adults, were included in the frailty meta-analysis. Three studies were multi-centre studies and another two were multi-country studies. Therefore, the number of prevalence estimates exceeded the number of studies. The random-effects pooled prevalence of frailty in community-dwelling older adults in LMICs was 17.4% (95% CI: 14.4%, 20.7%). Cochran's Q and I^2 indicated high heterogeneity between the included studies (Q=8756.8, df=68, p<0.001; I^2=99.2%) (Figure 3.3, page 124). Funnel plot asymmetry (Figure 3.4, page 125) revealed evidence of reporting biases and/or between study heterogeneity. Results of Egger's weighted regression test further confirmed the funnel plot asymmetry (p=0.042).

Figure 3.3 Random-effects pooled prevalence of frailty among community-dwelling older adults in low-and middle-income countries



Note: Figure was taken from a published paper by Siriwardhana et al[176].

Figure 3.4 Funnel plot for assessing publication or other types of biases in meta-analysis of prevalence of frailty

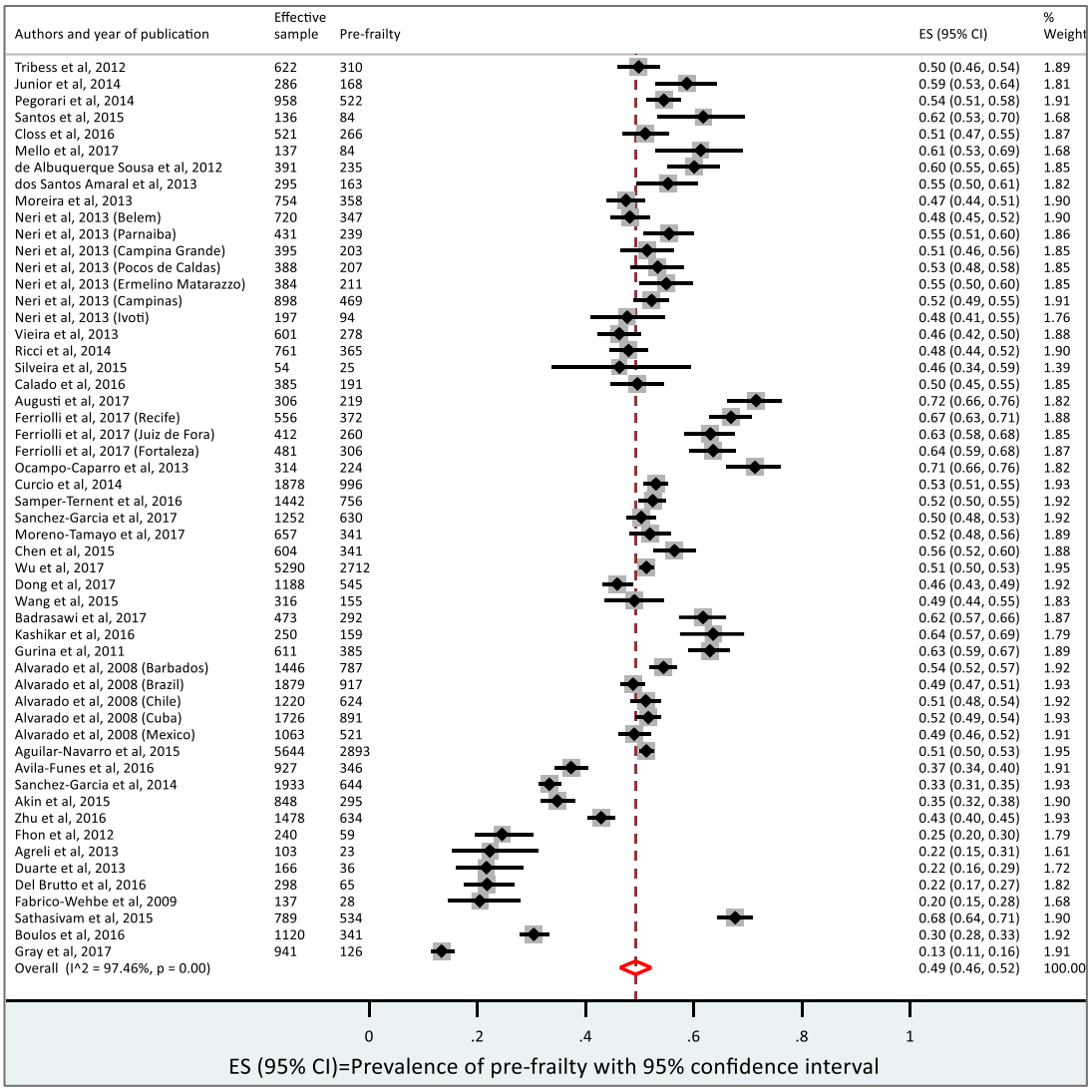


Note: Figure was taken from a published paper by Siriwardhana et al[176].

Pre-frailty

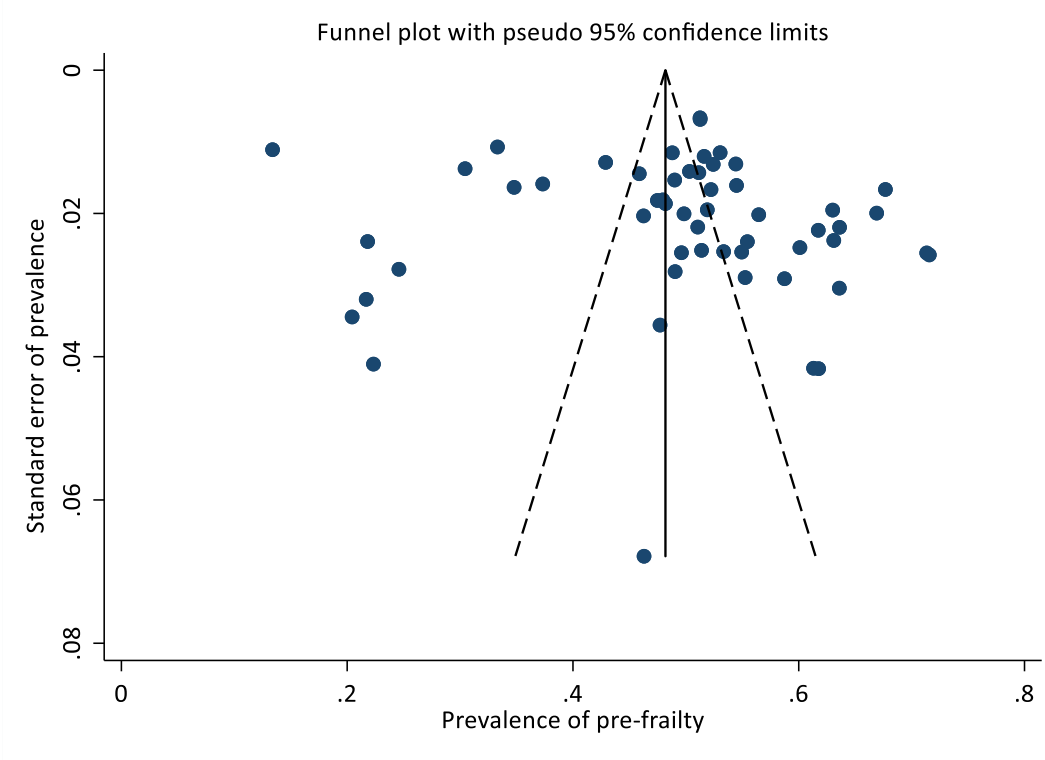
Fifty four prevalence estimates (42 studies) corresponding to 47,302 participants were included in the pre-frailty meta-analysis. The random-effects pooled prevalence of pre-frailty in community-dwelling older adults in LMICs was 49.3% (95% CI: 46.4%, 52.2%). High heterogeneity was observed between studies (Q=2082.6, df=53, p<0.001; I^2=97.5%) (Figure 3.5, page 126). The asymmetric funnel plot (Figure 3.6, page 127) suggested the existence of reporting biases and/or between study heterogeneity. However, results of Egger's weighted regression test was insignificant indicating no funnel plot asymmetry (p=0.817).

Figure 3.5 Random-effects pooled prevalence of pre-frailty among community-dwelling older adults in low-income and middle-income countries



Note: Figure was taken from a published paper by Siriwardhana et al[176].

Figure 3.6 Funnel plot for assessing publication or other types of biases in meta-analysis of prevalence of pre-frailty



Note: Figure was taken from a published paper by Siriwardhana et al[176].

3.5.2.3 Subgroup analyses

Frailty assessment method

Table 3.3 (page 129) presents the random-effects pooled prevalence of frailty and pre-frailty according to the frailty assessment method. Both pooled prevalence of frailty and pre-frailty varied by the assessment method. The highest prevalence of frailty was reported for the Edmonton Frail Scale (EFS): 35.9% (95% CI: 31.7%, 40.2%, I^2=61.9%, p=0.022). The lowest prevalence of frailty was reported for the FRAIL scale: 12.4% (95% CI: 8.4%, 17.1%). The pooled prevalence of frailty for the Fried phenotype with five components-weakness and slowness assessed using objective tests was 12.7% (95% CI: 10.9%, 14.5%, I^2=94.8%, p<0.001).

The highest prevalence of pre-frailty was reported for the Fried phenotype with five components-weakness and slowness assessed using objective tests: 55.2% (95% CI: 53.3%, 57.1%, I^2=89.7%, p<0.001) whilst the lowest was reported for the EFS: 22.3% (95% CI: 19.7%, 25.0%, I^2=0.0%, p=0.907). Also, the heterogeneity between the studies was lowest when the EFS was used. Due to the low number of prevalence estimates, Cochran's Q, p value, and I^2 were not computed for the following frailty assessments: Fried phenotype assessed only with four of the five components and FRAIL scale.

Table 3.3 Random-effects pooled prevalence of frailty and pre-frailty according to the frailty assessment method

Frailty assessment method	Number of studies (estimates)	Number of participants	Pooled prevalence 95% CI, (%)	Cochran's Q	Degrees of freedom	p value	I^2 (%)
Frailty							
Fried phenotype with five components- weakness and slowness assessed using objective tests	30 (38)	27,623	12.7 (10.9, 14.5)	709.9	37	<0.001	94.8
Fried phenotype with five components- weakness and slowness assessed using self-reported questions (subjective)	3 (7)	13,905	33.8 (27.6, 40.4)	359.1	6	<0.001	98.3
Fried phenotype with only four components	4 (13)	16,632	15.6 (11.4, 20.3)	772.1	12	<0.001	98.4
Edmonton Frail Scale	6 (6)	1,455	35.9 (31.7, 40.2)	13.1	5	0.022	61.9
Frailty index	4 (5)	16,303	18.0 (5.8, 35.0)	2085.5	4	<0.001	99.8
FRAIL scale	3 (3)	6,841	12.4 (8.4, 17.1)	-	2	-	-
Multi-dimensional frailty model	1 (10)	12,373	26.9 (20.6, 33.8)	628.8	9	<0.001	98.6
Pre-frailty							
Fried phenotype with five components- weakness and slowness assessed using objective tests	30 (38)	27,623	55.2 (53.3, 57.1)	360.6	37	<0.001	89.7
Fried phenotype with five components- weakness and slowness assessed using self-reported questions (subjective)	3 (7)	13,905	49.2 (46.0, 52.4)	79.5	6	<0.001	92.5
Fried phenotype with only four components	3 (3)	4,259	37.0 (30.9, 43.3)	-	2	-	-
Edmonton Frail Scale	5 (5)	944	22.3 (19.7, 25.0)	1.0	4	0.907	0.0
FRAIL scale	3 (3)	6,841	38.9 (27.6, 50.7)	-	2	-	-

Note: Table was taken from a published paper by Siriwardhana et al[176].

Geographic region

Fifty two prevalence estimates from 34 studies conducted in Latin America and the Caribbean (n=51,188) and fifteen estimates from 12 studies conducted in Asia (n=22,393) were available for the frailty subgroup analysis by region. The pooled prevalence of frailty was 19.3% (95% CI: 15.7%, 23.1%, I^2=99.0%, p<0.001) in Latin America and the Caribbean, and was 12.5% (95% CI: 8.6%, 16.9%, I^2=98.7%, p<0.001) in Asia.

Forty two prevalence estimates from 30 studies conducted in Latin America and the Caribbean (n=33,394) and ten estimates from 10 studies conducted in Asia (n=12,356) were available for the pre-frailty subgroup analysis. The pooled prevalence of pre-frailty was 49.8% (95% CI: 47.1%, 52.5%, I^2=95.7%, p<0.001) in Latin America and the Caribbean and was 50.2% (95% CI: 43.5%, 57.0%, I^2=98.0%, p<0.001) in Asia.

Sex

Twenty four prevalence estimates were available from 24 studies using the same assessment method (Fried phenotype with objective tests) for sex stratified analysis of prevalence of frailty and pre-frailty. In total there were 10,507 and 15,458 male and female participants respectively. The pooled prevalence of frailty in males was 11.1% (95% CI: 8.9%, 13.4%, I^2=91.4%, p<0.001) compared with 15.2% (95% CI: 12.5%, 18.1%, I^2=95.2%, p<0.001) in females. Frailty prevalence was significantly higher in females compared to males (Z=-7.38, p<0.001). The pooled prevalence of pre-frailty in males was 53.8% (95% CI: 51.3%, 56.3%,

I^2=80.9%, p<0.001) and in females was 56.3% (95% CI: 54.0%, 58.7%, I^2=86.2%, p<0.001). Similarly to frailty, prevalence of pre-frailty was significantly higher in females compared to males (Z=-3.51, p<0.001).

Age

The prevalence of frailty increased gradually with advancing age. The prevalence considerably increased after age 75 years. The prevalence of pre-frailty also slightly increased with advancing age and was above 50.0% in all age groups (Table 3.4, page 132).

Table 3.4 Pooled prevalence of frailty and pre-frailty by five-year age bands for studies used Fried phenotype with five components-weakness and slowness assessed using objective tests

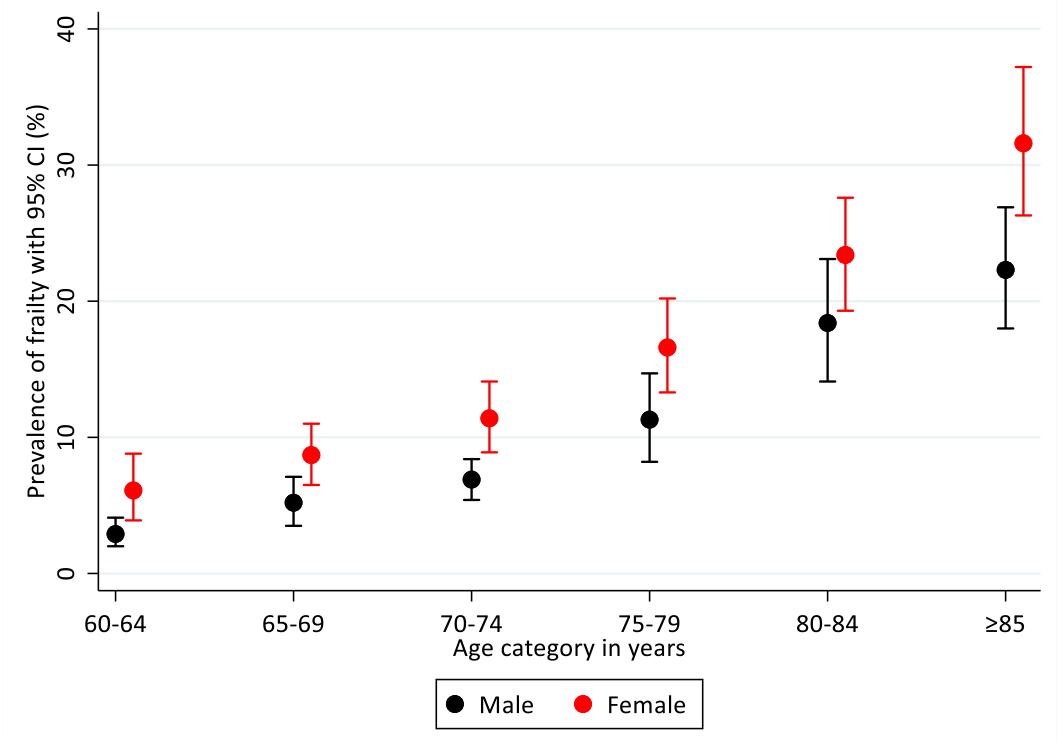
Age category	Number of studies	Number of participants	Pooled prevalence (95% CI), (%)	Cochran's Q	Degrees of freedom	p value	I^2 (%)
Frailty							
60-64	13	4,386	6.2 (4.0, 8.8)	100.4	12	<0.001	88.1
65-69	21	6,437	8.2 (6.3, 10.3)	138.2	20	<0.001	85.5
70-74	22	5,666	10.3 (8.2, 12.6)	136.4	21	<0.001	84.6
75-79	22	4,121	15.4 (12.6, 18.4)	115.6	21	<0.001	81.3
80-84	22	2,329	22.6 (18.5, 26.9)	97.7	21	<0.001	78.5
≥85	22	1,249	29.8 (25.6, 34.2)	42.1	21	0.004	50.1
Pre-frailty							
60-64	13	4,386	52.3 (47.9, 56.8)	86.7	12	<0.001	86.2
65-69	21	6,437	53.5 (49.8, 57.1)	148.1	20	<0.001	86.5
70-74	22	5,666	54.8 (51.6, 57.9)	100.6	21	<0.001	79.1
75-79	22	4,121	57.0 (55.0, 59.1)	30.6	21	0.080	31.5
80-84	22	2,329	57.9 (55.5, 60.3)	25.8	21	0.213	18.7
≥85	22	1,249	59.3 (55.9, 62.6)	25.4	21	0.229	17.4

Note: Table was taken from a published paper by Siriwardhana et al[176].

Age-and sex

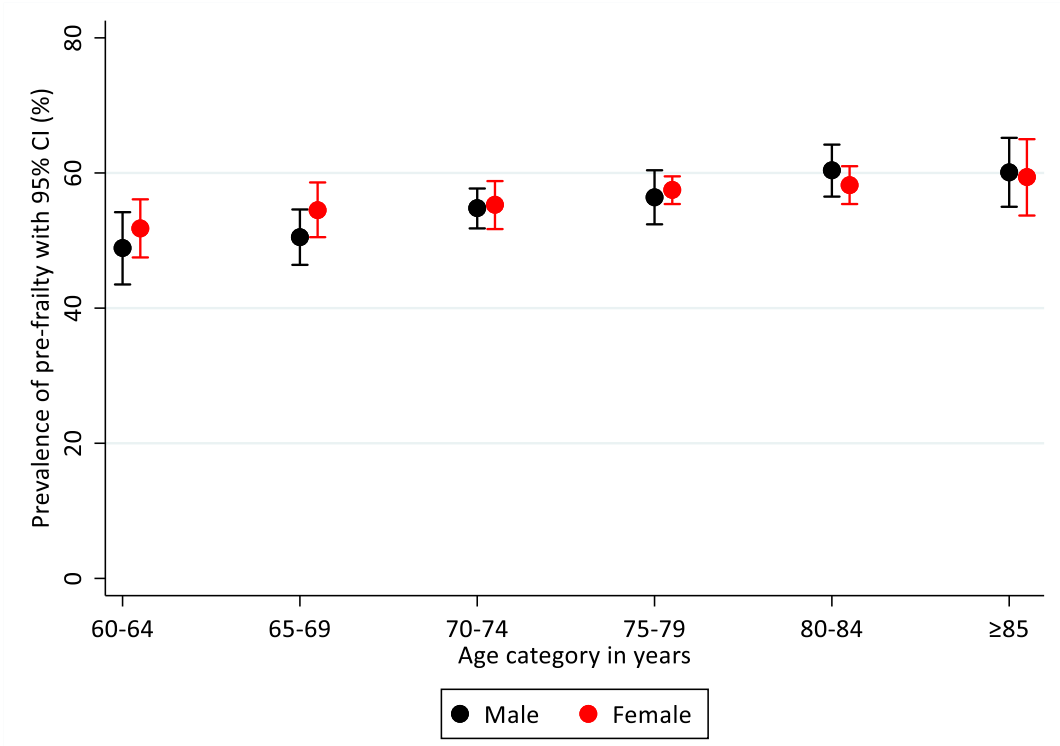
An age related incremental rise in frailty was evident even after stratification by sex (Figure 3.7, below). Prevalence of frailty was higher in females in all five-year age bands. There was no age related trend for pre-frailty after stratification by sex (Figure 3.8, page 134).

Figure 3.7 Pooled prevalence of frailty by 'age-and sex' for studies that used Fried phenotype with five components-weakness and slowness assessed using objective tests



Note: Figure was taken from a published paper by Siriwardhana et al[176].

Figure 3.8 Pooled prevalence of pre-frailty by 'age-and sex' for studies that used Fried phenotype with five components-weakness and slowness assessed using objective tests



Note: Figure was taken from a published paper by Siriwardhana et al[176].

3.5.2.4 Comparison of the pooled prevalence of frailty and pre-frailty of middle-income countries with high-income countries

Pooled prevalence of frailty

Twenty one prevalence estimates (13 studies), corresponding to a total of 9,586 community-dwelling older adults aged ≥65 years from middle-income countries and ten prevalence estimates (10 studies), corresponding to a total of 27,660 community-dwelling older adults aged ≥65 years from HICs were included in the frailty meta-analysis. The random-effects pooled prevalence of frailty in community-dwelling older adults in middle-income countries and in HICs was 12.3% (95% CI: 10.4%, 14.4%, I^2=88.4%, p<0.001) (Figure 3.9, page 136) and 8.2% (95% CI: 5.7%, 11.2%, I^2=98.5%, p<0.001) (Figure 3.10, page 137) respectively.

The prevalence of frailty in community-dwelling older adults from middle-income countries was significantly higher compared with the older adults residing in HICs (Z=-8.86, p<0.001). However, it is also of note that studies included in the meta-analysis of HICs were predominantly from USA whereas studies included in the middle- income countries meta-analysis were predominantly from Brazil and all the countries belonged to the upper middle-income category except one study from India. The pooled prevalence of frailty in middle-income countries excluding the study from India (upper middle-income countries) was 11.8% (95% CI: 10.0%, 13.6%, I^2=86.2%, p<0.001) and had a pooled frailty prevalence still significantly higher compared with that for HICs.

Figure 3.9 Pooled prevalence of frailty among community-dwelling older adults in middle-income countries

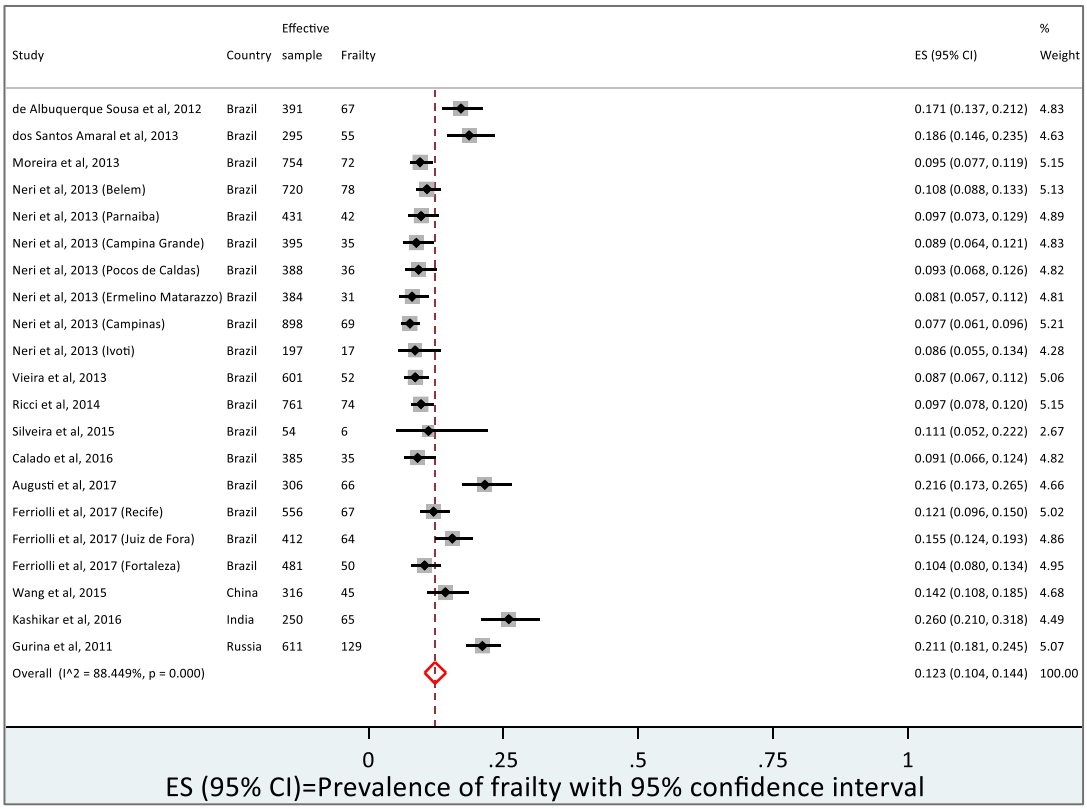


Figure was taken from a published paper by Siriwardhana et al[176].

Figure 3.10 Pooled prevalence of frailty among community-dwelling older adults in HICs

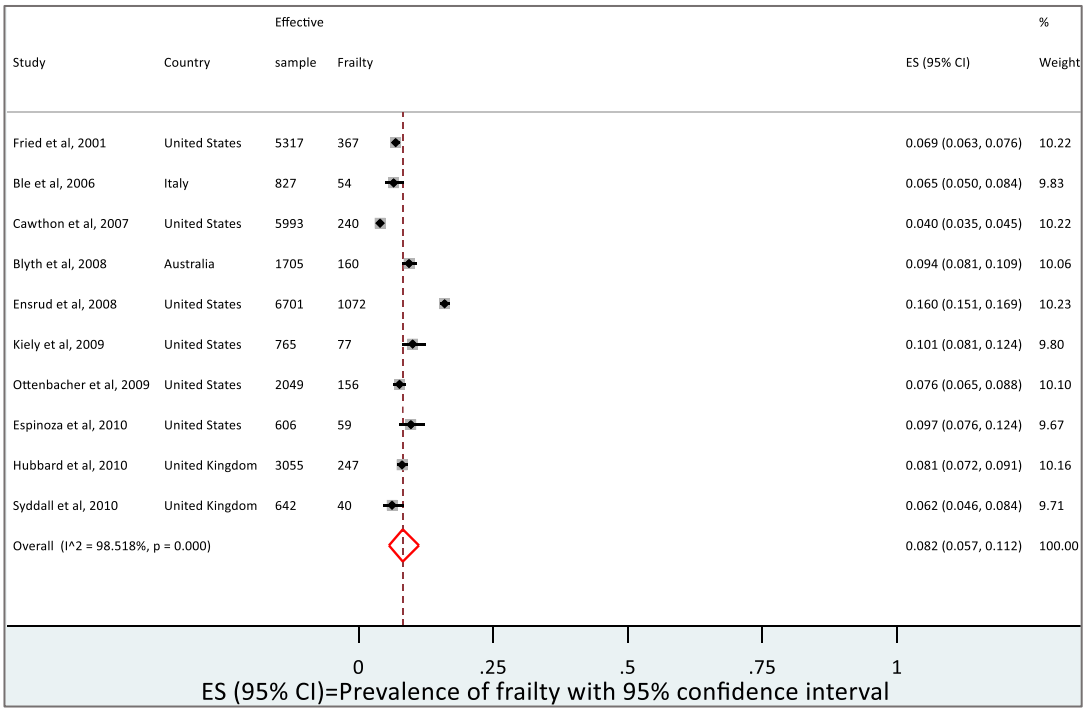


Figure was taken from a published paper by Siriwardhana et al[176].

Pooled prevalence of pre-frailty

The random-effects pooled prevalence of pre-frailty in community-dwelling older adults in middle-income and in HICs countries was 55.3% (95% CI: 52.0%, 58.6%, I^2=90.3%, p<0.001) (Figure 3.11, page 139) and 43.9% (95% CI: 40.9%, 46.9%, I^2=94.9%, p<0.001) (Figure 3.12, page 140) respectively. Like frailty, the prevalence of pre-frailty was significantly higher among the older adults in middle-income countries compared with HICs (Z=-17.14, p<0.001). The pooled prevalence of pre-frailty in middle-income countries excluding the study from India (upper middle-income countries) was 54.9% (95% CI: 51.6%, 58.2%, I^2 =90.4%, p<0.001) and had a pooled pre-frailty prevalence still significantly higher compared with that of HICs.

Figure 3.11 Pooled prevalence of pre-frailty among community-dwelling older adults in middle-income countries

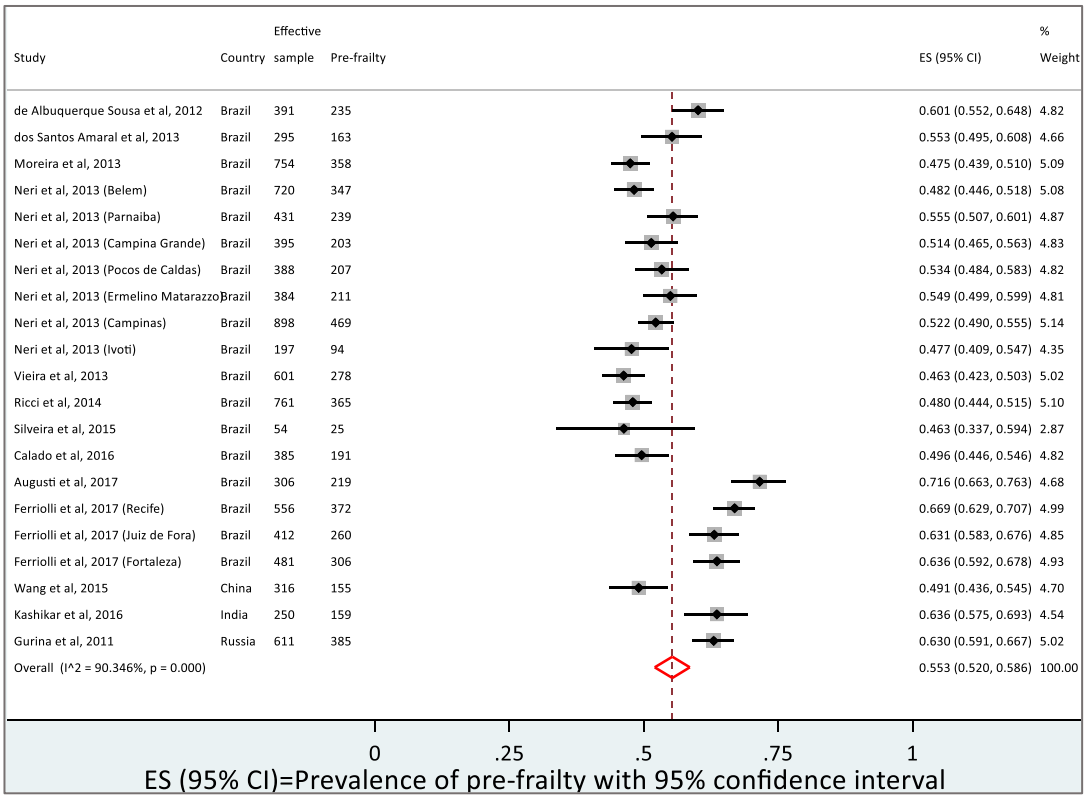


Figure was taken from a published paper by Siriwardhana et al[176].

Figure 3.12 Pooled prevalence of pre-frailty among community-dwelling older adults in HICs

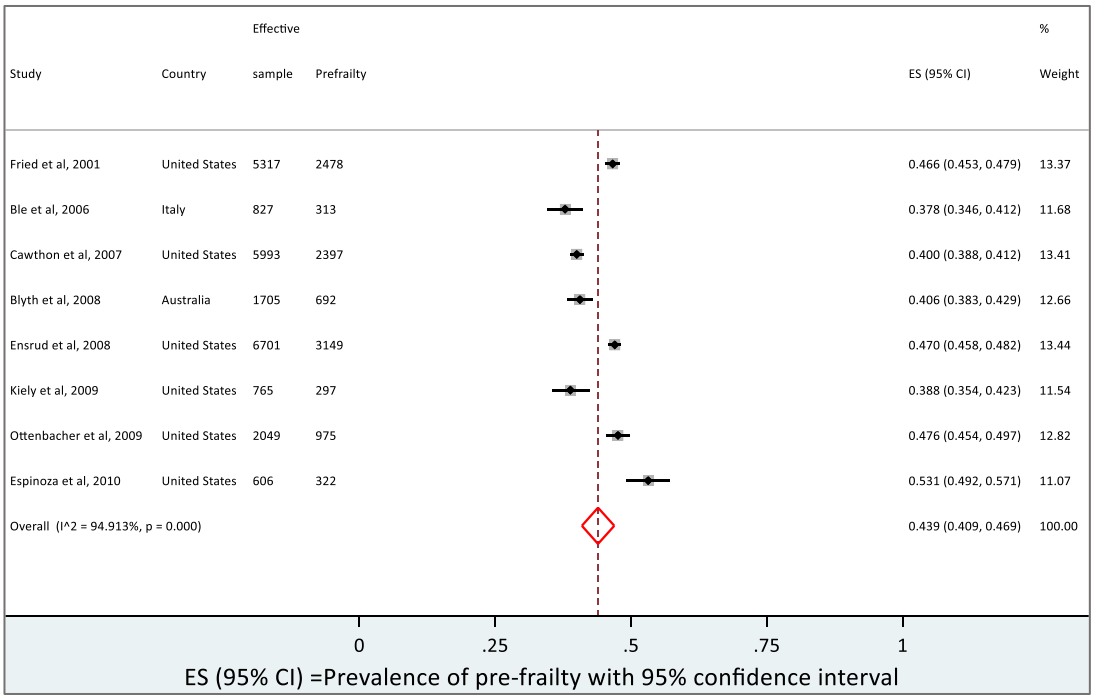


Figure was taken from a published paper by Siriwardhana et al[176].

3.5.3 Results of the meta-regression

All estimates (53) from 39 studies had data on the percentage of females in the sample, study quality assessment score, World Bank region classification, and frailty assessment method. Only 41 estimates from 32 studies had information on mean age. Therefore, the multivariable analysis included 41 prevalence estimates from 32 studies.

In univariable models, a significantly lower prevalence of frailty was observed in East Asia and Pacific compared with Latin America and the Caribbean region. Compared to Fried phenotype with five components where weakness and slowness assessed using objective tests, use of EFS and Fried phenotype (five components, weakness and slowness assessed using self-reported questions (subjective)) significantly increased the prevalence of frailty.

After adjusting for all the other study characteristics in a multivariable meta-regression model, statistically significant differences in frailty prevalence remained between different assessment methods. Use of EFS, frailty index, and Fried phenotype (five components, weakness and slowness assessed using self-reported questions (subjective)) was associated with a frailty prevalence approximately 20.0% higher than the reference method (Fried phenotype with five components where weakness and slowness assessed using objective tests). Geographic region was also a statistically significant predictor of frailty. The variables included in the multivariable model (mean age, % of females in the sample, study quality assessment score, geographic region, and frailty assessment

method) explained 58.4% of the variability between the studies included in the analysis. Please refer to Table 3.5 (page 143).

Table 3.5 Univariable and multivariable meta-regression results

Characteristic	Univariable			Multivariable-adjusted	
	No of estimates	Coefficient (β) (95% CI)	Adjusted R^2 (%)	No of estimates	Coefficient (β) (95% CI)
Mean age, years (per unit increase)	41	0.003 (-0.012, 0.018)	-2.48	41	0.003 (-0.009, 0.017)
Percentage of females in the sample (per unit increase)	53	0.002 (-0.001, 0.007)	0.96	41	-0.000 (-0.004, 0.004)
Study quality assessment score (per unit increase)	53	-0.007 (-0.046, 0.031)	-1.77	41	0.015 (-0.020, 0.051)
World Bank region classification			19.96		
Latin America and the Caribbean	38	0.000		29	0.000
East Asia and Pacific	11	**-0.138 (-0.212,-0.063)**		8	**-0.105 (-0.177,- 0.033)**
Europe and Central Asia	2	0.014 (-0.144, 0.173)		2	0.068 (-0.051, 0.189)
South Asia	2	-0.051 (-0.217,-0.114)		2	0.001 (-0.129, 0.132)
Frailty assessment method			47.11		
Fried phenotype*	23	0.000		20	0.000
Edmonton Frail Scale	6	**0.222 (0.124, 0.319)**		6	**0.215 (0.120, 0.309)**
Frailty index	4	0.053 (-0.041, 0.149)		2	**0.171 (0.056, 0.286)**
Fried phenotype‡	13	0.026 (-0.037, 0.089)		12	0.032 (-0.035, 0.100)
Fried phenotype†	7	**0.206 (0.129, 0.283)**		1	**0.223 (0.065, 0.382)**

*Fried phenotype with five components-weakness and slowness assessed using objective tests.
†Fried phenotype with five components-weakness and slowness assessed using self-reported questions (subjective).
‡Fried phenotype with four components.
The reference category is 0.000.
Statistically significant estimates (at the 5% level) are displayed in bold.
Adjusted R^2 for multivariable model =58.4%
Table was taken from a published paper by Siriwardhana et al[176].

3.6 Discussion

3.6.1 Summary of main findings

The present systematic review and meta-analysis focused on the burden of frailty in LMICs as it is crucial to identify the extent of this issue with the increasing ageing population in these countries. Of 56 studies included in the present review, 40 were from Latin American and Caribbean countries (predominantly from Brazil). In Asia, most of the studies were from China. One study on prevalence of frailty was found from the African region.[243] Only one epidemiological study on frailty (Tanzania) was found from countries with low-income economies[243] (US$1,005 or less) according to World Bank Classification, 2017[183]. Of countries with lower middle-income economies (US$ 1,006 to US$ 3,955) only two studies were found (both from India). One was a study site of a multi-country study[67] and the other was a small community-based cross-sectional study[227]. All the other studies have been conducted in countries with upper middle-income economies (US$ 3,956 to US$ 12,235)[183] indicating income inequality in frailty research. No study was found conducted in Sri Lanka, a lower middle-income country with per capita GNI US$ 3850 in 2017[135], and the study setting of Part B of this PhD.

The random-effects pooled prevalence of frailty and pre-frailty in community-dwelling older adults was 17.4% (95% CI: 14.4%, 20.7%) and 49.3% (95% CI: 46.4%, 52.2%) respectively. Frailty was significantly higher in females compared with males and as expected increased with age. This finding is consistent with previous research.[133, 177, 178, 228, 244] The pooled prevalence of pre-frailty was around half the

participants and prevalence only slightly increased across all age groups. Both the prevalence of frailty and pre-frailty appeared significantly higher in community-dwelling older adults in upper middle-income countries compared with high-income countries. The wide variation in prevalence estimates across studies was largely explained by the differences in frailty assessment method and the geographic region with higher prevalence using the Edmonton Frail Scale and higher prevalence in the Latin American and the Caribbean region.

3.6.2 Study findings in the context of existing literature

The pooled prevalence of frailty and pre-frailty in LMICs in the present review appeared to be higher than the weighted prevalence of frailty and pre-frailty in community-dwelling older adults in HICs reported previously (10.7%, (95% CI: 10.5%, 10.9%) and 41.6% (95% CI: 41.2%, 42.0%) respectively).[133] It is also of note that the participants in HICs included people aged ≥65 years, whereas 50.0% of studies in the present meta-analysis included participants aged ≥60 years. Given that the prevalence of frailty increases with age, when participants of a higher age group are selected, a higher prevalence would be expected in that sample. The present meta-analysis included 18 studies (36 estimates) with a population aged 65 years and above. The prevalence of frailty of this sub-sample was 14.6% (95% CI: 11.9%, 17.4%) and still higher compared to HICs. In the review of frailty prevalence in HICs, most studies were from Europe and North America. Studies included in the present review were predominantly from Latin America and Caribbean countries and belong to the countries with upper middle-income

economies, with little representation of lower middle-income and low-income countries. A recent meta-analysis in Latin America and the Caribbean showed findings consistent with the present review, with nearly one in-five older adults (19.6%; 95% CI: 15.4%, 24.3%) defined as frail.[245]

The review on frailty and pre-frailty which included only HICs has simply reported the weighted prevalence of frailty and pre-frailty.[133] Given the heterogeneity of the studies along with the differences of frailty estimates in different populations, I decided to perform a random-effects meta-analysis in the present review with studies included in the HICs review for a fair comparison of pooled frailty estimates between HICs and upper middle-income countries (Section 3.4.6.3, page 104). No studies were available from low-income countries and only one study was available from lower middle-income countries using the same frailty assessment method. Results indicated significantly higher prevalence of frailty and pre-frailty among community-dwelling older adults in upper middle-income countries compared with HICs. Another review of the prevalence of frailty measured by the Fried phenotype based on community-dwelling older adults aged ≥65 years in nationally representative samples reported a lower prevalence compared with the pooled estimate in the present review except in the countries of Southern Europe (France, Italy, Greece, and Spain).[246] A lower prevalence of frailty was also observed in high-income Asian countries (Japan, Singapore, and Taiwan).[178, 247-249]

One possible explanation for the difference of pooled frailty and pre-frailty prevalence estimates between HICs and upper middle-income countries could be the difference in the sex distribution of the overall samples used in the meta-analysis. The overall sample included in the frailty and pre-frailty meta-analysis of upper middle-income countries consisted of 66.4% of females compared with 51.6% of females included in the corresponding overall sample of the HICs. Of HICs, two studies[193, 194] included male participants only and one study[195] included female participants only. Generally prevalence of frailty is higher in females than in males. However, the sex specific prevalence of frailty and pre-frailty was higher in community-dwelling older adults from upper middle-income countries (10.1% frail and, 54.1% pre-frail for males; and 16.2% frail and, 56.4% pre-frail for females) compared with community-dwelling older adults from HICs (6.6% frail and, 42.6% pre-frail for males; and 9.6% frail and, 45.9% pre-frail for females). Please refer to Appendix 4 (page 432) for full results of this supplementary analysis. Therefore, differences in sex distribution are unlikely to explain the differences in the pooled prevalence of frailty and pre-frailty in upper middle-income and HICs fully.

Many of the health problems in later life are affected by early life exposures and living conditions. According to the findings of a cross-sectional analysis in Latin America, hunger, poor health, poor socioeconomic conditions in childhood and low education, non-white collar occupations, and insufficient income in adulthood were associated with higher odds of frailty.[228] Unlike in many high-income countries, living conditions and healthcare services in LMICs are generally

poor. This could be one explanation for the observed higher prevalence levels of frailty in middle-income countries compared with HICs.

In contrast to these findings, a single multi-country study conducted with data from 14 HICs in Europe and six LMICs (China, Ghana, India, Mexico, Russian Federation, and South Africa) reported higher levels of frailty (high mean frailty index) in HICs compared with the LMICs.[244] This study included nationally representative samples of adults with a lower age threshold of those aged ≥50 years. They also found an inverse association between level of frailty (using frailty index) and income and education in both HICs and low-income countries.[244] Individuals with poor education and low income were more likely to be frail. Higher levels of frailty in HICs could be due to the higher survival rate of participants living with multiple health conditions and disabilities with advanced healthcare and social protection. On the other hand, as the frailty index is based on a list of deficits including diagnosed diseases, many medical conditions could be under reported/diagnosed in the participants in LMICs. Similarly, in most LMICs where access to continued care is lacking, maintenance of medical records is poor making it more difficult to use cumulative deficit models.

The studies which used different assessment methods to identify frail older adults in the same study population demonstrated different frailty estimates highlighting the variation in prevalence due to use of different frailty assessment methods.[64-67] Similar to the present review, a review of HICs found differences in prevalence estimates according to frailty assessment method.[133] Using the

physical frailty definition (Frailty phenotype with 14 study estimates and chair stands and walking speed tests in one study) the weighted prevalence of frailty and pre-frailty was 9.9% (95% CI: 9.6%, 10.2%) and 44.2% (95% CI: 44.2%, 44.7%) respectively. Using instruments based on broader definition of frailty (SOF frailty index, Frailty scale, Assessing Care of Vulnerable Elders, FRAIL scale, frailty index, Tilburg Frailty Indicator, and problems in ≥2 functional domains: physical, nutritive, cognitive, and sensory) the weighted prevalence of frailty and pre-frailty was 13.6% (95% CI: 13.2%, 14.0%) and 33.5% (95% CI: 32.9%, 34.1%) respectively. In the present review, lower prevalence levels were observed when the meta-analysis was restricted only to the Fried phenotype with five components, including objective measures of weakness and slowness.

In the present review, even among the studies using Fried phenotype with objective criteria, there was considerable variation in operationalising the five phenotypic components. Furthermore, the approach of deriving frail cut-off points for weakness, slowness, and low physical activity components were varied. Of thirty studies, 17 had calculated their population specific cut-off points based on the anthropometry of their own study populations. Eight studies had used the cut-off points developed by Fried et al in the CHS.[10] The pooled prevalence of frailty is higher with the studies that used CHS cut-off points[10] compared with the studies that used their own population specific cut-off points. However, the pooled prevalence of pre-frailty was similar in both groups. Similarly the number of deficits used in frailty index and cut- off for defining frailty and pre-frailty status were inconsistent.[238-240] Among all the frailty assessment methods, only the

Edmonton Frail Scale (EFS) showed moderate heterogeneity between the studies. All the other assessment methods showed high heterogeneity. A possible explanation for this finding is that unlike the Fried phenotype or frailty index, EFS is less likely to be modified by researchers as it is comprised of a set of general questions and does not require special resources to perform any test (e.g. clock drawing test and timed up-and-go test).

The strengths, limitations, and implications of the present systematic review and meta-analysis are discussed in Chapter 9 in Section 9.4.1 (page 345) and Section 9.5.1 (page 365) respectively.

3.7 Conclusions

This chapter has documented the prevalence of frailty and pre-frailty among community-dwelling older adults in low-and middle-income countries and estimated the pooled prevalence of frailty and pre-frailty as 17.4% (95% CI: 14.4%, 20.7%) and 49.3% (95% CI: 46.4%, 52.2%) respectively. It appears that the prevalence of frailty in LMICs is higher compared with HICs. This review has further demonstrated that there is little evidence on the basic epidemiology of frailty in LMICs and my PhD is the first study to determine the epidemiology of frailty among community-dwelling older adults in Sri Lanka.

Chapter 4: Methodology: population-based cross-sectional study

4.1 Overview of the chapter

This chapter presents the methodology of Part B of this thesis “a population-based cross-sectional study” which comprised of three objectives mentioned in Section 2.3.2 (page 92); to describe the epidemiology of frailty and its association with disability and quality of life among rural community-dwelling older adults in Sri Lanka. A detailed description of the study setting, study population, sample size calculation and sampling design, data collection instruments, data collection procedures, measures taken to ensure data quality, statistical methods used, and ethical standards and practices is provided in this chapter.

4.2 Study setting

4.2.1 Sri Lanka

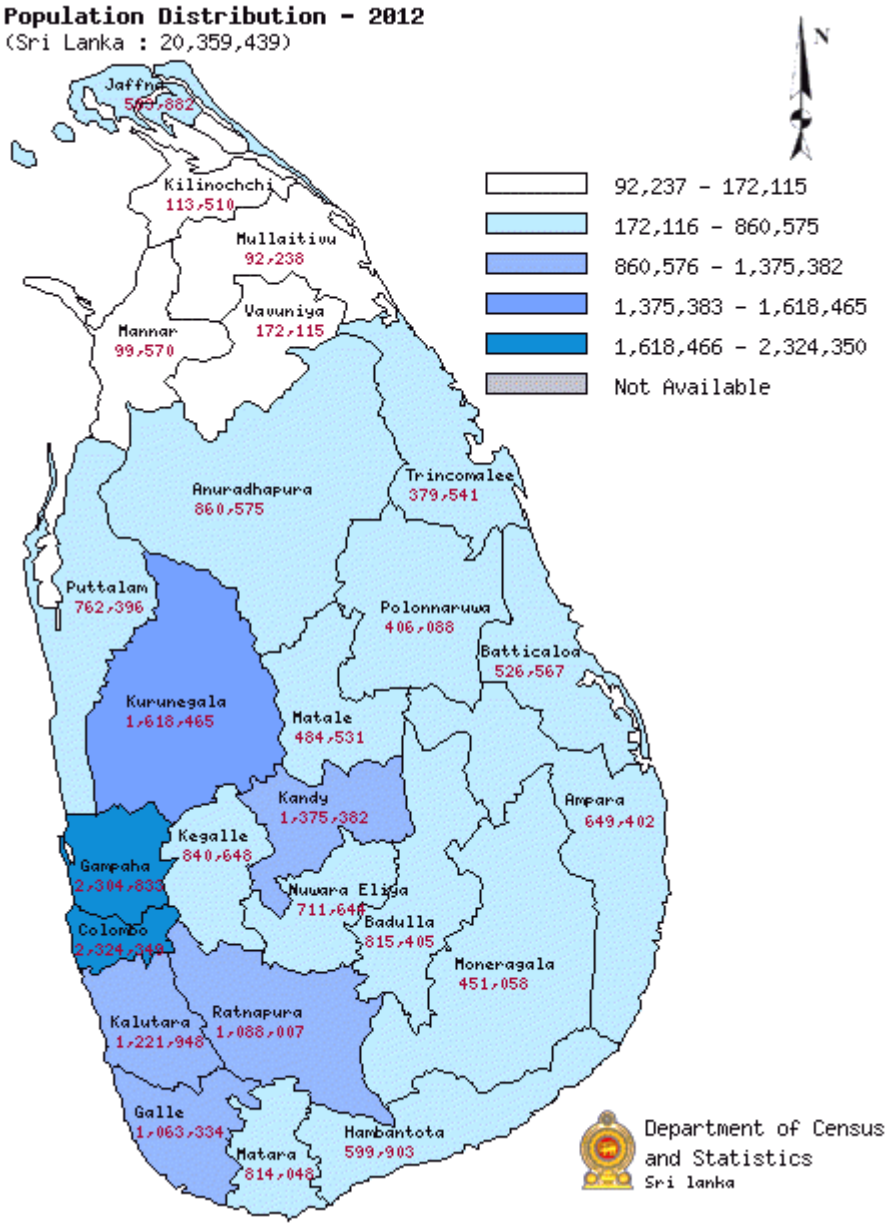
The study was conducted in the rural sector of Kegalle district in Sri Lanka, an island nation located South of India. For administrative purposes Sri Lanka is divided into nine provinces and twenty five districts. Provinces are the first level and districts are the second level administrative divisions. A district is further divided into a number of divisional secretariat divisions. A divisional secretariat division is again subdivided to a number of Grama Niladhari (GN) divisions: the smallest administrative division of Sri Lanka. In addition to these administrative divisions, Sri Lanka is divided into three sectors; urban, rural, and estate depending on geographical location and the availability of infrastructure facilities. The urban sector is designated as areas under municipal and urban councils. The estate sector consists of commercial agricultural lands of 20 acres or above which employ more than 10 labourers. All the other areas are considered as rural.[250] Of the total population in Sri Lanka in 2012, 18.2%, 4.4%, and 77.4% lived in the urban, estate, and rural areas respectively.[250]

According to the latest census of population and housing conducted in 2012[250], the total population of the country was 20,359,439. Of them, 48.4% were males whilst 51.6% were females. The ethnic distribution of Sri Lanka was Sinhalese (74.9%) followed by Sri Lankan Tamil (11.2%), Sri Lankan Moor (Muslim) (9.3%), Indian Tamil (4.1%), and other ethnicities (0.5%). Of the population aged 25 years and above 4.7% had no school education. 18.4%, 39.6%, and 37.3% had

completed primary, lower secondary, and upper secondary or tertiary education respectively. The overall language literacy rate of Sri Lanka is 95.7%. Males (96.9%) were more literate than females (94.6%).

Figure 4.1 (below) is a map of Sri Lanka which illustrates the distribution of the total population by district.

Figure 4.1 Population distribution of Sri Lanka by district according to census of population and housing conducted in 2012



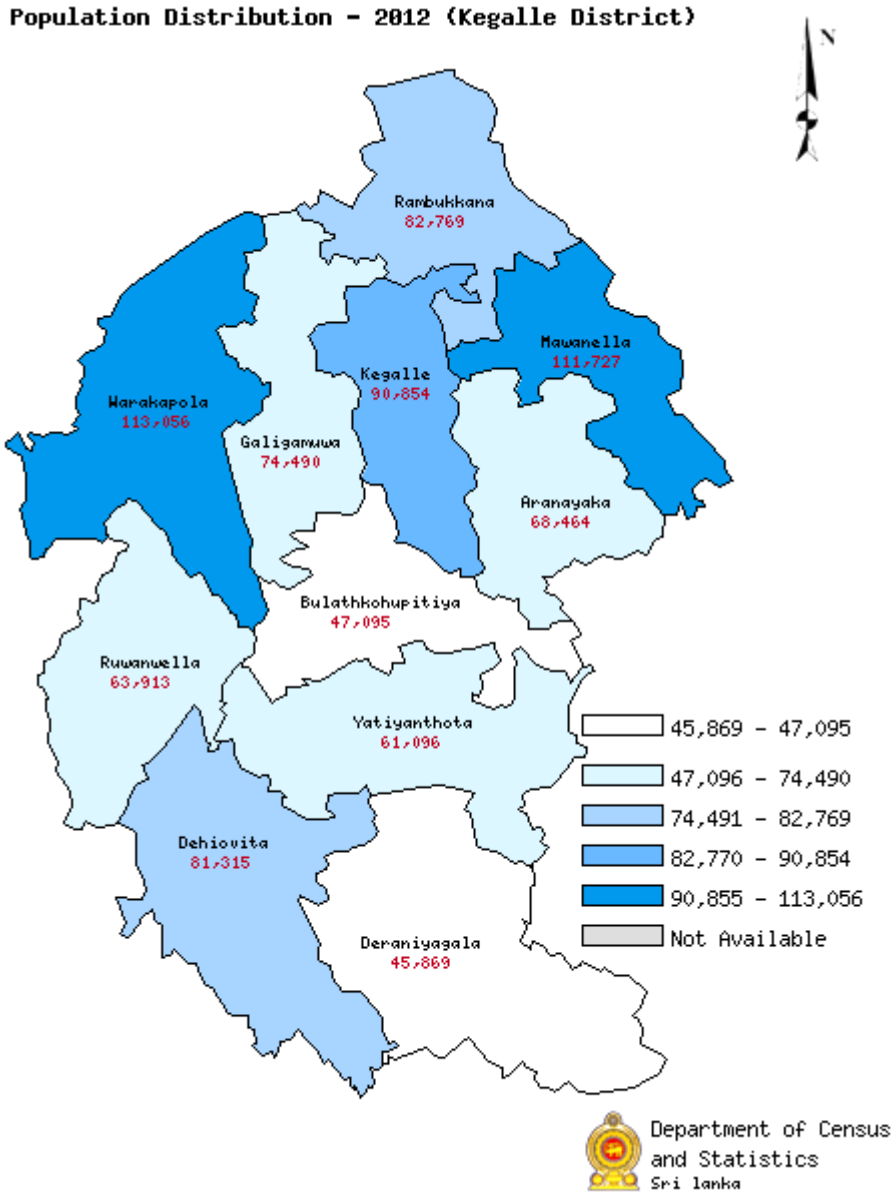
Note: Permission to reproduce this figure has been granted from Department of Census and Statistics, Sri Lanka.

4.2.2 Kegalle district

This study was conducted in the Kegalle district of Sri Lanka. Kegalle district is one of the two districts in Sabaragamuwa province. The 2012 census report indicated that nine percent of the Sri Lankan population lived in Sabaragamuwa province. Kegalle district accounted for 4.1% (840,648) of the Sri Lankan population. There are 11 divisional secretariat divisions in this district (Figure 4.2, page 156) which encompasses 573 GN divisions. In Kegalle district, the majority of the population lived in the rural areas (91.3%) and the rest in the estate (6.8%), and urban (1.9%) areas.[250]

The total number of males and females in the district were recorded as 400,820 and 439,828 respectively. The ethnic distribution of the district population was Sinhalese (85.5%), Sri Lankan Tamil (2.1%), Indian Tamil (5.2%), Sri Lankan Moor (Muslim) (7.1%), and other ethnicities (0.1%). 73.2% of the population had completed lower secondary education or above. The language literacy rate of the district was 96.0%. The corresponding figures for males and females were 97.3% and 94.9% respectively. The majority (84.0%) of the population have been living in the district since birth. The number of older adults (≥60 years) reported from the district was 125,069. Kegalle district was selected for the present study as it had the highest proportion of older adults in a district population (14.9%), according to the latest census (2012).[250] Only the rural population was included in the present study considering the dominant share of the rural population in the entire country (77.4%) and particularly in the Kegalle district (91.3%).

Figure 4.2 Population distribution of Kegalle district by divisional secretariat division according to census of population and housing conducted in 2012



Note: Permission to reproduce this figure has been granted from Department of Census and Statistics-Sri Lanka.

A comparison between the sociodemographic characteristics of Kegalle district and Sri Lanka as a whole is presented below (Table 4.1, below).

Table 4.1 Sociodemographic characteristics of Kegalle district and Sri Lanka

Characteristic	**Kegalle district**	**Sri Lanka**
Total population	**840,648**	**20,359,439**
	(%)	**(%)**
Females in total population	52.3	51.6
Population aged≥60 years	14.9	12.4
Females in aged≥60 years population	56.7	55.7
Population distribution by sector		
Urban	1.9	18.2
Rural	91.3	77.4
Estate	6.8	4.4
Population distribution by ethnicity		
Sinhalese	85.5	74.9
Sri Lankan Tamil	2.1	11.2
Indian Tamil	5.2	4.1
Sri Lankan Moor	7.1	9.3
Other	0.1	0.5
Education level for population aged≥25 years		
No school education	4.4	4.7
Primary	17.8	18.4
Lower secondary	40.3	39.6
Upper secondary or tertiary	37.5	37.3
Overall language literacy rate	96.0	95.7
Language literacy rate by sex		
Male	97.3	96.9
Female	94.9	94.6

Source: Department of Census and Statistics-Sri Lanka. Census of Population and Housing 2012[250].

4.3 Study population

4.3.1 Inclusion criteria

Older adults aged ≥60 years permanently residing in the rural sector of Kegalle district.

4.3.2 Exclusion criteria

Older adults who were unable to provide informed consent for the study were excluded. This included older adults with severe dual hearing and vision impairment, aphasia following a stroke, severe stages of dementia, and those with unstable and severe mental illnesses. In addition, terminally ill older adults were also excluded.

4.4 Sample size calculation

The sample size was initially calculated using the Equation 4.1 (below) for prevalence studies as described by Lwanga and Lemeshow.[251]

$$n = \frac{Z^2 P\ (1 - P)}{d^2} \qquad \text{Equation 4.1}$$

The first objective of this cross-sectional study was to estimate the prevalence of frailty. No published literature was identified on the prevalence of frailty in Sri Lanka (*P* in Equation 4.1). Data available on frailty prevalence from a single multi-centre study conducted in seven LMICs, including India were therefore used.[67] This Indian sample included urban community-dwelling older adults in Chennai, South India. The frailty assessment method used in this study was Fried

phenotype of frailty with four criteria excluding the weakness component.[67] The prevalence of frailty is dependent on the frailty assessment method used (Section 1.2.4, page 44). Although the frailty assessment method used in this Indian study is not identical to the frailty assessment method I used, this was the only available information I could use for the sample size calculation. The prevalence of frailty in the Indian sample was 11.4%. Therefore, the expected prevalence of frailty in Sri Lanka (P) was considered as 11.0%. The absolute precision required on either side of the prevalence estimate (d) was set at 3.5% and the critical value of the 95% confidence level (Z) was set at 1.96. Based on Equation 4.1 (page 158), a sample of 307 participants would be required if participants were to be recruited for the present study using a simple random sampling (SRS) design. In SRS, every sampling unit of the survey population has a known and equal probability of selection into the sample and sampling units are selected from a complete list of the survey population known as the sampling frame. Utilizing SRS is not a feasible option in large scientific surveys where construction of a sampling frame is cumbersome when one does not exist. The SRS process itself is time and resource consuming. Instead, single stage or multi-stage cluster sampling is considered as a feasible option to select the survey sample.[252]

A complex sampling design: three stage probability sampling (Section 4.5, page 166) was used in the present study to select sampling units by considering the issues of cost-effectiveness and efficiency as the sampling units of this study were widely spread out in a large geographic area and there was no available sampling

frame encompassing the survey population. Many large national and multi-national surveys incorporate 'complex' design features such as stratification, clustering, multi-stage sampling, and disproportionate sampling.

Relative to SRS, use of a complex sampling design leads to an increase in the size of the standard errors of survey estimates. Stratification typically reduces the standard errors of survey estimates compared to SRS (i.e. increases efficiency or precision) whilst clustering and unequal probability sampling designs tend to increase the size of standard errors of survey estimates (decrease efficiency) compared to a SRS of the same size. A summary measure of the impact of stratification, cluster sampling, and weighting (to correct for unequal probability sampling) on the standard error of a sample estimate from a complex survey relative to a SRS of equal size, is called the complex sampling design effect. It is a ratio of the sampling variances (complex / SRS) and it can be estimated directly from the survey data obtained using a complex survey design using the Equation 4.2 (below).[253]

$$d^2(\hat{\theta}) = \frac{var(\hat{\theta})_{complex}}{var(\hat{\theta})_{srs}} \quad \text{Equation 4.2}$$

where:

$d^2(\hat{\theta})$ = the estimated design effect for the sample estimate, $(\hat{\theta})$

$var(\hat{\theta})_{complex}$ = the estimated complex sample design variance of $(\hat{\theta})$

$var(\hat{\theta})_{srs}$ = the estimated SRS variance of $(\hat{\theta})$

As a result, the sample estimate obtained from the complex sample design is typically less precise than the SRS (design effects>1). Therefore, when sample size calculations are performed at the outset of a study, a correction is made to compensate for the clustered nature of the complex sample. The loss of precision expected from the complex sample design can be overcome by multiplying the size of the simple random sample (e.g. as initially calculated by the Equation 4.1, page 158) by the complex sample design effect Equation 4.3 (below).[253]

$$n_{complex} = n_{eff} * d^2(\hat{\theta}) \quad \text{Equation 4.3}$$

where:

$n_{complex}$	=	the actual or 'nominal' sample size selected under the complex sample design
n_{eff}	=	the effective sample size, or the size of a simple random sample required to achieve the same precision as the actual complex sampling design
$d^2(\hat{\theta})$	=	the estimated design effect for the sample estimate, $(\hat{\theta})$

A design effect of 2 for example implies that the use of cluster sampling to achieve the same precision as a SRS of the same size would require twice the sample size. A value for the design effect was needed before data collection to increase the size of the complex sample in order to achieve the same precision as a SRS of 307 participants. As mentioned earlier, the design effect of a particular complex sample design is a summary measure of the combined influences of stratification,

cluster sampling, and weighting on the precision of survey estimates.[253] The values of the design effect are typically provided after the data is collected for the sample estimates of major variables of interest in complex sample surveys.[254] The main sample estimate of interest in this study was the prevalence of those with frailty. There were no studies available from Sri Lanka on the prevalence of frailty and no studies were identified from the WHO South-East Asia region reporting the design effect for the prevalence of frailty accounting for the complex sampling structure of the survey data. Therefore, the design effect due to the multi-stage sampling embedded in this complex sampling design was computed based on the following assumptions and it was considered as an approximation of the complex sampling design effect.

There were two levels of clusters in this complex sampling design. Primary sampling units (PSUs) are the highest level groupings (clusters) of sampling units and secondary sampling units (SSUs) are area segments within PSUs. In the present study, PSUs were the divisional secretariat divisions and SSUs were the Grama Niladhari (GN) divisions. Generally sampling units within a cluster have greater similarities compared to the sampling units of other clusters.[252] Thus, prevalence of certain health variables can be more common or uncommon in some clusters than others. The Intraclass correlation (roh/ρ) is a statistic that is used to quantify the amount of homogeneity that exists within sample clusters and when sample size calculations are performed it is usually determined based on the evidence of previous studies that are similar to the planned study.[255] The

value of ρ is specific to the population characteristics and the size of the corresponding clusters. Usually the value of ρ decreases when the geographical size of the cluster increases.[253] A ρ value of 0 indicates no homogeneity; that is, each cluster is as heterogeneous as the population. Alternatively a ρ value of 1 indicates complete homogeneity within clusters (i.e. exact similarity between all members within a cluster). Usually the values of ρ observed for general population characteristics range from 0.0 to 0.2 with most being between 0.005 and 0.1.[256] The value of ρ is computed as the amount of between-cluster variability divided by the sum of the between-cluster and within-cluster variabilities: i.e. the proportion of the total variance in the characteristic of interest that is accounted for by the clustering (Equation 4.4, below).[257] According to Equation 4.4, when the within cluster variance (S_w^2) goes towards the value of 0 (that is, all elements within a cluster are very similar to each other), ρ gets closer to the value of 1.

$$\rho = \frac{S_b^2}{S_b^2 + S_w^2} \qquad \text{Equation 4.4}$$

where:

ρ = intraclass correlation for the survey characteristic

S_b^2 = the variance between the clusters

S_w^2 = the variance within clusters

In the present study context, the PSUs (divisional secretariat divisions) are large geographic areas that are reasonably heterogeneous. Therefore, within PSUs, the intraclass correlation of the main variable of interest (frailty) and other survey variables were treated as minimal. However, the SSUs (Grama Niladhari divisions) are relatively small areas and the sampling units are not as heterogeneous as the PSUs. In the absence of prevalence data on frailty in Sri Lanka using a cluster sampling design, it was not possible to calculate the ρ value for SSUs in advance of the study in order to determine the design effect required for the Equation 4.3 (page 161) to compute the complex sample size. Considering the general demographic and socioeconomic profile of the Kegalle district, it was reasonable to assume that the variability of factors associated with frailty such as education level and other aspects of socioeconomic status within a cluster is high compared to the variability between the clusters.[258, 259] Hence, the value of ρ was assumed as 0.1. The minimum number of participants to be recruited from each SSU was set at 15 considering the 'age-and sex' distribution of the older adults in the district (Table 4.2 page 165) and field logistics (number of participants that could feasibly be interviewed in one full day's work by a team of five interviewers).

Table 4.2 Number of participants selected from each SSU based on the 'age-and sex' distribution of older adults in Kegalle district

Age Category in years	Male	Number	Female	Number
60-64	(20,246/125,069) * 15	2.42~ 2	(24,364/125,069) * 15	2.92~3
65-69	(13,804/125,069) * 15	1.65~ 2	(17,843/125,069) * 15	2.13~2
70-74	(9,302/125,069) * 15	1.11~1	(11,939/125,069) * 15	1.43~1
75-79	(5,537/125,069) * 15	0.66~1	(8,441/125,069) * 15	1.01~1
≥80	(5,218/125,069) * 15	0.62~1	(8,375/125,069) * 15	1.00~1
Total		7		8

Therefore, the assumed design effect was calculated as 2.4 after substituting the following assumed values: ρ =0.1, $\bar{b}$ =15 to Equation 4.5[253] (below) to arrive at the value of the sample size required for the complex sampling design used in the present study.

$$d^2\left(\hat{\theta}\right) = 1 + \rho * (\bar{b} - 1) \quad \text{Equation 4.5}$$

where:

$d^2\left(\hat{\theta}\right) =$ design effect for the sample estimate, $\left(\hat{\theta}\right)$

$\rho =$ intraclass correlation for the survey characteristic y (rate of homogeneity)

$\bar{b} =$ average sample size for cluster

Based on Equation 4.1 (page 158) (which set out the required sample size under SRS) and Equation 4.3 (page 161) (which set out the formula for the sample size required under the complex design to achieve the same precision as the SRS), the

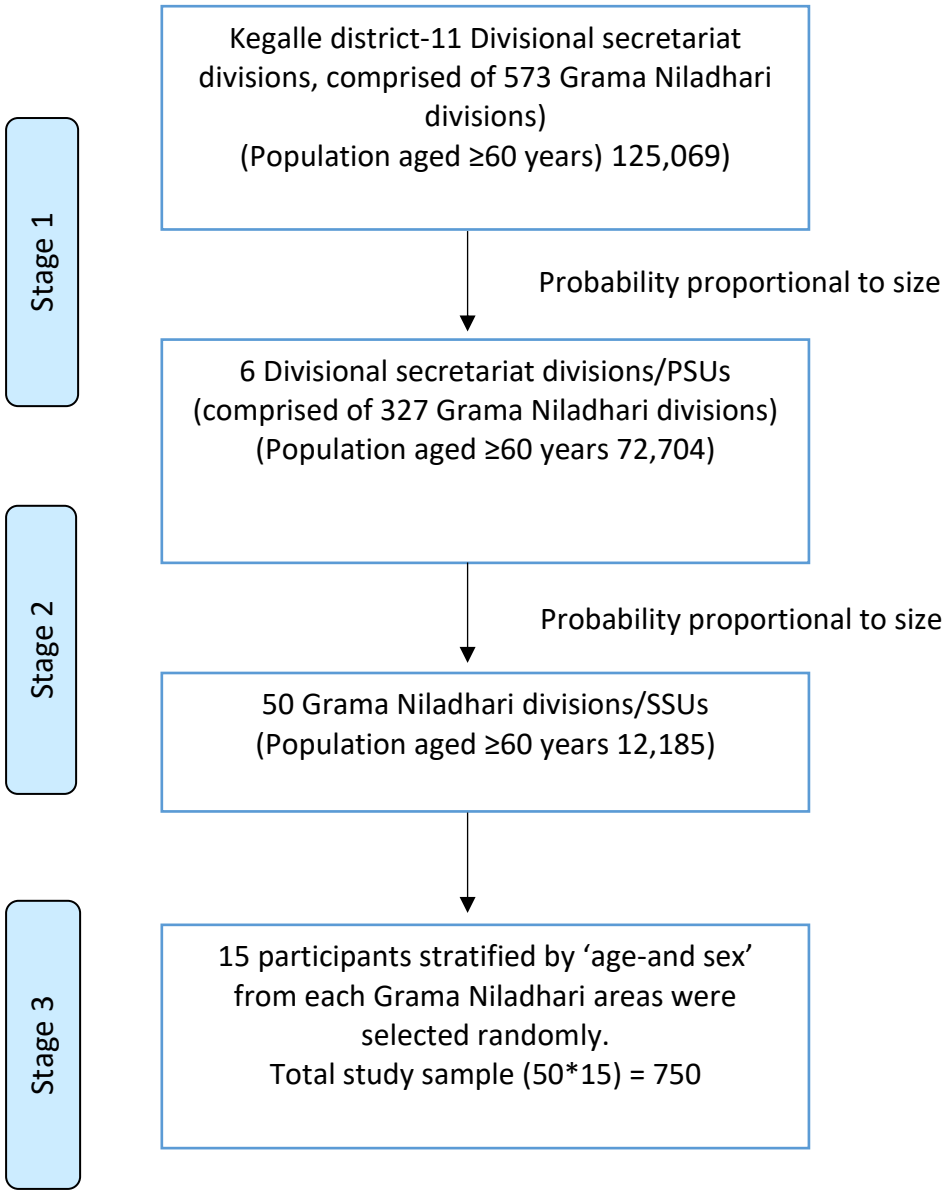
estimated sample size for SRS (Equation 4.1: n=307) was multiplied by the design effect of 2.4, giving a minimum sample size of 737 participants (i.e. 307*2.4). Therefore, fifty SSUs were required to select the study sample computed for complex sampling design (737 sampling units/15 sampling units per SSU). The final sample size required for the study was determined as 750 sampling units (15 sampling units*50 SSUs).

4.5 Sampling design

A complex sampling design comprised of three stage probability sampling was used to recruit the 750 participants for the present study representing the rural sector of the entire Kegalle district. Population data from the Sri Lankan census of population and housing 2012 were used for this purpose.[250]

Figure 4.3 (page 167) illustrates the stages of the sampling design. As mentioned in Section 4.4 (page 158), divisional secretariat divisions were considered as PSUs and GN divisions were considered as SSUs.

Figure 4.3 Schematic diagram representing the stages of sampling design



Note: Figure was taken from a published paper by Siriwardhana et al[260].

The steps followed in each stage of the sampling has been described in detail below.

4.5.1 Stage 1

During stage 1, six out of eleven divisional secretariats (PSUs) were selected according to the probability proportional to size (PPS) technique. The total number of older adults aged ≥60 years in the entire Kegalle district was 125,069. The population distribution by urban, rural, and estate sectors was 2,494 (2.0%), 115,663 (92.5%), and 6,912 (5.5%) respectively. However, sector wise data at micro level (divisional secretariat level and GN level) were not available at the time of designing this study. Hence, aggregated data were used considering the dominant share of the (older) population in the rural sector. Therefore, the sampling interval for PSUs was calculated as (125,069/6) =20,845.

The following steps were followed to select the six PSUs.

i. The number of older adults in each divisional secretariat and the cumulative number was listed according to the order presented in the Department of Census and Statistics-Sri Lanka (Table 4.3, page 169).
ii. A random number was generated using Winpepi software[261] between 1 and 20,845 as the random starting point.
iii. The random starting point was 12,685. Hence the first divisional secretariat to be included in the sample was where the 12,685th older individual laid (Mawanella).

iv. The sampling interval was added to the random generated number to select the second divisional secretariat (Aranayake).

v. This procedure continued until the sixth divisional secretariat was selected. Table 4.3 (below) presents the selected PSUs in stage 1.

Table 4.3 Selected divisional secretariats (PSUs) at stage 1 using PPS technique

Divisional secretariat	Total population	Cumulative population	Selected divisional secretariats from PPS
Rambukkana	12,515	12,515	
Mawanella	14,896	27,411	(12,685) Selected
Aranayake	10,566	37,977	(33,530) Selected
Kegalle	14,260	52,237	
Galigamuwa	11,479	63,716	(54,375) Selected
Warakapola	17,356	81,072	(75,220) Selected
Ruwanwella	9,880	90,952	
Bulathkohupitiya	7,156	98,108	(96,065) Selected
Yatiyanthota	8,878	106,986	
Dehiovita	11,251	118,237	(116,910) Selected
Deraniyagala	6,832	125,069	

4.5.2 Stage 2

The total number of GN divisions (SSUs) in the selected six divisional secretariats (PSUs) were 327. Fifty out of 327 GN divisions were selected at stage 2 using PPS technique. There were no exclusive urban or estate sector GN divisions in the selected PSUs. The total number of older adults in these six divisional secretariats according to the 2012 census was 72,704. Therefore, the sampling interval for SSUs was calculated as (72,704/ 50) =1,454.

The following steps were followed to select 50 SSUs.

i. The number of older adults in each GN division and cumulative number were listed according to the order presented in the Department of Census and Statistics-Sri Lanka.

ii. A random number was generated using Winpepi software[261] between 1 and 1,454 as the random starting point.

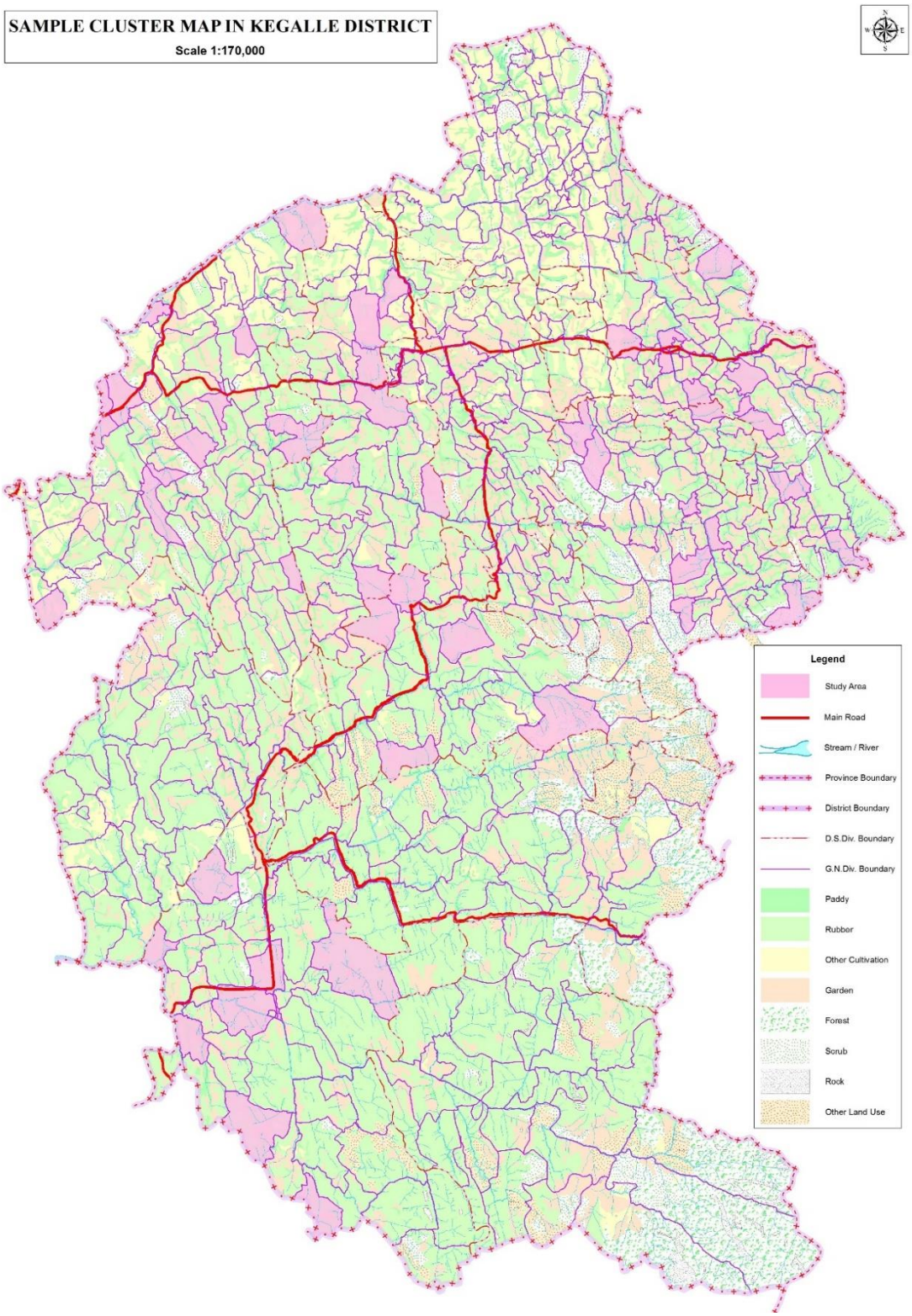
iii. The random starting point was 718. The first cluster to include in the sample was where the 718th individual laid.

iv. The sampling interval was added to the random generated number to select the second GN division.

v. This procedure was continued until the 50th GN division was selected.

Figure 4.4 (page 171) shows the fifty GN divisions of Kegalle district (marked in pink colour) included in the present cross-sectional study.

Figure 4.4 GN divisions of Kegalle district included in the present population-based cross-sectional study



Compiled using Kegalle District Map and SD_ALL_GND_SLD99_V10 database.
Prepared by The Survey Department of Sri Lanka, Special Mapping Unit II-2019
Ref No: 2019/301

4.5.3 Stage 3

During the third stage, 15 participants were recruited from each SSU using proportionate stratified sampling (i.e. the sample size of each stratum is proportionate to the population size of the stratum). The sampling frame was constructed using information (birth year was identified using the national identity card number and sex) available in the electoral register of each SSU. The electoral register is updated annually and it is mandatory to provide accurate information from each household to the Grama Niladhari officer (the government administrative officer in the respective area). When developing the sampling frame of each of the 50 selected SSUs, the Grama Niladhari officer was contacted to identify deceased persons and older adults who had moved out from the GN division.

Table 4.2 (page 165) demonstrates the number of participants recruited from each strata based on the 'age-and sex' distribution of older adults in Kegalle district. 'Age-and sex' strata were used as frailty is known to increase with age and vary by sex (generally females are frailer compared to males[133]). Three female and two male participants were selected from the 60-64 years age category. Two participants each from males and females were selected from the 65-69 years age category. For the other three age categories (70-74, 75-79, ≥80 years) one participant each from male and female per age category was selected. Only one participant was selected from a given household.

4.6 Survey weights calculation

Use of final survey weights is a standard practice in the analysis of data obtained from complex sample survey designs. These weights are typically provided with survey datasets to enable researchers to suitably correct for unequal probabilities of selection and make adjustments for non-response (including post-stratification, where the weight is adjusted at the final step to match the known population across key variables such as age and sex). Therefore, the final survey weights (ω_{final}) in a survey dataset are typically the product of the sample selection weight factor (ω_{sel}), a non-response adjustment factor (ω_{nr}), and the post-stratification factor (ω_{ps}).[253] Equation 4.6 (below) demonstrates the method of calculating the final survey weight for a given population element (*i*) included in the sample.[253] The final survey weight assigned to each survey participant reflects the number of population members represented by that participant. Thus, final survey weights allow the computation of unbiased estimates of descriptive parameters (e.g. the prevalence of frailty) and regression parameters.[262]

$$\omega_{final,i} = \omega_{sel,i} \times \omega_{nr,i} \times \omega_{ps,i.} \quad \text{Equation 4.6}$$

4.6.1 Sample selection weight factor

The sample selection weight factor (base weight) (ω_{sel}) is computed as the reciprocal of the probability that a population element (*i*) was selected to the sample, $\omega_{sel,i} = 1/f_i$. Therefore, the ω_{sel} is computed in multi-stage probability sampling by multiplying the probabilities of selection at each stage of sampling and then taking the reciprocal of the product of the probabilities.[253] The probability of selecting participants in the three-stage probability sampling used in the present study was computed using the Equation 4.7 (below) proposed by Kish.[263]

$$f = f_1 \times f_2 \times f_3 \qquad \text{Equation 4.7}$$

where;

f = overall three-stage sampling probability for participants

f_1 = stage 1 sampling probability for participants (selection of PSUs)

f_2 = Stage 2 sampling probability for participants (selection of SSUs)

f_3 = Stage 3 sampling probability for participants

The expanded version of the Equation 4.7 (page 175) is Equation 4.8 (below) and it was used to compute the sample selection weights of the participants included in the present study.

$$f = \frac{MOS_{\alpha} \times a_h}{MOS_h} \times \frac{b_{\alpha} \times MOS_{\beta(\alpha)}}{MOS_{\alpha}} \times \frac{C_h}{MOS_{\beta(\alpha)}} \quad \text{Equation 4.8}$$

Descriptions of the notations according to this study design is as follows;

where;

f = overall three-stage sampling probability for participants

MOS_{α} = total population measure of size in the selected PSU α

a_h = number of PSUs to be selected from design stratum h

MOS_h = total population measure of size in the design stratum h

b_{α} = number of SSUs (area segments) selected in the PSU α

$MOS_{\beta(\alpha)}$ = total population measure of size for the SSU β =1,…b_{α}

C_h = a stratum-specific constant

4.6.2 Non-response adjustment factor

Only four non-respondents out of the 750 potential participants were reported in the present study (response rate 99.5%). Hence, a non-response adjustment factor was not incorporated into the final survey weights in this study.

4.6.3 Post-stratification factor

Post-stratification is another weighting technique that adjusts the sampling selection weights of the survey participants to account for the oversampling and/or under sampling. Applying these stratification corrections to the observed sample is completed after collecting the survey data. Thus the weighted sample distributions conform to the known survey population distributions across the post-strata. The auxiliary variables used to form post-strata are required to satisfy the following criteria: (i) they should be variables such as age, sex, and region where accurate population totals are available from external sources; (ii) should be highly correlated with key survey variables; and (iii) predictive of noncoverage in the sampling frame. In order to assure the efficiency of post-stratification, post-strata are required to include a minimum of 15-25 participants.[253] The post-stratification option in Stata was used to incorporate the post-stratification weights to appropriately adjust the sample selection weights and thereby compute the final survey weights for use in statistical analyses of this study. Ten post-strata were defined for the present study by using age in the following five-year bands (60-64, 65-69, 70-74, 75-79, and ≥80 years) by sex. The survey population distribution in Kegalle district by 'age-and sex' strata was obtained from the latest available census of population and housing in Sri Lanka (2012).[250]

4.7 Study instruments and data collection

4.7.1 Assessment of frailty

4.7.1.1 Operationalising Fried phenotypic frailty components

Frailty was assessed in the present study using the Fried phenotype of frailty proposed in the Cardiovascular Health Study (CHS).[10] The Fried phenotype is an extensively used tool globally and has been used with different older populations due to its strong physiological base[53], and good concurrent, and predictive validity.[10, 56] All five phenotypic components (shrinking, poor endurance and energy, weakness, slowness, and low physical activity) proposed in the original study were retained for the present study. Of the five components, I only altered the methods used to operationalise the shrinking and low physical activity components, thereby preserving the methods used to operationalise the other three components. The rationale for any modifications and methods used to operationalise the five frailty components in this study are described below.

Shrinking/(weight loss): in the original study, shrinking was operationalised as self-reported unintentional weight loss of ≥10 pounds in the prior year or at follow-up, loss of ≥5.0% of body weight in the prior year by direct measurement of weight.[10] In the rural Sri Lankan context, the majority of older adults do not monitor their weight regularly. Hence, self-reported weight loss was not a reliable option to use in this study. Moreover, this study was a cross-sectional survey and I therefore had no access to valid serial weight measures. Instead, I used BMI<18.5

kg/m^2 as the indicator of shrinking, which is a commonly used alternative method to operationalise this component of frailty.[81] Anthropometric measurements were taken according to the protocol proposed by the International Society for Advancement of Kineanthropometry.[264] Weight was measured to the nearest 0.1 kg using a calibrated electronic scale (Seca 874) when participants were wearing light clothing. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 213). Both measurements were taken when participants were in a standing position and were barefoot. Weight and height measurements were taken in triplicate and the mean of those measurements were used to calculate BMI (BMI=Weight in kg/ (Height in metres squared).

Poor endurance and energy: this was operationalised in terms of self-reported exhaustion and assessed using two questions in the Center for Epidemiologic Studies-Depression (CES-D) scale.[265] The two questions (Questions 7 and 20) from the validated Sinhala version of the CES-D scale [266] and the Tamil translation of the two questions were used. The two questions were "I felt that everything I did was an effort" and "I could not get going". The participants were asked: "How often last week did you feel this way?" The answers were scored from 0 to 3: zero (0) for rarely or none (<1 day), 1 for some or a little (1-2 days), 2 for moderate amount (3-4 days), and 3 for most of the time (5-7 days). Participants scoring 2 or 3 on either of these two questions were considered as frail for this component.

Weakness: this was measured using isometric grip strength in kilogrammes (kg). The Southampton protocol for adult grip strength measurement was followed.[267]

Grip strength measurements were taken in triplicate in both hands using JAMAR hydraulic hand dynamometer model 5030J1. The highest of six grip strength measurements was taken for the analysis. Participants belonging to the lowest quintile of grip strength after adjusting for sex and BMI quartiles of the sample were considered as indicative of weakness (i.e. frail for this component).

Slowness: this was operationalised in terms of gait speed. A 15 feet distance was marked using a steel tape. Participants were asked to stand with both feet touching the standing line (one marker of 15 feet). Then the "begin" command was given. The stop watch was activated when the participant started to walk and it stopped when the participant crossed the end line. The time taken to walk 15 feet at a usual pace was measured twice and the mean of the two values was taken for the analysis. Participants were permitted to use assistive devices (i.e. cane, walker) if necessary. Participants' walking time in the highest time quintile after adjusting for sex and median height of the study sample was considered as indicative of slowness (i.e. frail for this component). Individuals unable to perform the walking test were also considered as frail for this component.

Low physical activity: this was measured using the short version of International Physical Activity Questionnaire (IPAQ)-Short Form[268] culturally adapted and validated in a Sri Lankan context (Sinhala version)[269] and its Tamil translation. The original instrument used to assess physical activity in the CHS (Minnesota Leisure Time Activity questionnaire)[10] has not been culturally adapted or validated in a Sri Lankan context, and could not therefore be used. The IPAQ-Short Form

questionnaire assessed the duration (minutes) and frequency (days) of vigorous intensity and of moderate intensity physical activities as well as walking over the last 7 days. Questions on sitting were also asked. Activities which lasted less than 10 minutes were not counted. Vigorous intensity physical activities included heavy construction, heavy lifting, digging, chopping fire wood, running fast, cycling fast, swimming, and climbing up a stair case or a hill. Moderate intensity physical activities included housework and house maintenance work, running, swimming, cycling at a slow pace, and engaging in outdoor games.

The total amount of time (in minutes) that older adults engaged in: (i) vigorous intensity activities, (ii) moderate intensity activities, and (iii) walking, over the last seven days were obtained by multiplying the frequency and duration of each activity type. A metabolic equivalent (MET) is defined as resting metabolic rate.[270] One MET is the amount of oxygen consumed at rest, sitting quietly in a chair.[270] MET values reflect the energy cost of physical activities as a multiple of the resting metabolic rate. The corresponding MET values for the three types of physical activity assessed in the IPAQ-Short Form are as follows: vigorous physical activities=8.0 METs, moderate physical activities=4.0 METs, and walking=3.3 METs. The time spent on each type of activity was multiplied by the average MET score derived for each type of activity to obtain MET-minutes per week by activity type. The sum of all three MET-minutes per week values yielded the total physical activity MET-minutes per week. A spreadsheet with automatic scoring[271] developed in line with the IPAQ scoring protocol[272] was used to calculate the MET-

minutes per week. MET minutes per week were converted to kilocalories to be comparable with other studies.[273] The lowest quintile of weekly kilocalorie expenditure adjusted for sex was considered as frail for this low physical activity component.

A data extraction form, Appendix 5 (page 433) was created to record the weight, height, grip strength, time taken for a 15 feet walk, and responses to the two questions of the CES-D scale.

4.7.1.2 Calculation of cut-off points for weakness, slowness, and low physical activity level frailty components

Cut-off points for the weakness, slowness, and low physical activity components of frailty were computed based on the anthropometry of the present study sample (where appropriate) after accounting for the complex sampling strategy. Participants with missing values were excluded while calculating the cut-off points for the relevant frailty component. Of all participants in the unweighted sample, nine did not have measurements of height and weight that were required to calculate BMI due to medical conditions (these participants could not stand independently). Grip strength data for these participants were also missing as BMI is required for calculating the grip strength cut-off points.

4.7.1.3 Comparison of methods used to operationalise Fried phenotypic frailty components in the present study with Cardiovascular Health Study[10]

Table 4.4 (page 184) presents a comparison between the methods used to operationalise each frailty component and cut-off points for weakness, slowness, and low physical activity computed for the present study with those used in the original Cardiovascular Health Study (CHS)[10]. The anthropometry of the present study sample of Sri Lankan older adults was markedly different to the original study of older adults aged ≥65 years in USA. BMI quartiles and median height of Sri Lankan older adults were low for both sexes compared with the original study. Respective grip strength and gait speed cut-off points were also low in this Sri Lankan sample compared with the original study. Weekly kilocalorie expenditure was higher in the present study as the IPAQ-Short Form assessed the time participants engaged in all types of vigorous and moderate physical activities and walking throughout the past week whereas the original study only assessed engagement in leisure activities.

Table 4.4 Comparison of Fried phenotypic frailty components and respective cut-off points used in the present study with the Cardiovascular Health Study (CHS)[10]

	Present study		CHS[10]	
Shrinking				
	BMI<18.5 (kg/m^2)		Unintentional weight loss of ≥10 pounds in prior year (self-reported)	
Poor endurance and energy (self-reported exhaustion)				
	Two questions in the Center for Epidemiologic Studies- Depression (CES-D) scale		Two questions in the Center for Epidemiologic Studies- Depression (CES-D) scale	
Weakness (assessed by grip strength)				
	Sex, BMI (kg/m^2)	*Estimate (kg)*	*Sex, BMI (kg/m^2)*	*Estimate (kg)*
	Female, BMI ≤ 19.7	≤13.0	Female, BMI ≤ 23.0	≤17.0
	Female, BMI 19.8-22.1	≤14.0	Female, BMI 23.1-26.0	≤17.3
	Female, BMI 22.2-24.7	≤16.0	Female, BMI 26.1-29.0	≤18.0
	Female, BMI > 24.7	≤16.0	Female, BMI > 29.0	≤21.0
	Male, BMI ≤ 18.8	≤20.0	Male, BMI ≤ 24.0	≤29.0
	Male, BMI 18.9-20.8	≤20.0	Male, BMI 24.1-26.0	≤30.0
	Male, BMI 20.9-23.3	≤18.0	Male, BMI 26.1-28.0	≤30.0
	Male, BMI > 23.3	≤27.0	Male, BMI > 28.0	≤32.0
Slowness (assessed by gait speed)				
	Walking distance is 15 feet			
	Sex, Height (cm)	*Estimate (seconds)*	*Sex, Height (cm)*	*Estimate (seconds)*
	Female, ≤146.5	≥10	Female, ≤159	≥7
	Female, >146.5	≥8	Female, >159	≥6
	Male, ≤160	≥8	Male, ≤173	≥7
	Male, >160	≥7	Male, >173	≥6
Low physical activity				
	Using IPAQ-Short Form		Minnesota Leisure Time Activity Questionnaire	
	Sex	*(Kcals/week)*	*Sex*	*(Kcals/week)*
	Female	<552	Female	<270
	Male	<528	Male	<383

4.7.1.4 Definition of frailty status

Participants who had completed data on ≥3 frailty components were used to evaluate the frailty status. As proposed in the original study[10], participants with three or more components were considered as frail, those with one or two components were considered as pre-frail, and those with none of the five components described above were considered as robust/non-frail.

4.7.2 Assessment of the factors associated with frailty

A pre-tested interviewer administered structured questionnaire in four parts (sociodemographic; health-related; social activity and social support; and lifestyle factors) was used to collect data on the factors potentially associated with frailty Appendix 6 (page 435). The questionnaire was comprised of questions originally developed for this study, questions used in previous studies, and standard questionnaires/scales that have been referenced appropriately. The questionnaire was originally designed in English language and then translated into both Sinhala and Tamil languages (the two main local languages spoken in Sri Lanka). I performed the Sinhala translation of the questionnaire (I am a native Sinhala speaker). Tamil translation was completed by a native Tamil speaker fluent in English with a bachelor's degree in Health Promotion (KK). The entire questionnaire was pre-tested with 10 older adults (five males and five females) living in a GN division of the same district that did not belong to a sampling area under the present study to identify the best order in which to administer the study instruments and to identify the questions that needed probing (i.e. follow-up

questions that needed participants to provide additional information). I briefly describe the four parts of the questionnaire in turn.

4.7.2.1 Sociodemographic factors

The first part of the questionnaire collected information on sociodemographic factors including age at last birthday, sex, ethnicity, marital status, number of children, education level, longest-held occupation, current income generation activity, availability of a monthly income and its type, monthly income of household, number of household members, and subjective financial strain[274] (Appendix 6, page 435).

4.7.2.2 Health-related factors

The second part of the questionnaire was on health-related factors, namely physical health and psychological health. It included questions on chronic disease conditions: either recorded as verified (where the participant showed the researcher medical documentation verifying the diagnosis) or as self-reported by the participant (non-verified). Other questions included whether the participant is taking medicine/s regularly, type of medicine/s taken, number of medicine/s currently taken from each type, number of visits to a physician during the last 3 months, the usual place for seeking medical assistance, number of hospital admissions during the preceding year, the duration of the last hospital admission, number of falls during the preceding year, fear of falling (measured using the shortened version of the falls efficacy scale-international (Short FES-I))[275], use of

assistive devices, type of assistive device used and frequency of use, chronic pain and the severity of it, self-perception of vision ability[276], hearing ability[276], oral health[277], and general health[278] (Appendix 6, page 435).

Cognitive function was assessed using Montreal Cognitive Assessment (MoCA).[279] It is a widely used, valid and reliable assessment of cognitive impairment. The MoCA has been translated into Sinhala, adapted and validated with Sri Lankan adults aged ≥50 years.[280] The Sinhala version of the MoCA showed a good internal consistency and concurrent validity (Cronbach's alpha was 0.82).[280] The sensitivity and specificity of the assessment in detecting dementia using a cut-off value of 24 were 98.1% and 79.6% respectively.[280] The 15-item Geriatric Depression Scale (GDS-15) was used to screen for the presence of depression symptoms.[281] The 15-item GDS has been translated into Sinhala (GDS-S) and evaluated for concurrent validity with a group of adults aged ≥55 years attending a psychogeriatric outpatient clinic in Sri Lanka.[282] The optimal cut-off score for 15-item GDS-S was 8 for differentiating non-depressed from mildly depressed older adults. Both sensitivity and specificity of 15-item GDS-S were estimated at 73.3% for differentiating depressed from non-depressed older adults.[282]

4.7.2.3 Social activity and social support

The third part of the questionnaire included questions on living arrangements, social participation in different activities, and social support. The social activity scale of the leisure participation questionnaire that has been used with Malaysian older adults[283] was used to assess participation in different social activities with

slight modifications according to the Sri Lankan cultural context. For instance, under religious activity: 'going to mosque and marhaban class' were replaced to 'going to temple and observing sil'. There was one item called 'window shopping' and it was not included in the questionnaire of the present study as it is not a common activity among Sri Lankan older adults. The Oslo 3-item social support scale[284] was used to assess the availability of social support. This is a short questionnaire with three questions about the number of close confidants, sense of concern or interest from other people, and relationship to neighbours (Appendix 6, page 435).

4.7.2.4 Lifestyle factors

The fourth part of the questionnaire was on lifestyle factors which included smoking status, alcohol consumption, and diet. The smoking section comprised of questions on ever smoking status, including two questions assessing current smoking status using the standard National Health Interview Survey (NHIS) current smoking definition.[285] Questions from the 'tobacco use' module of WHO STEPS instrument version 3.1[286] were also included (Appendix 6, page 435). These questions covered the type of tobacco product used if a daily smoker, the average units smoked from each listed tobacco product, age of smoking initiation, and age of smoking cessation if applicable.

The questions on alcohol consumption were taken from the alcohol module of the WHO STEPS instrument version 3.1 (Appendix 6, page 435).[286] The alcohol consumption section contained questions on whether adults had ever consumed

alcohol, alcohol consumption within the past 12 months and its frequency, alcohol consumption within the past 30 days and its frequency, and the number of standard drinks consumed on average in one drinking occasion. The amount of alcohol contained in a single standard drink or single unit vary by country. The UK is the only country that uses the term 'unit' to express the equivalent of a standard drink.[287] In a study conducted with a nationally representative sample of Sri Lankans, 8g of pure alcohol was considered as one unit.[288] Authors have presented a reference table which includes pure alcohol percentage by volume of different alcoholic beverages used in Sri Lanka, a single unit in mililiters and single unit in conventional measurements. A show card presenting this table was used to explain the standard drink/unit of alcohol to study participants (Appendix 7, page 451).

Questions on the frequency of vegetables and fruit consumption and their serving sizes were taken from the diet module of WHO STEPS instrument version 3.1 (Appendix 6, page 435).[286] Consumption of only vegetables and fruits is assessed in the WHO STEPS survey. A similar question format was followed to assess the consumption and serving sizes of the following food groups during this study: green leaves, animal protein sources, plant protein sources, milk, and diary products. A show card that included a table that explained the serving sizes of different food items produced by the Nutrition Division-Ministry of Health, Sri Lanka (in collaboration with the WHO) was used to explain the serving sizes to participants (Appendix 8, page 452).[289]

4.7.3 Assessment of disability

Disability was operationalised in terms of activity limitations in instrumental activities of daily living (IADL) and limitations in basic activities of daily living (BADL).

There was no culturally adapted and validated IADL scale to use with Sri Lankan older adults. Therefore, as a part of this PhD I undertook a cross-cultural adaptation of the Lawton Instrumental Activities of Daily Living (Lawton IADL) scale[290] following standard guidelines[291] and tested the reliability and validity of the Sinhala version of the scale. The process for cross-cultural adaptation and psychometric evaluation of the scale has been published[292] and is presented in Chapter 5 (page 213). IADL tasks relate to household management tasks and are used to determine an individual's ability to live independently in the community. The original Lawton IADL scale assessed eight activities which include: ability to use telephone, shopping, food preparation, housekeeping, laundry, transport, ability to handle finances, and responsibility for own medication. Self-reported capacity of performing each activity was recorded in the present study. According to the scoring protocol proposed in the scale, participants were classified into two categories as 'dependent' (0) and 'independent' (1) for each item.[290] Since the scale comprises of 8 items, the total score of the scale ranges from 0-8: a higher score means a higher level of independence. I used the classification proposed by Ng et al to further classify these IADL activities into two domains: physical and cognitive.[293]

BADL limitations were measured using the Barthel index[294] that has been validated in a Sri Lankan context.[292, 295] The Sinhala version of the 10-item Barthel index showed a high internal consistency with a Cronbach's alpha value of 0.92.[295] BADL tasks involve self-care activities that require fundamental skills to manage basic physical needs. The Barthel index consists of 10 items and measure basic activities of daily living and mobility.[294] Items of the index include: feeding, bathing, grooming, dressing, continence of bowels and bladder, toilet use, transfers from bed to chair and back, walking on a level surface (mobility), and going up and down stairs. Self-reported actual performance was recorded in the present study. According to the response for each item, participants were classified into two groups as 'dependent' (0) and 'independent' (1) (Table 4.5, page 192). The total score of the Barthel index therefore ranges from 0-10: a higher score means a higher level of independence.

Table 4.5 Classification of responses in the Barthel index as 'dependent' and 'independent' for the present study

Item	Response options	Dependent or Independent
Feeding	unable	Dependent
	needs help cutting, spreading butter, etc., or requires modified diet	Dependent
	independent	Independent
Bathing	dependent	Dependent
	independent (or in shower)	Independent
Grooming	needs to help with personal care	Dependent
	independent face/hair/teeth/shaving (implements provided)	Independent
Dressing	dependent	Dependent
	needs help but can do about half unaided	Dependent
	independent (including buttons, zips, laces, etc.)	Independent
Bowels	incontinent (or needs to be given enemas)	Dependent
	occasional accident	Independent
	continent	Independent
Bladder	incontinent, or catheterized and unable to manage alone	Dependent
	occasional accident	Independent
	continent	Independent
Toilet use	dependent	Dependent
	needs some help, but can do something alone	Dependent
	independent (on and off, dressing, wiping)	Independent

Table 4.5 continued. Classification of responses in the Barthel index as 'dependent' and 'independent' for the present study

Item	Response options	Dependent or Independent
Transfers (Bed to chair and back)	unable, no sitting balance	Dependent
	major help (one or two people, physical), can sit	Dependent
	minor help (verbal or physical)	Dependent
	independent	Independent
Mobility (on level surfaces)	immobile or < 50 yards	Dependent
	wheelchair independent, including corners, > 50 yards	Dependent
	walks with help of one person (verbal or physical) > 50 yards	Dependent
	independent (but may use any aid; for example, stick) > 50 yards	Independent
Stairs	unable	Dependent
	needs help (verbal, physical, carrying aid)	Independent
	independent	Independent

4.7.4 Assessment of quality of life

The quality of life of the participants was assessed using the Older People's Quality of Life Questionnaire (OPQOL-35). This was developed to measure QoL in older adults and found as a valid and reliable tool with an ethnically diverse community-dwelling older population in Britain.[296-298] It has 35 items, and participants were asked to what extent they agree with each item. Response options for the OPQOL-35 questionnaire were on a five point Likert scale, from "strongly agree" to "strongly disagree". Study participants were given a show card listing these five response options when administering the questionnaire (Appendix 9, page 453). The OPQOL-35 questionnaire has eight sub scales: (i) life overall; (ii) health; (iii) social relationships and participation; (iv) independence, control over life and freedom; (v) home and neighbourhood; (vi) psychological, and emotional wellbeing; (vii) financial circumstances; and (viii) leisure activities and religion. After reverse coding for positive items, the total QoL score ranges from 35 (worst possible) to 175 (best possible). The OPQOL-35 questionnaire has been translated into Sinhala and previously used to assess the quality of life of older adults in Sri Lanka.[174] The Sinhala version of the questionnaire demonstrated good internal consistency: Cronbach's alpha was 0.86 in a previous study conducted in Anuradhapura district of Sri Lanka.[174] I calculated the internal consistency of the OPQOL-35 questionnaire for the present study and it was good (alpha 0.86). However, the internal consistency of the different domains varied from poor in the 'leisure activities and religion' domain (alpha=0.33) to good in the 'financial circumstances' domain (alpha=0.82) (Table 4.6, page 195).

Table 4.6 Internal consistency of the different domains of quality of life in OPQOL-35 questionnaire

Domain	Questions representing each domain	Cronbach's alpha (N)
D1 **Life overall**	1. I enjoy my life overall (+) 2. I am happy much of the time (+) 3. I look forward to things (+) 4. Life gets me down (-)	0.57 (745)
D2 **Health**	5. I have a lot of physical energy (+) 6. Pain affects my wellbeing (-) 7. My health restricts me looking after myself or my home (-) 8. I am healthy enough to get out and about (+)	0.80 (746)
D3 **Social relationships and participation**	9. My family, friends or neighbours would help me if needed (+) 10. I would like more companionship or contact with other people (+) 11. I have someone who gives me love and affection (+) 12. I would like more people to enjoy life with (+) 13. I have my children around which is important (+)	0.64 (746)
D4 **Independence, control over life, and freedom**	14. I am healthy enough to have my independence (+) 15. I can please myself what I do (+) 16. The cost of things compared to my pension/income restricts my life (-) 17. I have a lot of control over the important things in my life (+)	0.57 (745)

Table 4.6 continued. Internal consistency of the different domains of quality of life in OPQOL-35 questionnaire

Domain	Questions representing each domain	Cronbach's alpha (N)
D5 **Home and neighbourhood**	18. I feel safe where I live (+) 19. The local shops, services and facilities are good overall (+) 20. I get pleasure from my home (+) 21. I find my neighbourhood friendly (+)	0.51 (745)
D6 **Psychological and emotional wellbeing**	22. I take life as it comes and make the best of things (+) 23. I feel lucky compared to most people (+) 24. I tend to look on the bright side (+) 25. If my health limits social/leisure activities, then I will compensate and find something else I can do (+)	0.52 (742)
D7 **Financial circumstances**	26. I have enough money to pay for household bills (+) 27. I have enough money to pay for household repairs or help needed in the house (+) 28. I can afford to buy what I want to (+) 29. I cannot afford to do things I would enjoy (-)	0.82 (746)
D8 **Leisure activities and religion**	30. I have social or leisure activities/hobbies that I enjoy doing (+) 31. I try to stay involved with things (+) 32. I do paid or unpaid work or activities that give me a role in life (+) 33. I have responsibilities to others that restrict my social or leisure activities (-) 34. Religion, belief or philosophy is important to my quality of life (+) 35. Cultural/religious events/festivals are important to my quality of life (+)	0.33 (745)

(+) positively worded questions (-) negatively worded questions

4.7.5 Data collection procedure

The data collection for this study was conducted from 3rd October to 23rd December 2016. Five research assistants who had completed a Bachelor's degree in Nursing collected the survey data from the entire sample. They were assisted by five field assistants who had passed the General Certificate of Education Advanced Level examination. Comprehensive training was given to both the research assistants and field assistants on all aspects of the study. A two day workshop, including field training was conducted to explain the protocol of the study, data collection methods, study instruments, and ethical aspects of the study, etc. Practical training experience on taking anthropometric measurements, conducting the physical performance tests, and administering questionnaires in the prescribed manner were provided to research teams with older adults in a GN division of the Kegalle district that was not included in the sampling design.

There were five teams and each team comprised of a research assistant and a field assistant. I supervised the field work on a daily basis and allocated the selected participants to each team. The Grama Niladhari officer of the respective GN division provided assistance to identify the households of potential participants and introduced the research team to the participants and their household members. In general each team collected data from three participants in a single GN division. The Sri Lankan supervisor of my PhD (MCW) also made 12 field visits

to assist with training the whole research team and supervise the data collection process.

4.7.6 Quality of data

This section briefly summarises the methods employed to assess the quality of data collected and corresponding results. The estimated internal consistency (measure of scale reliability that indicates to what extent the different items in an instrument measure the same concept[61]) of all study instruments was considered as 'good' with the present study sample except the 'Oslo 3-item social support scale' (Cronbach's alpha=0.61) and the 'Social activity participation scale' (Cronbach's alpha=0.27). The Oslo 3-item social support scale demonstrated a moderate Cronbach's alpha, 0.61 (a common measure of internal consistency) and therefore was used in subsequent analyses. However, this scale (Oslo 3-item social support scale) has not been validated in Sri Lanka yet. Due to poor internal consistency, 'Social activity participation scale' was excluded from the present study (Appendix 10, page 454).

In order to assess intra-rater reliability, the same research assistant measured height and weight, measured grip strength in both left and right hands of the participants in three trials, and measured the time taken to walk 15 feet in two trials. The intra-rater reliability of these anthropometric measurements and physical performance tests was excellent across all five research assistants (Appendix 11, page 456). Inter-rater reliability of the responses for selected questions was assessed between five research assistants and myself (DDS) ranging

from moderate to excellent except on a few occasions (Appendix 12, page 458). The inter-rater reliability of the Lawton IADL scale-Sinhala version is presented in Chapter 5 (page 213). The intra-rater and inter-rater analyses were only performed to explore the quality of the data collected. Any measurement or question was not excluded during the analyses based on these results.

4.8 Data analysis

4.8.1 Data entry, cleaning, and verification

In order to ensure the consistency of data entry, a booklet was developed with guidelines and coding instructions where appropriate for each variable in the questionnaire. Data were double entered into two SPSS databases, version 24 (SPSS Inc, Chicago, IL) by two operators (DDS and NK). The SPSS databases were imported into EpiData software version 3.1[299] and, if necessary, discrepancies were corrected with reference to the original questionnaires. The corrected database was imported into Stata version 15 (StataCorp, College Station, Texas, USA) for data cleaning. Variable codes in the database were checked against the actual codes in the codebook. Frequency analysis and cross-tabulations (where appropriate) of all variables were performed to identify missing values, outliers, and any data entry errors. Graphical explorations of distributions were performed using histograms, scatter plots, and box plots.

4.8.2 Covariates used in the analyses

4.8.2.1 Sociodemographic variables

Sociodemographic characteristics included: sex, age (age in years presented as five groups; 60-64, 65-69, 70-74, 75-78, ≥80), ethnicity, marital status, and living arrangements. Social support was measured using the Oslo-3 item social support scale. The total score of the scale ranged from 3-14 and participants were classified into three categories based on standard cut-offs: 3-8 as 'poor support', 9-11 as 'moderate support', and 12-14 as 'strong support'. The International Standard Classification of Education (ISCED) was used to classify the educational level of the participants. Classification of the longest-held income generation activity/occupation was performed using the Sri Lanka Standard Classification of Occupation[300] which is based on the International Standard Classification of Occupations 2008 (ISCO-08).[301] ISCO-08 comprised of 10 major occupation groups and is further divided into four skill levels where skill level four requires the highest intellectual capacity.[301] Subjective financial strain was assessed using a validated single question "How well would you say you are managing financially these days?".[274]

4.8.2.2 Health-related variables

Nine health-related factors were included in the analysis. Multimorbidity was defined as co-existence of two or more concurrent chronic medical conditions.[302, 303] The most common definition used to define polypharmacy (a numerical definition of five or more medications used daily[304]) was employed in the present study. Existence of chronic pain in any part of the body was self-reported (yes/no). Montreal Cognitive Assessment (MoCA) was used to assess cognitive status: the total score of the assessment ranged from 0-31, with a higher score indicating higher cognition. The cut-off value of <24 has provided the best balance between sensitivity (98.0%) and specificity (79.6%) in detecting dementia with a sample of Sri Lankan adults aged ≥50 years.[280] The original MoCA validation study reported sensitivity of 100.0% and specificity of 87.0% in detecting mild Alzheimer's disease and 90.0% sensitivity of detecting mild cognitive impairment at the cut-off of <26.[279] The MoCA website has provided cut-off scores for grading the severity of cognitive impairment as follows: mild cognitive impairment (18-25), moderate cognitive impairment (10-17), and severe cognitive impairment (<10).[305] However, research for these severity ranges has not been established yet. When I applied these cut-offs to this present Sri Lankan sample (after replacing the upper limit of mild cognitive impairment: score of 25 from 23), 28.5% and 7.0% belonged to the moderate and severe cognitive impairment categories respectively. It is also of note that I only recruited the participants who were capable of giving informed consent. Considering all these factors I used median

MoCA score=20 of the present sample to divide participants into two groups in order to use in the data analyses. The 15-item Geriatric Depression Scale (GDS-15) was used to assess the presence of depressive symptoms. The total score of the scale ranged from 0-15, where a higher score indicated higher depressive symptoms. Participants were classified into three categories based on the total score as follows: 'almost always indicative of depression'-high risk (score ≥10), 'suggestive of depression'-moderate risk (score 5-9), and 'normal'-low risk (score 0-4). Self-perceived vision and hearing ability and self-perceived oral health and general health were assessed using a five point Likert scale: the response options were 'poor', 'fair', 'good', 'very good', and 'excellent'.

4.8.2.3 Lifestyle variables

The National Health Interview Survey current smoking definition[285] was used to determine the smoking status of the participants. An adult who had never smoked or who had smoked less than 100 cigarettes in his or her life time was classified as a 'never smoker'. An adult who had smoked at least 100 cigarettes in his or her lifetime but who had quit smoking at the time of interview was classified as a 'former smoker'. An adult who had smoked 100 cigarettes in his or her lifetime and who reported currently smoking cigarettes was classified as a 'current smoker'.[306] Participants were asked whether they had consumed any alcohol within the past 12 months (yes/no).

The question format of the diet module of WHO STEPS instrument version 3.1 was employed to assess the weekly animal protein, plant protein, vegetable, and fruit

intake. The animal protein food group included all types of fish, meat, dried fish, and eggs. All types of pulses were considered as plant protein sources. Both leafy vegetables and root (excluding potatoes, sweet potatoes, and yams) and fruit vegetables were considered as vegetables. Participants were asked to report their food consumption of a typical week when the diet is not affected by cultural, religious or other events. As per the Sri Lankan guidelines, the recommended daily serving sizes for each food group were as follows: four servings from animal or plant protein sources, five servings from vegetables, and 2-3 servings from fruits.[289] The number of days each food item was consumed was multiplied by the number of servings consumed per day to obtain weekly servings intake for each food group. I decided to study animal and plant protein intake separately as the majority of the older adults, particularly in rural areas, are refraining or reducing consumption of animal proteins due to religious beliefs. For each food group, tertiles were computed as low, moderate, and high based on the weekly servings intake. Respective serving sizes for both animal and plant protein intake tertiles were as follows: ≤11 (low), 11.25-19 (moderate), and ≥19.25 (high). Serving sizes for animal protein intake tertiles were as follows: ≤4 (low), 4.5-7 (moderate), and ≥7.5 (high). Serving sizes for plant protein intake tertiles were as follows: ≤5 (low), 6-12 (moderate), and ≥12.5 (high). Serving sizes for vegetable intake tertiles were as follows: ≤18 (low), 18.5-28 (moderate), and ≥28.5 (high). Serving sizes for fruit intake tertiles were as follows: ≤2 (low), 3-5 (moderate), and ≥6 (high).

4.8.3 Statistical methods

All statistical analyses were performed in Stata version 15 accounting for the complex survey design unless otherwise stated.[307] Depending on the type of data, the following methods were used to summarise the data. Categorical data were analysed and presented using percentages. Both discrete and continuous data were summarised and presented using the mean and standard error (SE) if the distribution was normal and by using median and interquartile range (IQR) if the distribution was skewed. Depending on the nature of the dependent variable, regression analyses were performed to estimate the associations between frailty and other variables. As missing data were minimal, those with partial missing data were included in the descriptive analyses and a complete case analysis was conducted in the regression analyses.

4.8.3.1 Prevalence of frailty and sociodemographic, health-related, and lifestyle factors associated with frailty

The overall prevalence of frailty status (frail, pre-frail, non-frail) and frailty status by sociodemographic, health-related and lifestyle factors was estimated with 95% CIs. First, ordinal logistic regression was used to examine the association between sociodemographic variables and frailty status. The multivariable ordinal logistic regression model failed to hold the proportional odds assumption. Hence, multinomial logistic regression was used to estimate the separate associations between sociodemographic, health-related, and lifestyle covariates and frailty

status. Unadjusted, age-and sex-adjusted, and multivariable-adjusted relative risk ratios (RRRs) were computed with 95% CIs.

4.8.3.2 Frailty and disability

The prevalence of disability (having ≥1 IADL and ≥1 BADL limitations) was estimated with 95% CIs across sociodemographic characteristics and health-related factors. Prevalence of disability and specific IADL and BADL limitations was also estimated with 95% CIs in the overall sample and by frailty status. A Venn diagram and a stacked bar chart were used to illustrate the overlap between frailty, physical IADL limitations, and cognitive IADL limitations.

The association between frailty and number of IADL limitations was estimated as follows. The total number of IADL limitations is a count dependent variable ranging from 0-8. There was an excess number of zeros (overall 67.2% participants had no IADL limitations). Therefore I used zero-inflated Poisson (ZIP) regression models to estimate the associations between frailty status and the number of IADL limitations. ZIP regression models for a count dependent variable with excess zeros assume two latent groups: the first is the group of 'sure zeros'/ 'not-at-risk' latent class (the group expected to have a count of zero) and the second is the group of 'non-sure zeros' (or the 'at-risk' latent class).[308] ZIP models comprise of two parts. Firstly, a logistic regression model is used for predicting the probability of participants belonging to the latent class of 'sure zeros'. Secondly, a Poisson regression model is used for predicting the count of the dependent variable for those participants predicted to belong to the latent 'non-sure zero'/ 'at-risk'

group. As in other studies, to interpret the parameter estimates for the frailty groups, I interpret the parameters of the logistic regression model using Odds Ratios (ORs), and interpret the parameters of the Poisson regression model (count component among the non-sure zeros) using the rate ratios (RRs). Unadjusted, age-and sex-adjusted, and multivariable-adjusted ZIP models were fitted to estimate the associations between pre-frailty, frailty and number of IADL limitations. Multivariable models were built by a step-wise addition of covariates to the age-and sex-adjusted models. Variables included in the multivariable model were based on known potential confounders in the literature and clinical relevance/plausibility.

A Venn diagram was used to illustrate the overlap between frailty and BADL limitations. Modelling the association between frailty status and BADL limitations was not performed due to the lack of heterogeneity in the presence of ≥1 BADL limitations across the frailty groups (refer to Table 7.2 in the Chapter 7, page 293).

4.8.3.3 Frailty and quality of life

Participants were classified into three groups according to the lowest (76-127), intermediate (128-139), and highest (140-171) tertiles of the total OPQOL-35 score. Sociodemographic, health characteristics, and frailty status across the QoL tertiles were presented using percentages and medians (IQR) where appropriate. Box plots were used to illustrate the distribution of the total QoL score according to frailty status. Unadjusted means (SEs) of total and raw domain-specific quality of life scores were calculated and compared between the frailty groups using an

adjusted Wald test (the eight domains were outlined in Table 4.6 (page 195)). The maximum possible scores are not constant across the eight domains. Hence, standardised domain-specific QoL mean scores were computed as follows: (unadjusted mean score/maximum possible score)*100.[174] Therefore, the standardised scores have a minimum of 0 and maximum of 100.

The analysis was conducted in two main parts:

Part 1: The total QoL score was found to be normally distributed and I therefore used linear regression models to estimate the unadjusted, 'age-and sex'-adjusted and multivariable-adjusted association between frailty status and overall QoL, with total QoL score as the dependent variable. Multivariable models were built by a step-wise addition of covariates to the 'age-and sex'-adjusted models. Variables included in the multivariable model were decided a priori based on known potential confounders in the literature and clinical relevance. The final multivariable-adjusted model was further evaluated for model assumptions. Goodness of fit (R^2 statistic) was reported for the final models.

Part 2: I fitted further multivariable linear regression models to explore how the different domains of QoL were associated with frailty and pre-frailty. All models were adjusted for the covariates used in the final multivariable model of the part 1 analysis.

For parts 1 and 2, I present the results using the estimated difference in means between frailty groups (with the non-frail group as reference category) and also

computed the reduction from the maximum possible score as a percentage as follows: (mean difference in QoL score/maximum possible score)*100.

4.9 Ethical standards and procedures

4.9.1 Assessment of risks and potential benefits to the participants

Risks involved with research involving human participants could be classified into different domains such as physical, psychological, social, and financial. In the present study, no invasive procedures were used. Only anthropometric measurements (weight and height) were taken and participants were asked to perform two physical performance tests comprising of grip strength and walking speed. During the walking speed assessment a participant had to walk 15 feet. The walking test carried a small risk of falling, but a field assistant walked next to the participant to minimise this risk. Further, participants were permitted to use assistive devices, e.g. cane or walker if needed. On average a participant spent 1.5 to 2 hours with a research assistant to complete the whole interview. As it was tiring for older adults to complete the physical assessments and answer the questionnaire continuously, participants were offered small breaks in between parts of the interview. A few of the questions were of a personal nature, for example on mood and feelings. Participants were informed that they could choose not to answer any questions if they did not want to answer. The occupational activities of some participants (e.g. rubber tapping, tea picking, and some other agricultural activities, etc.) were interrupted for a short period as they agreed to participate in the study.

Immediate benefits for the participants included being informed about their BMI and performances of physical assessment tests (grip strength and gait speed) according to the age-and sex-specific cut-off points used in the original CHS[10] following the completion of interview. However, they were also informed of the need to calculate Sri Lankan population specific cut-off points based on the anthropometry of the survey sample as the original CHS cut-off points were developed for the USA population[10]. Clear procedures were in place if any concerns arose during the duration of the data collection. For example, if a participant was at risk of depression, the participant and a close relative were informed and advised to take the participant to the nearest healthcare facility.

4.9.2 Selection of study population and recruitment of research participants

A three stage probability sampling design was used to recruit the participants for the present study. Hence, the process of selecting the participants for this study was fair and impartial. However, participants who were not capable of giving informed consent were excluded.

4.9.3 Inducements, financial benefits, and financial costs for participants

No monetary or material incentives for taking part were provided for the participants. This was made clear to the potential participants at the very beginning while explaining the objectives and the nature of the study. Participants did not incur transport costs as the research team visited the households of the potential participants.

4.9.4 Protection of research participants' privacy and confidentiality of data

No personal identifiable information (e.g. name, address, and contact telephone numbers) were collected during the interview. Therefore, the privacy of the participants was protected. The following measures were taken to protect the confidentiality of data. Each questionnaire was assigned a unique identification number. This identification number was entered into the database while entering the data. The original questionnaires (which contained no identifiable information such as dates of birth, names, addresses, etc.) and consent forms were kept in a locked cupboard in a locked room at the Research Department of Primary Care and Population Health, University College London, UK. Access to the database and the questionnaires was restricted to the members of the research team. The database which contains no identifiable information has been stored in University College London's secure computer network. Data were collected in accordance with the United Kingdom's Data Protection Act, 1998. These collected personal data were processed in accordance with the Data Protection Act 2018 and General Data Protection Regulation 2018.

4.9.5 Informed consent process

Informed written consent was obtained from all the study participants. The potential participants were given the invitation letter about the study (Appendix 13 page 464) and the details of the study were explained. The information sheet (Appendix 14, page 465) was also attached with the invitation letter for more information. On occasions where potential participants were unable to read the

information, research assistants assisted participants and read information to them. Potential participants were given a chance to ask questions about the research and clarify any related issues and an opportunity to discuss the study with their family members if they felt necessary. If the potential participants agreed to take a part in the study, a consent form (Appendix 15, page 470) was completed and signed. In the cases where participants could not put their signature in writing, a thumb print signature was obtained. Participation for the study was voluntary. The participants were informed that they could withdraw from the study at any point despite having given consent at the beginning. Participants were made aware that the decision to participate or withdraw from the study did not affect their current medical care provision.

4.9.6 Results dissemination plan

A plain language summary of overall study results will be produced. Participants were given the opportunity to contact me if they wish to know the overall study results. The findings of the research were included in this thesis. Results have been disseminated through presentations at international conferences and through publications in peer-reviewed journals which is an on-going process. Results will also be disseminated to Health Policy makers in Sri Lanka at the Ministry of Health, Nutrition and Indigenous Medicine, National Health Research Council, Provincial Director of Health Services and Regional Director of Health Services in Kegalle district where the research was conducted. Anonymity of the participants will be protected in these communications by the research team.

4.9.7 Ethical approval and administrative permission

The ethical clearance for this study was obtained from two ethics review committees at University College London (Project ID: 8155/001) (Appendix 16, page 473) and Faculty of Medicine, University of Colombo, Sri Lanka (Protocol No. EC-16-071) (Appendix 17, page 475). Administrative permission for the study was obtained from relevant government authorities of national, provincial, district, and divisional level.

4.9.8 Patient and Public Involvement

Sri Lankan older adults were not involved in the study design as the study was developed in the UK as part of a Commonwealth Scholarship, with limited resources. I used standard study instruments and physical assessment tests, which had been developed elsewhere, and most of these have been cross-culturally adapted and validated for Sri Lankan population. Prior to data collection in Kegalle district, I obtained feedback from 10 Sri Lankan older adults (from a different location in Kegalle district) on the study processes, including how to phrase certain questions and the best order of administering the instruments. As mentioned in Section 4.9.6 (page 211) a plain language summary of overall study results will be produced in English and translated into Sinhala and Tamil languages. I will discuss with public representatives the best way to present and disseminate this information.

Chapter 5: Methodological sub-study: cross-cultural adaptation and psychometric evaluation of the Sinhala version of Lawton Instrumental Activities of Daily Living scale

5.1 Overview of the chapter

In this chapter I present the methodology used for the cross-cultural adaptation and psychometric evaluation, and the findings of the reliability and validity testing of the new culturally adapted Sinhala version of the Lawton Instrumental Activities of Daily Living scale. This methodological sub-study has been published as a peer-reviewed journal article by Siriwardhana et al in PLOS ONE journal in 2018.[292]

5.2 Introduction

'Activities of daily living' measurement instruments are commonly used to assess limitations people may experience in performing the various activities required in day-to-day life. Two types of activities are typically assessed: Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL). BADL are cognitively less complex self-maintaining tasks which include feeding, dressing, bathing, toileting, etc. These activities do not require attentional processes. Conversely, IADL are more complex tasks and require higher level cognitive functions such as memory, attention, and executive functions.[290, 309] Example IADL tasks are food preparation, housekeeping tasks, taking own medication, handling finances, etc. These activities are important for people to lead an independent life.[310] IADL limitations are often present within the context of mild cognitive impairment and early dementia.[311] IADL limitations are associated with both poor quality of life[312] and increased healthcare costs.[313]

Performance based assessments, self-reported questionnaires, and informant based questionnaires are the three main methods used to assess IADL. Of them, self-reported questionnaires are the more prevalent method[314], largely due to their ease of use in large-scale community surveys. Despite the existence of a number of questionnaires to assess IADL[310, 315], no gold-standard exists[315]. One of the most widely used is the Lawton Instrumental Activities of Daily Living scale developed in 1969.[290, 316] A few modifications to the original scale are also available in the literature: modified Lawton-Brody scale proposed in 1988[317],

Lawton IADL scale in MFA (Multidimensional Functional Assessment of Older Adults)[318], and Lawton IADL scale in MAI (Multilevel Assessment Instrument).[319] Cultural adaptability, reliability, and validity of the original[293, 320-322] and Lawton IADL scale in MAI[323] have been tested in older populations (aged ≥60 or ≥65 years) in studies conducted in Greece[320], Hong Kong[323], Iran[321], Singapore[293], and Spain[322]. Study populations included outpatients of memory clinics[320], patients with dementia[321], patients who attended emergency rooms with a hip or wrist fracture due to a fall[322], institutionalised older adults[323], and community-dwelling older adults[293].

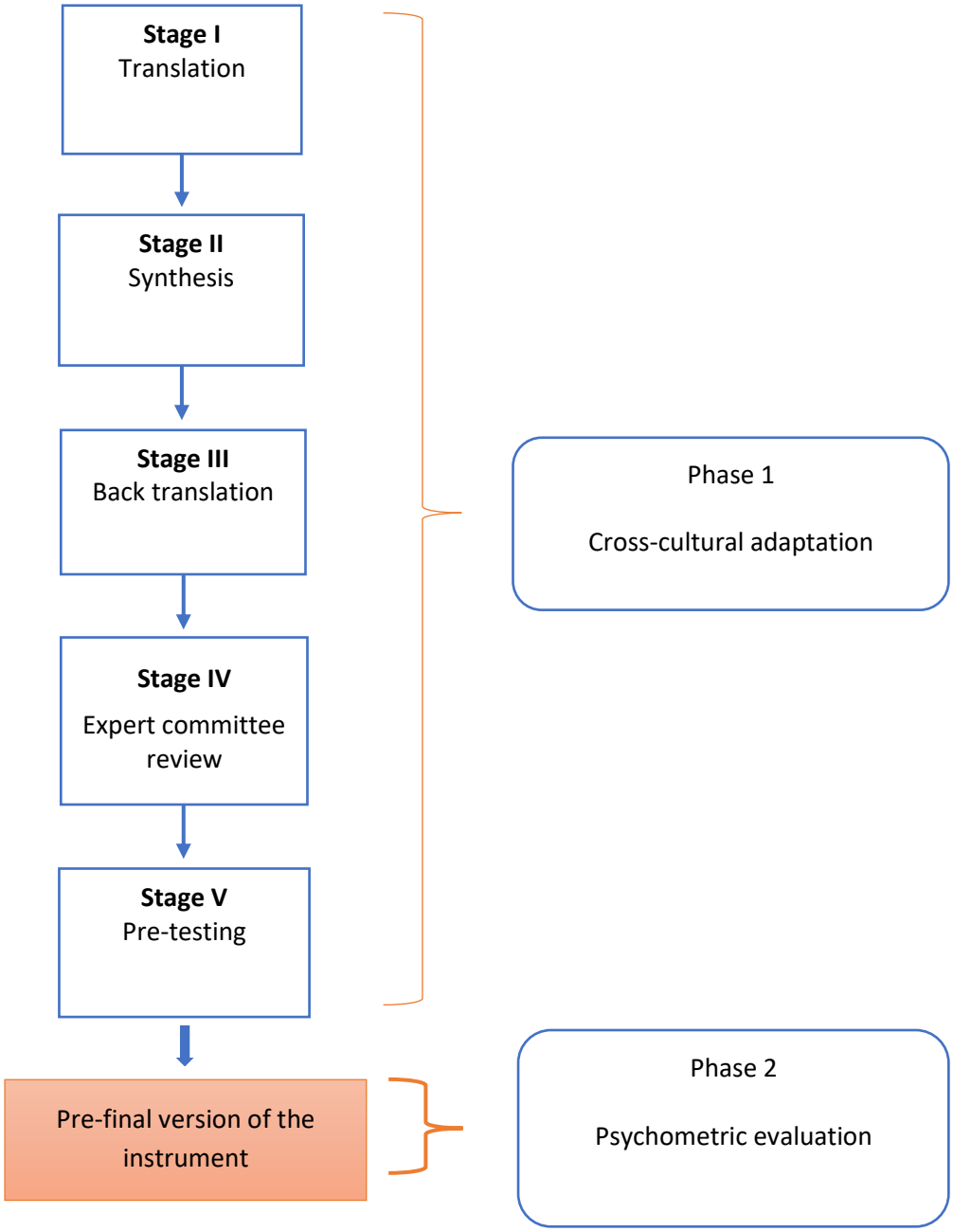
Three studies were found reporting IADL in Sri Lankan older adults.[324-326] However, none of the studies reported use of a standard questionnaire to assess IADL, and instead used a few selected IADL tasks. Only four of the eight IADL tasks have been assessed in two studies[324, 325] and six were assessed in the remaining study.[326] There was therefore no culturally adapted, psychometrically tested instrument available to assess instrumental activities of daily living in Sri Lanka. It is important to have a standard instrument for this purpose as Sri Lanka is one of the fastest ageing countries in WHO South-East Asia region.[141] One of the key objectives of this thesis (Part B) is evaluating the association between frailty and disability. Disability is an adverse outcome of frailty according to the Fried conceptualisation of frailty[107] and was operationalised in terms of limitations of IADL and BADL for the present study. Hence, a rigorously tested instrument was required to assess the IADL of study participants. Therefore, the objective of this methodological

sub-study was to translate and cross-culturally adapt the original Lawton Instrumental Activities of Daily Living scale from English to Sinhala and to evaluate the psychometric properties of the Sinhala version.

5.3 Methodology

The methodology of this sub-study comprised of two phases. Phase one involved cross- cultural adaptation of the Lawton IADL scale. Phase two involved evaluating the psychometric properties of the adapted Sinhala scale which included testing its reliability (internal consistency and inter-rater reliability) and validity (cross-cultural validity, structural validity, and convergent validity). Figure 5.1 (page 217) illustrates the study methodology.

Figure 5.1 Study methodology



Note: Figure was taken from a published paper by Siriwardhana et al[292] and has been modified slightly.

5.3.1 Lawton Instrumental Activities of Daily Living scale

The original Lawton IADL scale was selected for this study[290] (Table 5.1, page 219). It is a widely used instrument to measure IADL of older adults in different settings; community, clinics, and hospitals.[316] It is easy to administer (within 10-15 minutes) and most newer scales have also been derived from the original Lawton IADL scale.[315] The scale encompasses eight activities which include 'ability to use telephone', 'shopping', 'food preparation', 'housekeeping', 'laundry', 'transport', 'responsibility for own medication', and 'ability to handle finances'. Each activity has a varying number of response options indicating the participant's degree of ability to perform each activity starting from completely independent status to completely dependent status. Despite having a number of responses available under each activity, participants are classified into two categories as 'dependent' (0) and 'independent' (1). The total score of the scale therefore ranges from 0 (fully dependent) to 8 (fully independent). Historically females were scored on all the items of the scale and males were scored for only five items of the scale excluding the food preparation, housekeeping, and laundering activities. However, the current recommendation is to assess all activities with both sexes.[327]

Table 5.1 The Lawton Instrumental Activities of Daily Living (IADL) scale

A. Ability to Use Telephone	
1. Operates telephone on own initiative-looks up and dials numbers, etc.	1
2. Dials a few well-known numbers.	1
3. Answers telephone, but does not dial.	1
4. Does not use telephone at all.	0
B. Shopping	
1. Takes care of all shopping needs independently.	1
2. Shops independently for small purchases.	0
3. Needs to be accompanied on any shopping trip.	0
4. Completely unable to shop.	0
C. Food Preparation	
1. Plans, prepares, and serves adequate meals independently.	1
2. Prepares adequate meals if supplied with ingredients.	0
3. Heats and serves prepared meals or prepares meals but does not maintain adequate diet.	0
4. Needs to have meals prepared and served.	0
D. Housekeeping	
1. Maintains house alone or with occasional assistance (e.g., "heavy work-domestic help").	1
2. Performs light daily tasks such as dishwashing, bed making.	1
3. Performs light daily tasks, but cannot maintain acceptable level of cleanliness.	1
4. Needs help with all home maintenance tasks.	1
5. Does not participate in any housekeeping tasks.	0
E. Laundry	
1. Does personal laundry completely.	1
2. Launders small items, rinses socks, stockings, etc.	1
3. All laundry must be done by others.	0
F. Mode of Transportation	
1. Travels independently on public transportation or drives own car.	1
2. Arranges own travel via taxi, but does not otherwise use public transportation.	1
3. Travels on public transportation when assisted or accompanied by another.	1
4. Travel limited to taxi or automobile with assistance of another.	0
5. Does not travel at all.	0
G. Responsibility for own Medications	
1. Is responsible for taking medications in correct dosages at correct time.	1
2. Takes responsibility if medication is prepared in advance in separate dosages.	0
3. Is not capable of dispensing own medication.	0
H. Ability to Handle Finances	
1. Manages financial matters independently (budgets, writes cheques, pays rent, bills, goes to bank), collects and keeps track of income	1
2. Manages day-to-day purchases, but needs help with banking, major purchases, etc.	1
3. Incapable of handling money.	0

The original scale uses the self-report/surrogate report (proxy) 'actual performance' question stem, and later versions offered options of assessing self-report/surrogate report 'actual performance' and 'capacity'. Examples of 'actual performance' and 'capacity' question stems are "do you do shopping?" and "can you do shopping?" respectively. The self-reported 'capacity' question stem was used in the present study with the items and response structure of the original scale. I selected this option because in the Sri Lankan cultural context older adults are often supported by their own children and relatives, and therefore may not actually perform activities that they have capacity for. According to the recent Sri Lankan census 59.0% of older adults lived in extended households.[328] It is likely that some older adults are not fully engaged in doing certain IADL activities like housekeeping, shopping, preparing meals, and handling finances even though they are fully capable of these activities. Sri Lanka is a country with reasonable gender equality.[329] Therefore, all the items in the scale were used with both males and females. Permission was granted from Oxford University Press to translate and republish the original scale in Sinhala language.

5.3.2 Phase 1- Cross-cultural adaptation process

The systematic method proposed by Beaton and colleagues[291] was followed during the cross-cultural adaptation process.

Stage 1- Forward translation: two bilingual translators who have a background in public health (myself, DDS) and in community medicine (MCW, Sri Lankan supervisor) independently translated the English version of the entire instrument

into Sinhala. The first language of both translators was Sinhala. They independently recorded the issues they had while translating the instrument.

Stage 2- Synthesis of the translations: a common Sinhala version of the instrument was created using the two independent translated versions.

Stage 3-Back translation: the synthesis version created at the stage 2 was used for the back translation process. Two translators (TW, SJ different to stage 1 translators) who are fluent in both English and Sinhala languages conducted the back translations independently. Both were blind to the original instrument and original independent translated versions. Two back translated versions were compared with the original English version of the instrument for a validity check.

Stage 4- Expert committee review: a panel of experts from medical, allied health science, sociological backgrounds, and translators (forward and backward) reviewed the two forward translations, and two backward translations with the original scale. Consultations were conducted in person, and in addition by using email conversations, and via video conferencing. Issues raised at the translation process were addressed and a preliminary version of the instrument was created and circulated among the review members.

Stage 5- Pre-test: the preliminary version of the instrument was pre-tested with five male and five female older adults in different age categories living in the district where the psychometric testing was planned. The pre-final version of the instrument was created to use in the psychometric evaluation.

5.3.3 Phase 2- Psychometric evaluation

5.3.3.1 Study design, setting, participants, and data collection

Psychometric evaluation, namely reliability and validity testing of the instrument was carried out alongside the main study (Part B of thesis). Please refer to the following sections in the Chapter 4 for detailed descriptions on study setting (Section 4.2, page 152), study population (Section 4.3, page 158), sample size calculation (Section 4.4, page 158), sampling design (Section 4.5, page 166), data collection (Section 4.7, page 178), and ethical standards and procedures (Section 4.9, page 208).

According to the scale of sample size adequacy described by Comrey and Lee, a sample size of 500 would be considered as very good whereas 1000 or more would be considered as excellent in Exploratory Factor Analysis (EFA).[330] Alternatively, Nunnally (1978) recommended sampling at least ten times as many subjects as variables (items).[331]

5.3.3.2 Data analyses: participants' characteristics and distribution of Lawton IADL scale-Sinhala version scores

The sociodemographic characteristics of the study sample (overall and for those chosen for the methodological sub-study) was described using frequencies and percentages. The eight items of the IADL scale were coded to preserve the original response structure as they do not have uniform response structure (ability to use telephone (1-4), shopping (1-4), food preparation (1-4), housekeeping (1-5),

laundry (1-3), transport (1-5), responsibility for own medication (1-3), and ability to handle finances (1-3). The minimum number represents the response indicating complete dependent status for each item whilst the maximum number represents the response indicating highest independent status. However, when assigning scores according to the guidelines of the scale, response for each item was coded either as 0 (dependent) or 1 (independent). Hence, the total score of the IADL scale ranges from 0 to 8.

5.3.3.3 Reliability testing: internal consistency and inter-rater reliability

Measures of internal consistency indicate to what extent different items in an instrument measure the same construct.[61, 332] The standardised Cronbach's alpha was used as the scale items did not have a uniform response structure. Alpha values between 0.7 and 0.95 indicate a scale that has a good internal consistency.[61]

Inter-rater reliability (IRR) indicates the degree of agreement among different raters when performing the same assessment method on the same individual.[332] IRR was assessed in a randomly selected 12.0% of the total sample (n=89), representing 26 SSUs. The number of participants recruited from each GN division varied from 1-5 with the mode number of participants being 3 and 4. Research assistants (5 raters) administered the IADL scale. After a gap of 2.5 to 3 hours, I re-administered the scale with the same participants. Therefore, each participant had been assessed by two raters (one of A/B/C/D/E and the other DDS).

IRR of each individual item was assessed considering its original response structure (ordinal) and after scoring (binary). Participants with missing values were excluded. For the ordinal case, inter-rater reliability was calculated using weighted percentage agreement coefficient, weighted Cohen's kappa, and weighted Gwet's agreement (Gwet's AC_2).[333] Ordinal weights were used. For the binary case, unweighted percentage agreement coefficient, Cohen's kappa, and Gwet's AC_1 agreement were used. Both Gwet's AC_1 and AC_2 agreement coefficients are corrected for chance agreement and adjusted for misclassification errors.[334] Moreover, they are consistent with the percentage agreement.[334] Hence, Gwet's AC_1 and AC_2 measures are superior to the better known Cohen's kappa.[335] Values of Cohen's kappa, Gwet's AC_1 and AC_2 were interpreted using criteria proposed by Landis and Koch.[336] Values between 0 and 0.20, between 0.21 and 0.40, between 0.41 and 0.60, between 0.61 and 0.80, and >0.80 are indicative of slight, fair, moderate, substantial, and excellent agreement respectively.

The Intraclass Correlation (ICC) coefficient was used to assess the agreement of the total score of the scale between each rater and DDS. Single rating, absolute agreement, based on a two way mixed effects model was used.[337] An ICC value of less than 0.5 implies poor reliability, 0.50-0.75 moderate, 0.75-0.90 good, and greater than 0.90 excellent reliability.[337] All the agreement coefficients and ICCs were computed using the *kappaetc* user written Stata programme.[338] Stata version 14 (StataCorp, College Station, Texas, USA) was used for the analyses.

Guidelines for Reporting Reliability and Agreement Studies (GRRAS) proposed by Kottner et al were followed.[339]

5.3.3.4 Validity testing

Cross-cultural validation, structural validation, and hypothesis testing are the three main approaches used to establish construct validity.[340] The process of cross-cultural adaptation/validation of the IADL scale was described above. Factor analysis is the most commonly used method to understand the underlying factor structure of a construct.[332, 341] Hypothesis testing was used to establish the convergent validity of the scale.[340] Convergent validity indicates how well the new instrument relates to other measures of the same or related construct.[342]

Exploratory factor analysis (EFA)

Exploratory factor analysis explores the underlying factor structure of a construct.[343, 344] EFA was performed with 702 participants to test the hypothesis that the translated IADL scale is unidimensional, i.e. that the responses of the participants to the 8 items in the IADL scale represent one construct (instrumental activities of daily living). The original response structure of the scale was used in the analysis. Parallel analysis (PA) was run to determine the number of factors to retain in the model. PA was carried out on polychoric (two step) correlations with permuted samples, using principal component estimation and mean eigenvalue criterion.[345] Principal axis factoring was chosen as the factor extraction method because the study data is ordinal and it violates the assumption of multivariate

normality.[344] Principal axis factoring is also capable of detecting weak factors.[346] The Kaiser-Meyer-Olkin (KMO) statistic and Bartlett's test of sphericity were used to determine the appropriateness of running the factor analysis on the study data. KMO values vary from 0 to 1 and values >0.5 are typically described as acceptable for performing factor analysis (i.e. that the data is factorisable).[347] Result of the Bartlett's test requires to be significant ($p<0.05$). Communalities ≥0.4 and factor loadings ≥0.5 were considered as satisfactory (i.e. that the items correlate positively with the underlying structure).[343] The analysis was performed on the polychoric (two step) correlations using SPSS R-menu v2.0.[348]

Confirmatory factor analysis (CFA)

Confirmatory factor analysis was performed to explore whether the observed data fit the hypothesised single factor structure of the IADL scale. Analysis was performed with the original response structure. To accommodate the ordinal response structure of the scale items, CFA was performed on the asymptotic covariance matrix that was calculated using the polychoric correlations. Diagonally weighted least square technique was used as the estimation method, which is recommended for use when fitting structural equation models with ordinal variables.[349] Several goodness of fit indices were evaluated to determine the model fit. Evaluated fit indices include chi-square value (Satorra-Bentler scaled chi-square) with its degrees of freedom and associated p value, Relative/normed (χ^2/df) chi-square, Root Mean Square Error of Approximation (RMSEA), Non-Normed Fit Index (NNFI)/ Tucker Lewis Index (TLI), Comparative Fit

Index (CFI), Standardised Root Mean Residual (SRMR), and Parsimonious Normed Fit Index (PNFI). An insignificant chi square at a threshold of 0.05 is indicative of good model fit.[350] No consensus is available for the acceptable ratio of relative chi-square. Wheaton et al suggested a value of 5.0.[351] For RMSEA Tuker and Lewis[352] suggested a cut-off of 0.06 whereas Steiger[353] proposed a strict upper limit as 0.07. For NNFI and CFI a cut-off value of ≥0.95 is accepted as good model fit.[352, 354] For SRMR a value of ≤0.08 is considered as appropriate.[354] No threshold level has been specified for PNFI. CFA was performed on LISREL 9.30 student edition.

Historically Lawton et al (1969) proposed using the full scale (8 items) with females and five items (excluding food preparation, housekeeping, and laundry) for males.[290] However, they had not checked the structural validity of IADL scale on this aspect. Therefore, both EFA and CFA were performed with females and males separately including all items.

Convergent validity

The Barthel index of daily living measures the disability or dependence in basic activities of daily living (BADL), which are cognitively less complex tasks than IADL[294] (refer to Table 4.5, page 192). According to the response for each item, participants were classified into two groups as 'dependent' (0) and 'independent' (1). The scale comprised of 10 items and the total score ranges from 0-10: a higher score indicates a higher level of independency. Mild cognitive impairment is also associated with impairments in IADL.[355] The Montreal cognitive assessment

(MoCA) is a brief screening tool for mild cognitive impairment[279] (refer to Section 4.7.2.2, page 186). The total score of the assessment ranges from 0-31: with higher scores indicating higher cognition. To assess the convergent validity of the IADL scale, it was hypothesised that the IADL score is positively correlated with the Barthel index score and with the MoCA score. Spearman's correlation coefficient was used to quantify the magnitude of the correlation. The following criteria were used to interpret the size of the correlation coefficients: (0 to ±0.3) negligible, (±0.3 to ±0.5) low, (±0.5 to ±0.7) moderate, (±0.7 to ±0.9) high, and (±0.9 to 1.0) as very high correlation.[356]

5.4 Results

5.4.1 Cross-cultural adaptation of Lawton IADL scale

Stage 1- Forward translation was performed as planned. Both forward translators encountered the following issues. The last response for item 1-('Ability to use telephone') in the original scale is "does not use telephone at all". Both translators felt that this response could be interpreted in different ways. A person could be not using a telephone at all since he/she does not have a telephone or is incapable of using it. Incapability could be due to an impairment or the person has never used it before and has no skills to use it. The same issue was noted for the last response of item 6-('Mode of transportation'). Both translators were uncertain about the identical Sinhala word to "instrumental".

Stage 2- I prepared the synthesis version with the aid of both Sinhala versions.

Stage 3- Backward translation was also carried out as planned. Both backward translated versions showed good agreement with the original English version.

Stage 4- By considering the issues raised in the forward translation process (stage 1), the panel of experts agreed to replace the last response of item 1 with the meaning of "incapable of using the telephone at all" in Sinhala. However, they acknowledged that the response could still not be applicable to a person who has never used a telephone. Hence, the suggestion was to ask whether they have ever used a telephone if their response is "incapable of using the telephone at all" and make a note of this in the questionnaire. Similarly the last response for item 6 ("does not travel at all") was replaced with "incapable of travelling at all". Example apparels used in the second response of item 5-('Laundry') were changed from 'socks' and 'stockings' to 'small hanker-chief' and 'small towel', as these were more relevant to Sri Lankan older adults living in a tropical climate. Example activities used in the final item- ('ability to handle finances') were 'budgets, writes cheques, pays rent, bills, and goes to bank'. They were replaced for the present study with 'making a payment for electricity or water bills' and 'making bank transactions'. Both translators could not find an identical Sinhala word for the word "instrumental". Therefore, it was substituted to the word "non-basic" in Sinhala.

Stage 5- No difficulties were encountered in pre-testing and the IADL Sinhala version showed good acceptability.

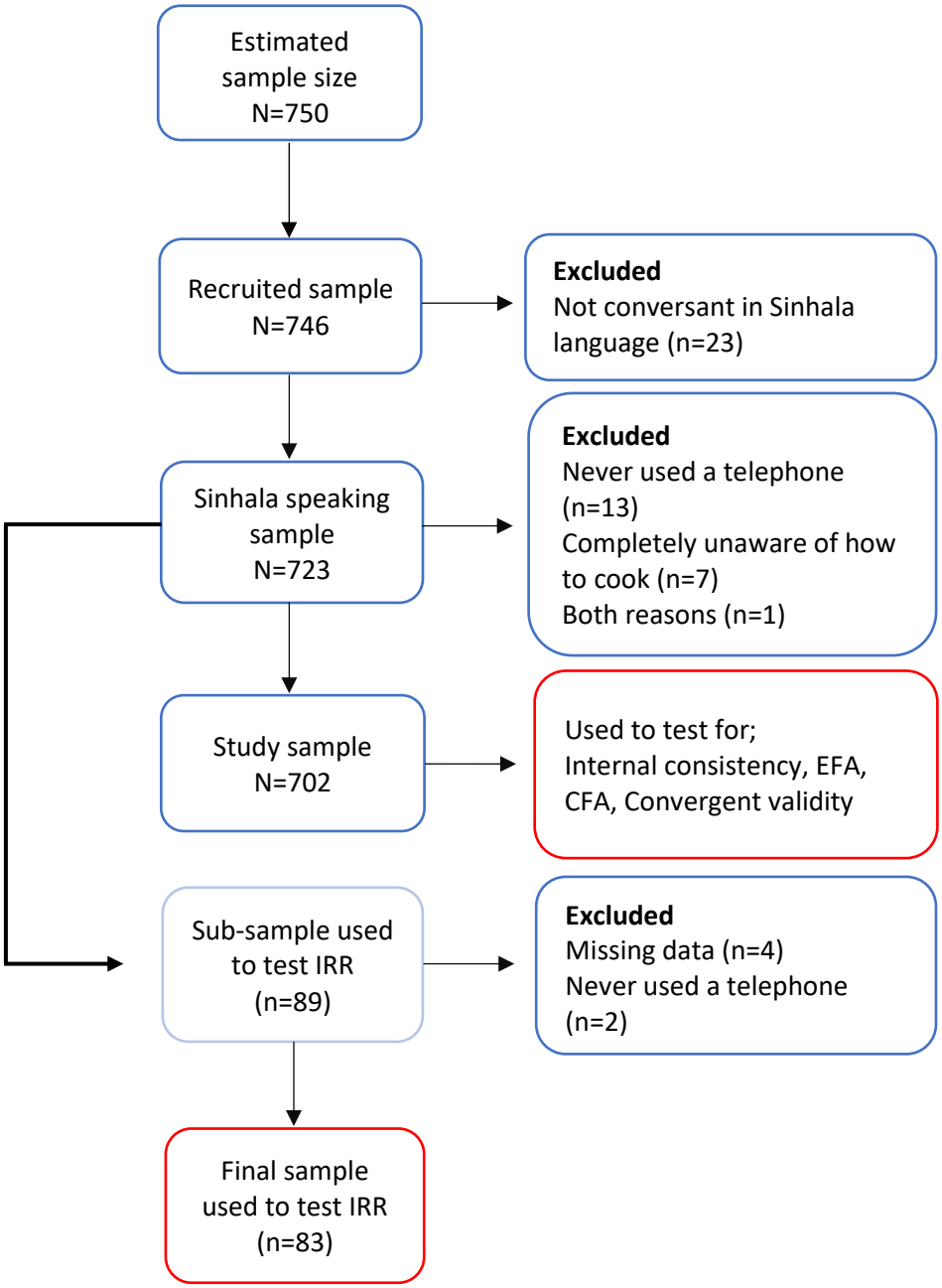
A copy of Lawton IADL scale-Sinhala version is included in Appendix 18 (page 477).

5.4.2 Psychometric evaluation of Lawton IADL scale-Sinhala version

5.4.2.1 Sociodemographic characteristics of the study participants

746 participants were recruited for the overall study. Twenty three participants were excluded from the psychometric evaluation sub-study as they are not fully conversant in Sinhala language. Twenty one participants were excluded as they had never used a telephone and/or were completely unaware of how to cook. Five males and eight females had never used a telephone. Seven males were unaware of how to cook. One male participant was excluded for both reasons. Therefore, the effective sample was 702. As described above, a sub-sample from the Sinhala speaking participants (n=89, 12.0%) was randomly selected to assess the magnitude of inter-rater reliability (IRR). Six participants invited were excluded when testing for IRR. Of the six, two had never used a telephone and response for one item in the scale was missing for four participants. Figure 5.2 (page 231) demonstrates the study flow chart.

Figure 5.2 Study flow chart of psychometric evaluation of Lawton IADL scale



Note: Figure was taken from a published paper by Siriwardhana et al[292] and has been modified slightly.

Table 5.2 (page 233) presents the sociodemographic characteristics of the study sample (n=702) and the sub-sample used to assess IRR (n=83). The percentage of the females in the study sample was 53.7%. The median age of the sample was 67 (IQR 63: 75) years. The age of the participants ranged from 60 years to 94 years. The median age of the sub-sample used to test IRR was 68 (IQR 63: 73) years. The age of the participants in the sub-sample was ranged from 60 years to 91 years.

Table 5.2 Sociodemographic characteristics of the study participants involved in the psychometric evaluation.

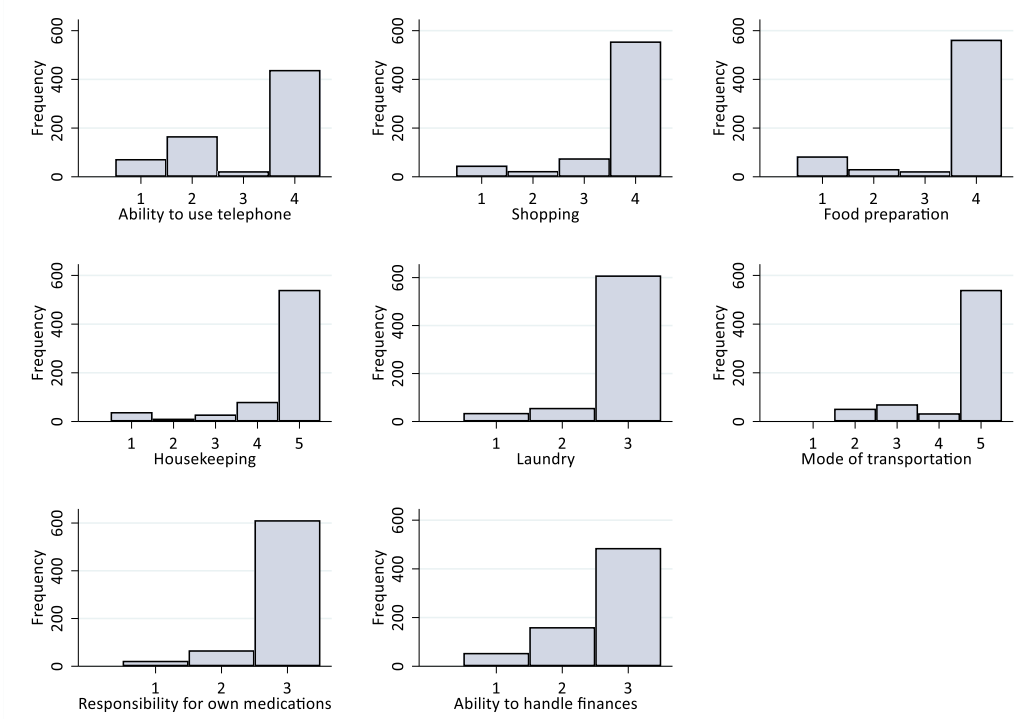
Characteristics		Study sample	Sub-sample used to test IRR
		N (%)	N (%)
Sex	Male	325 (46.3)	30 (36.1)
	Female	337 (53.7)	53 (63.9)
Age category (years)			
	60-64	238 (33.9)	28 (33.7)
	65-69	189 (26.9)	22 (26.5)
	70-74	91 (13.0)	15 (18.1)
	75-79	91 (13.0)	6 (7.2)
	≥80	93 (13.2)	12 (14.5)
Marital status			
	Never-married	33 (4.7)	7 (8.4)
	Married	427 (60.8)	43 (51.8)
	Separated	12 (1.7)	2 (2.4)
	Divorced	5 (0.7)	1 (1.2)
	Widowed	223 (31.8)	30 (36.2)
	Cohabiting	2 (0.3)	-
Living arrangement			
	With spouse	79 (11.3)	11 (13.3)
	With children/other family	580 (82.6)	65 (78.3)
	Alone	43 (6.1)	7 (8.4)
Educational status			
	No formal education	34 (4.8)	3 (3.6)
	Primary	163 (23.2)	22 (26.5)
	Lower secondary	246 (35.0)	29 (34.9)
	Upper secondary/ post-secondary non-tertiary/tertiary	259 (36.9)	29 (34.9)
Perceived financial status			
	Finding it difficult/very difficult to get by	140 (20.0)	15 (18.1)
	Just about getting by	380 (54.1)	48 (57.8)
	Living comfortably	182 (25.9)	20 (24.1)

Note: Table was taken from a published paper by Siriwardhana et al[292] and has been modified slightly.
Figures are column percentages.

5.4.2.2 Distribution of Lawton IADL scale-Sinhala version scores

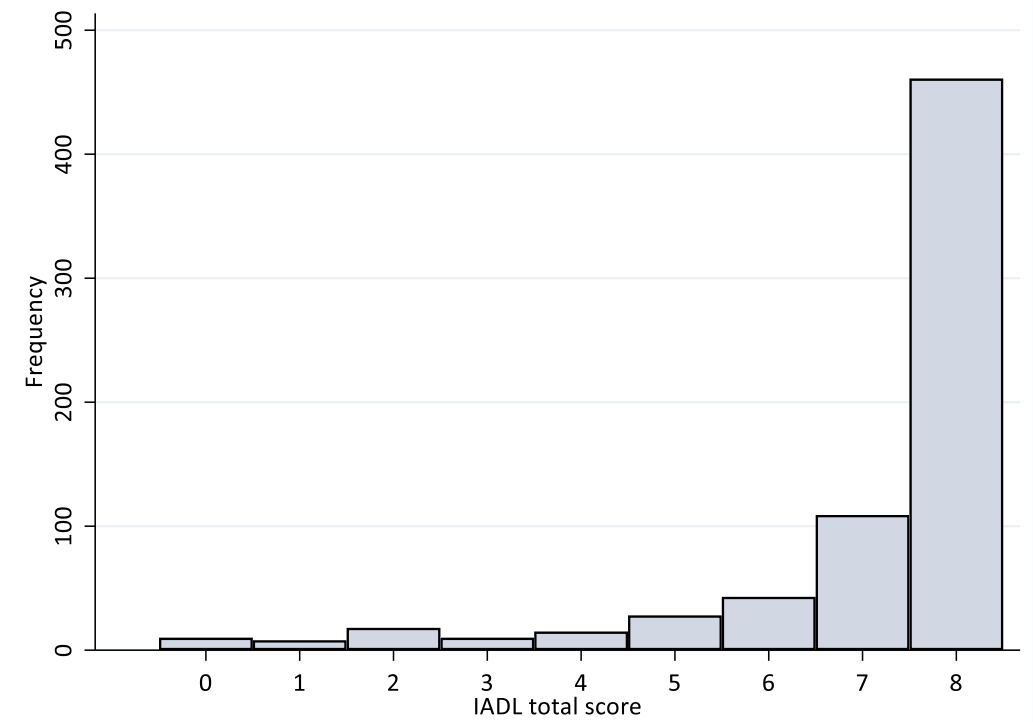
The frequency distributions of the responses for each item and overall score are presented in Figure 5.3 (below) and Figure 5.4 (page 235) respectively. A negatively skewed distribution (a tail is on the left side of the distribution, with the majority of participants being on the 'independent' right side of the distribution) was observed for responses of all the items and overall score.

Figure 5.3 The frequency distribution of the responses for each item of the Lawton IADL scale-Sinhala version



Note: Higher scores indicate independence

Figure 5.4 The frequency distribution of the overall Lawton IADL scale score-Sinhala version



Note: Higher scores indicate independence

Table 5.3 (below) presents the median and inter quartile range (IQR) for the scores of each item. None of the items' or total score was distributed normally.

Table 5.3 Descriptive statistics for item-wise and overall IADL scale score-Sinhala version

Item	Item description	Min, Max	Median (IQR)	Dependent N (%)	Independent N (%)
Item 1	Ability to use telephone	1,4	4 (2,4)	73 (10.4)	629 (89.6)
Item 2	Shopping	1,4	4 (4,4)	146 (20.8)	556 (79.2)
Item 3	Food preparation	1,4	4 (4,4)	139 (19.8)	563 (80.2)
Item 4	Housekeeping	1,5	5 (5,5)	39 (5.6)	663 (94.4)
Item 5	Laundry	1,3	3 (3,3)	36 (5.1)	666 (94.9)
Item 6	Mode of transportation	1,5	5 (5,5)	56 (8.0)	646 (92.0)
Item 7	Responsibility of own medication	1,3	3 (3,3)	90 (12.8)	612 (87.2)
Item 8	Ability to handle finances	1,3	3 (2,3)	55 (7.8)	647 (92.2)
Overall IADL score		0,8	8 (7,8)		

IQR: Inter quartile range
Note: Table was taken from a published paper by Siriwardhana et al[292].

5.4.2.3 Internal consistency

The internal consistency of the IADL scale with eight items assessed by standardised Cronbach's alpha was good (0.92) and in the acceptable range. This result indicates that the different items in this scale measure the same concept well.

5.4.2.4 Inter-rater reliability

For the ordinal scoring, Table 5.4 (page 238) presents the weighted percentage agreement coefficient, weighted Cohen's kappa, and Gwet's AC_2 agreement

coefficient for each item according to the responses in the original scale. I had very good weighted percentage agreement coefficient (range from 0.76 to 1.00), poor to excellent weighted Cohen's kappa (0.00 to 1.00), and substantial to almost perfect Gwet's AC_2 (0.62 to 1.00) agreement coefficient between myself and all five raters. Please refer to Table 5.5 (page 239) for the assessment of IRR on the binary scale; when response for each item was coded either as 0 (dependent) or 1 (independent) according to the guidelines of the scale. Interestingly, weighted Cohen's kappa was not computed when the percentage agreement was too high or too low indicating the 'kappa paradox'[357]. Kappa paradox is under special conditions even in the presence of a strong inter- or intra- agreement, the Cohen's kappa statistic tends to assume low values, which is counter-intuitive and leads to the conclusion that no agreement is present.[334]

With regard to the total score of the scale (treated as a continuous variable), raters A, C, and D showed ICC values above 0.8 indicating an excellent reliability. The lowest ICC value (0.57) was reported with rater E. Overall, the ICC values for all five raters were above 0.5 and indicate that the IADL scale used in the present study had moderate to excellent inter-rater reliability.[337]

Table 5.4 Item-wise inter-rater reliability with original response structure for Lawton IADL scale-Sinhala version

Item	Item description	DDS-A (n=13)			DDS-B (n=15)			DDS-C (n=17)			DDS-D (n=17)			DDS-E (n=21)		
		p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2
Item 1	Ability to use telephone	0.92	0.77	0.87	0.93	0.82	0.90	0.99	0.97	0.98	0.98	0.94	0.95	0.94	0.73	0.92
Item 2	Shopping	0.92	0.76	0.89	0.93	0.65	0.90	0.90	0.47	0.83	0.98	0.91	0.96	0.90	**-0.05**	0.90
Item 3	Food preparation	0.95	0.78	0.93	0.76	**0.00**	0.66	0.91	0.68	0.84	0.90	**0.00**	0.88	0.95	0.64	0.95
Item 4	Housekeeping	0.87	**0.27**	0.80	0.93	0.61	0.85	0.92	**0.52**	0.83	0.88	**0.26**	0.83	0.89	**0.00**	0.86
Item 5	Laundry	Not computed‡			0.89	**0.49**	0.85	0.96	0.73	0.95	0.90	**-0.06**	0.88	0.90	**0.00**	0.89
Item 6	Mode of transportation	0.92	0.81	0.84	0.88	0.60	0.80	0.92	0.78	0.86	0.95	0.82	0.91	0.91	**0.51**	0.87
Item 7	Responsibility of own medication	0.97	0.73	0.97	0.98	0.74	0.98	0.98	0.89	0.98	1.00	1.00	1.00	0.98	0.74	0.98
Item 8	Ability to handle finances	0.77	**0.41**	0.62	0.89	0.43	0.80	0.94	0.75	0.90	0.88	0.57	0.77	0.92	**0.41**	0.89

p- Unweighted percentage agreement coefficient, κ_w - Cohen's weighted kappa

Not computed‡ since ratings do not vary.

Statistically non-significant agreement coefficients (p>0.05) and zero agreement coefficients are displayed in bold.

Values of Cohen's kappa and AC_2 are interpreted as follows: 0.0-0.20 (slight), 0.21-0.40 (fair), 0.41-0.60 (moderate), 0.61-0.80 (substantial), and >0.80 (excellent) agreement.

Note: A negative Kappa means that there is less agreement than would be expected by chance given the marginal distributions of ratings.

Note: Table was taken from a published paper by Siriwardhana et al[292].

Table 5.5 Item-wise inter-rater reliability when original responses coded as binary for Lawton IADL scale-Sinhala version and ICC for overall IADL score

Item	Item description	DDS-A (n=13)			DDS-B (n=15)			DDS-C (n=17)			DDS-D (n=17)			DDS-E (n=21)		
		p	κ	Gwet's AC_1	p	κ	Gwet's AC_1	p	κ	Gwet's AC_1	p	κ	Gwet's AC_1	p	κ	Gwet's AC_1
Item 1	Ability to use telephone	0.92	0.75	0.88	Not computed‡			1.00	1.00	1.00	0.94	0.76	0.91	0.95	**0.64**	0.94
Item 2	Shopping	0.92	0.75	0.88	0.80	**0.44**	0.68	0.76	0.46	0.59	1.00	1.00	1.00	0.90	0.92	0.75
Item 3	Food preparation	0.92	0.75	0.88	0.66	**0.00**	0.53	0.94	0.86	0.89	0.82	**0.00**	0.78	0.95	0.92	0.75
Item 4	Housekeeping	Not computed‡			0.93	**0.00**	0.92	0.88	**0.00**	0.86	0.94	**0.00**	0.93	Not computed‡		
Item 5	Laundry	Not computed‡			0.93	**0.63**	0.91	1.00	1.00	1.00	0.94	**0.00**	0.93	Not computed‡		
Item 6	Mode of transportation	Not computed‡			0.93	0.76	0.90	Not computed‡			0.88	**0.43**	0.85	Not computed‡		
Item 7	Responsibility of own medication	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Item 8	Ability to handle finances	Not computed‡			0.93	**0.00**	0.92	0.82	**-0.08**	0.78	1.00	1.00	1.00	0.95	**0.00**	0.95
Intraclass Correlation (95% CI)		0.91 (0.74, 0.97)			0.62 (0.20, 0.85)			0.89 (0.73, 0.96)			0.88 (0.64, 0.96)			0.57 (0.20, 0.80)		

p- Unweighted percentage agreement coefficient, κ - Cohen's kappa

Not computed‡ since ratings do not vary. Statistically non-significant agreement coefficients (p>0.05) and zero agreement coefficients are displayed in bold.

Values of Cohen's kappa and Gwet's AC_1 are interpreted as follows: 0.0-0.20 (slight), 0.21-0.40 (fair), 0.41-0.60 (moderate), 0.61-0.80 (substantial), and >0.80 (excellent) agreement.

Note: A negative Kappa means that there is less agreement than would be expected by chance given the marginal distributions of ratings.

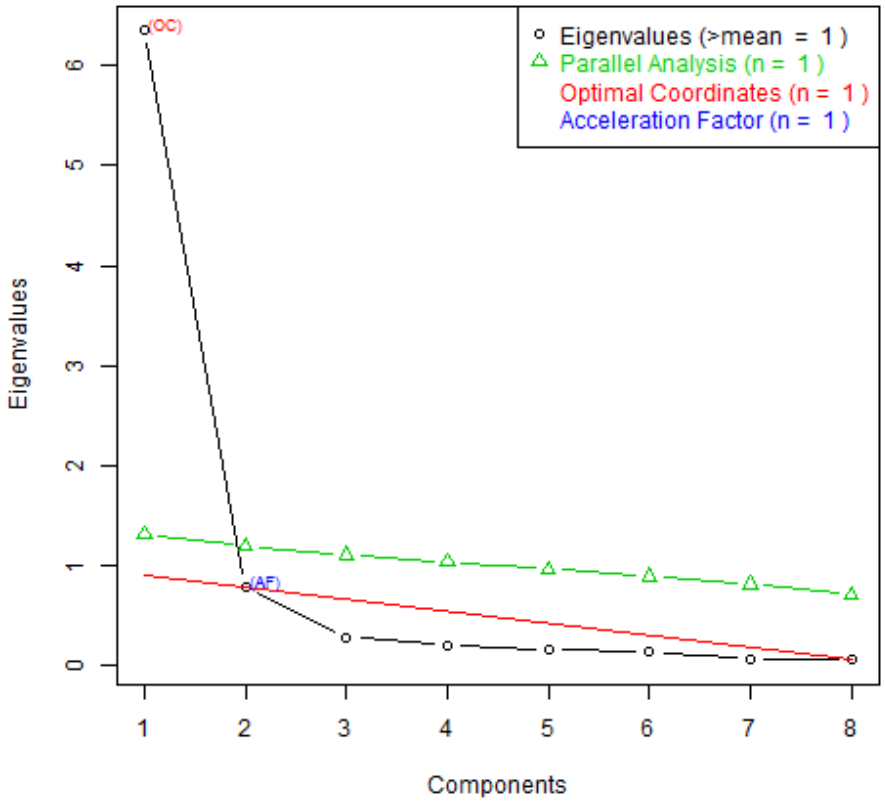
An ICC value of <0.5 (poor), 0.50-0.75 (moderate), 0.75-0.90 (good), and >0.90 (excellent) reliability.

Note: Table was taken from a published paper by Siriwardhana et al[292].

5.4.2.5 Exploratory factor analysis

Exploratory factor analysis explores the underlying factor structure of a construct. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.898 which is considered a 'very good' value.[358] The significance value of the Bartlett's test of sphericity was $p<0.001$, indicating that the correlations between the eight IADL items were significantly different from zero. Results of the parallel analysis suggested to extract one factor (Figure 5.5, page 241), indicating the unidimensionality of the IADL scale. The first factor extracted by principal axis factoring explained 79.4% of the total variance. As shown in Table 5.6 (page 242), the communalities of the eight items varied from 0.392 to 0.903 and the factor loadings varied from 0.626 to 0.950. Item scale correlation (corrected) for all the items were above 0.7 except for item 1.

Figure 5.5 Parallel analysis based on permuted data



Note: Figure was taken from a published paper by Siriwardhana et al[292].

Table 5.6 Results of the exploratory factor analysis

Items	Item description	Exploratory factor analysis*		
		Communality	Factor loading	Item-scale correlation†
Item 1	Ability to use telephone	0.392	0.626	0.503
Item 2	Shopping	0.892	0.944	0.865
Item 3	Food preparation	0.724	0.851	0.724
Item 4	Housekeeping	0.903	0.950	0.883
Item 5	Laundry	0.782	0.884	0.771
Item 6	Mode of transportation	0.848	0.921	0.819
Item 7	Responsibility of own medication	0.787	0.887	0.745
Item 8	Ability to handle finances	0.819	0.905	0.825

*Fit indices: GFI (ULS)=0.980, RMSR=0.063
†Item total correlation with its own Lawton IADL scale corrected for overlap.
Communalities ≥0.4 and factor loadings ≥0.5 were considered as satisfactory.
Note: Table was taken from a published paper by Siriwardhana et al[292].

EFA results by sex also showed a stable item structure (8 items) across both females and males. Parallel analysis suggested to extract one factor in both cases. The percentage of variance explained by the first factor was 80.2% for females and 81.5% for males. The communalities of 8 items varied from 0.357 to 0.934 and from 0.421 to 0.925 for females and males respectively. The factor loadings varied from 0.598 to 0.966 for females and from 0.649 to 0.962 for males.

5.4.2.6 Confirmatory factor analysis

Confirmatory factor analysis was performed to explore whether the observed data fitted the hypothesised single factor structure of the IADL scale. CFA results are presented in Table 5.7 (below). Standardised factor loadings ranged from 0.660 to 0.958. Values of goodness of fit indices; NNFI, CFI, and SRMR were in acceptable range indicating an excellent model fit. However, the chi-square value was significant, χ^2 (20, 702)= 144.42, p<0.001. The value of relative chi-square (χ^2/df) was 7.22 and not in the acceptable range. Similarly, the RMSEA value was too high and was not in the acceptable range.

Table 5.7 Results of confirmatory factor analysis (based on one factor)

Items	Item description	Confirmatory factor analysis‡	
		Standardised factor loading	Standard error
Item 1	Ability to use telephone	0.660	0.034
Item 2	Shopping	0.938	0.012
Item 3	Food preparation	0.871	0.021
Item 4	Housekeeping	0.958	0.008
Item 5	Laundry	0.926	0.017
Item 6	Mode of transportation	0.911	0.014
Item 7	Responsibility of own medication	0.873	0.023
Item 8	Ability to handle finances	0.918	0.013

‡ Fit indices: RMSEA (90% CI) = 0.283 (0.270, 0.297), NNFI/TLI= 0.977, CFI= 0.984, SRMR= 0.06, PNFI=0.701
Factor loadings ≥0.5 were considered as satisfactory.
Note: Table was taken from a published paper by Siriwardhana et al[292].

In CFA by sex, standardised factor loadings ranged from 0.645 to 0.973 and from 0.673 to 0. 981 for females and males respectively. All the goodness of fit indices except chi-square, and RMSEA were in the acceptable range for both sexes.

Item 1 (‘ability to use telephone’) consistently demonstrated low communality, factor loading and item-scale correlation in EFA and low standardised factor loading in CFA. This finding was consistent even in the sex stratified analysis.

5.4.2.7 Convergent validity

Convergent validity refers to the degree to which two measures of constructs that theoretically should be related, are in fact related. The Spearman’s correlation coefficients between the Lawton IADL score and the scores of the Barthel index and the MoCA were 0.61 and 0.41, indicating a moderate and a low strength of association respectively. Both correlation coefficients were significant at $p<0.001$.

5.5 Discussion

5.5.1 Summary of main findings

The Lawton Instrumental Activities Daily Living scale was successfully translated into Sinhala language and culturally adapted to the Sri Lankan context. The Sinhala version of the scale demonstrated overall good reliability and construct validity. The internal consistency of the scale was very high. According to the Gwet's AC_1 and AC_2 (measures of inter-rater reliability that are shown to be less affected by prevalence than the more commonly used Cohen's kappa coefficient[335]), a good agreement was observed between myself (DDS) and the five raters overall and for all the items in the IADL scale. With regard to the total score, ICC values were between 0.57 and 0.91 which is indicative of moderate to very good agreement. Findings of EFA and CFA strongly supported the unidimensionality of the IADL scale. In EFA, communalities and factor loadings for all the items were well above the cut-off values. Similarly all the goodness of fit indices in CFA were in the acceptable range except chi-square and RMSEA. The eight item structure scale was stable across both females and males. Results of the sex stratified EFA and CFA were also consistent with the main analysis. With regard to convergent validity, moderate and low positive correlations were observed between the IADL score and scores of the Barthel index and the MoCA respectively.

5.5.2 Reliability

In line with other studies, the Lawton IADL-Sinhala version demonstrated an excellent internal consistency. The standardised Cronbach's alpha coefficient was 0.92. Of all previous studies the Spanish version has demonstrated the highest alpha value of 0.94[322] whilst values of 0.86, and 0.84 were found in Hong Kong Chinese (Lawton IADL-CV) and in Greek versions respectively.[320, 323] The lowest value was observed in the Persian version (Lawton IADL-PV).[321]

In the present study, the ICC values ranged from 0.57 to 0.91 across the five raters, with three raters having values above 0.8, in a relatively large sample of 83 participants. The minimum and maximum number of participants assessed with a single rater were 13 and 21 respectively with a mode of 17 participants. The inter-rater reliability of the original scale was 0.85, however it was estimated on a small sample (n=12), with participants being interviewed by one interviewer in the presence of the second rater who did not participate in the interviewing process.[290] Two further studies have reported the inter-rater reliability of the IADL scale, with ICCs of 0.96[321] and 0.99[323] in similarly small studies. In the latter, inter-rater reliability was assessed with 9 participants on video-taped IADL abilities, and this method (videos) has been shown to produce higher inter-rater reliability.[359]

Unlike the present study, none of the prior studies have reported the item-wise inter-rater reliability of the IADL scale. In those studies, ICC was computed based on the total score of the scale. Estimating inter-rater reliability only on the overall score does not reflect how each rater marked the response for each item based

on participant's response. The main reason for minor discrepancies between myself (DDS) and the five raters in this study could be due to the use of the 'capacity' question stem. On certain occasions participants might have reported actual performance rather than their capacity to do the activity. Provision of thorough training to research assistants on this aspect is warranted.

5.5.3 Validity

The EFA results of this study strongly supported the unidimensionality of the IADL scale and corroborate the existing literature.[322, 323] In the present study, the first factor explained 79.4% variance whilst 70.6% and 50.1% variances were explained by the first factor in the corresponding Hong Kong Chinese and Spanish versions. The eight item structure has an excellent factorial validity across both sexes.[322] Eight male participants were excluded from the analysis since they were completely unaware of how to cook. However, this was only 2.4% of total males in the sample. In contrast, Ng et al (2006) found two strong factors underlying physical and cognitive domains of IADL in a multi-ethnic Asian population in Singapore.[293] Those two factors explained 87.5% of variance.

All the reported goodness of fit indices of CFA (RMSEA, TLI, and CFI) were satisfactory and all factor loadings were significant in the Spanish version.[322] Similarly all the factor loadings were significant in the Sinhala version and values of TLI, CFI, and SRMR were in the acceptable range. However, the RMSEA value was not in the acceptable range. One possible explanation could be use of diagonally weighted least square technique estimation. Nye et al showed that

RMSEA appears to be affected by sample size.[360] With a sample size of 400, they have observed an increase of the cut-off value for RMSEA whilst the SRMR seemed to perform relatively well, which is similar to the present study. While the chi-square value of this model was significant, this may often be the case with large sample sizes[361] and when data deviate from multivariate normality.[362]

A substantially low communality and factor loading were observed for the first item; 'ability to use the telephone' in EFA and relatively low standardised factor loading in CFA. Item one has demonstrated a relatively low inter-item correlation with item 3, 4, and 5. This pattern was consistent across both sexes. Interestingly, the same results were observed for EFA with the Spanish version.[322] A possible reason could be the transition of use of land/fixed telephones to mobile devices. At present, most households in Sri Lanka use mobile phones. According to the statistics of Telecommunications Regulatory Commission of Sri Lanka, 12.1 and 122 fixed access and cellular mobile subscriptions per 100 inhabitants were reported respectively in 2016.[363] However, ownership of mobile telephones is much higher in younger than older populations and therefore access to a usable phone might have been variable across this Sri Lankan population. Among older adults, use of new technology e.g. smart phones and mobile telephones successfully relies on an ability to learn a relatively new skill (technology) and may require therefore more cognitive capacity than sustaining longstanding life-long skills such as food preparation. It is also affected by the sensory function and fine motor skills. Therefore, the patterns of activity limitations being assessed here is

slightly different to the other IADL tasks. However, it is still measuring something different than the other items as it represents the ability to communicate with the outside world, an important part of ageing well. Therefore I decided to retain item 1 in the IADL scale in my analyses of the association between frailty and disability (Chapter 8, page 301).

The Spearman's correlation coefficient between the scores of Barthel index and Lawton IADL Spanish version was above 0.40. In the present study, value of the same correlation was moderate (0.61). It is unlikely to obtain a perfect correlation with the Barthel index as older adults can have IADL limitations without having BADL limitations. Moreover, the original Barthel index used in the present study was not sensitive enough to capture and differentiate minor limitations of BADL. The poor correlation of IADL score with MoCA score could be due to the nature of scoring in the Lawton IADL scale. According to the guidelines of the original scale, participants were classified as 'dependent' (0) or 'independent' (1). It does not therefore differentiate the stage in between independence and dependence where people can only perform these tasks with support ('need support'). If the Lawton IADL scale scores were coded according to the gradient of ability of performing each task, a higher correlation with the MoCA score would be expected.

In Sections 5.5.2 and 5.5.3 (above), I have compared my findings with the studies that have been translated and validated the Lawton IADL scale into other

languages (e.g. Chinese, Greek, and Spanish). However, it is also worth noting language, cultural, and study population differences in these studies.

5.5.4 Strengths and limitations of the study

The main strengths of this study were that I followed a comprehensive and rigorous methodology, and used a comprehensive cross-cultural adaptation process and advanced statistical techniques to address the structure and distribution of the IADL data. Moreover the psychometric evaluation was performed with a large random sample of Sinhala speaking rural community-dwelling older adults. According to the recent census, 99.0% of Sri Lankan older adults live in the community.[328] In the original validation study, Lawton and Brody (1969) had not explored the factor structure of the IADL scale.[290] Therefore, the present study performed both EFA and CFA. Set of guidelines and best practices available in the literature were followed when performing and reporting cross-cultural adaptation of instrument, reliability testing, EFA, and CFA.[291, 337, 339, 343, 364, 365]

Twenty one participants (<2.0%) were excluded from the study population who reported that they had never used a telephone or were completely unaware of how to cook. The present study sample comprised of only 23 participants who did not belong to Sinhalese ethnicity. All the interviews were conducted in Sinhala language but on a few occasions participants were given a copy of the Tamil questionnaire to explain certain questions if their first language was Tamil. Hence, participants who do not belong to Sinhalese ethnicity were excluded from the

analysis as some of them were not fully conversant in Sinhala language. However, the internal consistency of the scale was assessed both including and excluding the participants who does not belong to Sinhalese ethnicity and found no difference (standardised Cronbach's alpha=0.92: please refer to Appendix 10 (page 454).

The test-retest reliability and responsiveness of the scale were not assessed due to inadequate resources available. The limitation of the scale itself is absence of a reference point of time. However, no guidelines exist as to the appropriate choice of reference point of time either.[315]

5.5.5 Recommendations

Participant's self-reported capacity of performing each activity was used in Lawton IADL-Sinhala version as a measure of self-reported efficacy or capacity in performing activities. Some people may over- or under- estimate their true capacity and this may therefore not reflect the actual performance of these activities. Alternatively a researcher can also use the self-reported 'actual performance' question stem and make notes about non-applicable items (where the participant may be capable but does not regularly perform the activity). In the present study, an interviewer-administered questionnaire was used with the participant only. In future research self-reported and abilities of performing IADL tasks reported by a key informant could also be compared. Lawton IADL scale-Sinhala version has not specified a reference point of time, instead the scale asks the general ability of performing each activity in day-to-day life.

5.6 Conclusions

The Lawton IADL scale was successfully translated and culturally adapted to Sinhala language. The Sinhala version demonstrated a good reliability and construct validity with a large representative sample of Sinhala speaking rural community-dwelling older adults. Given its good psychometric properties, it is recommended for use in measuring/monitoring the limitations of instrumental activities of daily living of rural community-dwelling older adults in Sri Lanka.

In Chapter 8 (page 301) I have used this Lawton IADL scale-Sinhala version to estimate the association between frailty and IADL limitations.

Chapter 6: Results of epidemiology of frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka

6.1 Chapter overview

In this chapter, I present the results pertaining to the epidemiology of frailty in the present Sri Lankan study population. First, I report the sociodemographic characteristics, health- related, and lifestyle factors of this study population and the prevalence of frailty and its five separate components within study population. Subsequently, I describe the prevalence of frailty status (non-frail, pre-frail, and frail) by sociodemographic characteristics, health-related, and lifestyle factors. Then I report the results of a set of multinomial logistic regression models for: (i) sociodemographic characteristics, (ii) health-related factors, and (iii) lifestyle factors associated with the risk of frailty and with the risk of pre-frailty (versus non-frail). Some results sections of this chapter have been published in as a peer-reviewed journal article by Siriwardhana et al in BMJ Open journal in 2019.[260]

6.2 Sociodemographic characteristics

Data were collected from 746 from a total of of 750 older adults that were approached (response rate: 99.5%). One participant was excluded from the analysis, as I could not determine the frailty status of the participant with certainty due to missing data on three frailty components. This yielded a total sample of 745 participants for the final analysis. The age range of the participants was 60 to 94 years. The median age was 68 (IQR 64: 75) years in both the weighted and unweighted samples. In the weighted sample, 56.7% were females, 97.4% participants belonged to the Sinhalese ethnicity, and 59.1% were married. However, half of females in the present sample were widows (51.4%) while only 8.5% males were widowers. 83.0% were living with children or other family members, 79.0% reported that they have a 'strong' level of social support. Only 5.4% had no formal education. The majority (38.5%) had been engaged in occupations classified as Skill level 2 which included skilled agricultural and fishery work, craft and related work, etc. Of total sample, 55.0% reported "just about getting by" in response to the survey item on perceived financial strain (Table 6.1, page 255).

Table 6.1 Sociodemographic characteristics of the unweighted and weighted study samples

Sociodemographic characteristic	Unweighted sample %, (N)			Weighted sample (%)		
	All (N=745)	Male (N=349) 46.8 %	Female (N=396) 53.2%	All	Male 43.3 %	Female 56.7 %
Age category (years)						
60-64	33.3 (248)	28.7 (100)	37.4 (148)	35.7	37.4	34.3
65-69	26.7 (199)	28.4 (99)	25.2 (100)	25.3	25.5	25.1
70-74	13.3 (99)	14.3 (50)	12.4 (49)	17.0	17.2	16.8
75-79	13.4 (100)	14.3 (50)	12.6 (50)	11.2	10.2	11.9
≥80	13.3 (99)	14.3 (50)	12.4 (49)	10.8	9.6	11.8
Ethnicity						
Sinhalese	96.9 (722)	96.9 (338)	97.0 (384)	97.4	97.3	97.5
Sri Lankan Moor	2.8 (21)	2.6 (9)	3.0 (12)	2.4	2.2	2.5
Sri Lankan Tamil	0.1 (1)	0.3 (1)	0.0 (0)	0.1	0.2	0.0
Other (Malay)	0.1 (1)	0.3 (1)	0.0 (0)	0.1	0.3	0.0
Marital status						
Never-married	4.8 (36)	2.9 (10)	6.6 (26)	5.2	2.8	6.9
Married	61.1 (455)	86.8 (303)	38.4 (152)	59.1	88.0	37.1
Cohabiting	0.3 (2)	0.3 (1)	0.2 (1)	0.5	0.7	0.4
Separated	1.7 (13)	0.0 (0)	3.3 (13)	1.8	0.0	3.2
Divorced	0.7 (5)	0.0 (0)	1.2 (5)	0.6	0.0	1.0
Widowed	31.4 (234)	10.0 (35)	50.3 (199)	32.9	8.5	51.4
Living arrangements						
Alone	6.0 (45)	3.1 (11)	8.6 (34)	6.3	2.8	9.0
With spouse only	11.3 (84)	15.5 (54)	7.6 (30)	10.7	15.1	7.4
Children/other family	82.7 (616)	81.4 (284)	83.8 (332)	83.0	82.1	83.6
Social support						
Poor	4.3 (32)	3.7 (13)	4.8 (19)	4.3	2.7	5.5
Moderate	16.6 (124)	12.6 (44)	20.2 (80)	16.7	11.6	20.6
Strong	78.5 (585)	83.4 (291)	74.2 (294)	79.0	85.7	73.9
Missing	0.6 (4)	0.3 (1)	0.8 (3)	-	-	-
Education level						
No formal education	5.0 (37)	1.4 (5)	8.1 (32)	5.4	1.3	8.6
Primary	23.8 (177)	23.5 (82)	24.0 (95)	23.3	22.0	24.2
Lower secondary	35.1 (262)	37.0 (129)	33.6 (133)	35.3	37.6	33.5
Upper secondary/ Post-secondary non-tertiary	33.7 (251)	35.2 (123)	32.3 (128)	33.7	36.1	32.0
Tertiary	2.4 (18)	2.9 (10)	2.0 (8)	2.3	3.0	1.7

Table 6.1 continued. Sociodemographic characteristics of the unweighted and weighted study samples

Sociodemographic characteristic	Unweighted sample %, (N)			Weighted sample (%)		
	All (N=746)	**Male (N=349) 46.8 %**	**Female (N=396) 53.2%**	**All**	**Male 43.3 %**	**Female 56.7 %**
Longest-held occupation						
Never employed/ Skill level 1	42.4 (316)	23.8 (83)	58.8 (233)	43.8	24.7	58.4
Skill level 2	39.3 (293)	53.9 (188)	26.5 (105)	38.5	53.1	27.4
Skill level 3 or 4	18.3 (136)	22.3 (78)	14.7 (58)	17.7	22.2	14.2
Perceived financial strain						
Finding it difficult/ very difficult to get by	20.4 (152)	19.5 (68)	21.2 (84)	20.4	18.9	21.5
Just about getting by	54.5 (406)	54.7 (191)	54.3 (215)	55.0	56.8	53.8
Living comfortably	25.1 (187)	25.8 (90)	24.5 (97)	24.6	24.3	24.7

Figures are column percentages.
Skill level 1: elementary occupations (low skilled).
Skill level 2: skilled agricultural and fishery work, craft and related work, etc.
Skill level 3: technicians, associate professionals, and clerks.
Skill level 4: legislators, senior officials and managers, and professionals (highest skilled).
Note: Table was taken from a published paper by Siriwardhana et al[260] and has been modified slightly.

Table 6.2 (page 258) was compiled using the information available from two publications based on 2012 census data.[140, 328] The majority (61.0%) of older adults in the present study sample as well as in Sri Lanka belong to 'young-old' (age 60-69 years) age category. However, the present study sample was slightly higher educated, included a higher proportion of older adults who belonged to Sinhalese ethnicity and comprised a higher proportion of widows compared with the national older population. Of all 25 districts, Kegalle district has the highest proportion of older adults in a district population[250] and therefore a higher proportion of widows are expected given the difference of life expectancy between males and females[1]. A major difference between the present study sample (based in rural areas only) and the Sri Lankan population as a whole was observed with respect to living arrangement. It was found that 83.0% of older adults in the sample were living in extended households where more than one generation was living in the same household. However, only 59.0% of the Sri Lankan older adults as a whole lived in extended households in 2012. This may be due to differences between living arrangements in rural areas compared with urban and other areas, as the Sri Lankan population is a mix of rural, urban, and estate sectors.[250]

Table 6.2 Comparison of sociodemographic characteristics of the present study sample with entire Sri Lankan older population

Sociodemographic characteristic	Present study sample (%)	Sri Lanka (%)
Sex		
Male	43.3	44.3
Female	56.7	55.7
Age category (years)		
60-64	35.7	36.4
65-69	25.3	25.1
70-74	17.0	16.4
75-79	11.2	11.2
≥80	10.8	10.9
Ethnicity		
Sinhalese	97.4	79.7
Sri Lankan Tamil	0.1	9.9
Sri Lankan Moor	2.4	5.8
Indian Tamil	0.0	4.0
Other	0.1	0.6
Marital status		
Never-married	5.2	5.5
Married	59.1	72.6
Divorced/ separated	2.4	1.1
Widowed	32.9	20.9
Education level		
No formal education	5.4	10.4
Primary	23.3	32.4
Lower secondary	35.3	32.6
Upper secondary/ Post-secondary non-tertiary	33.7	22.2
Tertiary	2.3	2.5
Living arrangement		
Extended households	83.0	59.0
Nuclear families	17.0	41.0

Figures are column percentages.

6.3 Health-related factors

In the weighted sample, 41.4% had multimorbidity (defined in the present study as the co-existence of two or more concurrent chronic medical conditions). A quarter of the sample (23.7%) was taking five or more medicines daily (an indicator of polypharmacy used the present study), and 58.8% reported chronic pain. 32.6% were identified as in the high/medium risk category of depression (high risk: GDS-15 score of 10 or more; medium risk: GDS-15 score of 5-9; low risk: GDS-15 score of 0-4) and 57.0% reported their general health status as 'poor/fair'. Females reported poorer health (multimorbidity, polypharmacy, experiencing chronic body pain, cognitive status, depressive status, self-perceived vision, hearing, oral health, and general health) compared with males (refer to Table 6.3, page 260).

Table 6.3 Health-related factors of the unweighted and weighted study samples

Health-related factor	Unweighted sample %, (N)			Weighted sample (%)		
	All (N=745)	Male (N=349) 46.8 %	Female (N=396) 53.2%	All	Male 43.3 %	Female 56.7 %
Multimorbidity						
Yes	40.9 (305)	35.2 (123)	46.0 (182)	41.4	34.4	46.7
No	59.1 (440)	64.8 (226)	54.0 (214)	58.6	65.6	53.3
Polypharmacy						
Yes (≥5 medicines)	24.3 (181)	21.5 (75)	26.8 (106)	23.7	19.9	26.7
No (<5 medicines)	75.7 (564)	78.5 (274)	73.2 (290)	76.3	80.1	73.3
Having a chronic pain						
Yes	57.1 (425)	46.4 (162)	66.4 (263)	58.8	47.0	67.7
No	42.0 (313)	51.6 (180)	33.6 (133)	41.2	53.0	32.3
Missing	0.9 (7)	2.0 (7)	0.0 (0)	-	-	-
Cognitive assessment						
<Median MoCA score	47.8 (356)	42.4 (148)	52.5 (208)	48.7	40.6	54.8
≥ Median MoCA score	52.2 (389)	57.6 (201)	47.5 (188)	51.3	59.4	45.2
Depressive status (GDS-15)						
High risk	7.9 (59)	4.6 (16)	10.9 (43)	8.0	4.1	11.0
Moderate risk	24.3 (181)	22.3 (78)	26.0 (103)	24.6	21.7	26.8
Low risk	67.7 (504)	73.1 (255)	62.9 (249)	67.4	74.2	62.2
Missing	0.1 (1)	0.0 (0)	0.2 (1)	-	-	-
Self-perceived vision ability						
Poor/Fair	50.9 (379)	49.9 (174)	51.8 (205)	50.0	47.2	52.2
Good/ Very good/Excellent	49.1 (366)	50.1 (175)	48.2 (191)	50.0	52.8	47.8
Self-perceived hearing ability						
Poor/Fair	34.0 (253)	34.4 (120)	33.6 (133)	32.8	30.9	34.2
Good/ Very good/Excellent	66.0 (492)	65.6 (229)	66.4 (263)	67.2	69.1	65.8
Self-perceived oral health						
Poor/Fair	57.2 (426)	55.3 (193)	58.8 (233)	56.0	53.6	57.8
Good/ Very good/Excellent	42.7 (318)	44.4 (155)	41.2 (163)	44.0	46.4	42.2
Missing	0.1 (1)	0.3 (1)	0.0 (0)	-	-	-
Self-perceived general health						
Poor/Fair	56.5 (421)	53.0 (185)	59.6 (236)	57.0	52.4	60.5
Good/ Very good/Excellent	43.4 (323)	46.7 (163)	40.4 (160)	43.0	47.6	39.5
Missing	0.1 (1)	0.3 (1)	0.0 (0)	-	-	-

Figures are column percentages.

6.4 Lifestyle factors

Table 6.4 (page 262) presents the distribution of lifestyle factors in the study sample. 72.0% males were former/current smokers compared with 0.3% of females. Nearly a half of males (45.0%) reported alcohol consumption in the last year compared to no females. Males had higher protein and vegetable intakes than females.

Table 6.4 Lifestyle related factors of the unweighted and weighted study samples

Health-related factor	Unweighted sample %, (N)			Weighted sample (%)		
	All (N=745)	Male (N=349) 46.8 %	Female (N=396) 53.2%	All	Male 43.3 %	Female 56.7 %
Smoking status						
Never smoker	66.0 (492)	27.8 (97)	99.8 (395)	68.6	28.0	99.7
Former smoker	23.0 (171)	48.7 (170)	0.2 (1)	20.8	47.5	0.3
Current smoker	11.0 (82)	23.5 (82)	0.0 (0)	10.6	24.5	0.0
Alcohol consumption in past 12 months						
Yes	20.3 (151)	43.3 (151)	0.0 (0)	19.5	45.0	0.0
No	79.7 (594)	56.7 (198)	100.0 (396)	80.5	55.0	100.0
Weekly protein (animal and plant) intake						
Low	35.7 (266)	28.4 (99)	42.3 (167)	38.0	30.1	44.1
Moderate	31.6 (235)	28.6 (100)	34.2 (135)	31.9	29.4	33.7
High	32.7 (243)	43.0 (150)	23.5 (93)	30.1	40.6	22.2
Weekly animal protein intake						
Low	35.1 (261)	29.5 (103)	40.0 (158)	36.2	30.0	41.0
Moderate	41.5 (309)	40.1 (140)	42.8 (169)	41.5	39.8	42.8
High	23.4 (174)	30.4 (106)	17.2 (68)	22.3	30.2	16.2
Weekly plant protein intake						
Low	39.2 (292)	30.9 (108)	46.5 (184)	41.1	33.0	47.3
Moderate	31.1 (232)	32.4 (113)	30.0 (119)	31.3	33.0	30.0
High	29.7 (221)	36.7 (128)	23.5 (93)	27.6	34.0	22.7
Weekly vegetable intake						
Low	33.7 (251)	29.5 (103)	37.4 (148)	34.6	29.8	38.2
Moderate	33.0 (246)	33.0 (115)	33.1 (131)	32.7	32.2	33.1
High	33.3 (248)	37.5 (131)	29.5 (117)	32.7	38.0	28.7
Weekly fruit intake						
Low	37.2 (277)	39.3 (137)	35.4 (140)	39.1	40.9	37.8
Moderate	30.2 (225)	26.6 (93)	33.3 (132)	30.3	27.5	32.4
High	32.6 (243)	34.1 (119)	31.3 (124)	30.6	31.6	29.8

Figures are column percentages.

6.5 Prevalence of frailty and its components

As mentioned in Section 4.7.1.4 (page 185), participants with three or more of the five Fried phenotypic frailty components (low BMI, poor endurance and energy, weakness, slowness and low physical activity) were considered as frail, those with one or two components were considered as pre-frail, and those with none of the five components were considered as robust/non-frail. The prevalences of frailty, pre-frailty, and non-frailty among rural community-dwelling older adults in Kegalle district in 2016 were 15.2% (95% CI: 12.3%, 18.6%), 48.5% (95% CI: 43.8%, 53.2%), and 36.3% (95% CI: 32.4%, 40.2%) respectively.

The most prevalent frailty component in the overall sample was poor endurance and energy (self-reported exhaustion) (37.5%) followed by weakness (23.6%), slowness (19.6%), low physical activity (19.2%), and shrinking (low BMI) (18.2%). All of the frailty components were more prevalent among females than males, except for low BMI which was more prevalent in males (Table 6.5, page 264).

Table 6.5 Prevalence of each frailty component and the total number of frailty components in the overall sample and by sex

	Total (%)	Male (%)	Female (%)
Frailty component			
Low BMI	18.2	20.2	16.6
Self-reported exhaustion	37.5	31.9	41.7
Weakness (low grip strength)	23.6	19.6	26.6
Slowness (low gait speed)	19.6	18.7	20.3
Low physical activity	19.2	17.4	20.5
Total number of frailty components			
0	36.2	41.3	32.3
1	30.8	29.7	31.6
2	17.8	14.7	20.2
3	10.5	10.4	10.6
4	4.2	3.0	5.0
5	0.5	0.8	0.3

Note: Table was taken from a published paper by Siriwardhana et al[260].
Column percentages for the total number of frailty components.

6.6 Prevalence of frailty status across sociodemographic characteristics

The prevalence of frailty increased with age, however, it did not vary markedly by sex (Figure 6.1, below). For example, 3.8% of older adults aged 60-64 years were classified as frail whilst nearly half (47.9%) of those aged 80 years or older were frail. A higher prevalence of frailty was observed in older adults who reported 'poor' social support, with low education, those who had low skilled occupations or never had an employment, and those who reported higher financial strain. There was an increasing gradient of pre-frailty prevalence across education level and perceived financial strain, with higher levels of pre-frailty in those with low education level and higher perceived financial strain (Table 6.6, page 266).

Figure 6.1 Prevalence of frailty, pre-frailty, and non-frailty by age-and sex among rural community-dwelling older adults in Kegalle district in 2016

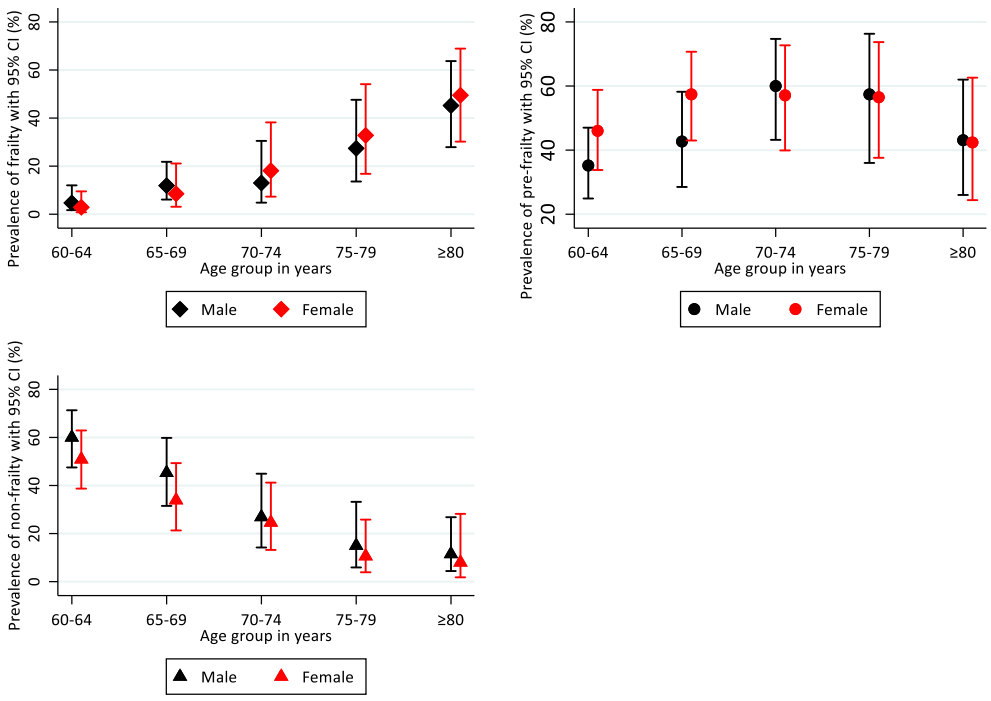


Table 6.6 Prevalence of frailty status across sociodemographic characteristics

Sociodemographic characteristic	Unweighted sample %, (N)			Prevalence (95% CI) in weighted sample %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Sex						
Female	33.1 (131)	51.0 (202)	15.9 (63)	32.4 (26.9, 38.2)	51.6 (44.0, 59.0)	16.0 (11.8, 21.1)
Male	37.3 (130)	46.1 (161)	16.6 (58)	41.3 (36.2, 46.6)	44.4 (39.3, 49.5)	14.3 (10.9, 18.3)
Age category (years)						
60-64	55.3 (137)	40.7 (101)	4.0 (10)	55.0 (45.2, 64.4)	41.1 (32.3, 50.5)	3.8 (1.7, 7.9)
65-69	37.2 (74)	52.3 (104)	10.5 (21)	38.9 (27.6, 51.5)	51.0 (39.6, 62.2)	10.0 (5.6, 17.2)
70-74	27.3 (27)	58.6 (58)	14.1 (14)	25.6 (16.4, 37.7)	58.4 (47.7, 68.2)	15.9 (8.6, 27.4)
75-79	14.0 (14)	57.0 (57)	29.0 (29)	12.4 (6.3, 22.9)	56.9 (43.0, 69.7)	30.7 (19.3, 44.9)
≥80	9.1 (9)	43.4 (43)	47.5 (47)	9.3 (4.2, 19.3)	42.7 (28.4, 58.3)	47.9 (33.1, 63.0)
Marital status						
Married/cohabiting	40.3 (184)	46.6 (213)	13.1 (60)	42.6 (37.1, 48.3)	45.9 (41.3, 50.5)	11.5 (7.9, 16.2)
Never-married/ widowed/separated/divorced	26.7 (77)	52.1 (150)	21.2 (61)	26.8 (20.6, 34.0)	52.4 (44.4, 60.1)	20.8 (14.8, 28.4)
Living arrangements						
Alone	26.7 (12)	64.4 (29)	8.9 (4)	26.8 (14.6, 43.9)	62.2 (38.1, 81.4)	11.0 (2.1, 41.3)
With spouse only	40.5 (34)	46.4 (39)	13.1 (11)	42.9 (27.5, 59.7)	45.9 (30.4, 62.1)	11.2 (4.7, 24.0)
Children/other family	34.9 (215)	47.9 (295)	17.2 (106)	36.0 (32.0, 40.3)	47.9 (42.9, 52.6)	16.1 (12.7, 20.1)
Social support						
Poor	15.6 (5)	50.0 (16)	34.4 (11)	14.8 (5.0, 36.3)	48.0 (24.0, 73.0)	37.0 (17.1, 62.6)
Moderate	28.2 (35)	51.6 (64)	20.2 (25)	28.3 (18.4, 40.8)	54.3 (40.2, 67.7)	17.3 (9.7, 28.9)
Strong	37.6 (220)	47.9 (280)	14.5 (85)	39.2 (34.2, 44.5)	47.0 (41.3, 52.8)	13.6 (10.5, 17.4)

Table 6.6 continued. Prevalence of frailty status across sociodemographic characteristics

Sociodemographic characteristic	Unweighted sample %, (N)			Prevalence (95% CI) in weighted sample %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Education level						
No formal education/primary	19.6 (42)	54.7 (117)	25.7 (55)	21.0 (14.0, 30.0)	55.4 (46.8, 63.7)	23.6 (16.4, 32.6)
Lower secondary	35.1 (92)	49.6 (130)	15.3 (40)	35.8 (29.5, 42.5)	49.3 (42.1, 56.3)	14.9 (9.9, 21.8)
Upper secondary or above	47.2 (127)	43.1 (116)	9.7 (26)	48.8 (41.9, 55.7)	42.2 (34.7, 50.1)	8.9 (5.4, 14.2)
Longest-held occupation						
Never-employed/Skill level 1	28.2 (89)	49.0 (155)	22.8 (72)	29.5 (23.5, 36.3)	49.4 (43.3, 55.4)	21.1 (16.2, 26.8)
Skill level 2	36.8 (108)	50.2 (147)	13.0 (38)	38.5 (31.5, 46.0)	49.1 (41.5, 56.6)	12.4 (8.2, 18.2)
Skill level 3 or 4	47.1 (64)	44.8 (61)	8.1 (11)	47.9 (39.2, 56.7)	45.1 (35.8, 54.6)	7.0 (3.3, 14.1)
Perceived financial strain						
Finding it difficult/very difficult to get by	24.4 (37)	52.6 (80)	23.0 (35)	26.7 (18.8, 36.2)	54.0 (44.1, 63.6)	19.3 (13.3, 27.0)
Just about getting by	34.5 (140)	50.0 (203)	15.5 (63)	36.1 (31.0, 41.5)	48.7 (42.6, 54.7)	15.2 (11.7, 19.3)
Living comfortably	44.9 (84)	42.8 (80)	12.3 (23)	44.5 (35.7, 53.5)	43.5 (32.6, 54.9)	12.0 (6.4, 21.3)

Figures are row percentages.

6.7 Sociodemographic characteristics associated with frailty and pre-frailty

Table 6.7 (page 270) presents the results from the unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression models for sociodemographic factors. Frailty status was the three-category dependent variable with non-frail as reference category.

Frailty versus non-frail

In 'age-and sex'-adjusted models, age, social support, education level, longest-held occupation, and perceived financial strain were significantly associated with frailty. However, the associations were attenuated when adding other factors. Education level and perceived financial strain were no longer statistically significant in the final multivariable model. In the multivariable-adjusted model, the relative risk of being frail compared with being non-frail increased with advancing age. The relative risk of being frail (versus non-frail) was 3.7 times higher in older adults who have never been employed or who had an occupation in the lowest skill level rather than the highest skill level. The relative risk of being frail compared with non-frail was nine times higher for those who reported 'poor' social support compared with those who reported 'strong' social support.

Pre-frailty versus non-frail

In 'age-and sex'-adjusted models, age, education level, longest-held occupation, and perceived financial strain were significantly associated with pre-frailty. However, the longest-held occupation and perceived financial strain were no longer statistically significant in the final multivariable model. In the multivariable-adjusted model, the relative risk of being pre-frail compared with being non-frail was two-thirds lower for participants aged 60-64 years relative to those aged 70-74 years. Older adults in the lowest education group compared to those in the highest education group had an approximately 2.5 times higher risk of being pre-frail compared with being non-frail.

Table 6.7 Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: sociodemographic factors

Sociodemographic characteristic	**Relative Risk Ratio (95% CI)**					
	Pre-frailty versus non-frail			**Frailty versus non-frail**		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Sex						
Female	1.48 (1.00, 2.18)	1.45 (0.96, 2.20)	1.24 (0.75, 2.04)	1.43 (0.91, 2.23)	1.34 (0.77, 2.35)	0.87 (0.45, 1.68)
Male	1.00	1.00	1.00	1.00	1.00	1.00
Age category (years)						
60-64	**0.32 (0.16, 0.65)**	**0.32 (0.16, 0.66)**	**0.33 (0.15, 0.72)**	**0.11 (0.02, 0.41)**	**0.11 (0.02, 0.41)**	**0.11 (0.02, 0.48)**
65-69	0.57 (0.27, 1.20)	0.57 (0.27, 1.21)	0.56 (0.24, 1.30)	0.41 (0.11, 1.45)	0.41 (0.11, 1.45)	0.38 (0.08, 1.66)
70-74	1.00	1.00	1.00	1.00	1.00	1.00
75-79	2.01 (0.87, 4.64)	1.99 (0.86, 4.60)	1.97 (0.83, 4.64)	**3.98 (1.46, 10.84)**	**3.94 (1.44, 10.75)**	**4.15 (1.44, 11.96)**
≥80	1.99 (0.69, 5.74)	1.96 (0.67, 5.71)	1.77 (0.53, 5.88)	**8.20 (2.24, 30.00)**	**8.09 (2.20, 29.75)**	**8.13 (2.02, 32.67)**
Living arrangements						
Alone	1.75 (0.74, 4.13)	1.58 (0.56, 4.49)	1.21 (0.42, 3.52)	0.91 (0.17, 4.75)	0.90 (0.18, 4.54)	0.51 (0.10, 2.49)
With spouse only	0.80 (0.37, 1.73)	0.87 (0.38, 1.98)	0.76 (0.38, 1.50)	0.58 (0.18, 1.82)	0.75 (0.20, 2.78)	0.66 (0.18, 2.41)
Children/other family	1.00	1.00	1.00	1.00	1.00	1.00
Social support						
Poor	2.71 (0.65, 11.3)	2.51 (0.52, 12.2)	2.13 (0.42, 10.60)	**7.18 (1.92, 26.89)**	**8.80 (1.69, 45.69)**	**9.04 (1.59, 51.19)**
Moderate	1.60 (0.78, 3.30)	1.52 (0.68, 3.37)	1.41 (0.63, 3.15)	1.75 (0.76, 4.03)	1.74 (0.75, 4.02)	1.68 (0.72, 3.90)
Strong	1.00	1.00	1.00	1.00	1.00	1.00

Table 6.7 continued. Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: sociodemographic factors

Sociodemographic characteristic	**Relative Risk Ratio (95% CI)**					
	Pre-frailty versus non-frail			**Frailty versus non-frail**		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Education level						
No formal education/primary	**3.05 (1.71, 5.42)**	**2.63 (1.51, 4.56)**	**2.49 (1.28, 4.87)**	**6.15 (2.66, 14.23)**	**4.04 (1.67, 9.77)**	2.26 (0.72, 7.05)
Lower secondary	**1.59 (1.02, 2.47)**	1.57 (0.98, 2.52)	1.50 (0.79, 2.82)	**2.28 (1.13, 4.60)**	**2.30 (1.09, 4.88)**	1.34 (0.53, 3.36)
Upper secondary or above	1.00	1.00	1.00	1.00	1.00	1.00
Longest-held occupation						
Never-employed/ Skill level 1	**1.77 (1.04, 3.02)**	**1.77 (1.07, 2.94)**	0.94 (0.44, 2.00)	**4.88 (2.27, 10.46)**	**6.33 (2.84, 14.13)**	**3.71 (1.34, 10.28)**
Skill level 2	1.35 (0.83, 2.18)	1.48 (0.89, 2.46)	0.86 (0.42, 1.74)	2.20 (0.84, 5.70)	**2.92 (1.12, 7.62)**	1.86 (0.54, 6.35)
Skill level 3 or 4	1.00	1.00	1.00	1.00	1.00	1.00
Perceived financial strain						
Finding it difficult/very difficult to get by	**2.07 (1.08, 3.96)**	**2.23 (1.16, 4.28)**	1.48 (0.70, 3.09)	**2.66 (1.24, 5.73)**	**3.53 (1.35, 9.19)**	1.75 (0.58, 5.29)
Just about getting by	1.37 (0.80, 2.36)	1.54 (0.93, 2.54)	1.31 (0.80, 2.14)	1.55 (0.74, 3.22)	2.11 (0.85, 5.23)	1.51 (0.57, 4.03)
Living comfortably	1.00	1.00	1.00	1.00	1.00	1.00

‡adjusted for sex, age group, and sociodemographic characteristics (living arrangements, social support, education level, longest-held occupation, and perceived financial strain).
The reference category is 1.00.
Statistically significant estimates (at the 5% level) are displayed in bold.

6.8 Prevalence of frailty status across health-related factors

Table 6.8 (page 273) presents the prevalence of frailty status across health-related factors. As expected, a higher prevalence of frailty was observed in older adults with multimorbidity, taking five or more medicines daily (polypharmacy), who reported experiencing chronic pain, those who have lower (below the median) cognitive assessment score, and those who reported being 'poor' or 'fair' in the following factors: self-perceived vision ability, hearing ability, oral health, and general health. There was an increasing gradient of frailty prevalence across depressive symptoms categories, with higher levels of frailty in those at high risk of depression.

The prevalence of pre-frailty was approximately half and relatively stable across those who were taking five or more medicines daily, reported to have chronic pain, had cognitive assessment scores below the median score of the sample, were at high and moderate levels of risk of depression, and considered as 'poor' or 'fair' health in the following factors: self-perceived vision ability, hearing ability, and general health.

Table 6.8 Prevalence of frailty status across health-related factors

Health-related factor	Unweighted sample, %, (N)			Prevalence (95% CI) in weighted sample, %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Multimorbidity						
Yes	29.2 (89)	50.5 (154)	20.3 (62)	40.1 (34.5, 46.0)	47.2 (41.3, 53.1)	19.0 (13.0, 26.8)
No	39.1 (172)	47.5 (209)	13.4 (59)	30.6 (25.3, 36.5)	50.3 (42.5, 58.0)	12.5 (9.3, 16.6)
Polypharmacy						
Yes (≥5 medicines)	21.6 (39)	50.8 (92)	27.6 (50)	21.1 (14.8, 29.2)	51.6 (43.7, 59.4)	27.1 (19.7, 36.0)
No (<5 medicines)	39.4 (222)	48.0 (271)	12.6 (71)	40.9 (36.0, 45.9)	47.5 (42.5, 52.5)	11.5 (8.7, 15.0)
Having a chronic pain						
Yes	27.3 (116)	51.8 (220)	20.9 (89)	28.4 (23.9, 33.3)	51.5 (44.6, 58.4)	20.0 (15.7, 25.0)
No	45.4 (142)	44.7 (140)	9.9 (31)	47.0 (40.3, 53.8)	44.3 (38.4, 50.3)	8.6 (5.8, 12.6)
Cognitive assessment						
<Median MoCA score	21.3 (76)	52.3 (186)	26.4 (94)	23.0 (17.9, 29.0)	52.8 (46.6, 59.0)	24.1 (19.1, 29.8)
≥ Median MoCA score	47.6 (185)	45.5 (177)	6.9 (27)	48.7 (42.8, 54.7)	44.3 (38.5, 50.2)	6.8 (3.6, 12.4)
Depressive status (GDS-15)						
High risk	8.5 (5)	52.5 (31)	39.0 (23)	8.3 (2.5, 24.3)	51.7 (35.4, 67.6)	39.9 (24.1, 58.1)
Moderate risk	17.7 (32)	52.5 (95)	29.8 (54)	19.6 (13.3, 27.9)	53.8 (43.6, 63.7)	26.5 (18.4, 36.6)
Low risk	44.5 (224)	47.0 (237)	8.5 (43)	45.6 (40.7, 50.6)	46.3 (40.8, 51.8)	8.0 (5.9, 10.8)
Self-perceived vision ability						
Poor/Fair	26.1 (99)	50.7 (192)	23.2 (88)	27.5 (22.9, 32.7)	50.5 (44.0, 57.0)	21.8 (17.4, 27.0)
Good/Very good/Excellent	44.3 (162)	46.7 (171)	9.0 (33)	44.9 (38.9, 50.9)	46.4 (39.9, 53.1)	8.6 (5.7, 12.6)

Table 6.8 continued. Prevalence of frailty status across health-related factors

Health-related factor	Unweighted sample, %, (N)			Prevalence (95% CI) in weighted sample, %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Self-perceived vision ability						
Poor/Fair	26.1 (99)	50.7 (192)	23.2 (88)	27.5 (22.9, 32.7)	50.5 (44.0, 57.0)	21.8 (17.4, 27.0)
Good/Very good/Excellent	44.3 (162)	46.7 (171)	9.0 (33)	44.9 (38.9, 50.9)	46.4 (39.9, 53.1)	8.6 (5.7, 12.6)
Self-perceived hearing ability						
Poor/Fair	22.1 (56)	56.1 (142)	21.8 (55)	22.5 (15.0, 32.3)	56.0 (47.8, 63.9)	21.3 (15.1, 29.2)
Good/Very good/Excellent	41.7 (205)	44.9 (221)	13.4 (66)	42.9 (37.1, 48.8)	44.8 (39.4, 50.3)	12.2 (8.4, 17.4)
Self-perceived oral health						
Poor/Fair	31.9 (136)	48.6 (207)	19.5 (83)	33.4 (28.6, 38.6)	48.2 (42.3, 54.1)	18.2 (13.7, 23.9)
Good/Very good/Excellent	39.0 (124)	49.0 (156)	12.0 (38)	39.5 (32.7, 46.8)	48.9 (41.4, 56.5)	11.4 (7.4, 17.2)
Self-perceived general health						
Poor/Fair	26.1 (110)	51.1 (215)	22.8 (96)	26.5 (22.0, 31.5)	51.6 (46.0, 57.1)	21.8 (17.4, 27.0)
Good/Very good/Excellent	46.8 (151)	45.5 (147)	7.7 (25)	49.1 (41.3, 57.0)	44.2 (36.1, 52.8)	6.5 (3.7, 11.0)

Figures are row percentages.

6.9 Health-related factors associated with frailty and pre-frailty

Table 6.9 (page 277) presents the results from the unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression models for health-related factors.

Frailty versus non-frail

In 'age-and sex'-adjusted models, the relative risks of being frail compared with being non-frail increased with polypharmacy (taking five or more medicines daily), having chronic pain, a lower (below the median) cognitive assessment score (MoCA), higher risk of depression and those who have 'poor'/'fair' self-perceived vision ability compared with their counterparts without these conditions. However, in the multivariable-adjusted model, chronic pain and 'poor'/'fair' self-perceived vision ability were no longer significantly associated with frailty.

In the multivariable-adjusted model, polypharmacy, lower (below the median) cognitive assessment score and presence of higher levels of depressive symptoms were significantly associated with frailty. The relative risk of being frail compared with being non-frail increased by six times for older adults who had the high/moderate risk of depression compared with their low risk counterparts. Similarly, the relative risk of being frail compared with being non-frail was approximately four times higher in older adults taking five or more medicines daily (the definition of polypharmacy used in the present study) compared with those taking four or less.

Pre-frailty versus non-frail

All the factors associated with frailty in the 'age-and sex'-adjusted models and additionally having 'poor'/'fair' self-perceived hearing ability were also associated with pre-frailty (versus non-frail).

In the multivariable-adjusted model, the relative risk of being pre-frail compared with being non-frail was two times higher for older adults with high/moderate risk of depression compared with their low risk counterparts. Similarly, having a lower (below the median) cognitive score also increased the relative risk of being pre-frail compared with being non-frail.

Table 6.9 Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: health-related factors

Health-related factor	**Relative Risk Ratio (95% CI)**					
	Pre-frailty versus non-frail			**Frailty versus non-frail**		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Multimorbidity						
Yes	1.39 (0.93, 2.09)	1.23 (0.84, 1.81)	0.94 (0.58, 1.53)	**1.97 (1.06, 3.66)**	1.71 (0.83, 3.54)	0.88 (0.34, 2.28)
No	1.00	1.00	1.00	1.00	1.00	1.00
Polypharmacy						
Yes (≥5 medicines)	**2.09 (1.29, 3.40)**	**1.95 (1.14, 3.34)**	1.74 (0.88, 3.42)	**4.54 (2.26, 9.12)**	**4.44 (1.99, 9.92)**	**3.85 (1.39, 10.66)**
No (<5 medicines)	1.00	1.00	1.00	1.00	1.00	1.00
Having a chronic pain						
Yes	**1.92 (1.31, 2.82)**	**1.67 (1.13, 2.46)**	1.23 (0.78, 1.91)	**3.81 (2.28, 6.37)**	**2.97 (1.60, 5.50)**	1.51 (0.73, 3.11)
No	1.00	1.00	1.00	1.00	1.00	1.00
Cognitive assessment						
<Median MoCA score	**2.53 (1.71, 3.72)**	**2.08 (1.41, 3.08)**	**1.66 (1.10, 2.53)**	**7.47 (3.23, 17.27)**	**4.52 (1.89, 10.81)**	**2.41 (1.02, 5.69)**
≥ Median MoCA score	1.00	1.00	1.00	1.00	1.00	1.00
Depressive status (GDS-15)						
High/moderate risk	**3.11 (1.85, 5.25)**	**2.93 (1.73, 4.95)**	**2.21 (1.21, 4.07)**	**10.02 (5.22, 19.22)**	**10.39 (5.35, 20.20)**	**6.24 (3.13, 12.42)**
Low risk	1.00	1.00	1.00	1.00	1.00	1.00

Table 6.9 continued. Unadjusted, 'age- and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: health-related factors

Health-related factor	Relative Risk Ratio (95% CI)					
	Pre-frailty versus non-frail			Frailty versus non-frail		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Self-perceived vision ability						
Poor/Fair	**1.77 (1.19, 2.62)**	**1.60 (1.01, 2.52)**	1.15 (0.70, 1.89)	**4.12 (2.56, 6.63)**	**3.24 (1.82, 5.76)**	1.61 (0.79, 3.28)
Good/Very good/Excellent	1.00	1.00	1.00	1.00	1.00	1.00
Self-perceived hearing ability						
Poor/Fair	**2.38 (1.30, 4.35)**	**1.86 (1.05, 3.29)**	1.63 (0.89, 3.02)	**3.32 (1.38, 7.97)**	1.61 (0.64, 4.07)	1.19 (0.42, 3.32)
Good/Very good/Excellent	1.00	1.00	1.00	1.00	1.00	1.00
Self-perceived oral health						
Poor/Fair	1.16 (0.77, 1.75)	1.12 (0.72, 1.72)	0.92 (0.58, 1.48)	1.88 (0.94, 3.75)	1.64 (0.78, 3.46)	1.20 (0.54, 2.64)
Good/Very good/Excellent	1.00	1.00	1.00	1.00	1.00	1.00

‡adjusted for sex, age group, longest-held occupation, social support, multimorbidity, polypharmacy, having chronic pain, cognitive assessment, depressive status, self-perceived vision ability, hearing ability, and oral health.
The reference category is 1.00.
Statistically significant estimates (at the 5% level) are displayed in bold.

6.10 Prevalence of frailty status across lifestyle factors

Table 6.10 (page 280) presents the prevalence of frailty status across the lifestyle factors: smoking, alcohol consumption, and diet. The prevalence of frailty did not vary markedly across smoking status. The prevalence of frailty was low among the older adults who reported consumption of alcohol within the past 12 months. However, this finding should be interpreted in the context of a low prevalence of alcohol consumption in the sample (one-in-five reported consuming alcohol in the past year) and all alcohol consumers were being males (Table 6.4, page 262). A higher prevalence of frailty was observed in older adults who were in the 'low' tertiles of weekly protein (both plant and animal), plant protein, and vegetable intake. There was a decreasing gradient of frailty prevalence across the tertiles of the aforementioned three food groups. For instance, the prevalence of frailty in the 'low' weekly vegetable intake tertile was 21.9% whereas the prevalence of frailty was 7.8% in the 'high' vegetable intake tertile.

The prevalence of pre-frailty was low among the older adults who reported consumption of alcohol within the past 12 months. The prevalence of pre-frailty was above 44.0% across all the tertiles of all food groups.

Table 6.10 Prevalence of frailty status across lifestyle factors

Lifestyle factors	Unweighted sample, %, (N)			Prevalence (95% CI) in weighted sample, %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Smoking status						
Never smoker	33.7 (166)	50.8 (250)	15.5 (76)	33.7 (28.4, 39.4)	51.2 (44.7, 57.7)	15.0 (11.3, 19.8)
Former smoker	41.9 (70)	40.9 (70)	18.2 (31)	44.6 (36.2, 53.4)	38.8 (30.5, 47.7)	16.5 (10.6, 24.8)
Current smoker	30.5 (25)	52.4 (43)	17.1 (14)	36.2 (20.9, 55.1)	49.9 (36.2, 63.5)	13.8 (5.6, 30.1)
Alcohol consumption (Consumed alcohol within past 12 months)						
Yes	51.0 (77)	41.7 (63)	7.3 (11)	52.8 (43.5, 61.9)	41.0 (33.3, 49.1)	6.1 (3.1, 11.5)
No	31.0 (184)	50.5 (300)	18.5 (110)	32.2 (28.0, 36.7)	50.3 (45.0, 55.6)	17.4 (13.8, 21.7)
Weekly protein (animal and plant) intake						
Low	27.1 (72)	53.0 (141)	19.9 (53)	27.9 (21.8, 34.9)	53.6 (44.9, 62.0)	18.4 (12.9, 25.5)
Moderate	36.6 (86)	48.5 (114)	14.9 (35)	38.9 (29.7, 49.0)	46.4 (36.0, 57.2)	14.5 (9.2, 22.0)
High	42.0 (102)	44.4 (108)	13.6 (33)	43.5 (35.1, 52.3)	44.3 (35.8, 53.2)	12.0 (8.1, 17.4)
Weekly animal protein intake						
Low	31.4 (82)	51.7 (135)	16.9 (44)	33.1 (27.0, 39.8)	51.6 (41.7, 61.3)	15.2 (9.6, 23.3)
Moderate	34.3 (106)	46.9 (145)	18.8 (58)	35.7 (30.6, 41.2)	46.0 (40.1, 51.9)	18.2 (13.4, 24.2)
High	41.4 (72)	47.7 (83)	10.9 (19)	41.8 (31.2, 53.3)	48.3 (37.8, 58.9)	9.8 (6.3, 14.8)

Table 6.10 continued. Prevalence of frailty status across lifestyle factors

Lifestyle factors	Unweighted sample, %, (N)			Prevalence (95% CI) in weighted sample, %		
	Non-frail	Pre-frail	Frail	Non-frail	Pre-frail	Frail
Weekly plant protein intake						
Low	30.8 (90)	50.7 (148)	18.5 (54)	32.1 (25.7, 39.2)	50.4 (42.4, 58.5)	17.3 (12.6, 23.4)
Moderate	33.6 (78)	49.6 (115)	16.8 (39)	35.5 (26.6, 45.4)	48.5 (37.8, 59.3)	15.9 (11.2, 22.0)
High	42.1 (93)	45.2 (100)	12.7 (28)	43.1 (34.7, 52.0)	45.5 (37.5, 53.7)	11.3 (6.9, 17.9)
Weekly vegetable intake						
Low	30.3 (76)	46.2 (116)	23.5 (59)	31.1 (23.4, 40.1)	46.8 (39.2, 54.6)	21.9 (16.8, 28.0)
Moderate	34.5 (85)	49.2 (121)	16.3 (40)	36.5 (27.7, 46.3)	47.8 (38.3, 57.5)	15.5 (10.2, 22.9)
High	40.3 (100)	50.8 (126)	8.9 (22)	41.2 (33.5, 49.4)	50.8 (43.4, 58.1)	7.8 (4.3, 13.8)
Weekly fruit intake						
Low	30.7 (85)	51.6 (143)	17.7 (49)	33.8 (27.3, 41.0)	50.0 (42.0, 57.9)	16.1 (11.7, 21.6)
Moderate	36.0 (81)	48.9 (110)	15.1 (34)	36.6 (29.3, 44.7)	49.3 (41.9, 56.7)	13.9 (8.8, 21.4)
High	39.1 (95)	45.3 (110)	15.6 (38)	38.8 (30.4, 48.0)	45.7 (37.3, 54.4)	15.3 (10.9, 21.0)

Figures are row percentages.

6.11 Lifestyle factors associated with frailty and pre-frailty

Table 6.11 (page 284) presents the results from the unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression models for lifestyle factors.

Frailty versus non-frail

In 'age-and sex'-adjusted models, those who reported to have consumed alcohol within the past 12 months (compared with those who did not) had three quarters lower relative risk of being frail compared with being non-frail. In contrast, the relative risk of being frail compared with being non-frail increased in those in the 'low' tertile of weekly protein (both plant and animal), plant protein, and vegetable intake compared with those in the respective 'high' tertile.

In the multivariable-adjusted model, the relative risk of being frail was four-fifths lower for those who reported to have consumed alcohol within the past 12 months compared with those who did not consume any alcohol. Conversely, the relative risk of being frail compared with being non-frail was 2.8 times higher for older adults who were in the 'low' tertile of weekly vegetable intake compared with those in the 'high' tertile.

Pre-frailty versus non-frail

In ‘age-and sex’-adjusted models, the relative risk of being pre-frail compared with non-frail was nearly half (43.0%) lower for those who reported to have consumed alcohol within the past 12 months compared to those who did not consume any alcohol. The relative risk of being pre-frail compared with being non-frail increased in those in the ‘low’ tertile of weekly protein (both plant and animal) and in the ‘low’ tertile of plant protein intake compared to those in the ‘high’ tertiles respectively.

In the multivariable-adjusted model, the relative risk of being pre-frail compared with non-frail was half lower for those who reported to have consumed alcohol within the past 12 months compared to those who did not consume any alcohol.

Table 6.11 Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: lifestyle factors

Lifestyle factor	**Relative Risk Ratio (95% CI)**					
	Pre-frailty versus non-frail			**Frailty versus non-frail**		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Smoking status						
Current smoker	0.90 (0.39, 2.07)	1.18 (0.48, 2.93)	1.53 (0.47, 4.94)	0.85 (0.22, 3.35)	1.64 (0.28, 9.43)	2.50 (0.22, 28.27)
Former smoker	**0.57 (0.35, 0.92)**	0.67 (0.32, 1.40)	0.74 (0.35, 1.57)	0.82 (0.45, 1.50)	1.12 (0.39, 3.18)	1.17 (0.31, 4.44)
Never smoker	1.00	1.00	1.00	1.00	1.00	1.00
Alcohol consumption (past 12 months)						
Yes	**0.49 (0.32, 0.76)**	**0.57 (0.34, 0.94)**	**0.51 (0.28, 0.93)**	**0.21 (0.09, 0.49)**	**0.24 (0.09, 0.65)**	**0.16 (0.05, 0.54)**
No	1.00	1.00	1.00	1.00	1.00	1.00
Weekly protein (animal and plant) intake						
Low	**1.88 (1.16, 3.04)**	**1.84 (1.10, 3.07)**	Not included in the model	**2.38 (1.28, 4.42)**	**2.25 (1.10, 4.59)**	Not included in the model
Moderate	1.17 (0.57, 2.38)	1.16 (0.56, 2.41)		1.34 (0.64, 2.82)	1.27 (0.59, 2.71)	
High	1.00	1.00		1.00	1.00	
Weekly animal protein intake						
Low	1.35 (0.71, 2.55)	1.18 (0.63, 2.20)	0.98 (0.46, 2.08)	1.96 (0.92, 4.16)	1.48 (0.67, 3.26)	0.75 (0.28, 1.97)
Moderate	1.11 (0.61, 2.00)	0.98 (0.52, 1.85)	0.93 (0.47, 1.82)	**2.17 (1.02, 4.62)**	1.63 (0.74, 3.58)	1.12 (0.41, 3.04)
High	1.00	1.00	1.00	1.00	1.00	1.00

Table 6.10 continued. Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted multinomial logistic regression results: lifestyle factors

Lifestyle factor	Relative Risk Ratio (95% CI)					
	Pre-frailty versus non-frail			Frailty versus non-frail		
	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡	Unadjusted	'Age-and sex'-adjusted	Multivariable-adjusted‡
Weekly plant protein intake						
Low	**1.48 (1.02, 2.15)**	**1.56 (1.05, 2.33)**	1.38 (0.83, 2.30)	**2.06 (1.04, 4.05)**	**2.23 (1.02, 4.89)**	1.50 (0.57, 3.95)
Moderate	1.29 (0.63, 2.61)	1.23 (0.60, 2.52)	1.24 (0.59, 2.63)	1.71 (0.79, 3.68)	1.53 (0.69, 3.38)	1.19 (0.48, 2.93)
High	1.00	1.00	1.00	1.00	1.00	1.00
Weekly vegetable intake						
Low	1.22 (0.70, 2.10)	1.08 (0.61, 1.91)	1.07 (0.62, 1.84)	**3.68 (1.72, 7.87)**	**2.84 (1.16, 6.94)**	**2.81 (1.08, 7.27)**
Moderate	1.06 (0.61, 1.83)	1.03 (0.59, 1.82)	1.01 (0.55, 1.83)	2.22 (0.85, 5.82)	2.06 (0.63, 6.64)	1.67 (0.47, 5.95)
High	1.00	1.00	1.00	1.00	1.00	1.00
Weekly fruit intake						
Low	1.25 (0.69, 2.26)	1.32 (0.71, 2.45)	1.02 (0.46, 2.27)	1.20 (0.65, 2.19)	1.43 (0.69, 2.94)	0.71 (0.28, 1.83)
Moderate	1.14 (0.63, 2.04)	1.19 (0.67, 2.10)	1.12 (0.59, 2.09)	0.96 (0.42, 2.18)	1.05 (0.42, 2.58)	0.87 (0.33, 2.26)
High	1.00	1.00	1.00	1.00	1.00	1.00

‡adjusted for sex, age group, longest-held occupation, social support, weekly animal protein, plant protein, vegetable, and fruit intake, smoking status, and alcohol consumption

The reference category is 1.00.

Statistically significant estimates (at the 5% level) are displayed in bold.

These findings are discussed with existing literature in Chapter 9, Section 9.3.2 (page 323).

Chapter 7: Results of cross-sectional association between frailty and disability among rural community-dwelling older adults in Kegalle district of Sri Lanka

7.1 Chapter overview

In this chapter, I present the results of my main analysis to evaluate the cross-sectional association between frailty and disability. The assessment of frailty, disability and statistical analysis specific to this chapter were discussed in Sections 4.7.1 (page 178), 4.7.3 (page 190), and in Section 4.8.3.2 (page 205) respectively. First, I describe missing data relating to the analysis of this chapter followed by prevalence of disability (presence of one or more instrumental activities of daily living (≥1 IADL) and basic activities of daily living (≥1 BADL) limitations separately) in the total sample and across sociodemographic and health-related characteristics. Next, I report the prevalence of disability and specific IADL and BADL limitations by frailty status. Finally, the association between frailty status and IADL limitations was assessed using a set of zero-inflated Poisson (ZIP) regression models. The association between frailty status and BADL limitations was not modelled due to the overwhelming concentration of BADL limitations in the frail group (refer to Table 7.2, page 293).

7.2 Data screening and missing values

Thirteen participants reported they had never used a telephone and nine participants reported they had never cooked. One participant reported never having done both. Therefore, there was missing data for 23 participants for ≥1 IADL items. These were subsequently excluded from the main analysis. The social support score was missing for four participants, resulting in the exclusion of a total of 27 (3.6%) participants from final regression analysis. There was no missing data for the BADL items.

7.3 Prevalence of disability across sociodemographic characteristics and health-related factors

The prevalence of ≥1 IADL limitations and ≥1 BADL limitations was slightly higher among males compared with females. The prevalence of ≥1 IADL limitations and ≥1 BADL limitations was also higher across advancing age, older adults with lower education level, long-held occupation belong to low skilled category, and with low social support. As expected, older adults with multimorbidity (co-occurrence of two or more chronic disease conditions), those who were taking five or more medicines daily (the definition of polypharmacy used in the present study), those who reported experiencing chronic pain, those with a cognitive assessment (MoCA) score below the median score of the sample, those who were at high/moderate risk of depression, those who reported 'poor/fair' self-perceived vision, and 'poor/fair' hearing ability reported higher prevalence of ≥1 IADL limitations and ≥1 BADL limitations compared with their counterparts without these conditions (Table 7.1, page 290). The median MoCA score of older adults with ≥1 IADL limitations was lower (median 16; IQR 11.5: 21) compared with adults with no IADL limitations (median 21; IQR 18: 23).

Table 7.1 Prevalence of disability across sociodemographic characteristics and health- related factors

Covariate	Prevalence of the limitations (95% CI), %	
	≥1 IADL	≥1 BADL
Sex		
Male	35.2 (30.1, 40.6)	9.0 (5.9, 13.6)
Female	31.0 (26.0, 36.5)	5.8 (3.6, 9.3)
Age group (years)		
60-64	13.6 (8.9, 20.1)	1.2 (0.2, 5.6)
65-69	21.2 (13.2, 32.0)	3.4 (1.4, 8.0)
70-74	40.2 (28.4, 53.2)	5.2 (1.9, 13.3)
75-79	57.8 (43.8, 70.6)	15.7 (7.8, 29.0)
≥80	85.9 (74.4, 92.7)	30.1 (20.0, 42.6)
Ethnicity		
Sinhalese	33.0 (28.6, 37.6)	7.2 (4.9, 10.5)
Other	27.5 (17.4, 40.5)	6.1 (1.0, 30.0)
Marital status		
Married/cohabiting	27.4 (20.9, 35.2)	6.3 (3.7, 10.5)
Never-married/widowed/separated/divorced	40.7 (34.0, 47.8)	8.5 (5.5, 13.1)
Living arrangement		
Children/other family	33.3 (28.9, 38.0)	7.3 (5.1, 10.4)
With spouse only	32.4 (20.3, 47.6)	7.9 (3.1, 18.8)
Alone	27.2 (12.9, 48.4)	4.5 (0.6, 27.5)
Social support		
Poor	62.6 (35.1, 83.8)	16.0 (5.4, 39.1)
Moderate	35.3 (24.3, 48.0)	10.3 (5.6, 18.0)
Strong	31.1 (26.3, 36.4)	6.1 (3.7, 9.7)
Education level		
No formal education/primary	49.6 (39.3, 59.9)	11.3 (6.9, 18.0)
Lower secondary	32.9 (26.4, 40.1)	6.8 (3.4, 12.9)
Upper secondary or above	19.5 (15.5, 24.3)	4.4 (2.4, 7.8)
Longest-held occupation		
Never-employed/Skill level 1	40.7 (33.7, 48.2)	8.3 (5.3, 12.8)
Skill level 2	28.0 (21.9, 35.1)	6.8 (3.7, 12.0)
Skill level 3 or 4	23.9 (17.2, 32.1)	5.4 (2.6, 11.0)
Perceived financial strain		
Finding it difficult/very difficult to get by	45.2 (35.1, 55.7)	9.5 (5.4, 16.3)
Just about getting by	29.8 (24.8, 35.2)	7.7 (4.9, 11.8)
Living comfortably	29.9 (22.7, 38.2)	4.2 (1.4, 12.2)
Multimorbidity		
Yes	37.0 (27.9, 47.2)	9.3 (5.6, 15.1)
No	29.8 (24.7, 35.6)	5.7 (3.6, 9.0)

Table 7.1 continued. Prevalence of disability across sociodemographic characteristics and health-related factors

Covariate	Prevalence of the limitations (95% CI), %	
	≥1 IADL	≥1 BADL
Having a chronic pain		
Yes	37.0 (30.1, 44.5)	9.3 (6.0, 14.1)
No	26.3 (21.4, 32.0)	4.2 (2.3, 7.8)
Cognitive status		
<median MoCA score	47.5 (39.2, 56.1)	12.8 (8.4, 19.0)
≥median MoCA score	19.1 (15.0, 24.0)	1.9 (0.9, 4.3)
Depressive status (GDS-15)		
High/moderate risk	48.6 (40.9, 56.3)	16.3 (11.4, 22.8)
Low risk	25.3 (21.5, 29.6)	2.6 (1.3, 5.3)
Self-perceived vision ability		
Poor/Fair	42.4 (36.9, 48.0)	10.2 (6.8, 15.1)
Good/Very good/Excellent	23.4 (18.3, 29.4)	4.2 (2.3, 7.6)
Self-perceived hearing ability		
Poor/Fair	45.4 (37.2, 53.8)	10.0 (6.5, 15.0)
Good/Very good/Excellent	26.7 (21.4, 32.7)	5.9 (3.6, 9.5)
Self-perceived oral health		
Poor/Fair	36.7 (29.7, 44.4)	7.7 (4.5, 12.7)
Good/Very good/Excellent	28.0 (21.6, 35.5)	6.6 (4.2, 10.4)
Self-perceived general health		
Poor/Fair	41.5 (36.0, 47.3)	10.5 (7.1, 15.2)
Good/Very good/Excellent	21.7 (16.3, 28.3)	2.9 (1.5, 5.4)

7.4 Prevalence of disability and specific IADL and BADL limitations by frailty status

Approximately one-in-three older adults had ≥1 IADL limitations and less than one-in-ten had ≥1 BADL limitations (the prevalence of ≥1 IADL limitations and ≥1 BADL limitations in the total sample was 32.8% (95% CI: 28.7%, 37.2%) and 7.2% (95% CI: 5.0%, 10.4%) respectively). Of the frail participants, 84.4% (95% CI: 68.9%, 93.0%) and 38.7% (95% CI: 26.1%, 53.1%) reported ≥1 IADL limitations and ≥1 BADL limitations respectively. Approximately two thirds of frail older adults had limitations in physical IADLs like shopping and food preparation. In comparison, nearly half of frail participants had limitations in managing their own medication. Limitations in physical IADLs were more prevalent compared with those for cognitive IADL limitations among frail older adults (Table 7.2, page 293). Prevalence of total number of IADL and BADL limitations in the total sample and by frailty status is presented in the Appendix 19 (page 480).

Table 7.2 Prevalence of disability and specific IADL and BADL limitations in the total sample and by frailty status

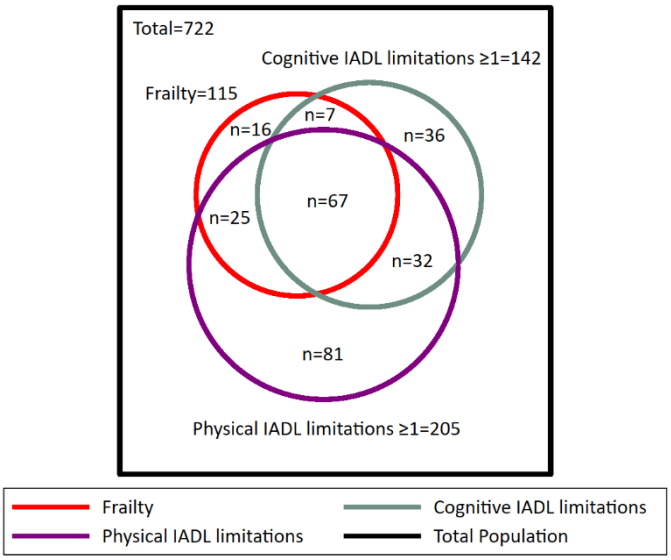
Limitations in IADL/BADL	Prevalence across total sample and by frailty status (95% CI), %			
	All	Non-frail	Pre-frail	Frail
Self-reported disability				
≥1 IADL limitations	32.8 (28.7, 37.2)	13.4 (9.3, 18.9)	31.4 (26.0, 37.3)	84.4 (68.9, 93.0)
≥1 Physical IADL limitations	27.0 (23.7, 30.6)	11.1 (7.1, 17.2)	22.3 (17.9, 27.4)	79.8 (66.9, 88.6)
≥1 Cognitive IADL limitations	18.6 (15.1, 22.7)	4.7 (2.5, 8.7)	15.1 (10.8, 20.8)	62.5 (44.2, 77.9)
≥1 BADL limitations	7.2 (5.0, 10.4)	0.0	2.7 (1.1, 6.2)	38.7 (26.1, 53.1)
Specific limitations in IADL				
Physical IADL				
Shopping	19.6 (16.6, 23.1)	4.1 (1.6, 9.7)	16.1 (12.4, 20.7)	67.9 (55.6, 78.1)
Food preparation	18.1 (14.9, 22.0)	8.2 (4.9, 13.4)	11.9 (8.8, 15.9)	61.7 (49.7, 72.4)
Mode of transportation	7.3 (5.1, 10.5)	0.0	3.2 (1.2, 8.3)	37.8 (26.3, 50.8)
Housekeeping	4.8 (3.1, 7.4)	0.0	1.0 (0.3, 3.3)	28.1 (19.9, 38.2)
Laundry	4.5 (2.5, 7.7)	0.4 (0.0, 5.2)	0.7 (0.2, 2.7)	26.0 (14.7, 41.8)
Cognitive IADL				
Responsibility of own medication	11.7 (9.1, 15.0)	1.7 (0.5, 5.2)	8.3 (5.5, 12.2)	46.6 (32.8, 60.9)
Ability to use telephone	9.5 (7.1, 12.5)	3.2 (1.4, 7.6)	7.6 (4.5, 12.5)	30.5 (18.7, 45.5)
Ability to handle finances	7.4 (5.1, 10.6)	0.5 (0.0, 5.5)	3.7 (1.6, 7.9)	35.7 (22.4, 51.6)
Specific limitations in BADL				
Feeding	4.2 (2.5, 6.9)	0.0	0.7 (0.1, 3.4)	25.1 (15.1, 38.8)
Bathing	3.7 (2.4, 5.7)	0.0	0.7 (0.1, 4.7)	22.0 (14.7, 31.6)
Dressing	3.5 (1.6, 7.7)	0.0	0.3 (0.0, 3.9)	22.1 (9.8, 42.4)
Toilet use	3.1 (1.6, 5.7)	0.0	0.2 (0.0, 2.4)	19.4 (10.2, 33.8)
Grooming	2.4 (1.2, 4.8)	0.0	0.5 (0.1, 2.0)	14.4 (7.3, 26.4)
Transfers	2.4 (1.2, 4.9)	0.0	0.5 (0.0, 6.0)	14.3 (6.5, 28.7)
Stairs	2.1 (1.0, 4.3)	0.0	0.4 (0.1, 3.3)	12.4 (6.0, 23.9)
Mobility	1.5 (0.4, 5.0)	0.0	0.0	9.8 (3.0, 27.7)
Bladder	0.5 (0.1, 2.2)	0.0	0.1 (0.0, 1.5)	2.8 (0.5, 13.3)
Bowels	0.4 (0.0, 3.1)	0.0	0.0	2.3 (0.3, 17.5)

0.0-no observations

7.5 Overlap of frailty, physical IADL limitations, and cognitive IADL limitations

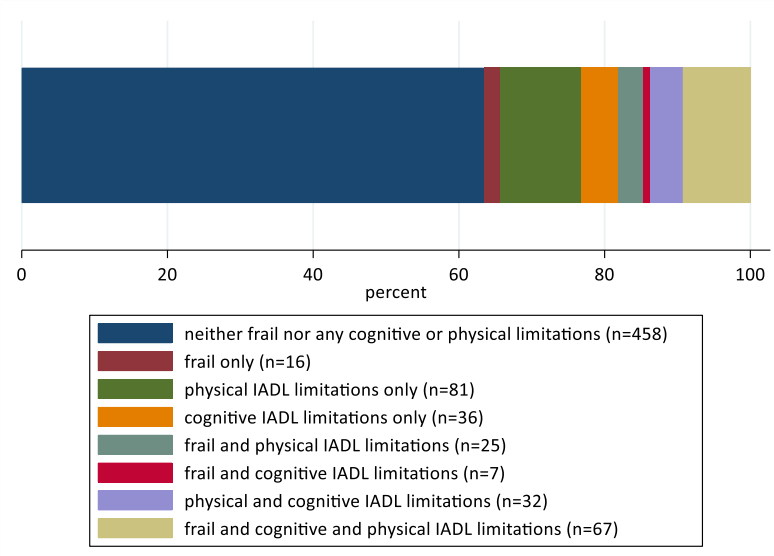
Based on unweighted data, 36.6% (264/722) of all participants were either frail or had ≥1 physical or ≥1 cognitive IADLs. Figure 7.1 (page 295) is a Venn diagram which shows the overlaps between frailty, physical IADL limitations, and cognitive IADL limitations in the unweighted sample. In the overall sample, only 9.3% (67/722) of older adults were frail and had both ≥1 physical and ≥1 cognitive IADL limitations. 20.6% (149/722) of the overall sample reported to have either ≥1 physical or ≥1 cognitive IADL limitations but were not classed as being frail. However, among the frail participants (shown by the red circle in Figure 7.1), 58.3% (67/115) reported both ≥1 physical and ≥1 cognitive IADL limitations. Figure 7.2 (page 295) clearly illustrates all other overlaps observed in the present study sample.

Figure 7.1 Venn diagram illustrating the overlap of frailty, physical IADL limitations, and cognitive IADL limitations



Physical IADL tasks: shopping, food preparation, mode of transportation, housekeeping, laundry
Cognitive IADL tasks: responsibility of own medication, ability to use telephone, ability to handle finances

Figure 7.2 Stacked bar chart illustrating the overlap of frailty, physical IADL limitations, and cognitive IADL limitations

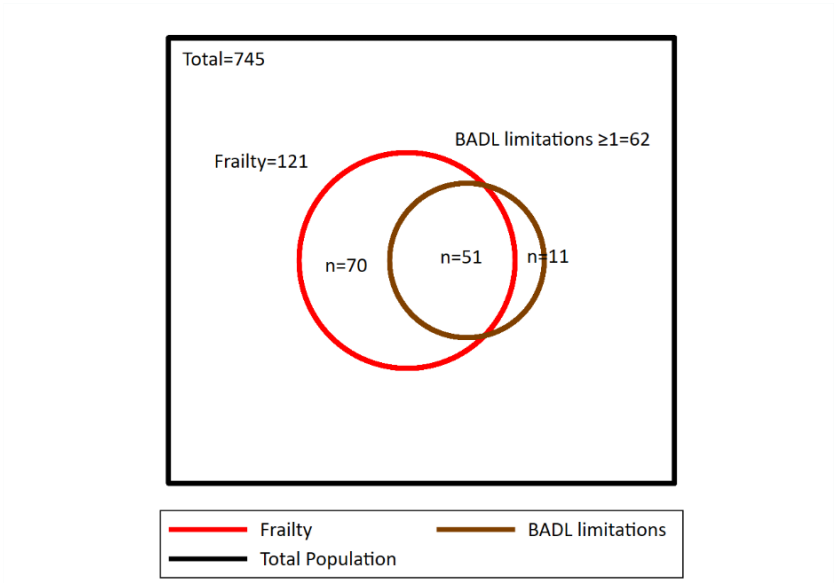


Physical IADL tasks: shopping, food preparation, mode of transportation, housekeeping, laundry
Cognitive IADL tasks: responsibility of own medication, ability to use telephone, ability to handle finances

7.6 Overlap of frailty and BADL limitations

Based on unweighted data, 17.7% (132/745) of all participants were either frail or had ≥1 BADL limitations. Figure 7.3 (page 296) illustrates the overlap between frailty and BADL limitations in the unweighted sample. In the overall sample, only 6.8% (51/745) of older adults were frail and had ≥1 BADL limitations. Of frail participants, 42.1% (51/121) reported ≥1 BADL limitations. In contrast, among the participants who reported ≥1 BADL limitations, the majority (82.3%, 51/62) were frail. Only 1.5% (11/745) of older adults reported ≥1 BADL limitations but were not classed as being frail. I further explored the BADL limitation patterns of these 11 participants who were not frail. Of them 9 reported one limitation whilst one each reported two and three limitations. Appendix 20 (page 481) presents the distribution of BADL limitations among these 11 participants.

Figure 7.3 Venn diagram illustrating the overlap of frailty and BADL limitations



BADL tasks: feeding, bathing, dressing, toilet use, grooming, transfers, stairs, mobility, bladder, bowels

7.7 Association between frailty status and IADL limitations

The association between frailty and the number of IADL limitations in unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted ZIP regression models adjusted for different covariates at each stage is presented in Table 7.3 (page 298). ZIP models were discussed in Section 4.8.3.2 (page 205). In the logistic regression section of the model, being frail as opposed to being non-frail significantly decreased the odds of having no IADL limitations. In the Poisson regression section of the model, being frail as opposed to being non-frail increased the estimated count of IADL limitations by four times. However, the strength of the association gradually attenuated with the addition of covariates. I did not find any statistically significant association (in both parts of the ZIP model) with pre-frailty (versus non-frail) and IADL limitations (Table 7.3, page 298).

Table 7.3 Association between frailty, pre-frailty and IADL limitations: Unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted ZIP regression results

Models	**Logistic section, OR (95% CI)[†]**		**Poisson section, RR (95% CI)[‡]**	
	Frailty	Pre-frailty	Frailty	Pre-frailty
Model 1: Unadjusted	**0.06 (0.02, 0.24)**	0.47 (0.18, 1.21)	**5.93 (2.99, 11.75)**	1.81 (0.87, 3.74)
Model 2: Model 1+ Age and sex	**0.10 (0.02, 0.47)**	0.44 (0.15, 1.31)	**3.92 (2.21, 6.95)**	1.29 (0.73, 2.30)
Model 3: Model 2+ Longest-held occupation	**0.11 (0.02, 0.56)**	0.46 (0.16, 1.32)	**3.94 (2.11, 7.36)**	1.30 (0.70, 2.43)
Model 4: Model 3+ Social support	**0.13 (0.02, 0.79)**	0.49 (0.15, 1.63)	**4.35 (2.31, 8.22)**	1.36 (0.73, 2.53)
Model 5: Model 4+ Multimorbidity	**0.12 (0.02, 0.69)**	0.44 (0.14, 1.40)	**4.21 (2.26, 7.83)**	1.30 (0.71, 2.39)
Model 6: Model 5+ Self-perceived vision ability	**0.11 (0.02, 0.68)**	0.34 (0.05, 2.25)	**4.13 (2.25, 7.59)**	1.22 (0.68, 2.20)
Model 7: Model 6+ Self-perceived hearing ability	**0.11 (0.02, 0.59)**	0.33 (0.06, 1.84)	**4.16 (2.27, 7.60)**	1.21 (0.67, 2.16)

[†]Logistic section of the regression model estimates the log-odds of belonging to the 'sure-zero'/'not-at-risk' class.
[‡]Poisson section of the regression model estimates the count of IADL limitations for those estimated to belong to the 'non-sure zero'/'at risk' latent class.
OR: Odds Ratio; RR: Rate Ratio
Statistically significant estimates (at the 5% level) are displayed in bold.

Table 7.4 (page 300) presents complete results of the final multivariable ZIP model (Model 7 in Table 7.3, page 298). According to the results of the logistic section of the regression model, frail older adults and those aged ≥80 years had lower estimated odds of being in the 'sure zero'/ 'not-at-risk' latent class (versus those non-frail and those aged 60-64 respectively). In contrast, being female and the longest-held occupation belonging to skill level 3 or 4 (highest skill occupations) increased the odds of being in the 'sure zero' group (Table 7.4, page 300). The estimated odds of reporting no IADL limitations (i.e. being in the 'sure zero'/ 'not-at-risk group') were approximately 90.0% lower for frail participants compared with their non-frail counterparts.

Among those estimated to be 'at-risk' (according to the results of the Poisson section of the regression model), the estimated count of IADL limitations was four times higher for frail as opposed to non-frail participants (RR: 4.16; 95% CI: 2.27, 7.60). Apart from frailty status, among those estimated to be 'at-risk', who were ≥80 years of age, with greater social support, and multimorbidity (co-occurrence of two or more chronic disease conditions) were independently associated with a higher count of IADL limitations.

Table 7.4 ZIP regression results for the association between frailty status and IADL limitations (Model 7)

Covariate	Logistic section OR (95% CI)[†]	Poisson section RR (95% CI)[‡]
Frailty		
Non-frail	1.00	1.00
Pre-frailty	0.32 (0.06, 1.84)	1.21 (0.67, 2.16)
Frailty	**0.11 (0.02, 0.59)**	**4.16 (2.27, 7.60)**
Sex		
Male	1.00	1.00
Female	**6.17 (1.31, 29.40)**	1.02 (0.69, 1.50)
Age group (years)		
60-64	1.00	1.00
65-69	1.88 (0.23, 15.80)	1.88 (0.71, 4.96)
70-74	0.62 (0.08, 4.85)	2.22 (0.78, 6.32)
75-79	0.24 (0.02, 2.66)	2.26 (0.91, 5.60)
≥80	**0.05 (0.00, 0.79)**	**3.44 (1.31, 9.02)**
Longest-held occupation		
Never-employed/Skill level 1	1.00	1.00
Skill level 2	4.34 (0.89, 21.33)	1.04 (0.69, 1.57)
Skill level 3 or 4	**6.42 (1.34, 30.57)**	1.37 (0.97, 1.93)
Social support		
Poor/Moderate	1.00	1.00
Strong	5.81 (0.45, 74.44)	**1.38 (1.08, 1.78)**
Multimorbidity		
None or one	1.00	1.00
≥Two	1.49 (0.45, 4.95)	**1.37 (1.03, 1.83)**
Self-perceived vision ability		
Poor/Fair	1.00	1.00
Good/Very good/Excellent	3.03 (0.61, 15.49)	1.11 (0.76, 1.63)
Self-perceived hearing ability		
Poor/Fair	1.00	1.00
Good/Very good/Excellent	0.76 (0.16, 3.71)	0.88 (0.71, 1.10)

[†]Logistic section of the regression model estimates the log-odds of belonging to the 'sure-zero'/'not-at-risk' class.
[‡]Poisson section of the regression model estimates the count of IADL limitations for those estimated to belong to the 'non-sure zero'/'at risk' latent class.
OR: Odds Ratio; RR: Rate Ratio; the reference category is 1.00.
Statistically significant estimates (at the 5% level) are displayed in bold.

These findings are discussed with existing literature in Chapter 9, Section 9.3.3 (page 340).

Chapter 8: Results of cross-sectional association between frailty and quality of life among rural community-dwelling older adults in Kegalle district of Sri Lanka

8.1 Chapter overview

In this chapter, I present the results of my analyses evaluating the cross-sectional association between frailty and quality of life among rural community-dwelling older adults in Kegalle district in Sri Lanka. The assessment of frailty, quality of life, and statistical analysis specific to this chapter were discussed in Sections 4.7.1 (page 178), 4.7.4 (page 194), and in Section 4.8.3.3 (page 206) respectively. First, I outline the missing data pertaining to the analysis of this chapter. Second, I describe the sociodemographic and health-related characteristics of the study sample by total quality of life score (OPQOL-35) tertiles. Next, I describe the distribution of total and domain-specific QoL scores according to frailty status. Finally, the association between frailty status and total and domain-specific QoL is evaluated using unadjusted, 'age-and sex'-adjusted, and multivariable-adjusted linear regression models. The findings of this chapter have been published as a peer-reviewed journal article by Siriwardhana et al in Quality of Life Research journal in 2019.[366]

8.2 Data screening and missing values

A total of seven participants had missing data on the total QoL score. This was due to the fact that there was missing data for one or more domain-specific QoL scores and therefore overall QoL could not be calculated. Of all covariates, chronic pain was missing for seven participants and social support score was missing for four participants. This resulted exclusion of 17 (2.3%) participants from the final regression analysis.

8.3 Frailty status, sociodemographic characteristics, and health-related factors of the overall sample by OPQOL-35 score tertiles

Three quarters (75.0%) of frail older adults were in the 'low' QoL tertile. 47.5% of participants in the non-frail group were in the 'high' QoL tertile compared with 9.6% of participants in the frail group. A higher proportion of females were in the 'low' QoL tertile compared with males (37.7% and 29.1% respectively). 82.4% of older adults in the 'poor' social support category were in the 'low' QoL tertile. 43.6% of the older adults who had never employed or who had engaged in longest-held occupations belonging to Skill level 1 (lowest skill level) were in the 'low' QoL tertile. The majority of the older adults who were classed as multimorbid (co-occurrence of two or more chronic disease conditions), taking five or more medicines daily (polypharmacy), experiencing chronic pain, had a cognitive assessment (MoCA) score below the median score of the sample, at higher risk of depression, reported being 'poor'/'fair' in the following items: self-reported vision ability, self-reported hearing ability, oral health, and self-reported general health were in the 'low' QoL tertile (Table 8.1, page 304).

Table 8.1 Frailty status, sociodemographic characteristics, and health-related factors of the overall sample and by OPQOL-35 score tertiles

Covariate	Weighted percentage (%) (OPQOL-35 score tertiles)		
	Low (76-127)	Intermediate (128-139)	High (140-171)
Frailty status			
Non-frail	11.5	41.0	47.5
Pre-frail	37.7	32.4	29.9
Frail	75.8	14.6	9.6
Sex			
Male	29.1	34.3	36.6
Female	37.7	31.7	30.6
Age category (years)			
60-64	23.1	37.0	39.9
65-69	26.8	37.4	35.8
70-74	44.5	28.2	27.3
75-79	55.5	24.8	19.7
≥80	48.1	24.0	27.9
Ethnicity			
Sinhalese	34.0	32.8	33.2
Other	33.2	34.0	32.8
Marital status			
Married/cohabiting	29.1	34.1	36.8
Never-married/widowed/separated/ Divorced	41.3	31.0	27.7
Living arrangement			
Children/other family	33.1	33.1	33.8
With spouse only	29.0	33.8	37.2
Alone	53.3	28.5	18.2
Social support			
Poor	82.4	15.3	2.3
Moderate	58.1	23.3	18.6
Strong	26.4	35.6	38.0
Education level			
No formal education/primary	48.3	33.2	18.5
Lower secondary	34.3	37.7	28.0
Upper secondary or above	22.1	27.8	50.1
Longest-held occupation			
Never-employed/Skill level 1	43.6	32.7	23.7
Skill level 2	31.4	38.0	30.6
Skill level 3 or 4	15.7	22.0	62.3

Table 8.1 continued. Frailty status, sociodemographic characteristics, and health-related factors of the overall sample and by OPQOL-35 score tertiles

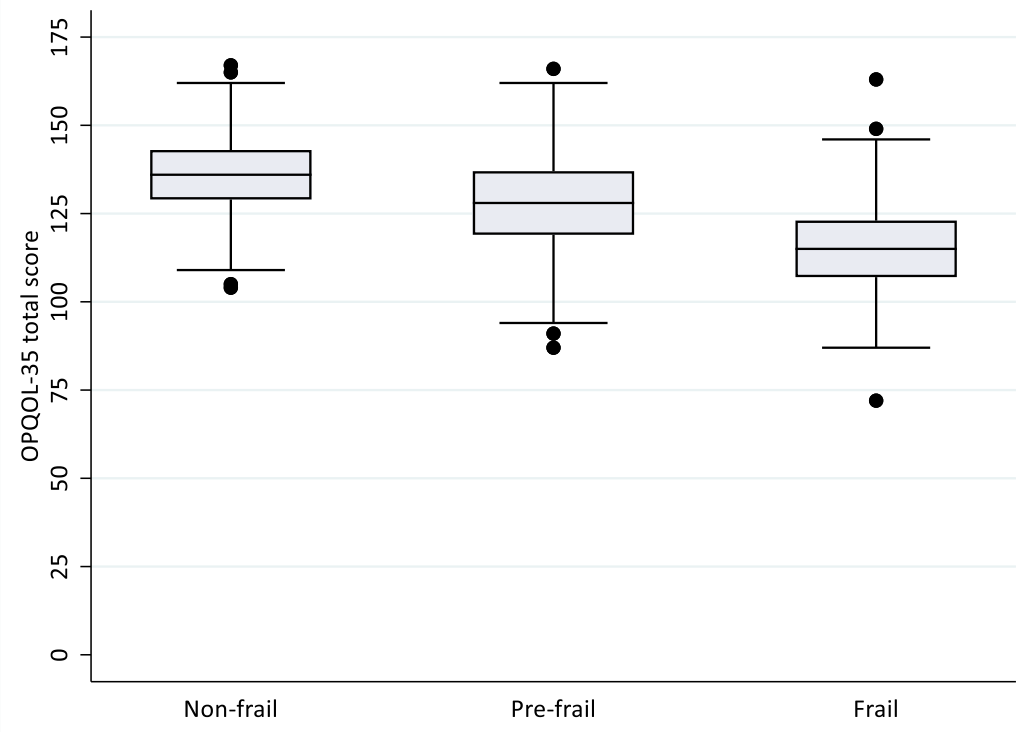
Covariate	Weighted percentage (%) (OPQOL-35 score tertiles)		
	Low (76-127)	Intermediate (128-139)	High (140-171)
Perceived financial strain			
Finding it difficult/very difficult to get by	59.4	29.6	11.0
Just about getting by	32.5	37.2	30.3
Living comfortably	16.7	25.7	57.6
Multimorbidity			
Yes	39.3	36.5	24.2
No	30.2	30.3	39.5
Polypharmacy			
Yes (≥5 medicines)	47.5	31.2	21.3
No (<5 medicines)	29.8	33.3	36.9
Having a chronic pain			
Yes	44.8	34.7	20.5
No	19.0	30.6	50.4
Cognitive status			
< Median MoCA score	48.7	29.8	21.5
≥ Median MoCA score	20.1	35.7	44.2
Depressive status (GDS-15)			
High/moderate risk	68.2	20.7	11.1
Low risk	17.6	38.7	43.7
Self-perceived vision ability			
Poor/Fair	44.8	30.2	25.0
Good/Very good/Excellent	23.2	35.5	41.3
Self-perceived hearing ability			
Poor/Fair	42.7	29.3	28.0
Good/Very good/Excellent	29.7	34.6	35.7
Self-perceived oral health			
Poor/Fair	38.8	32.8	28.4
Good/Very good/Excellent	28.0	32.7	39.3
Self-perceived general health			
Poor/Fair	46.6	32.0	21.4
Good/Very good/Excellent	17.4	33.8	48.8

Figures are row percentages.

8.4 Distribution of total and domain-specific quality of life scores according to frailty status

Figure 8.1 (below) illustrates the distribution of the total QoL score according to frailty status. The median QoL score decreased across the frailty spectrum. The unadjusted means (SE) of the total QoL score for the non-frail, pre-frail, and frail groups were 139.2 (0.64), 131.8 (1.04), and 119.2 (1.35) respectively (Table 8.2, page 308).

Figure 8.1 Distribution of total OPQOL-35 score according to frailty status



Participants in the frail group had on average a lower total QoL score compared with their pre-frail and non-frail counterparts (Table 8.2, page 308). According to this unadjusted mean comparison, all domains were associated with frailty except ‘social relationships and participation’ and ‘home and neighbourhood’.

Appendix 21 (page 482) reports the distribution of domain-specific QoL scores according to frailty status.

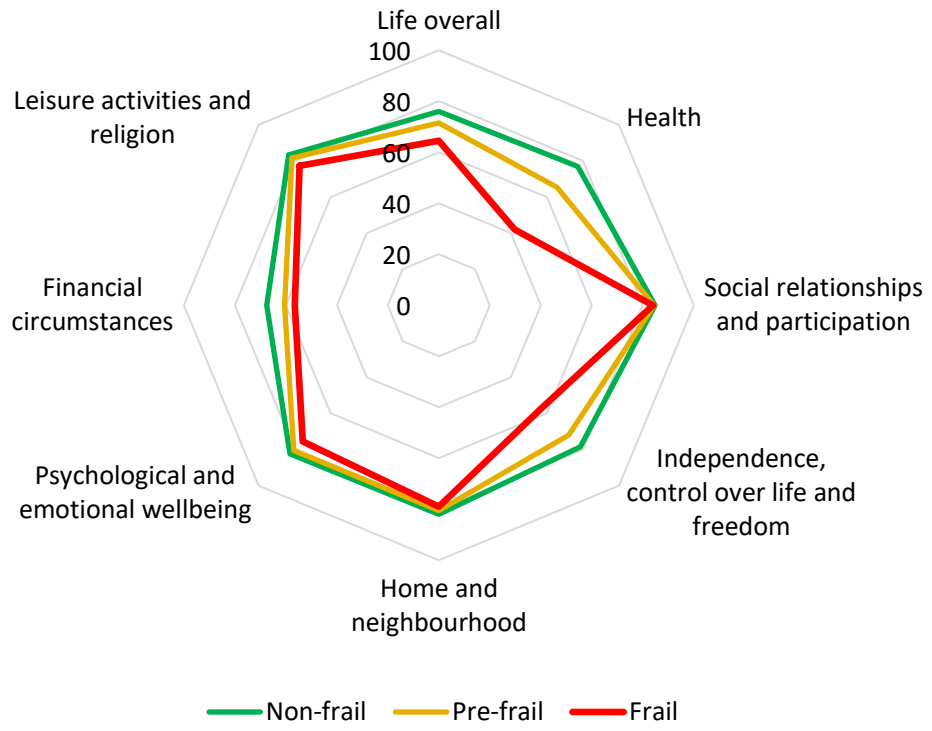
Table 8.2 Unadjusted mean comparison of total and domain-specific raw QoL scores according to frailty status

Domain	Weighted mean (SE)			p-value‡
	Non-frail	Pre-frail	Frail	
Total OPQOL-35 score (score 35-175)	139.2 (0.64)	131.8 (1.04)	119.2 (1.35)	<0.001
Life overall (score 4-20)	15.2 (0.18)	14.3 (0.12)	12.9 (0.22)	0.007
Health (score 4-20)	15.4 (0.19)	13.1 (0.18)	8.4 (0.29)	<0.001
Social relationships and participation (score 5-25)	21.2 (0.15)	21.1 (0.16)	21.0 (0.26)	0.777
Independence, control over life and freedom (score 4-20)	15.7 (0.12)	14.4 (0.17)	11.4 (0.24)	<0.001
Home and neighbourhood (score 4-20)	16.4 (0.20)	16.1 (0.18)	15.8 (0.21)	0.252
Psychological and emotional wellbeing (score 4-20)	16.5 (0.12)	16.1 (0.14)	15.1 (0.18)	0.005
Financial circumstances (score 4-20)	13.5 (0.21)	12.1 (0.32)	11.3 (0.42)	0.010
Leisure activities and religion (score 6-30)	25.0 (0.16)	24.5 (0.16)	23.2 (0.33)	0.018

‡p-values for mean difference calculated using Wald tests adjusted for complex sampling design.
Note: Table was taken from a published paper by Siriwardhana et al[366].

Figure 8.2 (below) shows unadjusted domain-specific standardised mean scores by frailty status (Section 4.8.3.3, page 206).

Figure 8.2 Unadjusted domain-specific standardised mean scores by frailty status



Note: Figure was taken from a published paper by Siriwardhana et al[366].

8.5 Part 1: association between frailty status and total quality of life

Table 8.3 (page 311) presents the association between frailty and pre-frailty (versus non-frail) with the total QoL score in unadjusted, 'age-and sex'-adjusted, and multivariable linear regression models adjusted for different covariates at each stage. In the unadjusted model, the estimated mean difference of the QoL score between older adults in the frail and non-frail groups was -20.0 (95% CI: -23.3, -16.7) points. This was an 11.4% reduction from the maximum possible score of the scale (175). However, the mean difference in QoL scores gradually attenuated with the addition of other covariates that were associated with both frailty and QoL. The final model showed an significant association of frailty with total QoL after adjusting for other sociodemographic covariates, multimorbidity, chronic pain, cognitive assessment score, and self-perceived vision and hearing ability. The estimated reduction in the total QoL score between older adults in the frail and non-frail groups was -12.7 (95% CI: -16.3, -9.0) points; a 7.3% reduction from the maximum possible score. Similarly, there was a small but significant association between pre-frailty and total QoL in the final multivariable model. The estimated reduction in the total QoL score between older adults in the pre-frail and non-frail groups was -3.7 (95% CI: -6.4, -1.1) points, a 2.1% reduction from the maximum possible score (175). The full results of the final multivariable model (model 7 in Table 8.3, page 311) is presented in Table 8.4 (page 312).

Table 8.3 Multivariable linear regression models: association between frailty and pre-frailty and total quality of life

Model	Coefficient (95% CI)		R^2 (%)
	Frailty	Pre-frailty	
Model 1: Unadjusted	-20.0 (-23.3, -16.7)	-7.4 (-10.0, -4.8)	20.3
Model 2: Model 1+ Age and sex	-19.8 (-23.3, -16.3)	-6.9 (-9.5, -4.4)	21.5
Model 3: Model 2+ Longest-held occupation	-18.0 (-21.9, -14.1)	-6.3 (-8.7, -3.9)	26.3
Model 4: Model 3+ Social support	-16.0 (-20.0, -12.1)	-5.3 (-7.9, -2.6)	33.6
Model 5: Model 4+ Multimorbidity, chronic pain	-14.5 (-18.1, -10.9)	-4.5 (-7.3, -1.8)	37.0
Model 6: Model 5+ Cognitive assessment score	-12.9 (-16.4, -9.5)	-3.9 (-6.4, -1.3)	39.1
Model 7: Model 6+ Perceived vision and hearing ability	-12.7 (-16.3, -9.0)	-3.7 (-6.4, -1.1)	39.3

Coefficients represent the estimated mean difference in total QoL score between frailty and non-frail, and between pre-frailty and non-frail.

Note: Table was taken from a published paper by Siriwardhana et al[366].

Apart from frailty and pre-frailty, 'poor' and 'moderate' social support, and experiencing chronic pain were significantly associated with lower QoL. In contrast, the longest-held occupation that belonging to Skill level 3 or 4 (higher skill occupations) and increased cognitive assessment score were associated with increased QoL Table 8.4 (page 312).

Table 8.4 Linear regression results for the association between frailty status and total QoL (Model 7)

Covariate	Coefficient (95% CI)
Frailty status	
Non-frail	0.0
Pre-frail	**-3.7 (-6.4, -1.1)**
Frail	**-12.7 (-16.3, -9.0)**
Sex	
Male	0.0
Female	1.1 (-1.3, 3.4)
Age category (years)	
60-64	0.0
65-69	0.5 (-2.1, 3.2)
70-74	-0.8 (-5.6, 3.9)
75-79	-0.8 (-4.2, 2.7)
≥80	3.4 (-1.9, 8.8)
Social support	
Poor	**-13.1 (-19.9, -6.4)**
Moderate	**-8.4 (-11.7, -5.1)**
Strong	0.0
Longest-held occupation	
Never-employed/Skill level 1	0.0
Skill level 2	0.7 (-1.9, 3.4)
Skill level 3 or 4	**4.7 (0.4, 9.0)**
Multimorbidity	
No	0.0
Yes	-1.4 (-3.6, 0.7)
Chronic pain	
No	0.0
Yes	**-5.3 (-7.8, -2.8)**
Cognitive assessment score (MoCA)	**0.5 (0.2, 0.8)**
Self-perceived vision ability	
Poor/Fair	0.0
Good/Very good/Excellent	1.6 (-1.4, 4.7)
Self-perceived hearing ability	
Poor/Fair	0.0
Good/Very good/Excellent	0.1 (-2.3, 2.6)

The reference category is 0.0.
Statistically significant estimates (at the 5% level) are displayed in bold.

8.6 Part 2: association between frailty status and domain-specific quality of life

After adjusting for covariates in the final multivariable model in the main analysis (model 7 in Table 8.3 (page 311) , coefficients shown in Table 8.4, page 312), the estimated mean difference was significantly lower for older adults in the frail group versus those in the non-frail group in the 'health'; 'independence, control over life and freedom'; 'life overall'; 'leisure activities and religion'; and 'psychological and emotional wellbeing' domains. Likewise, the estimated mean difference were lower for older adults in the pre-frail group versus those in the non-frail group in the 'health'; 'financial circumstances'; and 'independence, control over life and freedom' domains (Table 8.5, page 314).

Of the five QoL domains significantly associated with frailty, the 'health' and 'independence, control over life and freedom' domains appeared to have the largest reduction in sub-scale score. In the multivariable model, the estimated mean difference in the 'health' domain score between participants in the frail and non-frail groups was -5.4 (95% CI: -6.2, -4.5) points (27.0% reduction in maximum possible sub-scale score (20)). I performed sensitivity analyses excluding the question "I have a lot of physical energy" from the 'health' domain as it was highly related to the self-reported exhaustion component of the Fried phenotype frailty assessment. This did not change the reduction in the health domain sub-scale score.

Table 8.5 Domains of quality of life associated with frailty and pre-frailty

Model	Coefficient (95% CI)[†]		R^2 (%)
	Frailty	Pre-frailty	
Health	**-5.36 (-6.19, -4.54)**	**-1.43 (-1.98, -0.88)**	49.1
Independence, control over life and freedom	**-2.93 (-3.72, -2.14)**	**-0.64 (-1.15, -0.13)**	40.1
Financial circumstances	-0.96 (-1.95, 0.03)	**-0.83 (-1.52, -0.13)**	25.2
Life overall	**-1.39 (-2.14, -0.63)**	-0.43 (-0.95, 0.07)	20.0
Psychological and emotional wellbeing	**-0.97 (-1.56, -0.38)**	-0.16 (-0.62, 0.28)	14.3
Home and neighbourhood	-0.17 (-0.86, 0.52)	-0.01 (-0.57, 0.54)	10.9
Leisure activities and religion	**-1.09 (-1.99, -0.19)**	-0.18 (-0.63, 0.27)	10.6
Social relationships and participation	0.38 (-0.42, 1.17)	0.18 (-0.40, 0.77)	10.0

[†]Results of eight different linear regression models each adjusted for sex, age group, longest-held occupation, social support category, multimorbidity, chronic pain, cognitive assessment (MoCA) score, self-perceived vision ability, and self-perceived hearing ability
Coefficients represent the estimated mean difference in QoL score between frailty and non-frail, and between pre-frailty and non-frail.
Statistically significant estimates (at the 5% level) are displayed in bold.
Note: Table was taken from a published paper by Siriwardhana et al[366].

These findings are discussed with existing literature in Chapter 9, Section 9.3.4 (page 343).

Chapter 9: Discussion

9.1 Chapter overview

In this final chapter of my thesis, I present a summary of my findings, discuss them with reference to the existing literature and provide a detailed description of the strengths and limitations of my PhD. Finally, I consider the potential public health and policy implications and scope for future research, and present the conclusions of my PhD.

9.2 Summary of findings

9.2.1 Systematic review and meta-analysis

The systematic review and meta-analysis of the prevalence of frailty and pre-frailty in LMICs included 56 studies. The majority (40 studies) were from Latin American and Caribbean countries and 24 studies were from Brazil. Of 12 studies that included Asian countries, eight were from mainland China and two each were from Malaysia and India. Only one study was found from African region-Tanzania; this was the only study found from countries with low-income economies (US$ 1,005 or less) according to World Bank Classification, 2017 (based on 2016 data)[183]. Of countries with lower-middle-income economies (US$ 1,006 to US$ 3,955)[183], two studies were found and both were from India. All the other studies have been conducted in countries with upper middle-income economies (US$ 3,956 to US$ 12,235)[183]. No study was conducted in Sri Lanka-a lower middle-income country with GNI per capita of US$ 3,790 in 2016.

Based on the present meta-analysis (Chapter 3: Section 3.5.2.2, page 123), the random-effects pooled prevalence of frailty and pre-frailty in community-dwelling older adults in LMICs from correspondingly 69 prevalence estimates (47 studies) and 54 prevalence estimates (42 studies) were 17.4% (95% CI: 14.4%, 20.7%) and 49.3% (95% CI: 46.4%, 52.2%) respectively.[176] As shown in Chapter 3, Section 3.5.2.3 (page 128), use of different frailty assessment methods makes it difficult to exactly compare the prevalence of frailty between studies. In my subgroup analysis with studies conducted in middle-income countries only and with frailty

assessed with a single method; Fried phenotype-weakness and slowness assessed using objective tests, the pooled prevalence of frailty and pre-frailty was estimated as 12.3% (95% CI: 10.4%, 14.4%) and 55.3% (95% CI: 52.0%, 58.6%) respectively.

Among the studies covered in the present meta-analyses, frailty was significantly higher in females compared with males and as expected increased with age. The pooled prevalence of pre-frailty was at around half of the participants in included studies and only slightly increased across all age groups. Both the prevalence of frailty and pre-frailty appeared significantly higher in community-dwelling older adults in upper middle-income countries compared with high-income countries. The wide variation in prevalence levels across studies included in the present meta-analysis appeared to be largely explained by the differences in frailty assessment method and the geographic region with higher levels of prevalence found using the Edmonton Frail Scale and higher levels in the Latin America and the Caribbean region.

In summary, very little research was found on the basic epidemiology of frailty in LMICs. Furthermore little is known on patterns of frailty in WHO South-East Asia and no studies prior to mine had been undertaken in Sri Lanka.

9.2.2 Population-based cross-sectional study in Kegalle district of Sri Lanka

To address this research gap, I undertook a population-based cross-sectional study in 2016 with older adults (aged ≥60 years) living in rural areas in Kegalle district of Sri Lanka, a predominantly rural area which includes 4.1% of the Sri Lankan population. Using the data collected by this study, I estimated the prevalence of frailty (using the Fried phenotype) and its five components, and the prevalence of frailty across sociodemographic, health, and lifestyle factors and associated sociodemographic, health, and lifestyle characteristics with frailty and pre-frailty. I further explored the potential impact of frailty by examining the cross-sectional associations of frailty with disability and with quality of life.

9.2.2.1 Epidemiology of frailty

Based on my own data, the prevalence of frailty (having three or more components) and pre-frailty (having one or two components) among rural community-dwelling older adults aged ≥60 years in Kegalle district in Sri Lanka in 2016 was estimated as 15.2% (95% CI: 12.3%, 18.6%) and 48.5% (95% CI: 43.8%, 53.2%) respectively. The prevalence of frailty in the 60-64 years age group was 3.8% (95% CI: 1.7%, 7.9%). Nearly half of those aged ≥80 years were frail. The most prevalent frailty component in the overall sample was self-reported exhaustion (37.5%) followed by weakness (23.6%), slowness (19.6%), low physical activity (19.2%), and low BMI (18.2%).

Multivariable-adjusted multinomial logistic regression models were fitted and relative risk ratios were computed to explore the sociodemographic, health-related, and lifestyle characteristics associated with frailty and pre-frailty (versus being non-frail). No statistically significant association was found between sex and being frail or pre-frail. Increasing age, having never been employed or having had a low-skilled longest-held occupation, and those who have 'poor' social support were associated with increased relative risk of being frail compared with being non-frail. Similarly being in the lowest education level was associated with increased relative risk of being pre-frail compared with being non-frail.

According to the multivariable-adjusted model including health-related factors, polypharmacy (taking five or more medicines daily), lower cognitive assessment score, and high/moderate risk of depression were associated with increased relative risk of being frail compared with being non-frail. Only lower cognitive assessment score and high/moderate risk of depression were significantly associated with increased relative risk of being pre-frail compared with being non-frail.

In the multivariable-adjusted model including lifestyle factors, consumption of alcohol within the past 12 months (versus none) was associated with decreased relative risk of being frail compared with being non-frail, while lower vegetable intake was associated with increased relative risk of being frail compared with being non-frail. Only alcohol consumption within the past 12 months (versus

none) was associated with decreased relative risk of being pre-frail compared with being non-frail.

9.2.2.2 Frailty and disability

In separate analyses I examined the prevalence of having ≥1 limitations in instrumental activities of daily living and in basic activities of daily living (IADL and BADL as measures of disability) according to frailty status. The prevalence of ≥1 IADL was high at 84.4% (95% CI: 68.9%, 93.0%) among frail older adults. The prevalence of ≥1 BADL was 38.7% (95% CI: 26.1%, 53.1%) among frail older adults. Over half of frail older adults (58.2%) reported both ≥1 physical and ≥1 cognitive IADL limitations. Physical IADL limitations were more prevalent compared to cognitive IADL limitations in the present Sri Lankan study population. Using a ZIP regression model to separately examine the excess zeros and count values for the number of IADL limitations, I found that being frail lowered the odds of having no IADL limitations and was associated with a four times higher count of IADL limitations compared with non-frail counterparts even after adjustment for sociodemographic and health covariates. Interestingly, there was no statistically significant association between pre-frailty and IADL limitations. I could not empirically estimate the association between frailty and BADL limitations due to the lack of heterogeneity in the presence of ≥1 BADL limitations across the frailty groups (0.0%, 2.7%, and 38.7% for the non-frail, pre-frail, and frail groups respectively).

9.2.2.3 Frailty and quality of life

I examined the quality of life (QoL) scores (assessed using the 35-item Older People's Quality of Life Questionnaire (OPQOL-35)) according to frailty status. Both frailty and pre-frailty were associated with lower on average QoL in the present Sri Lankan study population, and this remained after adjustment for a range of covariates. However, while statistically significant in the final multivariable-adjusted model, the contribution of frailty and pre-frailty to the QoL score was small (7.3% and 2.1% reduction respectively from the maximum possible total score). Of the eight domains of QoL, five domains were associated with frailty (health; independence, control over life and freedom; life overall; psychological and emotional wellbeing; and leisure activities and religion) and three domains (health; independence, control over life and freedom; and financial circumstances) were associated with pre-frailty.

9.3 Study findings in the context of existing literature

9.3.1 Systematic review and meta-analysis

The pooled prevalence of frailty and pre-frailty in LMICs calculated in the present review appears to be higher compared with the pooled estimates reported in a review which included high-income countries (USA, Italy, Canada, France, Australia, UK, The Netherlands, 10 European countries, and Taiwan)[133], a review from Japan[178], and a review from China including mainland China, Hong Kong, Macao, and Taiwan published in 2019[367]. However, the pooled prevalence of frailty in LMICs estimated in the present review (17.4%; 95% CI: 14.4%, 20.7%)

was consistent with a meta-analysis reporting nearly one out of five older adults as frail (19.6%; 95% CI: 15.4%, 24.3%), with studies from Latin America and the Caribbean[245]. This close level of agreement was expected as the majority of the studies (32 of 47) included in the present meta-analysis were from this region. However, it is not possible to make exact comparisons of frailty prevalence across the studies given the methodological heterogeneity between the studies.

The prevalence of frailty is highly dependent on the type of frailty assessment methods used. In order to make a fair comparison between the studies mentioned above, I estimated the pooled prevalence of frailty with 13 studies (21 estimates) that used Fried phenotype-weakness and slowness assessed using objective tests and restricted the analyses to participants aged ≥65 years. The prevalence of frailty of this sub-sample was 12.3% (95% CI: 10.4%, 14.4%) and was still higher compared to the weighted prevalence of frailty reported in HICs (9.9%; 95% CI: 9.6%, 10.2%) using physical frailty assessment methods[133]; in Japan (7.4%; 95% CI: 6.1%, 9.0%) using Fried phenotype[178]; and in China (8.0%; 95% CI: 7.0%, 9.0%) using Fried phenotype[367]. The findings of systematic review and meta-analysis of the prevalence of frailty and pre-frailty in LMICs have been discussed in detail with the existing literature in detail in Chapter 3, Section 3.6.2 (page 145).

9.3.2 Epidemiology of frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka

9.3.2.1 Prevalence of frailty

The prevalence of frailty varied across the studies. True differences of frailty prevalence are likely to be largely due to the differences in countries' social, economic, and cultural contexts. For instance, inherent differences in the sample populations with respect to ethnicity, gender roles, lifestyles, prevalence of long term conditions, social characteristics, and access to and the nature of healthcare systems are likely to account for a significant proportion of heterogeneity between studies. In addition to the true variation of frailty prevalence across different populations and geographic settings, heterogeneity in study methodology, particularly the use of different frailty assessment methods, study recruitment age, sample sizes, sampling techniques, and sample composition could also contribute to the magnitude of the prevalence estimates; making it difficult to precisely compare findings (prevalence and empirical associations) between the studies.

The Fried phenotype is, to date, the most commonly used method to assess frailty.[81] Nonetheless, the five phenotypic components proposed originally (shrinking, poor endurance and energy, weakness, slowness, and low physical activity) have been extensively operationalised with various adjustments across studies. Modifying phenotypic components could substantially change the prevalence estimates of frailty status and the predictive ability of the tool.[81] These

modifications are usually seen in number of areas. Please refer to Section 1.2.4.1 (page 62).

In the following section, I compare findings of the present study with all published studies from the WHO South-East Asian region and with those studies that only used the Fried phenotype with rural populations from other low-and middle-income countries. I briefly highlight the methodological and context specific differences that could partly explain the differences between prevalence estimates. Finally, I have compared the present study findings with the pooled prevalence estimates of frailty in upper middle-income and high-income countries presented in Chapter 3, Section 3.5.2.4 (page 135). Frailty prevalence using the Fried phenotype is highly dependent on the type of cut-off points applied for grip strength and gait speed (e.g. study population specific or external such as CHS[10] proposed cut-off points). In order to enable a more direct comparison to other studies available in the literature, in three occasions, I examined the prevalence applying the same cut-off points and minimum recruitment age to the present Sri Lankan study sample.

Cross-sectional studies from the WHO South-East Asian region

As noted in the findings of present systematic review, there is a paucity of epidemiological research on frailty from low-and middle-income Asian countries. Among the published studies to date, India was a study site of two multi-country studies[67, 368] and there were four small studies from (i) Pune, India[227]; (ii) Nepal[369]; (iii) Nakhon Pathom, Thailand[370]; and (iv) Thung Hua sub-district, Lampag

province, Thailand[371]. The reported prevalence of frailty in these studies ranged from 11.4% (Fried phenotype with four components)[67] to 56.9% (frailty index)[368].

A small community-based study of older adults aged ≥65 years conducted in Pune, India in 2014-2015[227] using Fried phenotype, a similar assessment method to the present study but with Cardiovascular Health Study (CHS) cut-off points[10] for gait speed and three grip strength cut-off points adjusted for sex and BMI, found a prevalence of frailty and pre-frailty of 26.0% and 63.6% respectively.[227] The corresponding prevalence of frailty and pre-frailty in the present study after restricting the sample to those aged ≥65 years and after applying the same CHS[10] grip strength and gait speed cut-off points was 34.6% (95% CI: 29.3%, 40.4%) and 49.7% (95%: 44.6%, 54.9%) respectively, indicating higher frailty but lower pre-frailty in the present Sri Lankan population. Besides the inherent differences in study samples, this difference may be due to the heterogeneity of operationalising the other Fried phenotypic components, e.g. shrinking, poor endurance and energy, and low physical activity.

A small study (n=280) with a voluntary sample of community-dwelling older adults aged ≥60 years from Thailand reported the prevalence of frailty as 17.2% with CHS cut-off points[10] for grip strength and gait speed.[371] When I used the same CHS cut-off points, the prevalence of frailty increased to a higher prevalence of 24.4% (95% CI: 21.0%, 28.3%) with the present Sri Lankan sample (≥60 years). The lower prevalence of frailty in this Thai study compared with the present study when I used the same CHS cut-off points[10] could be partially explained by the voluntary

Thai sample compared with the probabilistic sample selected for the present study, if the voluntary sample is healthier on average than a randomly selected sample. Another study conducted in Thailand in 2015 with a small urban sample of n=141 older adults aged≥65 years reported a higher prevalence of frailty (22.7%) and pre-frailty (55.3%) compared with the present study. This study had only used two grip strength cut-off points for males and females separately and one gait speed cut-off point.[370] This was a follow-up study of an initial sample of n=427 individuals selected using systematic random sampling. There may be higher attrition rates within the group of frail people taking part in the study and thus the true prevalence of frailty could be underestimated.

Cross-sectional studies from rural populations in low-and middle-income countries

The present study was conducted in rural areas of Kegalle district. Six other studies have also examined the prevalence of frailty among rural older adults in Tanzania, Malaysia, Colombia, Mexico, and Turkey. The prevalence of frailty in rural community-dwelling Tanzanian older adults aged≥60 years was found to be lower than the present study at 9.3% (95% CI: 4.4%, 14.1%) in 2017 with complete data for 196 participants.[372] The observed relatively low frailty prevalence in this study may be explained by healthy survivorship bias (e.g. early mortality of people with multimorbidities or frailty with reduced access to healthcare) or methodological differences. Similarly a low prevalence of frailty, 9.4% (95% CI: 7.8%, 11.2%) was reported in a probability sample of 2,324 rural community-dwelling older adults aged ≥60 years with an extensive list of study exclusion

criteria in Kuala Pilah, a district of Malaysia in 2013-2014.[373] However, in a small study with 279 randomly selected community-dwelling older adults aged≥60 years in another rural district of Kuala Nerus, Malaysia conducted in 2013, the reported prevalence of frailty was higher at 18.3%.[374] A lower prevalence of frailty compared with the present study was also reported among community-dwelling older adults in rural areas of coffee-growing zones of the Colombian Andes Mountains (12.2%) in 2005[218], rural areas of Mexico (10.7%) in 2013[221], and central villages of Kars Province, Turkey (7.1%) in 2014[375]. The minimum recruitment age of the participants in the aforementioned studies was ≥60[218], ≥70[221] and ≥65[375] years respectively.

In summary, the prevalence of frailty in the present study appears to be higher compared with many studies included in the comparison above, even after accounting for design differences (e.g. grip strength and gait speed cut-off points, and minimum recruitment age) with two studies from Pune, India[227] and Thailand[371]. However, it is worth noting the uncertainty around the study estimates given that many of the aforementioned studies had been conducted with small samples. Also, a lower prevalence of frailty was observed when participants were recruited from voluntary sampling[218, 371] compared with probability sampling. Selection and exclusion bias may have also contributed to the observed differences in the levels of frailty. For example, excluding individuals who were unable to travel to assessments or participate in an interview was likely to have led to an underestimation of frailty in some populations (e.g. Colombian

study).[218] Poor health is a predictor of study attrition; thus higher attrition of frail older adults was also probable in subsequent follow-up studies reporting lower frailty prevalence.[370] Similarly, in some studies the selection process may have favoured the inclusion of individuals with lower propensity for frailty and thereby leading to lower estimates of the prevalence of frailty.[218, 221, 373, 375]

Comparison with pooled frailty prevalence estimates from upper middle-income and high-income countries

In the present study, the prevalence of frailty and pre-frailty in older adults among those who were aged ≥65 years in Sri Lanka, was 21.6% and 52.6% respectively using population-specific grip strength and gait speed cut-off points. This is much higher than the pooled prevalence of frailty reported in high-income (8.2% ; 95% CI: 5.7%, 11.2%) and upper middle-income (11.8% ; 95% CI: 10.0%, 13.6%) countries using the same frailty assessment method and the same minimum recruitment age (≥65 years).[176] This finding supports existing literature showing a strong relationship among middle-aged and older Europeans between national economic indicators and a country's level of frailty and fitness.[180]

9.3.2.2 Sociodemographic characteristics associated with frailty status

Age-and sex

Older age and female sex are two well-known biological risk factors for frailty.[159] Advancing age is associated with progressive loss of homeostatic regulations and functional reserves of different physiological systems, making the human body less resilient. In the present study, there was a steep increase in the prevalence of frailty among Sri Lankan older adults in the older age groups (75-79; ≥80 years). In keeping with the findings of previous cross-sectional studies[133, 177], increasing age was associated with both frailty and pre-frailty in the present study. Older age was positively associated with incident or higher levels of frailty among community-dwelling older adults in all studies included in a systematic review that explored risk and protective factors associated with frailty using longitudinal studies.[159]

The prevalence of frailty has been reported to be higher in older females compared with males with studies using Fried phenotype[133]; however, authors did not examine the degree of variability between sexes across different age groups. Comparable with many other studies, I found a slightly higher overall prevalence of frailty among females (16.0%) compared with males (14.3%). However, the prevalence of frailty was very similar between Sri Lankan females and males across all five age groups, and no statistically significant sex difference in frailty or pre-frailty was found in the present study. Similarly, no association was found between sex and frailty in a Malaysian study.[374] In contrast, a meta-analysis of

seven large studies of community-dwelling older adults from 19 different countries from high-income and upper middle-income economies consistently reported higher frailty index scores for females compared with males even after stratifying by age groups.[376] A common hypothesis of this sex difference is that females are likely to acquire more deficits over time and live with those deficits for longer than males.[376] Sex differences in biological factors such as having lower muscle mass compared with males, hormonal changes, and increased risk of osteoporosis could further explain this sex difference.[231] A systematic review revealed mixed findings for the longitudinal association between sex and frailty[159]; two studies reported female sex as a risk factor for frailty[196, 377] while two studies reported no association[378, 379].

Social support

Living arrangement was not associated with frailty or pre-frailty in the present study. Longitudinal findings for the association between living alone and frailty have been conflicting.[159] One study reported a significant negative association (being protective) between living alone and frailty[380], this is because more frail older adults could have lost the capability to live independently in the community; however another study reported no association.[378] In line with previous cross-sectional literature[381] lack of or poor social support measured using Oslo-3 item social support scale was associated with increasing frailty in the present study. Findings of a recent longitudinal study reported that people who experience a higher level of loneliness, but not social isolation, are at increased risk of

becoming physically frail.[382] It is difficult to explain the causal mechanisms involved due to the cross-sectional nature of the present study, but it may be that good social support might delay the onset of frailty through improved mental wellbeing, access to health services, and nutritional status of older people.

Socioeconomic factors

A strong association between longest-held occupation and frailty was found in the present study. Older adults who have never been employed or having had an occupation belonging to the lowest skill level (skill level 1) were more likely to be frail compared with their high skilled counterparts. Education level was only associated with pre-frailty in the present study; older adults who had no schooling and those who reported to have had only primary education were more likely to be pre-frail compared with those who have completed upper secondary or above level of education. One study included in the systematic review of longitudinal studies[380] reported lower education as a risk factor for frailty while three studies reported no association. Perceived financial strain was not associated with frailty or pre-frailty in the final multivariable-adjusted model. Lower income was a risk factor for frailty in two studies included in a systematic review of longitudinal studies.[380] Similar to the present study, financial strain was not associated with frailty in a longitudinal study.[380]

This highlights the importance of exploring what aspects of socioeconomic status are most relevant to today's older populations.[383] Education level is often regarded as the first choice as a marker of socioeconomic status since education

level is usually attained in early life, and it is unlikely to be affected by reverse causality (i.e. frailty leading to lower educational attainment). Also, the education level of a person has a complex relationship with health and it is closely connected to occupation and other aspects of socioeconomic status.[384] More often the educational level of a person reflects the childhood and adolescent socioeconomic status based on the socioeconomic status of parents. Therefore, educational level partially determines the occupation and income of adulthood. However, according to the results of the multivariable-adjusted regression including sociodemographic characteristics, the longest-held occupation had a stronger association with frailty rather than education level or perceived financial strain in the present study. The level of education in the present sample of older Sri Lankan adults does not necessarily reflect the individual's occupation. For instance, of older adults who had completed the upper secondary or above level of education, only 47.6% had engaged in longest held occupations that belonged to skill level 3 or 4 (highest skilled). Alternatively, 95.2% of older adults who were engaged in high skilled longest-held occupations (skill level 3 or 4) had completed upper secondary or above level of education. This means that the possibility of extent of differentiation is limited and education level variable may only allow the most advantaged to be distinguished from the rest of the population.

A systematic review explored the relationship between occupational factors and frailty and has suggested a possible association between the life-course occupation and frailty in advanced age; intrinsically harder, manual or blue collar

occupations were viewed as the probable determinants for manifestation and severity of frailty at older age.[385] This review was the first in the literature on this aspect and there appears to be a complex and dynamic relationship between occupation and frailty that needs further investigation. Engagement in low skilled occupations could possibly be associated with increased work stress and psychological problems (e.g. depression) and unhealthy lifestyle practices (e.g. adherence to unhealthy diet, smoking, etc.) and exposure to work place risk factors (e.g. musculoskeletal complaints/back pains) that could eventually contribute to the development of chronic disease conditions that could possibly share common underlying biological mechanisms with frailty. On the other hand, it is complex to extrapolate how the observed social gradient in frailty is only related to longest-held occupation itself as the other variables related to socioeconomic status of older adults (e.g. education level, occupation class, wealth, income, financial strain) can sometimes overlap.[381]

9.3.2.3 Health-related factors associated with frailty status

Frailty was significantly associated with three health-related factors in the present study: polypharmacy (talking five or more medicines daily), low cognitive performance, and presence of higher number of depressive symptoms. All of these associations are consistent with extensive literature documenting these associations predominantly from studies conducted in high-income countries.[101, 386, 387]

Multimorbidity

Multimorbidity was defined in the present study as the presence of two or more concurrent chronic disease conditions. The prevalence of frailty among those who were multimorbid, was 19.0% (95% CI: 13.1%, 26.8%) in the present study. A similar pooled prevalence of frailty was reported among multimorbid individuals, 16.0% (95% CI: 12.0%, 21.0%) in a meta-analysis, after excluding three studies where the majority of participants were 80 years and older.[388] The percentage of older adults who reported to have two, three, four, five, and six concurrent chronic disease conditions in the present Sri Lankan sample was 19.1%, 12.9%, 7.0%, 1.5%, and 0.5% respectively. However, it is also worth noting the methodological differences between studies (e.g. the definition of multimorbidity employed in the previous studies, which medical conditions were included, and whether the medical conditions were self-reported or were verified by documents). Of all chronic conditions reported in the present sample, over 70.0% were verified conditions (72.3%). Multimorbidity was associated with frailty in the present study in the unadjusted model, however it was not associated with either frailty or pre-frailty in the final multivariable-adjusted model.

Polypharmacy

In the present study, the prevalence of frailty among those taking five or more medicines daily was 27.1% (95% CI: 19.7%, 36.0%). Taking five or more medicines daily (compared to taking four or less) increased the relative risk of being frail by four times compared with being non-frail (Table 6.9, page 277). Of 18 cross-

sectional studies included in a systematic review, 16 demonstrated significant associations between polypharmacy and frailty.[389] However, longitudinal studies on this aspect are limited[386] and available results were inconclusive.[389] Thus, it is difficult to establish any potential causal relationships.[386] A complex bidirectional relationship has been suggested between these two factors.[389] Polypharmacy is a proxy marker for multimorbidity (i.e. a greater number or severity of chronic conditions) which in turn is associated to frailty. In addition, use of a higher number of drugs may cause clinical or subclinical adverse drug reactions or side effects that increase the risk of frailty.[386, 389] Certain components of frailty can be linked with the number of drugs taken, e.g. weight loss, balance disorders, poor nutritional status, and functional decline.[390, 391]

Multimorbidity and polypharmacy are two interrelated constructs. Although many would have multimorbidity in these older age groups, most of those chronic disease conditions may not be debilitating. In the present study sample, the majority of multimorbid adults were not taking five or more medicines daily (58.7%). However, the majority of older adults who were taking five or more medicines daily were multimorbid (72.0%). The correlation between these two variables in the present Sri Lankan sample was weak (Spearman's rho=0.36). I decided to keep both variables in the final multivariable-adjusted model to explore the independent association of multimorbidity and polypharmacy.

Cognitive performance

In keeping with previous studies, lower cognitive performance indicated by screening test results was associated with increased risk of both frailty and pre-frailty in the present study. Similarly, a number of cross-sectional studies have consistently demonstrated the association between general cognitive function and frailty assessed with both Fried phenotype and frailty index.[101] Evidence suggests a bidirectional relationship. According to the findings of longitudinal studies; higher levels of frailty predict cognitive decline among samples of both community-dwelling and long term care resident older adults.[101] The reverse association has also been found; cognitive impairment predicts future frailty.[101] A number of mechanisms have been proposed to explain the link between frailty and cognition and both conditions are hypothesised to share common risk factors including chronic diseases, poor cardiovascular health, inflammation or hormonal dysregulation.[101]

Depression

In keeping with previous research[387] older adults at higher risk of depression were at increased risk of having being frail (versus non-frail) and pre-frail (versus non-frail) in the present study. Results of a meta-analysis suggest a consistent bidirectional relationship between frailty and depression among older adults.[387] Later life depression and frailty are assumed to share several pathophysiological mechanisms, e.g. subclinical cerebrovascular disease, role of chronic inflammation, HPA dysregulation of hormones, etc.[26]

Vision and hearing ability, chronic pain, and oral health

The prevalence of frailty among those who reported 'poor' or 'fair' vision and 'poor' or 'fair' hearing ability in the present sample was approximately double, 21.8% (95% CI: 17.4%, 27.0%) and 21.3% (95% CI: 15.1%, 29.2%) compared with their counterparts who reported 'good'/'very good'/'excellent' vision and hearing ability respectively. However, self-perceived vision ability and hearing ability were not associated with either frailty or pre-frailty in the present multivariable-adjusted model for health-related factors. In contrast, self-reported 'poor' vision was associated with both frailty and pre-frailty combined after adjusting for several sociodemographic and health-related covariates in a cross-sectional analysis of the English Longitudinal Study of Ageing (ELSA).[392] Similarly 'poor' self-reported hearing was also associated with frailty and pre-frailty in a multivariable-adjusted cross-sectional analysis.[393] Self-reported chronic pain and self-perceived oral health were not associated with either frailty or pre-frailty in the present multivariable-adjusted model for health-related factors.

9.3.2.4 Lifestyle factors associated with frailty status

Smoking, alcohol consumption, and unhealthy dietary patterns, are important modifiable lifestyle factors that are associated with many chronic disease conditions.

Smoking

I found no association between smoking status and frailty or pre-frailty (versus non-frail). In contrast, a previous cross-sectional analysis showed a dose-response association between smoking and frailty (assessed with the frailty index); heavy smokers had the highest degree of frailty, light smokers had intermediate frailty status, and never smokers were the fittest.[394]

Alcohol consumption

In the present multivariable-adjusted model for lifestyle factors, the risk of frailty and pre-frailty was lower for those who reported that they had consumed alcohol within the past 12 months. Likewise, alcohol consumption was associated with lower incident frailty compared with those abstaining among community-dwelling middle-aged older adults in a systematic review and meta-analysis that explored the prospective associations between alcohol consumption and incident frailty.[395] However, the pooled estimate of this study was mostly based on unadjusted risk estimates. The potential explanations for this finding could be the 'sick quitter' effect (i.e. that those who are ill or frail stop drinking) and/or healthy survival bias (i.e. that those who were susceptible to alcohol related diseases might have died at an earlier age).

Diet

In age-and sex-adjusted models, there were significant associations with: (i) low plant protein and (ii) low plant and animal combined protein intake with frailty and pre-frailty (versus non-frail). However, this was attenuated and was non-significant in the multivariable-adjusted model. A systematic review and meta-analysis that included four cross-sectional studies found that higher protein intake was negatively associated with frailty status in older adults with unadjusted risk estimates.[396] Similar results were observed in two of three longitudinal studies found in this review indicating higher protein consumption was associated with lower risk of frailty.[396]

In the final multivariable-adjusted model, being in the lowest tertile of weekly vegetable intake (≤18 servings) compared with being in the highest tertile (≥28.5 servings) increased the risk of being frail compared with non-frail. The level of fruit consumption seemed to be very low in the present study population, the weekly consumption was ≤6 servings for 72.2% of the sample. However, no association was observed between weekly fruit intake and frailty status in the present study. The potential mechanisms that would explain this finding are: (i) fruits and vegetables are natural sources of anti-oxidants, (ii) contain certain nutrients that are protective against risk factors for frailty, and (iii) contain phytochemicals that have anti-inflammatory properties.[397] However, a systematic review and meta-analysis published in 2019 emphasized the importance of investigating the association between dietary patterns and frailty rather than assessing the

relationship between single nutrients or foods and frailty. The findings of this review suggested that a diet high in fruit, vegetables, and whole grains may be associated with reduce risk of frailty.[398]

9.3.3 Cross-sectional association between frailty status and disability

In a separate analysis I examined the prevalence of ≥1 limitations in activities of daily living according to frailty status. The prevalence of ≥1 IADL limitations (e.g. shopping, food preparation, responsibility of own medication, etc.) appears to be higher among frail Sri Lankan older adults (84.4%) compared with frail older adults in Canada (60.0%)[10], England (64.5%)[155], and Egypt (72.1%)[156]. In contrast, the prevalence of ≥1 BADL limitations (feeding, bathing, toilet use, etc.) was higher among frail older adults in England (57.1%)[155] and in Egypt (44.2%)[156] than in the present Sri Lankan sample (38.7%). The prevalence of ≥1 BADL limitations among frail older adults in the Canadian study was lower (27.4%) compared with the level among frail Sri Lankan older adults. The minimum age of the participants included in the Egyptian and English studies was ≥60 years whereas it was ≥65 years in the Canadian study.

In the present study, Sri Lankan frail older adults had much higher levels of dependency in IADL tasks compared with the ELSA participants at Wave 4 (2008-09).[155] This provides a good illustration of how differences in findings across countries/studies may be explained both by study methodological heterogeneity (e.g. disability assessment methods, measurement wording, nature of respondent: older adult or a caregiver, and study population characteristics) and

in socio-cultural contexts. For example, in the present study, 69.6% and 64.4% of the frail older adults reported dependency for shopping and meal preparation respectively whilst the corresponding figures in the ELSA were 36.3% and 16.7%.[155] However, it is also worth noting the cultural and context specific differences associated with these two tasks. In the present study I asked participants about meal preparation whereas ELSA participants were asked about preparing a hot meal. In the Sri Lankan context, food preparation is a fairly complex task particularly in rural areas (i.e. cleaning and cutting vegetables, scraping coconut, handling wood burners, etc.) whereas in England it could just involve heating a 'ready to cook' meal. A similar pattern was observed for cognitive IADL tasks (e.g. responsibility of own medication, ability to use telephone, ability to handle finances). In the present study 50.0% and 37.4% of frail older adults reported that they were not capable of managing their own medications and handling finances respectively. The respective figures among frail older adults were very low in the ELSA study at 5.6% and 8.0% [155]. However, the ELSA survey items mention 'taking medications' and 'managing money' [155] rather than handling/managing medications and handling finances.

In the present study population, physical IADL limitations appeared to be more common among frail participants compared with cognitive IADL limitations. However, this finding was in line with my expectations given that the Fried phenotype captures physical frailty. In the Sri Lankan context, certain physical IADL tasks (e.g. food preparation and shopping) could be more demanding for frail

older adults in remote rural areas compared with cognitive IADL tasks. However, in the present study the vast majority (96.0%) of older adults lived with their spouse or children and therefore family support for older adults is very high. In Sri Lanka, family members may often assist older adults with performing IADL activities even though they do not have any difficulty of performing these. These cultural elements could also contribute to deskilling (accelerating the loss of function) and increasing dependency levels in the long run.

I further explored the characteristics of the present Sri Lankan frail sub-sample in order to understand the presence of higher levels of IADL limitations. The median MoCA score of older adults with ≥1 IADL limitations was lower (median 16; IQR: 11.5-21) compared with adults with no IADL limitations (median 21; IQR: 18-23). There is a potential bidirectional relationship between frailty and cognitive impairment.[399] It has also been found that IADL limitations are consistently present with those who have mild cognitive impairment.[400]

With regard to BADL tasks, frail older adults in ELSA reported more difficulties with more intimate activities such as dressing (40.0%) and bathing or showering (34.1%)[155] whilst Sri Lankan frail older adults reported higher dependency for feeding (25.1%) followed by dressing (22.1%), and bathing (22.0%). It is interesting to note the lower prevalence of limitations for bathing in the present study considering the low facilities existing in the rural Sri Lankan environment. For instance not all households in rural areas have regular water supply and many household members have to go to public wells, rivers, or streams for bathing.

Though I recruited a representative sample based on the age-and sex composition of the older adults living in the Kegalle district, 61.0% of them were between 60 to 69 years old ('young old'). 1.2%, 3.4%, and 5.2% older adults in 60-64, 65-69, and 70-74 years age groups reported ≥1 BADL limitations respectively. There were few older adults belong to 'middle-old' (age 70-79 years) and 'oldest-old' (age ≥80 years) age groups, which could explain low BADL prevalence in the present sample.

9.3.4 Cross-sectional association between frailty status and quality of life

I further explored the association of quality of life and frailty status. My findings corroborate the findings of previous studies: frailty and/or pre-frailty were significantly associated with lower QoL/HRQoL scores on average compared with non-frail older adults.[106, 165, 401] However, direct comparisons of the present study findings with these other studies is not feasible due to the differences in study methodology; mainly the method of assessment of frailty and of QoL/HRQoL, study participants, and analysis techniques. Previous studies that have estimated the associations between frailty and HRQoL had adjusted for several covariates.[162-164] However, I only found one study (conducted by Bilotta and colleagues) that had attempted to estimate the association between frailty and the broader concept of QoL after adjusting for other covariates.[401] In this study, Bilotta and colleagues recruited community-dwelling older adults referred to an outpatient geriatric clinic in Milan, Italy (such outpatients probably represent a less healthy population).[401] They used the same QoL instrument as used in the

present study (the 35-item Older People's Quality of Life Questionnaire) but used a different frailty evaluation method (Study of Osteoporotic Fractures (SOF) frailty index), and adjusted for different covariates. It is therefore not possible to directly compare my findings.

A systematic review and meta-analysis published in 2019 which predominantly included studies from HICs which measured both HRQoL and QoL has also reported worse QoL among community-dwelling older adults with frailty than their counterparts without frailty.[402] This association remained robust even after adjusting for age, sex, and depression. Furthermore, a clear and substantial association was observed between frailty and lower QoL across a range of QoL domains.

9.4 Strengths and limitations

9.4.1 Part A: systematic review and meta-analysis

Strengths and limitations

In this thesis, I conducted the first systematic review and meta-analysis on the prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs. The strengths of this review include: (i) conducting a comprehensive literature search in six electronic databases with a comprehensive search strategy, including WHO Global Health library to capture studies published regionally, (ii) no language restriction, (iii) screening by two reviewers, (iv) using a quality assessment tool, (v) subgroup analysis of prevalence of frailty and pre-frailty with substantial number of studies, (vi) using a meta-regression technique to identify the sources of heterogeneity between the studies, and (vii) contacting authors to directly obtain the additional information from the studies required for subgroup analyses. The systematic review and meta-analysis have been reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[181]

Both funnel plot asymmetry and the results of the Egger's weighted regression test indicated the presence of reporting biases and/or between study heterogeneity in the random-effects meta-analysis of frailty. The nature of this study effect (prevalence) is unlikely to be affected by publication bias. However, publication bias could also be affected by study size, funding source or research group.[191] I noted that the majority of the studies included in this meta-analysis have large samples. Multiple sources have been identified that could affect funnel

plot asymmetry including reporting biases (publication bias, selective outcome reporting, and selective analysis reporting), poor methodological quality, true heterogeneity, and chance.[189, 190] In the present review funnel plot asymmetry is likely to be mainly due to the true heterogeneity between the studies as a result of the use of different frailty assessment methods. It is also possible to have a true underlying difference of frailty prevalence in different populations. Another limitation of the present review was non-inclusion of grey literature; it may be that some small unpublished studies could have been missed.

9.4.2 Part B: population-based cross-sectional study

9.4.2.1 Study design

Strengths and limitations

Cross-sectional studies are an appropriate and efficient design to evaluate the prevalence of diseases, explore the aetiology of non-fatal diseases, and identify healthcare needs of the populations.[403] Moreover, these studies can be quicker and more economical to perform[404] than longitudinal panel cohort designs and do not have limitations of attrition over time. Cross-sectional studies are therefore suitable in resource or time constrained conditions such as my PhD to initiate the understanding of health issues that have never been studied before. I conducted a population-based cross-sectional study to achieve the study objectives of Part B of my PhD. To the best of my knowledge, this is the first study conducted in Sri Lanka on the epidemiology of frailty assessed with the Fried phenotype and is the

first study from the WHO South-East Asian region assessing cross-sectional association of frailty with disability and with quality of life among rural community-dwelling older adults. Some GN areas of the present study setting were very remote and had access only by foot (e.g. six or seven kilometers walk). I had an excellent research team, Department of Community Medicine, University of Colombo, Sri Lanka to coordinate field work activities, and received maximum support from the local community as well as from government administrative officers of respective GN areas to overcome many logistical challenges and to achieve a very high response rate. I followed Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[405] when reporting present cross-sectional study.

In cross-sectional studies, disease outcome and exposures are measured at the single point in time although the recruitment can take place over a long period of time. As a result, cross-sectional studies lack prospectively collected information on past exposures and time sequence of events making it difficult to establish causal inference or temporal relationship between variables.[403] Findings should therefore be interpreted with caution.

9.4.2.2 Study population

Strengths and limitations

I recruited a large representative sample of older adults from the entire Kegalle district based on the census data of 'age-and sex' composition of the older adults

in the district.[259] The sample studied is therefore representative of the base population and has internal validity. Nevertheless, census data were not available for the other sociodemographic characteristics (except sex and age) for the entire older population in Kegalle district hindering the comparison with the present study sample. However, there is unlikely to be much selection bias as the present study response rate is extremely high (99.5%). Table 6.2 (page 258) compares sociodemographic characteristics of the present study sample with the entire Sri Lankan older population. The present study sample was comparable with the Sri Lankan older population in terms of sex and age composition. However, the present study sample was slightly higher educated, included higher proportion of older adults belonged to Sinhalese ethnicity, who were widows, and living in extended households. Ethnic homogeneity (Sinhalese) and having a sample exclusively drawn from the rural areas limit the generalisability or external validity of findings across older adults from other ethnic groups and from older adults living in urban and estate areas in Sri Lanka. However, it is worth noting that the majority of Sri Lankan older adults (79.7%) as well as Sri Lankans (74.9%) are Sinhalese and the majority of Sri Lankan older adults (77.0%) and Sri Lankan population (77.4%) live in the rural areas.[250]

Compared with contemporary studies in the literature, I did not employ an extensive list of study exclusion criteria. I only excluded participants who could not give informed consent (e.g. advanced stages of dementia) and those who were terminally ill. Therefore, number of excluded participants was very small and

less restrictive than other studies. Even though the number of excluded participants are minimal, there is still a small possibility of underestimating the true prevalence of frailty status as well as true values of other data collected during the study as excluded participants (e.g. those unable to give informed consent) were likely to be less healthy compared to the included participants.

9.4.3 Study setting, sampling design, and sampling frame

Strengths and limitations

Kegalle district was chosen as this district reported the highest proportion (14.9%) of older adults in a district population out of 25 districts in Sri Lanka.[250] However, Kegalle district only accounted for 5.0% of total Sri Lankan older population according to 2012 census data (8th place of 25 districts: where minimum was 0.3% and maximum was 12.5%).[140] Utilizing simple random sampling was not a feasible option in the present study as there was no readily available complete list of older adults (sampling frame) living in the Kegalle district. Construction of a sampling frame for the entire district through visiting all the households was not feasible as Kegalle district is over a large geographic area (1692.8 km^2) with a 125,069 target population of interest. Therefore, considering the cost-effectiveness and efficiency of a complex sampling design, a three stage probability sampling design was used to recruit the participants, using the most accurate and up-to-date information available at each stage of the sampling.

9.4.4 Study instruments

9.4.4.1 Fried phenotype

Strengths and limitations

The Fried phenotype and the Frailty index are the most commonly used instruments to assess frailty among older adults.[56] I chose the Fried phenotype frailty assessment method to use in the present study as it has a biological basis, has been extensively used in community-based research, and has been shown to have good predictive validity.[8] However, I did not find any study conducted in WHO South-East Asia assessing the cultural adaptability, reliability, and validity of Fried phenotype. This was later confirmed by a systematic review published in 2016 claiming that none of the frailty assessment tools used have been fully validated to use in LMICs.[58] The Fried phenotype model has been criticised as it does not capture cognitive frailty or psychosocial factors.[8] All five phenotypic components proposed in CHS[10] were retained in the present study but the methods I used to operationalise two components: 'shrinking' and 'low physical activity' were modified compared to the original CHS[10] due to the cross-sectional nature of the present study and cultural appropriateness of the chosen physical activity instrument (IPAQ-Short Form) to the Sri Lankan context respectively. Since three components (shrinking, weakness, and slowness) were based on anthropometric measurements and measures of physical performance they were unlikely to be affected by cultural differences. I evaluated the intra-rater reliability of these measurements (height, weight, grip strength, and walking time) and

assessed its magnitude as excellent: intraclass correlation>0.9 (Appendix 11, page 456). The two questions and physical activity questionnaire used to assess 'poor endurance and energy' and 'low physical activity' components respectively were also culturally adapted and validated in Sri Lanka. I have described the impact of my operationalisation of each frailty component below.

Shrinking

I did not have access to valid repeated weight measures to calculate the shrinking/unintentional weight loss component of frailty. The only alternative was asking participants to self-report any unintentional weight loss in the prior year, however, I felt that this was an unreliable question to ask from rural Sri Lankan older adults as they do not monitor their weight regularly. Thus, in keeping with many studies using the Fried phenotype[81] I used BMI<18.5 kg/m^2 to operationalise 'shrinking'. However, BMI is often used as a measure of being underweight rather than unintentional weight loss and is a different construct to the original. Also, modifying the unintentional weight loss component with BMI<18.5 kg/m^2 has been associated with a decrease in the prevalence of frailty compared with using direct weight loss measures.[81] Hence, use of BMI might have underestimated the true prevalence of frailty in this Sri Lankan study population to some extent.

Exhaustion

As in the original CHS[10], I used the two questions of Center for Epidemiologic Studies Depression Scale to measure 'poor endurance and energy' component,

however this is subjective, personal, and culturally dependent. The reference period of the questions was the 'last week' and the responses could therefore be specifically influenced by personal circumstances such as bereavements, experiencing a critical health event or illness episode, etc. Moreover, older adults with undiagnosed or untreated depression may be positive for this component. On the other hand, the responses could also be affected by the social desirability bias due to the stigma attached with negative responses. This measurement error therefore could possibly lead to both over- and under- estimating the true prevalence of frailty in the present study population.

Weakness and slowness

Regardless of different body sizes and compositions across different ethnic groups in different regions, there is no consensus at present on which cut-off points should be used for grip strength and gait speed to evaluate the weakness and slowness components of frailty respectively. Some studies have used study population independent cut-off points either proposed in the original CHS[10] or age-and sex-specific grip strength norms proposed for different geographic regions,[372] whilst others have used underlying study population-specific cut-off points derived considering the anthropometry of their own study populations. I used study population-specific cut-off points. The sex-specific BMI quartiles and respective grip strength cut-off points were considerably lower in the present Sri Lankan sample compared with CHS[10] (Table 4.4, page 184). A similar pattern was observed in a Chinese study.[223] In contrast, three studies conducted in Brazil[209, 214]

and Mexico[165] reported approximately similar sex-specific BMI quartiles to CHS[10] but with substantially lower grip strength cut-off points compared with CHS[10]. When I used the CHS[10] proposed grip strength cut-off points, half of the present Sri Lankan study population was categorised as frail for the weakness component compared to just below one-in four based on the present study population-specific cut-points (50.7% vs. 23.6%). Similarly when I used the CHS[10] proposed walking time cut-off points, the prevalence of slowness component was also increased compared to present study population-specific cut-off points (30.7% vs. 19.7%).

When I apply the CHS[10] proposed cut-off points for grip strength and gait speed that were computed for a group of USA older adults aged≥65 years, it increased the estimates of both prevalence of frailty (24.4% vs. 15.2%) and pre-frailty (51.8% vs. 48.5%) in the present Sri Lankan study population (≥60 years) compared to those obtained in my main analyses which used study population-specific cut-off points. Similar results were found with the studies conducted in Germany[406] and Mexico[220, 407] with community-dwelling older adults. The prevalence of frailty was almost doubled (20.6%)[407] with a same sample of Mexican older adults aged ≥60 years when applying study population independent cut-off points (CHS[10]) for grip strength and gait speed compared with study population specific cut-off points (11.2%)[231]. The prevalence of pre-frailty also increased from 50.3%[231] to 57.6%[407]. Some researchers therefore were cautious to avoid the use of CHS[10] proposed cut-off points in order to prevent overestimation of prevalence of frailty status,

as these cut-off points are dependent on anthropometric variables and intrinsic characteristics of each population.[209, 214, 374] Furthermore, they posited that CHS[10] cut-off points would be most suitable for Caucasian populations as they have a larger body frame compared to Asian populations.[374]

A systematic review and meta-analysis of normative hand grip strength data found substantially lower values from developing regions of the world compared with developed regions.[408] I favoured the use of underlying study-population specific grip strength and gait speed cut-off points considering the anthropometry of each study population. However, to implement this approach, it is extremely important to have a large representative sample from the base study population. Or else, it is worthwhile developing population specific norms for each population-based on demographic characteristics as sex and age.

Low physical activity

The 'low physical activity' component was originally measured in the CHS using the Minnesota Leisure Time Activity Questionnaire.[10] This questionnaire captures the weekly engagement of persons in leisure time activities. However, physical activities included in this questionnaire (e.g. playing tennis) are atypical in many cultures and this instrument has been found to be less applicable to other populations and settings.[207, 209, 211] I therefore measured low physical activity using the widely used[202, 203, 248, 409] culturally adapted IPAQ-Short Form[209] as suitable for a Sri Lankan population. The strengths of this IPAQ-Short Form are that it is comprised of activities such as house work and house maintenance work,

gardening and walking that older adults are frequently expected to take part in on a daily basis. Thus, IPAQ-Short Form counts weekly engagement of total physical activities; number of days and time engaged in vigorous and moderate physical activities and in walking. Participants in the lowest quintile of weekly kilocalorie expenditure adjusted for sex were considered as frail for this component. The reference period of the IPAQ-Short Form was the last seven days (prior to interview) and engagement of physical activities could be affected by acute disease conditions, accidents (snake bites, falls, etc.), presence or absence of rain (e.g. engagement of physical activities were low in rainy days), and bereavements, etc.

9.4.4.2 Interviewer-administered questionnaire

Strengths and limitations

I followed a systematic process to develop the interviewer-administered questionnaire used in the present cross-sectional study including a literature review, establishing the content of the questionnaire, inclusion of validated established study instruments, review of the selected questions and instruments, pre-testing and refinement.[410] There were no self-completion items in the questionnaire and therefore older adults with low literacy or experiencing vision related problems could participate fully. Additional clarification about the questions could be offered for participants when needed. However, recording participants' responses was a time consuming and costly process. Participant responses may also be affected by 'interviewer bias'.

The questionnaire was comprised of questions originally developed for this study, questions used in previous studies and standard questionnaires/scales. I assessed the internal consistency of translated and adapted and/or validated versions of standard questionnaires included in my main questionnaire booklet (Appendix 10, page 454). The assessments used to screen for depressive symptoms (GDS-15 scale), cognitive dysfunction (MoCA), and limitations in basic activities of daily living (Barthel index) have been validated in Sri Lanka and showed a very good internal consistency with the present study sample: Cronbach's alpha values were 0.83, 0.85 and 0.92 respectively (Appendix 10, page 454). The validation of MoCA had been conducted in Colombo (the commercial capital of Sri Lanka). However, it was not clear whether the study included participants from rural areas.

I used a quality of life questionnaire specifically designed to assess the overall QoL of older adults (OPQOL-35). The internal consistency for the overall OPQOL-35 questionnaire was estimated as good (0.85) in the present study. However, use of the OPQOL questionnaire to assess the association of frailty with QoL is still scarce, limiting direct comparisons with studies in other settings. The OPQOL-35 questionnaire has only been translated into Sinhala language and tested for internal consistency in a previous study.[174] The validity of the questionnaire in a Sri Lankan context has not been established yet. Not all the QoL domains of the OPQOL-35 questionnaire reported satisfactory internal consistency in the present study (Table 4.6, page 195). It is also of note that values of Cronbach's alpha are affected by the length of the instrument. For instance, if an instrument has a

higher number of items, the alpha values tend to be higher. Low values of alpha could be due to the low number of items, poor inter-relatedness between items, or heterogeneous constructs.[411] Therefore, a comprehensive psychometric evaluation including the structural validity of the OPQOL-35 questionnaire in Sri Lankan context is warranted, but was beyond the scope of my PhD.

At the time of designing my study there was no culturally adapted, psychometrically tested instrument to measure the limitations in instrumental activities of daily living among Sri Lankan older adults. Therefore, to increase the robustness of my findings I cross-culturally adapted and evaluated the reliability and validity of the Sinhala version of Lawton IADL scale (Chapter 5, page 213).

9.4.5 Data analysis

Strengths and limitations

In complex sampling, unlike in simple random sampling, all the members in the study population do not necessarily have an equal probability of being selected into the sample. Use of final survey weights is therefore a standard practice in design-based analysis of complex sample survey data to correct for any differences in the probability of sample selection. These weights are compensating for unequal probabilities of selection, non-response adjustment and/or post-stratification adjustments. Unit non-response and items non-response were minimal and hence no adjustment was required in the present study. Post-stratification adjustments to the sample selection weights were

undertaken (Section 4.6.3, page 177) to minimise the bias caused by under and over represented groups as the number of participants recruited from each 'age-and sex' strata was only approximately proportional to the survey population distribution of each strata (Table 4.2, page 165). The post-stratification technique also typically reduces the variance of the survey estimates.[307] Except in few occasions my entire data analyses were performed after accounting for complex sampling design.

9.4.6 Role of chance

Chance occurs through sampling error.[412] Sampling error can be quantified and controlled in probability sampling designs if sampling principles are carefully applied within the budgetary constraints.[413] In general, increasing the size and improving the representation of the sample minimise the sampling error.[410] Considering the features of my complex sampling design, I computed the sample size that was required to estimate the prevalence of frailty at the desired level of precision. The number of participants recruited from each cluster was set at 15, which is the minimum possible number to include participants representing ten 'age-and sex' strata within a cluster. The number of participants recruited from each strata was approximately proportional to the district population distribution of each strata. Recruiting a small number of participants from one cluster increased the number of clusters required to cover the estimated sample size and thereby increased the geographical representation of the sample. Multiple testing could lead to chance findings. In Chapter 8 (Section 8.6, page 313) results involved

multiple testing and were performed for exploratory purposes only; therefore findings should be interpreted with caution.

9.4.7 Sources of bias

Bias refers to systematic difference between study measurements and true population values.[414] Researchers have used different terminologies and classification systems to describe all sources of biases or in other words non-random errors/systematic errors in epidemiological studies. I have described the possible biases that arose in the present study below broadly under two topics: selection bias and information bias and the measures I have taken to minimise these possible biases. This section is therefore about how I fully or partially overcame limitations emerged from these biases that mainly apply to my study population and to the instruments used.

9.4.7.1 Selection bias

Selection bias occurs if respondents are systematically different from non-respondents.[415] This can happen when the response rate is inadequate. I recruited 'age-and sex' representative sample of my base population and missing data were minimal as there was a very high response rate (only four non-respondents of 750) and the survey was interviewer-administered. There are four major types of non-response: unit non-response, surrogate response, noncontacts, and item non-response.[416] The following steps were taken in order to minimise non-response bias in the present study.

Unit non-response error was minimised by visiting the eligible participants with the Grama Niladhari officer of the respective SSU (in some occasions with a permanent resident of the respective GN division as a representative of the Grama Niladhari officer) and training the research assistants to communicate effectively and revisiting the potential participants those who could not locate at the first visit. Grama Niladhari officer/representative only helped to identify the randomly selected participants from the sampling frame of each GN division without any difficulty. In rural villages outsiders need to be introduced to the community by a person known to the villages. It is known as an acceptable practice in Sri Lanka and this improved the participant's credibility on the present study as Grama Niladhari officer is a government representative. A maximum of three visits were made to a household of a potential participant at different occasions if required.

Surrogate response error occurs when responses from a non-specified person (a person other than the eligible participant occur). Participants were interviewed individually and the other household members were informed about the nature of the interview at the beginning. Therefore, interference from other household members was minimal.

The item non-response error in the present study was minimised as follows: all the study instruments and physical performance tests were pre-tested with a similar group of participants (n=10) to identify issues pertaining to the study instruments. The questions which need probes (e.g. some questions in OPQOL,

GDS-15, etc.) were identified and research assistants were trained in probing the questions to the participants in a similar manner if they could not understand the initial question. They used show cards to explain some concepts e.g. standard alcohol drink (Appendix 7, page 451), food serving size (Appendix 8, page 452), and answers on a Likert scale (Appendix 9, page 453). It helped participants to think and select the most appropriate answer.

9.4.7.2 Information bias

Interviewer-related measurement errors can occur when interviewers intentionally or accidentally record incorrect data, influence the respondent's responses, or assume the responses based on the respondent's appearance or other characteristics, etc. To minimise these errors, trained research assistants and field assistants were employed with a manageable workload and close supervision.

Most of the domains included in household surveys such as my PhD cannot be measured directly e.g. quality of life, social support, depression, etc. Therefore, researchers use proxy measures in questionnaires to operationalise these constructs. If the construct validity of the study instruments is poor, estimates are biased as they are based on incomplete instruments. Even though I used culturally adapted, psychometrically tested study instruments to collect data on all important outcomes and some covariates, the construct validity of the following study instruments has not been tested in Sri Lanka yet e.g. OPQOL-35, Oslo-3 item social support scale, Barthel index, MoCA, and GDS-15.

All of the anthropometric measurements and grip strength were measured in accordance with standard protocols.[264, 267] Two instruments from each (weighing scale, stadiometer (for height), and dynamometer (for grip strength)) were used for data collection, thus variation between the instruments was minimal. The instruments were regularly calibrated before use.

72.3% of data collected on chronic disease conditions were verified using clinical records. Some information collected may have tendency to be subject to social desirability bias and cause misclassification: providing socially acceptable answers rather than the truth, particularly with respect to behavioural aspects e.g. smoking, alcohol consumption, and health conditions associated with stigma e.g. depression. Recall bias can occur when collecting some information retrospectively, e.g. smoking history, drinking history, diet history, and 'falling at least one time during last year', etc. As I was only exploring the lifestyle factors associated with frailty as a component of one of my study objectives, I did not use lengthy smoking, alcohol consumption, and dietary assessments or any objective tests for these factors.

Although I only recruited participants capable of giving informed consent to take part in the present study, there appeared to be a small number participants with severe cognitive impairment (according to proposed MoCA score ranges). This might have an impact on the reliability of the self-reported data provided by these participants.

9.4.8 Confounding

Despite having limitations on aetiological inference, it is common to examine the associations between various factors and certain health conditions in cross-sectional studies. Therefore, possible confounding factors need to be addressed. Confounding is simply referred to as 'mixing of effects'.[412] It is a distortion of true association between exposure and outcome as exposure is associated with other factor/s that influence the outcome under study.[412] I used multivariable regression techniques to adjust simultaneously for the effects of several confounding variables. Multivariable models in the Chapter 7 and Chapter 8 were built to estimate the cross-sectional association between frailty and disability as well as between frailty and QoL respectively. I was cautious not to over adjust the models by including some health-related factors that could potentially lie on the causal pathway as well as those presumed to have bidirectional relationships with frailty. For instance when studying the association between frailty and disability (≥1 IADL limitations) I did not adjust the final model for depression and cognitive impairment as I felt that these may be on the causal pathway. Similarly when studying the association between frailty and QoL, depression and functional impairment (IADL and BADL limitations) were not included in the final model. Therefore, I only adjusted these models for minimum set of confounding factors and I did not consider the mediation or effect modification. The mediation analyses are better suited to longitudinal data rather than cross-sectional data.[417] Also, other stronger research designs/strategies would be needed to provide stronger causal inference. However, as in all studies, potential residual

confounding remains in all my models predominantly from incomplete measurement of a particular domain (e.g. I was not able to fully capture poverty, list of chronic disease conditions was not exhaustive). I did not collect data on some variables that might be important such as access to healthcare and transport.

It is also of note that all the multivariable multinomial logistic regression models in the Chapter 6 (mutually adjusted models for set of sociodemographic, health-related or lifestyle variables) were only built to explore potential cross-sectional risk factors associated with frailty status in Sri Lankan context. This work is exploratory only and each risk factor included in these models may be studied separately and has its own confounders and mediators. Also, establishing independent associations of factors with health outcomes such as frailty is difficult when sociodemographic, health-related and lifestyle variables likely to correlate.

9.5 Public health and policy implications

In this section I present the public health and policy implications based on the findings of the present systematic review, meta-analysis, and population-based cross-sectional study. This considers the current sociodemographic and health profile of the Sri Lankan older population along with country's present readiness of health and social care systems to cater for the demands of the current and increasing ageing population.

9.5.1 Systematic review and meta-analysis

The findings of the systematic review and meta-analysis suggest that the prevalence of frailty appears higher among community-dwelling older adults in upper middle-income countries compared with high-income countries. However, my results need to be interpreted and generalised cautiously as there is a large difference between the studies in terms of demography, methodology, and geography in addition to the true frailty differences between the populations. My review highlighted in particular the lack of evidence on the basic epidemiology and burden of frailty in LMICs: one study was identified from low-income countries and two studies from a lower middle-income country. No studies were identified from Sri Lanka, the topic of my PhD. This is despite evidence that populations are rapidly ageing in many LMICs. Therefore, we do not currently know the prevalence of frailty in these populations to inform health and social care planning. A higher prevalence of frailty could be expected from these regions

as many people in these countries are socially disadvantaged, e.g. lifelong exposure to poor living conditions, adverse life events, etc.

9.5.2 Population-based cross-sectional study

9.5.2.1 Anticipated burden of frailty

There appears to be a socioeconomic gradient in frailty both between countries[180] and within a country as revealed in the present analysis, where those who had been engaged in low skilled or no occupation had an approximately four times high risk of frailty than those in the highest skilled occupational category.[260] Interventions focusing on frailty prevention in Sri Lanka and other similar settings should therefore consider targeting lower socioeconomic groups at higher risk of frailty. Frailty is also known to be increased with advancing age, and this was confirmed in my analysis. Although the majority of the Sri Lankan older population belonged to 'young-old' (60-69 years) age group, the overall prevalence of frailty estimated in Kegalle district of Sri Lanka is slightly higher compared with the pooled prevalence of frailty in upper middle-income countries. Therefore, with the anticipated ageing of the Sri Lankan population, it is likely that the burden of frailty will be greater than expected. This should be accounted for in health and social care planning in future years.

9.5.2.2 Creating public awareness on population ageing

During the data collection, I visited and talked personally with all 746 participants to briefly introduce my study. The majority of the participants or their household members were not aware of the ageing population in Sri Lanka. In the first instance, regardless of regional (provincial/district) variation in population ageing, creating a national awareness about the rapidly shifting demographic profile of the country and associated complex and multidimensional economic, health, and social challenges including frailty is important. For almost all the participants, the present study was the first time they heard the term 'frailty' (or its Sinhala or Tamil equivalent terms). Considering these facts, communication on health conditions of older age is needed along with the anticipated rapid population ageing in Sri Lanka. These awareness programmes could be merged with the existing programmes conducted by different agencies in the country.

9.5.2.3 Prevention of frailty

Understanding the health conditions of older age and their consequences is key to informing prevention activities (primary, secondary, and tertiary) and reorient the existing care systems accordingly. The increasing proportion of frail older population is one of the biggest challenges to health and social care services today as these older adults are vulnerable to developing a number of adverse health outcomes, which leads to increasing consumption of services and an escalation of associated costs.[418] The evidence base is currently limited on the best interventions to prevent frailty, particularly in LMIC settings. A range of

preventable or modifiable risk factors or conditions for people at risk of developing frailty have been reported including cognitive impairment, falls, functional impairment, hearing problems, mood problems, nutritional compromise, physical inactivity, polypharmacy, smoking, vision problems, social isolation, and loneliness.[419] In the present cross-sectional analysis not all of these factors were associated with frailty risk. For example self-perceived hearing ability, self-perceived vision ability, and smoking had no significant associations with frailty in the present Sri Lankan study population, despite good evidence of associations in previous research largely from high-income countries. The reasons for these discrepancies are unclear and should be explored in future.

With the limited evidence in the literature, Sri Lanka needs to consider how to incorporate broad frailty prevention and specific frailty severity reduction activities to existing health service delivery. In the absence of strong evidence to tailor advice to the Sri Lankan context education should focus on healthy ageing, and well-established factors such as physical activity that have potential to reduce frailty across all settings. This education could be undertaken across spectrum of education, e.g. in schools, universities, workplaces, and hospitals. Since some of risk factors for frailty are also risk factors for other chronic conditions we may need to initiate inter-sectoral collaboration between different agencies working on care provision, education, and financing in the country.

9.5.2.4 Management of frailty

This PhD demonstrated that frailty in the present Sri Lankan study population was associated with a higher level of limitations in undertaking instrumental activities of daily living (IADL e.g. shopping, cooking, managing medications, etc.) and a small but significant lower quality of life. This supports the need for interventions that may improve these outcomes for frail older adults in Sri Lanka. Frailty is still an evolving area and multiple interventions are under investigation, mainly in high-income countries. The most effective components for interventions to improve outcomes in frail older adults are uncertain though the most consistent evidence from high-income countries is for exercise.[128, 420] Guidelines in UK recommended 'Comprehensive Geriatric Assessment' with a focus on reduction of polypharmacy[95], though evidence for this approach is mixed, and it is resource intensive and costly to deliver in a LMIC setting. In the present cross-sectional study polypharmacy was associated with frailty, though causal links are not established and we do not know if reducing polypharmacy in a Sri Lankan setting would either prevent frailty or improve outcomes for frail older adults.

The higher dependency levels in IADL limitations found in the present study may be associated with a higher need for support and care provision which in turn may lead to subsequent higher caregiver burden. This is a further consideration for policy makers in anticipating potential social care needs and associated costs. I found a small (though still significant) reduction of QoL associated with frailty. The association between frailty and QoL appears to be largely explained by 'health'

and ‘independence, control over life and freedom’ domains. This may be due to the strong intergenerational social support given through the extended families in Sri Lankan rural society that mitigate the non-health impacts of frailty in older adults. In the present study population, experiencing lower social support was associated with increasing frailty. This minority of older people with lower social support might need to receive greater consideration in rural Sri Lankan setting. Changes of existing family structure due to internal (moving to urban areas) and external (abroad) migration, and shrinking family size are disrupting the traditional family-based support system. Due to existing strong family support, residential care of frail older adults has not been widely established. In keeping with Sri Lankan traditional value systems, it is worth exploring alternative mechanisms to support families to provide care for older adults with frailty in an extended household setting that enable them to live in the community.

Overall, findings of this thesis are important to policy makers and healthcare planners to quantify the extent of frailty and be prepared for establishing appropriate integrated continuing health and social services for older adults with frailty and multiple chronic disease conditions. Investing in health of the older adults is important to mitigate the medical and social implications of ageing.

9.6 Future research

I have identified a range of further areas of research from my thesis findings.

In the first instance, a clear consensus is required on methods of assessing frailty to allow for more robust comparisons across populations and countries. This would include both consideration of the choice of assessment tool and how it is operationalised. A further important consideration for researchers using the Fried phenotype measurement of frailty is a clear justification for the choice of cut-off points for definition of frailty components, as my research demonstrated how use of the original CHS criteria[10] or study population specific cut-off points can have a marked impact on prevalence of frailty. Further robust research is required from low-income and lower middle-income countries with rapidly ageing populations to estimate the burden of frailty, understand how frailty affects the day-to-day lives of older people (e.g. activity limitations and lower quality of life) and inform policy making.

I conducted this cross-sectional study only with older adults living in rural areas of Kegalle district. Conducting an island-wide study to estimate the prevalence of frailty and its consequences representing all provinces, areas (urban, rural, and estate) and ethnicities is warranted in order to identify the differences if any for policy planning. Empirical research is required to estimate the health and social care costs (direct and indirect) associated with frailty in a Sri Lankan older population. Since there is no single longitudinal study on ageing in Sri Lanka, initiating a longitudinal study with a cohort of middle-aged older adults will enable

to understand the risk factors, trajectories, and adverse outcomes of frailty as well as other geriatric conditions that have not been studied to date. Studying the lifestyle factors associated with frailty in detail would facilitate the identification of modifiable risk factors of frailty.

Future research should also further evaluate the prevalence of IADL and BADL limitations in frail older populations, along with the caregiver burden. In the present study a higher prevalence of IADL limitations among frail older adults was observed than in previous studies in other countries. One possible explanation would be deskilling (accelerating the loss of function) where older adults have a high level of social and practical support, not allowing them to perform these tasks when older adults live in extended family settings. This is supported by the following findings in the present study: greater social support was independently associated with reporting higher count of IADL limitations and a lower quality of life on the 'independence, control over life and freedom' sub-scale in frail older adults in the present study population. The reasons for this should be explored in future research.

In general, studies on ethnic differences on quality of life of older adults are limited.[421] Similarly, both cross-sectional and longitudinal studies estimating the magnitude of the association between frailty and QoL as well as different domains of QoL are scarce from the many parts of the world. Further work could explore more in-depth associations between frailty and QoL e.g. how factors such as depression and limitations of instrumental and basic activities of daily living

mediate this association. Comparable cross-country studies investigating the prevalence of disabilities across frailty status and the evaluation of QoL will enable researchers to understand context specific macro and micro level factors that are associated with higher levels of disability as well as QoL. This is an important necessity for low-and middle-income countries in the Asian region with the predicted rapid population ageing. Assessment of IADL/BADL limitations needs to be performed with standardised instruments and questions.

Since there are abundance of frailty screening tools in the literature and in use, Sri Lanka is required to adapt or develop a screening tool that matches best with its older population, available infrastructure, and human resources in the primary healthcare settings. Also, it is worth exploring the feasibility and cultural appropriateness of introducing an e-health initiatives for frailty screening along with preventive health education messages for young and middle-age older adults.

9.7 Conclusions

To best of my knowledge, I conducted the first exhaustive systematic review and meta-analysis to describe and estimate the prevalence of frailty status among community-dwelling older adults in low-and middle-income countries. Similarly, the present population-based cross-sectional study is the first study conducted in Sri Lanka using the Fried phenotype frailty assessment method to estimate the prevalence of frailty and to describe the range of factors associated with frailty and pre-frailty. This is also the first study conducted in World Health Organization South-East Asia region to estimate the cross-sectional association between frailty status and disability and quality of life among community-dwelling older adults.

From the present systematic review, the prevalence of frailty and pre-frailty appears higher in community-dwelling older adults in upper middle-income countries compared with high-income countries. There is limited evidence on frailty prevalence in lower middle-income countries and low-income countries, and identifying the scale of the problem will help these growing economies to prepare and respond to the challenges associated with increasing longevity. Although comparisons between studies are difficult, the prevalence of frailty in the rural Sri Lankan older population was high in comparison to both upper middle-income countries and high-income countries. Advancing age, having never being employed or having engaged in a low-skilled occupation, having a poor social support, polypharmacy, lower cognitive assessment score, and presence of higher levels of depressive symptoms were associated with increasing frailty

among Sri Lankan older adults. The prevalence of limitations in instrumental activities of daily living was also high among rural community-dwelling frail older adults in Sri Lanka. Being frail decreased the odds of having no limitations in instrumental activities of daily living, and was associated with a higher count of limitations in instrumental activities of daily living among those who are experiencing ≥1 IADL limitations. However, the prevalence of basic activities of daily living was low among Sri Lankan rural community-dwelling frail older adults. Frailty was associated with a small but significantly lower quality of life in this rural Sri Lankan population of older adults. This was largely explained by 'health' and 'independence, control over life and freedom' domains in the present Sri Lankan study population. Interventions aiming to improve quality of life in frail older adults should consider targeting these aspects. The overall burden of frailty was higher than expected but there was lower than anticipated levels of basic activities of daily living limitations and deterioration of quality of life. Thus, understanding the multidimensional nature of challenges associated with population ageing in different contexts is very important. Moreover, the high level of frailty demonstrated in the present study emphasizes the need to pay urgent attention to strengthening and establishing health and social care systems targeting Sri Lanka's rapidly ageing population.

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Appendix 1 Electronic search strategy

MEDLINE search strategy

1. Frail Elderly.sh,kf.

2. (frail* or geriatric syndrome* or geriatric disorder*).ti,ab.

3. ((elder* or old* or senior* or geriatric*) adj4 function* adj4 (declin* or impair*)).af.

4. 1 or 2 or 3

5. Developing Countries.sh,kf.

6. (Africa* or Asia* or Caribbean* or West Indi* or South America* or Latin America* or Central America*).hw,kf,ti,ab,cp.

7. ((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or under served or deprived or poor*) adj (countr* or nation? or population? or world)).ti,ab.

8. ((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)).ti,ab.

9. (low* adj (gdp or gnp or gni or gross domestic or gross national)).ti,ab.

10. (low adj3 middle adj3 countr*).ti,ab.

11. (lmic or lmics or third world or lami countr*).ti,ab.

12. transitional countr*.ti,ab.

13. (Afghanistan or Albania* or Algeria* or Angola* or Antigua or Barbuda or Argentin* or Armenia* or Aruba or Azerbaijan or Bahrain or Bangladesh* or Barbados or Benin or Byelarus or Byelorussian or Belarus or Belorussian or Belorussia or Belize or Bhutan or Bolivia or Bosnia or Herzegovina or Hercegovina or Botswana or Brasil* or Brazil* or Bulgaria* or Burkina Faso or Burkina Fasso or Upper Volta or Burundi or Urundi or Cambodia* or Khmer Republic or Kampuchea or Cameroon or Cameroons or Cameron or Camerons or Cape Verde or Cabo Verde or Central African Republic or Chad or Chile or China or Chinese or Colombia* or Comoros or Comoro Islands or Comores or Mayotte or Congo or Zaire or Costa Rica or Cote d'Ivoire or Ivory Coast or Croatia or Cuba* or Cyprus or Czechoslovakia or Czech Republic or Slovakia or Slovak

Republic or Djibouti or French Somaliland or Dominica or Dominican Republic or East Timor or East Timur or Timor Leste or Ecuador or Egypt* or United Arab Republic or El Salvador or Eritrea or Estonia* or Ethiopia* or Fiji or Gabon or Gabonese Republic or Gambia or Gaza or Georgia or Georgian or Ghana or Gold Coast or Greece or Grenada or Grenadines or Guatemala or Guinea or Guam or Guiana or Guyana or Haiti* or Honduras or Hungary or India* or Maldiv* or Indonesia* or Iran* or Iraq* or Isle of Man or Jamaica* or Jordan* or Kazakhstan or Kazakh or Kenya* or Kiribati or Korea* or Kosovo or Kyrgyzstan* or Kirghizia or Kyrgyz Republic or Kirghiz or Kirgizstan or Lao PDR or Laos or Latvia* or Lebanon or Lebanese or Lesotho or Basutoland or Liberia or Libya* or Lithuania* or Macedonia* or Madagascar or Malagasy Republic or Malaysia* or Malaya or Malay or Sabah or Sarawak or Malawi or Nyasaland or Mali or Malta or Marshall Islands or Mauritania or Mauritius or Agalega Islands or Mexic* or Micronesia or Middle East or Moldova or Moldovia or Moldovian or Mongolia* or Montenegro or Morocco or Ifni or Mozambique or Myanmar or Myanma or Burma or Namibia or Nepal* or Netherlands Antilles or New Caledonia or Nicaragua or Niger or Nigeria* or Northern Mariana Islands or Oman or Muscat or Pakistan or Palau or Palestine or Panama or Paraguay or Peru* or Philippines or Philipines or Phillipines or Phillippines or Poland or Portugal or Principe or Puerto Rico or Romania* or Rumania or Roumania or Russia or Russian or Rwanda or Ruanda or Saint Kitts or St Kitts or Nevis or Saint Lucia or St Lucia or Saint Vincent or St Vincent or Grenadines or Samoa* or Samoan Islands or Navigator Island or Navigator Islands or Sao Tome or Saudi Arabia or Senegal or Serbia* or Montenegro or Seychelles or Sierra Leone or Slovenia or Sri Lanka* or Ceylon or Solomon Islands or Somalia* or South Africa* or Sudan* or Suriname or Surinam or Swaziland or Syria or Tajikistan or Tadzhikistan or Tadjikistan or Tadzhik or Tanzania* or Thailand or Thai or Togo or Togolese Republic or Tonga or Trinidad or Tobago or Tunisia* or Turk* or Turkmenistan or Turkmen or Tuvalu or Uganda* or Ukrain* or Uruguay or USSR or Soviet Union or Union of Soviet Socialist Republics or Uzbekistan or Uzbek or Vanuatu or New Hebrides or Venezuela or Vietnam* or Viet Nam* or West Bank or Yemen* or Yugoslavia or Zambia* or Zimbabwe* or Rhodesia*).hw,kf,ti,ab,cp.

14. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13

15. 4 and 14

Appendix 2 Quality assessment results of the studies

Authors and year of publication	Random sample or whole population	Unbiased sampling frame	Adequate sample size (>300 participants)	Used standard measures	Outcomes measured by unbiased assessors	Adequate response rate (70.0%), refusers described	Confidence interval (CI) for prevalence, subgroup analysis	Study subjects are described	Risk of bias assessment
Tribess et al, 2012[201]	√	×	√	√	×	√,√	×,√	√	5.5
De Andrade et al, 2013[409]	√	√	√	√	×	×,×	×,√	√	5.5
Júnior et al, 2014[202]	√	N/A	×	√	×	√,√	×,√	√	4.5
Pegorari et al, 2014[203]	√	×	√	√	√	√,√	×,√	√	6.5
Corona et al, 2015[422]	√	√	√	√	√	√,×	×,√	√	7.0
Santos et al, 2015[204]	×	×	×	√	√	√,×	×,√	√	4.0
Closs et al, 2016[205]	√	√	√	√	√	×,×	√,√	√	7.0
Mello et al, 2017[206]	√	√	×	√	√	√,×	×,√	√	6.0
de Albuquerque Sousa et al, 2012[207]	√	√	√	√	√	√,×	×,√	√	7.0
dos Santos Amaral et al, 2013[208]	×	×	√	√	√	√,×	×,×	√	4.5
Moreira et al, 2013[209]	√	×	√	√	×	√,√	√,×	√	5.5
Neri et al, 2013[210]	√	√	√	√	√	×,×	×,√	√	6.5
Vieira et al, 2013[211]	√	√	√	√	×	×,√	×,×	√	5.5
Ricci et al, 2014[212]	√	√	√	√	√	√,√	×,√	√	7.5
Silveira et al, 2015[213]	√	√	×	√	×	×,×	×,×	√	4.0
Calado et al, 2016[214]	√	√	√	√	√	√,×	×,√	√	7.0
Augusti et al, 2017[215]	√	√	√	√	√	√,×	×,√	√	7.0
Ferriolli et al, 2017[216]	√	×	√	√	×	√,×	×,√	√	5.0
Grden et al, 2017[423]	√	√	×	√	√	√,×	×,√	√	6.0
Ocampo-Chaparro et al, 2013[217]	√	√	√	√	√	√,×	×,√	√	7.0
Curcio et al, 2014[218]	×	×	√	√	√	×,×	×,√	√	4.5
Samper-Ternent et al, 2016[219]	√	×	√	√	√	×,√	×,√	√	6.0
Garcia-Pena et al, 2016[64]	√	√	√	√	√	√,√	×,√	√	7.5
Sanchez-Garcia et al, 2017[220]	√	√	√	√	√	√,×	×,√	√	7.0
Moreno-Tamayo et al, 2017[221]	√	√	√	√	×	√,√	×,√	√	6.5
Chen et al, 2015[222]	×	×	√	√	√	×,√	×,√	√	5.0

Appendix 2 continued. Quality assessment results of the studies

Authors and year of publication	Random sample or whole population	Unbiased sampling frame	Adequate sample size (>300 participants)	Used standard measures	Outcomes measured by unbiased assessors	Adequate response rate (70.0%), refusers described	Confidence interval (CI) for prevalence, subgroup analysis	Study subjects are described	Risk of bias assessment
Wu et al ,2017[223]	√	√	√	√	√	√,×	√,√	√	7.5
Dong et al, 2017[224]	√	√	√	√	√	×,×	×,×	√	6.0
Wang et al, 2015[225]	×	×	√	√	√	×, ×	×,√	√	4.5
Badrasawi et al, 2017[226]	√	√	√	√	√	√,√	×,√	√	7.5
Kashikar et al, 2016[227]	√	√	×	√	√	√,√	×,√	√	6.5
Gurina et al, 2011[65]	√	√	√	√	√	×,√	×,√	√	7.0
Alvarado et al, 2008[228]	√	√	√	√	×	√,×	×,√	√	6.0
Aguilar-Navarro et al, 2015[229]	√	√	√	√	√	×,×	×,√	√	6.5
Avila-Funes et al, 2016[230]	√	√	√	√	√	√,√	×,√	√	7.5
Sanchez-Garcia et al, 2014[231]	√	√	√	√	√	N/A	×,√	√	6.5
Akin et al, 2015[66]	√	√	√	√	×	×, ×	×,√	√	5.5
Zhu et al, 2016[232]	√	√	√	√	√	√, √	×, ×	√	7.0
Jotheeswaran et al, 2015[67]	√	N/A	√	√	√	√,×	×,×	√	5.5
Fhon et al, 2012[233]	√	√	×	√	√	√,×	×,√	√	6.0
Agreli et al, 2013[234]	√	√	×	√	×	√,×	×,√	√	5.0
Duarte et al, 2013[235]	√	×	×	√	×	√,×	×,×	√	3.5
Del Brutto et al, 2016[236]	√	N/A	√	√	×	√,√	×,√	√	5.5
Fabricio-Wehbe et al, 2009[62]	√	√	×	√	√	×,×	×,√	√	5.5
Carneiro et al, 2016[237]	√	√	√	√	√	×,×	×,√	√	6.5
Bennett et al, 2013[424]	×	×	√	√	√	×, ×	×,√	√	4.5
Woo et al, 2015[238]	√	√	√	√	√	×, ×	×,√	√	6.5
Hao et al, 2016[425]	√	√	√	√	√	×, ×	√,√	√	7.0
Sathasivam et al, 2015[239]	√	√	√	√	×	√,×	×,√	√	6.0
García-González et al, 2009[426]	√	√	√	√	√	×,×	×,√	√	6.5
Perez-Zepeda et al, 2016[240]	√	√	√	√	√	√,×	×,×	√	6.5
de Leon Gonzalez, 2015[427]	√	×	√	√	×	×,×	×,√	√	4.5

Appendix 2 continued. Quality assessment results of the studies

Authors and year of publication	Random sample or whole population	Unbiased sampling frame	Adequate sample size (>300 participants)	Used standard measures	Outcomes measured by unbiased assessors	Adequate response rate (70.0%), refusers described	Confidence interval (CI) for prevalence, subgroup analysis	Study subjects are described	Risk of bias assessment
Rosero-Bixby et al, 2009[428]	√	√	√	√	√	×,√	×,√	√	7.0
Galbán et al, 2009[241]	×	×	√	√	×	√,×	×,√	√	4.0
Boulos et al, 2016[242]	√	√	√	√	√	√,×	×,√	√	7.0
Gray et al, 2017[243]	√	√	√	√	√	×,×	×,√	√	6.5
Parentoni et al, 2013[429]	×	×	×	√	×	√,×	×,√	√	3.0
Bastone et al, 2015[430]	×	×	×	√	×	√,√	×,×	√	3.0
Cakmur et al, 2015[375]	×	×	×	√	×	√,×	×, ×	√	2.5
Sampaio et al, 2015[431]	×	×	×	√	×	×,×	×,×	√	2.0
Zainuddin et al, 2017[432]	×	×	×	√	×	×,×	×,√	√	2.5

√- Criteria is satisfied; ×- Criteria is not satisfied/ not documented; N/A- Not applicable

Appendix 3 Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Tribess et al, 2012[201]	Brazil	Population Study of Physical Activity and Aging (EPAFE), City of Uberaba, Minas Gerais Conducted from May to August 2010	Cross-sectional study	622	65	≥ 60 (71.0±7.7) 60-96	Random sampling	Fried phenotype*	19.9	49.8	1. Sociodemographic characteristics of the elderly in this study are similar to those reported in surveys in Latin America. This indicates the potential generalisation of the present results to other populations.	1. The measurements of self-perception might have influenced by the low educational level of participants and their motivational aspects.
De Andrade et al, 2013[409]	Brazil	SABE study (Wave 2-2006) Survivors from baseline study (2000) and new participants of the second wave São Paulo	Cross-sectional study with SABE data	1,374	59.7	≥ 60	Cluster sampling	Fried phenotype*	8.5	40.7	1. Use of a large representative sample of community-dwelling elderly increases the generalisability of results; 2. Frailty was measured using a well-defined method.	1. Use of self-reported data on physical activities may introduce biases that are difficult to control.
Júnior et al, 2014[202]	Brazil	Epidemiological study titled Nutritional status, risk behaviours and health conditions of the elderly people of Lafaiete Coutinho-BA Urban area	Cross-sectional study	286	54.2	≥ 60	Census of all older adults in the area	Fried phenotype*	23.8	58.7	-	1. Some instruments used in this study required subjective or self-reported information that can be possibly lead to memory bias.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Pegorari et al, 2014[203]	Brazil	Urban area of the city of Uberaba, MG	Cross-sectional observational and analytical household survey	958	64.4	≥ 60 (73.7±6.7)	Stratified proportional sampling	Fried phenotype*	12.8	54.5	1. Results of the study contribute to expand the knowledge of frailty syndrome among Brazilian elderly and support planning and implementation of interventions and care actions.	-
Corona et al, 2015[422]	Brazil	SABE study (Wave 3-2010), Survivors from baseline (2000) and second wave (2006) and new participants of the third wave São Paulo	Cross-sectional population-based study	1,171	65.0	≥ 60	Probability sampling	Fried phenotype*	11.3	50.6	1. This study included a large representative sample of community-dwelling older adults from the largest city in Brazil.	-
Santos et al, 2015[204]	Brazil	Database called "Identifying the health disease process enrolled population at the Family Health Units" Pau Ferro, municipality of Jequie/BA Conducted from May to November 2013	Observational cross-sectional study	136	75.5	≥60 (72.3±8.4) 60-101	-	Fried phenotype*	16.9	61.8	-	-

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Closs et al, 2016[205]	Brazil	Multidimensional Study of the Elderly in the Family Health Strategy (EMI-SUS) Conducted from March 2011 to December 2012	Cross-sectional study	521	64.3	≥60 (68.5 ± 6.8)	Random sampling	Fried phenotype*	21.5 (17.97-25.03)	51.1 (46.81-55.39)	-	1. Being a cross-sectional study; 2.Access to the study by immobile or bedridden elderly people was limited as evaluation of frailty and other geriatric syndromes was performed in an outpatient setting (not in their own homes).
Mello et al, 2017[206]	Brazil	Survey on Conditions of Health and Use of Health Services in the Territory of Manguinhos, Rio de Janeiro Municipality Manguinhos neighbourhood of Rio de Janeiro	Cross-sectional study	137	67.9	≥60 (70.2±7.4)	Probability sampling	Fried phenotype*	12.4	61.3	-	1. Sample size was small and it represented around 10.0% of the population of this age group in the region; 2.Causal inference was not possible; 3. Grip strength, physical activity, and gait speed, were adapted to fit the local reality of the research, which may lead to some differences when comparing with the results of other studies.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
de Albuquerque Sousa et al, 2012[207]	Brazil	FIBRA- urban zone of Santa Cruz city	Cross-sectional study	391	61.4	≥ 65 (74.0±6.5) 65-96	Random sampling	Fried phenotype*	17.1	60.1	-	1. Adapted version of the Minnesota Questionnaire of Physical Activities and Leisure was used in this study as original questionnaire did not match with Brazilian cultural context. The used cut-off point (20th percentile), might have underestimated the low physical activity frailty component in this study.
dos Santos Amaral et al, 2013[208]	Brazil	This study is a part of a project titled "Allostatic load, frailty and functionality in the elderly" Neighbourhood Rocas, Natal	Analytical observational cross-sectional study	295	67.3	≥ 65 (74.3±6.9) 65-100	-	Fried phenotype*	18.6	55.3	1. Sample is representative; 2.Low percentage of refusals.	-
Moreira et al, 2013[209]	Brazil	FIBRA-Northern area of the city of Rio de Janeiro Conducted from January 2009 to January 2010	Cross-sectional descriptive study	754	66.9	≥ 65 (76.6±6.9)	Inverse random sampling stratified by gender and age	Fried phenotype*	9.5	47.5	-	1. An adapted version of Minnesota Questionnaire of Physical Activities and Leisure was used in this study. However, it was problematic as reference activities in the questionnaire are atypical in Brazilian culture. This may lead to errors in estimating the weekly caloric expenditure.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Neri et al, 2013[210]	Brazil	FIBRA Seven cities		3,413	67.6	≥ 65	Probability sampling	Fried phenotype*	9.0	51.9	1. Measures were taken to avoid the systematic distortions of data. i.e. encouraging participation of the elderly; 2. Standardisation of procedures, instruments and equipment; 3. A comprehensive training was given staff in all locations; 4. Procedures were adopted to ensure greater reliability of data entered in the electronic databases.	1. More female representation in the study sample limited the generalisability of results; 2.Loss of information during the data collection could affect the reliability of data; 3. Study participation in Ivoti was lower than expected due to the problems of time and transport; 4. Selection of older adults without cognitive impairment and required to attend to the data collection site by their own might have introduced the survival bias into the study.
		Belem		720	69.5				10.8	48.2		
		Parnaiba		431		73.9			9.7	55.5		
		Campina Grande		395	70.1				8.9	51.4		
		Pocos de Caldas		388	61.4				9.3	53.4		
		Ermelino Matarazzo, Sao Paulo		384	67.2				8.1	54.9		
		Campinas		898	69.3				7.7	52.2		
		Ivoti		197	70.1				8.6	47.7		
Vieira et al, 2013[211]	Brazil	FIBRA-Belo Horizonte, Minas Gerais State Conducted from December 2008 to September 2009	Population-based cross-sectional study	601	66.2	≥ 65 (74.3±6.4)	Probability sampling	Fried phenotype*	8.7	46.3	-	1. Fried Phenotype limited the evaluation of possible frail elderly with cognitive impairment, gait restriction, and severe motor sequale; 2. Minnesota Questionnaire of Physical Activities and Leisure is not fitting with the Brazilian cultural context.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Ricci et al, 2014[212]	Brazil	FIBRA- Barueri and Cuiaba urban municipalities	Cross-sectional population-based study	761	64.3	≥ 65 (71.9±5.9)	Census of older adults in 27 census tracts	Fried phenotype*	9.7	48.0	-	1. The Fried phenotype used in this study comprised of physical frailty and not included other markers such as cognitive decline and psychosocial aspects.
Silveira et al, 2015[213]	Brazil	Uberaba, Minas Gerais Conducted from July to October 2011	Analytical observational cross-sectional study	54	59.3	≥ 65 (72.9±6.0)	Random sampling	Fried phenotype*	11.1	46.2	-	-
Calado et al, 2016[214]	Brazil	FIBRA-Ribeirão Preto, state of São Paulo	Cross-sectional study	385	64.7	≥65 (73.9 ± 6.5)	Random sampling	Fried phenotype*	9.1	49.6	-	1. Cross-sectional nature of this study does not allow to establish any temporal relationship between the variables; 2. Cross-sectional study design is subjected to survival bias, which could lead to underestimation of the associations observed; 3. This study has excluded patients who were already known to be dependent. This might have affected the prevalence of frailty.
Augusti et al, 2017[215]	Brazil	Amparo in the state of Sao Paulo	Cross-sectional study	306	60.2	≥65 (72.6± 5.7)	Random sampling	Fried phenotype*	21.5	71.6	-	-

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Ferriolli et al, 2017[216]	Brazil	Recife	Cross-sectional study	556	70.6	≥ 65 (73.9±6.8)	Probability sampling	Fried phenotype*	12.1	66.9	-	1. It is difficult to establish causal relationships between study variables; 2. The method used to assess body composition of older adults in this study is debatable.
		Juiz de Fora		412	69.6	≥ 65 (74.2±6.6)			15.5	63.1		
		Fortaleza		481	67.9	≥ 65 (74.8±7.2)			10.4	63.6		
Grden et al, 2017[423]	Brazil	Area covered by three basic health units belong to the Boa Vista Sanitary District, in the city of Curitiba, Paraná Conducted from January 2013 to September 2015	Cross-sectional study	243	66.3	≥80 (84.4±3.8)	Proportional stratified sampling	Fried phenotype*	14.8	63.8	-	1. It is difficult to establish causal relationships between study variables due to the cross-sectional nature of the study; 2. Study sample only represented the local community, and therefore the results cannot be extrapolated to other territories.
Ocampo-Chaparro et al, 2013[217]	Colombia	Commune 18, City of Cali (urban area) Conducted in 2009	Population-based cross-sectional study	314	64.3	≥ 60	Single stage cluster sampling	Fried phenotype*	12.7	71.3	-	1. This study was conducted in a localised area and not in the entire city of Cali; 2. Study population did not include rural or institutionalised older adults. Hence it limits the external validity of the study findings.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Curcio et al, 2014[218]	Colombia	Four villages located in the coffee growing zone of the Andese mountains, (rural area) Conducted in 2005	Cross-sectional study	1,878	52.2	≥ 60 (70.9±7.4)	Voluntary participation	Fried phenotype*	12.2	53.0	1. Large sample size; 2. Study used a comprehensive set of measurements; 3. First study that measured the prevalence of frailty in older adults living in rural areas in the Latin American and Caribbean region; 4. This study established the relationship between frailty, higher prevalence of chronic conditions and disabilities among elderly people in Latin America.	-
Samper-Ternent et al, 2016[219]	Colombia	Data from Salud Bienestary Enve-Jecimiento (SABE) Bogota study Both urban and rural areas of Bogota Data were collected in 2012	Cross-sectional survey	1,442	61.0	≥ 60 (70.7±7.7)	Probability sampling by clusters with block stratification	Fried phenotype*	9.4	52.4	1. First population-based study with adults aged ≥60 years in Colombia to explore the conditions that affect their health and quality of life; 2. Study followed international guidelines previously used in other capital cities in Latin America (with modifications to fit the social and historical situation of Colombia).	1. Modification of the frailty phenotype definition could have introduced bias to the analysis; 2. A large proportion was excluded from this study as there was missing data for construction of frailty and sarcopenia variables (n=558).

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Samper-Ternent et al, 2016[219] cont.											1.Used constructs in this study have been previously validated in similar populations to assessed frailty.	1. Excluded individuals were significantly different from study population which could introduce bias to this study; 2. Some data are self-reported so recall bias could affect the results.
Garcia-Pena et al, 2016[64]	Mexico	Mexican Health and Aging Study (MHAS) Wave 3 Conducted in 2012	Secondary analysis	1,108	54.6	≥ 60 (69.8±7.6)	Probability sampling	Fried phenotype* Frailty index-32 variables	24.9 27.5	61.0 -	1. A large comprehensive dataset; 2. Use of previously validated frailty assessments. (Fried phenotype and frailty index)	1. The cut-off value of frailty index was arbitrary although it was based on previous research; 2. Frailty index included 32 deficits as self-rated hearing and abdominal pain were not available in the 2012 wave, 3. Categorisation of physical activity in Fried phenotype was different from previous reports.
Sánchez-García et al, 2017[220]	Mexico	Baseline assessment ''Cohort of Obesity, Sarcopenia and Frailty of Older Mexican	Cross-sectional analysis	1,252	59.9	≥60 (68.5 ± 7.2)	Random sampling	Fried phenotype*	11.2	50.3	-	1. Cross-sectional design does not allow to establish a causal relationship between frailty and quality of life of elderly included in this study.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Sánchez-García et al, 2017[220] cont.		Adults'' (COSFOMA) Mexico city Conducted from April to September 2014										
Moreno-Tamayo et al, 2017[221]	Mexico	Rural Frailty Study (Prospective study) Follow up data collected in 2013	Cross-sectional study	657	52.9	≥70 (76.3 ± 3.3)	Random sampling	Fried phenotype*	11.9	51.9	1. Use of Fried phenotype frailty assessment.	1. Cross-sectional design does not allow for drawing conclusions about the direction of causality.
Chen et al, 2015[222]	China	Data from a cross-sectional study, Comprehensive Geriatric Assessment and Healthcare Service Study Chengdu and Suining, Southwest China Conducted from October 2010 to August 2012	Cross-sectional study	604	57.9	≥ 60 (70.6±6.8) 60-91	Convenience sampling	Fried phenotype*	12.7	56.5	-	1. Data must be interpreted with caution: the number of the participants was below 1000, although the study population was representative of the ≥60 years old community-dwelling adults in this specific area; 2. Information about diseases and some of the frailty items were taken through self-reported questionnaires;

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Chen et al, 2015[222] cont.												3. Older people who refused to participate had lower level of functionality which might have caused non-response bias or selection bias; 4. This study only included Han people. Therefore, conclusions might not be generalisable to other ethnic populations.
Wu et al, 2017[223]	China	The China Health and Retirement Longitudinal Study 28 provinces in China (2011-2012)	Baseline survey of an ongoing longitudinal study	5,290	49.0	≥60 (69.2±7.0)	Multistage probability sampling	Fried phenotype*	6.3	51.3	1. First study that utilised the Fried phenotype of frailty scale to examine prevalence of frailty in a nationally representative sample of non-institutionalised Chinese adults aged ≥60 years; 2. Constructed cut-off points to define frailty for Fried phenotype components based on Chinese elders; 3. first study that examined the regional variation in frailty in mainland China;	1. Non-inclusion of nursing home residents could have underestimated the prevalence of frailty among the entire Chinese elderly population. However, it is worthy to note that only 1.5% of older adults live in nursing homes in China; 2. All five frailty components were only measured once. These measures may vary over time;

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Wu et al, 2017[223] cont.											4. First study that investigated the association of biomarkers with frailty among Chinese older adults.	3. Unable to establish a causal associations between frailty and chronic conditions and disability since this study is a cross-sectional analysis
Dong et al, 2017[224]	China	Jinan City, Shandong Province, Eastern China Conducted from July to December 2016	Cross-sectional study	1,188 1,215	69.1 69.5	≥60 (69.5±6.7) 60-95	Multistage stratified sampling	Fried phenotype*	3.9 17.4	45.9 21.5	-	1. Generalisation of study results should be done cautiously because the study participants were just from one city in China.
Wang et al, 2015[225]	China	Changsha city and its surrounding area Conducted from August 2012 to August 2014	-	316	48.1	≥ 65 (75.6±4.8) (males) (76.9±5.2) (females)	-	Fried phenotype*	14.2	49.1	1. Participants were recruited from a community-based elderly population.	1. Individuals were originally excluded from this study based on several health conditions. This might have biased the results towards an underestimation of the risk of frailty associated with sarcoosteopenia.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Badrasawi et al, 2017[226]	Malaysia	Neuroprotective model for healthy longevity among Malaysian older adults Conducted from 5th July 2013 to 22nd February 2014	Part of a longitudinal study	473	55.6	≥60 (68.2±5.8)	Multistage random sampling	Fried phenotype*	8.9	61.7	-	1. Use of original Fried's cut-off values for grip strength and gait speed; 2. Causal relationships should be interpreted with caution since the study is cross-sectional.
Kashikar et al, 2016[227]	India	Warje-Karvenagar, Pune city	Cross-sectional study	250	50.0	≥65 (73.9± 6.4)	Multi stage random sampling	Fried phenotype*	26.0	63.6	-	-
Gurina et al, 2011[65]	Russia	Data from "Crystal" prospective cohort study Kolpino district of St. Petersburg Conducted from March to December 2009	Cross-sectional study	611	71.7	≥ 65 (75.1±5.9)	Random sampling stratified by age	Fried phenotype* (whole study population) Fried phenotype* (adjusted for MMSE score <18, Parkinson's disease, and stroke) Steverink–Slaets model, Groningen Frailty Indicator Extended Puts model	21.1 17.9 32.6 43.9	63.0 65.5 24.7 42.9	1. This analysis provided a better understanding of the health status of older adults in Russia.	1. Cross-sectional analysis is not adequate as this phenotype is more dynamic than static; 2. The tested frailty models in this study were modified by using proxies for some of the original indicators; 3. Findings can be generalised to the whole population of St. Petersburg only with caution, the Kolpino district represents one of the 18 districts of the city.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Alvarado et al, 2008[228]	Barbados Brazil Chile Cuba Mexico	Health, Wellbeing and Ageing study (SABE) study Conducted from 1999 to 2000	Multi centric cross-sectional study	7,334	-	≥ 60	Multi-staged sampling	Fried phenotype†	-	-	-	1. Operationalisation of Fried phenotypic criteria is different from the original Cardiovascular Health Study (CHS)[10]; 2. possible background risk differences (cultural and other social biological factors) might have limited the comparison of this study results with other studies.
		Bridgetown, Barbados		1,446	61.1				26.7	54.4		
		São Paulo, Brazil		1,879	59.3				40.6	48.8		
		Santiago de Chile, Chile		1,220	66.1				42.6	51.4		
		Havana, Cuba		1,726	62.7				39.0	51.6		
		Mexico, DC, Mexico		1,063	60.4				39.5	49.0		
Aguilar-Navarro et al, 2015[229]	Mexico	Subset from Mexican Health and Aging Study (MHAS) Wave 1 Conducted in summer of 2001	Longitudinal study (cross-sectional data)	5,644	53.6	≥ 60 (68.7±6.9)	Random sample	Fried phenotype†	37.2	51.3	1. Population-based design; 2. Study sample size is large.	1. Operationalisation of Fried phenotypic criteria is different from the original CHS[10]. The original metrics were not available in the MHAS cohort. It could have resulted possible overestimation of prevalence of frailty.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Avila-Funes et al, 2016[230]	Mexico	Subset of Mexican Study of Nutritional and Psychosocial Markers of Frailty (prospective cohort study) Coyoacán cohort Conducted from April 2008 to July 2009	Cross-sectional study using the data of prospective cohort study	927	54.9	≥ 70 Median age-76.5 70.3-104.4	Random sampling stratified by age-and sex	Fried phenotype†	14.1	37.3	1. A population-based sample, from a cohort specifically designed to identify the correlates of frailty.	1. Recruitment was carried out in only one district of Mexico city, therefore these results might not be representative of rural areas of Mexico.
Sanchez-Garcia et al, 2014[231]	Mexico	Data from Study on Aging and Dementia in Mexico (SADEM) Conducted from September 2009 to March 2010	Not mentioned in the article	1,933	58.0	≥ 60 70.1±7.1 (females) 71.7±7.4 (males)	Random sample from original database	Fried phenotype‡	15.7	33.3	-	1. Definitions used to evaluate frailty and pre-frailty.
Akin et al, 2015[66]	Turkey	Kayseri (urban area) Data of Kayseri Elderly Health Study (KEHES) Kayseri Conducted from August to December 2013	Cross-sectional population-based study	848 897	50.6	≥ 60 (71.5±5.6)	Stratified random sampling and any Individual older than 60 years who requested to participate was also included.	Fried phenotype‡ FRAIL scale	27.8 10.0	34.8 45.6	-	1. Absence of physical activity in this study might have under- or over- estimated the prevalence of frailty; 2. Study sample comprised of a relatively small sample of elderly participants aged ≥ 85 years.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Zhu et al, 2016[232]	China	Cross-sectional data from the ageing arm of the Rugao Longevity and Ageing Study 31 villages in Jiang'an township, Rugao city Conducted from November 2014 to December 2014	-	1,478	53.0	≥ 70 (75.3±3.9) 70-84	Random sampling	Fried phenotype‡	12.0	42.9	1. The study participants were randomly selected with a higher response rate (91.2%) representing approximately 16.0% of the elderly in Jiang'an township. Therefore findings from such a representative population-based sample might be generalisable to most elderly people in China.	-
Jotheeswaran et al, 2015[67]	China Mexico Peru Cuba Dominican Republic Venezuela India	10/66 Dementia Research Group's (10/66 DRG) population-based studies of ageing and dementia in LMICs Data were collected between 2003 and 2007	Cross-sectional survey	12,373	62.3	≥ 65 (74.1±7.0)	Census	Fried phenotype‡ Multi dimentional frailty model	17.5 29.1	- -	1. Study was conducted with large population-based cohorts in Latin America, India, and China allowing to assess the consistency or cultural specificity of the observed Associations; study design was prospective, limiting information bias with modest attrition.	1. Hand grip strength was not measured in this study. Hence physical frailty construct was only an approximation to the original Fried definition. The impact of this omission is difficult to assess.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Jotheeswaran et al, 2015[67] cont.		China (Urban)		989	56.6	(74.1±6.3)		Fried phenotype‡	7.8	-	1. In this study, walking speed, under nutrition, cognitive impairment, visual and auditory impairment were measured objectively.	-
		China (Rural)		1,002	55.5	(72.4±6.0)			8.7	-		
		Cuba (Urban)		2,637	65.0	(75.2±7.1)			21.0	-		
		Dominican Republic (Urban)		1,706	66.3	(75.4±7.6)			34.6	-		
		India (Urban)		748	57.2	(71.4±6.1)			11.4	-		
		Mexico (Urban)		909	66.5	(74.4±6.6)			10.1	-		
		Mexico (Rural)		933	60.9	(74.1±6.6)			8.5	-		
		Peru (Urban)		1,245	64.7	(75.0±7.4)			25.9	-		
		Peru (Rural)		507	53.2	(74.1±7.3)			17.2	-		
		Venezuela (Urban)		1,697	63.2	(72.3±6.8)			11.0	-		
		China (Urban)		989	56.6	(74.1±6.3)		Multi dimentional frailty model	11.3	-		
		China (Rural)		1,002	55.5	(72.4±6.0)			22.5	-		
		Cuba (Urban)		2,637	65.0	(75.2±7.1)			33.7	-		
		Dominican Republic (Urban)		1,706	66.3	(75.4±7.6)			47.8	-		
		India (Urban)		748	57.2	(71.4±6.1)			26.1	-		
		Mexico (Urban)		909	66.5	(74.4±6.6)			22.9	-		
		Mexico (Rural)		933	60.9	(74.1±6.6)			36.2	-		
		Peru (Urban)		1,245	64.7	(75.0±7.4)			28.2	-		
		Peru (Rural)		507	53.2	(74.1±7.3)			25.6	-		
		Venezuela (Urban)		1,697	63.2	(72.3±6.8)			20.0	-		
Fhon et al, 2012[233]	Brazil	Municipality of Ribeirao Preto, Sao Paulo Conducted from Nov 2010 to February 2011	Cross-sectional study	240	62.9	≥ 60 (73.5±8.4)	Two stage conglomerate sampling	Edmonton frail scale	39.2	24.6	-	-

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Agreli et al, 2013[234]	Brazil	Embu, City in metropolitan region of Sao Paulo Conducted from June to July 2010	Observational descriptive cross-sectional study	103	62.1	≥ 60 (68.9±7.8) 60-103	Simple random sampling	Edmonton frail scale	30.1	22.3	-	1. Older adults who did not respond to the clock drawing test were unable to classify for their degree of frailty.
Duarte et al, 2013[235]	Brazil	This study is a sub project of the survey "Living conditions, health and ageing: a comparative study" City of Joao Pessoa, the state capital of Paraiba Conducted from April to June 2011	Cross-sectional study	166	100.0	≥ 60 (73.0±6) 60-96	Two staged cluster sampling	Edmonton frail scale	39.2	21.7	-	-
Del Brutto et al, 2016[236]	Ecuador	Atahualpa, a rural village of costal Ecuador	Population-based cross-sectional study	298	57.0	≥ 60 (70.0±8.0)	Individuals identified through yearly door-to-door survey	Edmonton frail scale	31.2	22.0	1. Population-based design; 2. Lack of selection bias; 3. Used a reliable instrument to identify frailty.	-

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Fabricio-Wehbe et al, 2009[62]	Brazil	Ribeirao Preto, Sao Paulo Conducted from September 2007 to June 2008	-	137	74.5	≥ 65 (75.3±8.0) 65-100	Probability sampling	Edmonton frail scale	31.4	20.4	-	-
Carneiro et al, 2016[237]	Brazil	City of Montes Claros, northern Minas Gerais Conducted from May to July 2013	Cross-sectional study	511	64.0	≥65 (74.0± 7.1)	Two stage cluster sampling	Edmonton frail scale	41.3	-	1. This study included a representative sample.	1. Losses or refusals were compensated by adding new older adults. However, more active older adults who were probably without frailty were not found at home during the visits. This can limit the generalisability of findings; 2. Cross-sectional nature of the study does not allow to establish temporal relationships among the observed associations.
Bennett et al, 2013[424]	China	Longevity Study (CLHLS) 22 provinces of China	Secondary analysis	6,300	-	80-99	-	Frailty index 38 deficits	FI≤ 0.05-15.0 0.05< FI≤ 0.15-53.2 0.15< FI≤ 0.25-20.2 0.25< FI≤ 0.35-6.7 0.35< FI≤ 0.45-3.3 FI >0.45-1.6		-	1. The baseline cohort included 36.0% centenarians and they have been excluded from this analysis. Hence, results should be interpreted with caution.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Woo et al, 2015[238]	China	Data from Beijing Longitudinal Study of Aging II (BLSA II) Three urban districts (Xuanwu, Xicheng and Dongcheng) and one rural county (Shunyi) from the 18 administrative districts or counties in Beijing. Participants were recruited from July to November 2009	-	6,320 (urban) 978 (rural)	61.5 57.2	≥ 65 74.6±5.6 (males) 73.8±5.2 (females) (74.8±5.7) (males) (73.9±5.0) (females)	Multistage cluster sampling	Frailty index 34 variables	17.0 5.2	- -	-	-
Hao et al, 2016[425]	China	Data from Project of Longevity and Aging in Dujiangyan Dujiangyan region, Sichuan province	Cross-sectional study	767	68.0	≥ 90 (93.7±3.4) 90-108	Based on a census of older people above 90 years	Frailty index 35 variables	61.8	-	1. Frailty index does not rely on specific set of variables. Hence evaluation of frailty is more feasible.	1. Data needed to be interpreted with caution. The number of participants who gave the consent was limited; 2. The study population clearly represented a survivor group.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Sathasivam et al, 2015[239]	Malaysia	Urban district	Multistage cross-sectional study	789	59.4	≥ 60 (69.6±7.2)	Multi stage random sampling	Frailty index 40 variables	5.7	67.7	1. Population-based study.	1. There are no normative values that have been consensually established to date to define severity of frailty levels in Malaysia; 2. Findings cannot be generalised to other ethnic groups from similar middle-income countries.
García-González et al, 2009[426]	Mexico	Mexican Health and Aging Study (MHAS) Wave 1	Follow up study	4,082	52.5	≥65 (73.0)	Probability sampling	Frailty index (FI) -34 variables	5 FI levels .00-.07-17.4 .07-.14-30.8 .14-.21-24.0 .21-.35-21.4 .35-.65-6.5		-	-
Perez-Zepeda et al, 2016[240]	Mexico	Nationwide survey representing urban and rural areas, Mexican Survey on Nutrition and Health (ENSANUT), 2012	Cross-sectional analysis	7,108	54.7	≥ 60 (70.7±8.1)	Multistage stratified sampling	Frailty index-44 variables	45.2	-	-	-
de Leon Gonzalez, 2015[427]	Mexico	Mexican Health and Aging Study (MHAS) Wave 1	-	4,729	-	≥60	Probability sampling	FRAIL scale	10.4	44.8	1. Study sample comprised of a large number of males and females living in the community.	1. Participants who did not complete the performance measures in the population study, and did not include in the present

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
de Leon Gonzalez, 2015[427] cont.												analysis are expected to be less healthy and more likely to die. This increases the possibility of survival bias.
Rosero-Bixby et al, 2009[428]	Costa-Rica	Costa Rican Study on Longevity and Healthy Aging (CRELES)	-	2,704	-	≥ 60	Random sampling	Physical frailty using five physical tests	17.8 (60-79 years 57.0 (80+ years)	- -	-	-
Galban et al, 2009[241] cont.	Cuba	Antonio Maceo, Cerro municipality, Havana, Cuba Data were collected in 2005	Observational descriptive cross-sectional study	541	58.0	≥ 60	-	Geriatric Functional Assessment Scale was applied to classify the participants to frail and non-frail groups according to Cuban frailty criteria	51.4	-	-	-
Boulos et al, 2016[242]	Lebanon	Rural areas Conducted from March 2011 to 2012	Cross-sectional study	1,120	50.8	≥ 65 (75.7±7.1)	Multi stage cluster sampling	Study of Osteoporotic Fractures (SOF) frailty index	36.4	30.4	1. Results may be generalisable to rural Lebanese elderly as this study involved a large representative sample with high response rate.	1.Self-reported information might be affected by memory and education bias due to educational disparities.

Appendix 3 continued. Characteristics of the studies included in the systematic review of prevalence of frailty and pre-frailty among community-dwelling older adults in LMICs

Authors and year of publication	Country	Data source/study setting/time period	Study design	Effective sample	Female %	Participants' mean age/Age range (years)	Sampling technique	Frailty assessment method	Prevalence (%), 95% CI		Study strengths reported by the authors	Study limitations reported by the authors
									frailty	pre-frailty		
Boulos et al, 2016[242] cont.											1.First study to report the prevalence and associated factors of frailty in community-dwelling Lebanese older adults; 2. Data collection for frailty was based on a widely used and well validated instrument.	1.Cognitive impairment might have affected the accuracy of the SOF frailty index and underestimated the frailty; 2. Widely used Fried phenotype was not used in this study due to the difficulty of performing the walking test (possible space constraints and lack of standardised conditions in Lebanese rural households.)
Gray et al, 2017[243]	Tanzania	Six villages in the rural Hai District of northern Tanzania	Follow up cohort	941	55.8	≥70 (77.2± 6.4)	Census of selected villages	Brief Frailty Instrument for Tanzania (B-FIT)	4.6	13.4	1. The screening tool proposed in this study could be administered without the need of any specialist knowledge or training and may be suited for use in low-resource settings.	1. The B-FIT requires further assessment of its face, content, and constructs validity, and the inclusion of a broader range of items should be considered.

*Fried phenotype with five criteria-weakness and slowness assessed using objective tests.
†Fried Phenotype with five criteria-weakness and slowness assessed using self-reported questions (subjective).
‡Fried Phenotype with four criteria.

Appendix 4 Pooled prevalence of frailty and pre-frailty by sex: a comparison between upper middle-income and high-income countries

Data was available from six studies conducted in upper middle-income countries corresponding to total of 2,608 male and 5,071 female participants. The pooled prevalence of frailty in males and females in upper-middle-income countries was 10.1% (95% CI=6.0, 15.0%, I^2 =85.7%, p<0.001) and 16.2% (95% CI= 10.1, 23.4, I^2 =95.0%, p<0.001) respectively. The pooled prevalence of pre-frailty in males and females in upper-middle-income countries was 54.1% (95% CI=44.9, 63.3%, I^2 =91.1%, p<0.001) and 56.4% (95% CI=51.0, 61.8%, I^2 =85.5%, p<0.001) respectively.

Total of 12,747 male participants from seven studies and 13,480 female participants from six studies were available from HICs. The pooled prevalence of frailty in males and females in HICs was 6.6% (95% CI=4.8, 8.7%, I^2 =93.6%, p<0.001) and 9.6% (95% CI=6.4, 13.4%, I^2 =97.4%, p<0.001) respectively. The pooled prevalence of pre-frailty in males and females in HICs was 42.6% (95% CI=39.3, 46.0%, I^2 =89.9%, p<0.001) and 45.9% (95% CI=43.5, 48.3, I^2 =80.0%, p<0.001).

Appendix 5 Data Extraction Form: Fried phenotype

Date	Participant Identification Number

Data Extraction Form- Fried Phenotype

Identification

Code of the Data Collector	
Divisional Secretary Division	
Grama Niladhari Division	
Start Time	
End Time	

1	**Shrinking/ Unintentional weight Loss**	Response
1.1	Device ID for height and weight	Height ……. Weight …….
1.2	Height	First reading cm
		Second reading cm
		Third reading cm
1.3	Weight	First reading kg
		Second reading kg
		Third reading kg

2	**Self-reported exhaustion**				
	Please indicate how often you have felt this way during the past week.				
		Rarely or none of the time (less than 1 day)	Some or a little of the time (1-2 days)	Occasionally or a moderate amount of time (3-4 days)	All of the time (5-7 days)
	I felt that everything I did was an effort				
	I could not get going				

3	**Weakness**	Response	
3.1	Device ID for grip strength	…….	
3.2	Right hand	First reading	kg
		Second reading	kg
		Third reading	kg
3.3	Left hand	First reading	kg
		Second reading	kg
		Third reading	kg

4	**Slowness**	Response	
4.1	Time taken to 15 feet walk	First reading	s
		Second reading	s

Appendix 6 Questionnaire on Health and Wellbeing of Older People in Sri Lanka

Date	Participant Identification Number

Questionnaire on Health and Wellbeing of Older People in Sri Lanka

This questionnaire comprises of four (4) parts and collects information on factors that may be related to health and wellbeing for older people in Sri Lanka.

Instructions: Please write the answer in the provided space or circle the appropriate response.

Identification

Code of the Research Assistant	
Divisional Secretary Division	
Grama Niladhari Division	
Start Time	
End Time	

Part 1- About you

Now I am going to ask some questions about you. This includes your age, sex, ethnicity, marital status, education level, and income generation activities.

1.1	How old are you? (Age for last birth day)	…….. years	
1.2	What is your sex?	Male	0
		Female	1
1.3	What is your ethnicity?	Sinhalese	1
		Sri Lankan Tamil	2
		Indian Tamil	3
		Sri Lankan Moor	4
		Other (please specify)	5
1.4	What is your marital status?	Never-married	1
		Currently married	2
		Separated	3
		Divorced	4
		Widowed	5
		Cohabiting	6
1.5	Do you have/had children? *(if **no** go to question **1.7**, if **yes** go to question **1.6**)*	No	0
		Yes	1
1.6	If yes, how many children do you have/had?		

1.7	Please state the years of education completed.	Never schooled: unable to read and write	0
		Never schooled: able to read and write	1
		Passed Grade 1-5	2
		Passed Grade 6-10	3
		Passed G.C.E. O/L	4
		Passed G.C.E. A/L	5
		Higher education	6
1.8	Were you involved in a job/ income generation activity? *(if **no** go to question **1.10**, if **yes** go to question **1.9**)*	No	0
		Yes	1
1.9	What type of work was it? *(If a person has engaged in multiple activities select the main/ longest activity he/she involved in)*		
1.10	Are you currently involve in any income generation activity? *If yes, please state it*	No	0
		Yes	1
1.11	Do you have your own monthly income? *(if **no** go to question **1.14**, if **yes** go to question **1.12**)*	No	0
		Yes	1

1.12	What is the type of monthly income?	Pension	1
		Bank deposits/interest	3
		Income from property	4
		Income from current job/ income generation activity	5
		Money from children	6
		Government aid (e.g. Samurdhi, elderly allowance)	7
		Other (please specify)	8
1.13	If you have your own monthly income, please state the amount		LKR
1.14	How many members are in your household live with you?		
1.15	What is the approximate monthly income of your household? *(Ask them to consider all the sources of income. If the respondent lives with his/her children, verify the answer from an adult member of the family)*		LKR
1.16	How well would you say you are managing financially these days?	Living comfortably or doing alright	3
		Just about getting by	2
		Finding it difficult or very difficult	1

Part 2- Health-related information

Now I am going to ask few questions about your general health status. You will ask to show your clinic records/ diagnosis cards if available.

2.1	Physician diagnosed chronic health conditions/symptoms *(Please check for the documentary evidence; clinic records/diagnosis card)* *Verified- verified from the documentary evidence* *Not verified- Patient reported health conditions: not verified from the documentary evidence*		Verified	Not verified
		Diabetes mellitus		
		Heart Disease (coronary heart disease, myocardial infarction, congestive heart failure, arrhythmia)		
		Cerebrovascular disease (stroke, transient ischaemic attack, subarachnoid haemorrhage)		
		Chronic Obstructive Pulmonary Disease		
		Asthma		
		Any kind of arthritis		
		Kidney disease		
		Liver disease		
		Dementia		
		Cancer (please specify type)		
		Psychiatric/ mental disorders e.g. depression (please specify)		
		Hypertension		
		Hyperlipidemia (high cholesterol)		
		Other (please specify)		

2.2	Are you currently taking some drug/s regularly? *(If **no** go to question **2.5.** If **yes** go to question **2.3**)*		No	0
			Yes	1
2.3	Please state the type of drug/s you take.		Western	1
			Ayurvedic	2
			Western & Ayurvedic	3
2.4	How many drugs do you take currently? *(Check for documentary evidence)* *(Please include the drugs taking regularly)*		Verified	Not verified
		Western		
		Ayurvedic		
2.5	How many times did you visit a healthcare provider during last 3 months? Please state the type of healthcare provider/s you met.			
2.6	From where do you seek the medical assistance generally?	Government hospital (Western)	1	
		Private Medical Practices (Western)	2	
		Government hospital (Ayurveda)	3	
		Private Medical Practices (Ayurveda)	4	
		Other (please specify)	5	

2.7	How many times were you admitted to a hospital during the last year? *(If **0 times** go to question **2.9. if not** go to question **2.8**)*		
2.8	How long were you admitted for last time?		
2.9	How many times did you fall during last year? *(If **0 times** go to question **2.11. if not** go to question **2.10**)*		
2.10	During last year, did you suffer from an injury following the fall which required medical attention?	No	0
		Yes	1
2.11	**Short FES-I: a shortened version of the Falls Efficacy Scale-international to assess fear of falling**		
	Now I would like to ask some questions about how concerned you are about the possibility of falling. Please reply thinking about how you usually do the activity. If you currently do not do the activity, please answer to show whether you think you would be concerned about falling if you did the activity. For each of the following activities, please state which is closest to your own opinion to show how concerned you are that you might fall if you did this activity		

	Activity	Not at all concerned (1)	Somewhat concerned (2)	Fairly concerned (3)	Very concerned (4)
a	Getting dressed or undressed				
b	Taking a bath or shower				
c	Getting in or out of a chair				
d	Going up or down stairs				
e	Reaching for something above your head or on the ground				
f	Walking up or down a slope				
g	Going out to a social event (e.g. religious activity, family gathering or meeting of a society)				

2.12	Do you use any assistive devices (excluding glasses)? *(If **no** go to question **2.15.** If **yes** go to question **2.13**)*	No	0
		Yes	1
2.13	What are the types of assistive devices you use?	Walking stick	1
		Crutches	2
		Walker	3
		Wheel chair	4
		Commode chair	5
		Bath chair/stool	6
		Magnifiers	7
		Personal alarm for call assistance	8
		Other (please specify)	9
2.14	What is the frequency of the use of assistive device?	Always	4
		Very often	3
		Sometimes	2
		Rarely	1
2.15	Do you have a chronic pain in any part of your body? *(If **no** go to question **2.17.** If **yes** go to question **2.16**)*	No	0
		Yes	1

2.16	How would you rate your pain in the below scale? No pain Worst imaginable 0 1 2 3 4 5 6 7 8 9 10		
2.17	How would you rate your vision (with glasses if used)?	Excellent	5
		Very good	4
		Good	3
		Fair	2
		Poor	1
2.18	How would you rate your hearing (with hearing aids if used)?	Excellent	5
		Very good	4
		Good	3
		Fair	2
		Poor	1
2.19	How would you describe the overall condition of your teeth, dentures, or gums?	Excellent	5
		Very good	4
		Good	3
		Fair	2
		Poor	1
2.20	How would you rate your general health?	Excellent	5
		Very good	4
		Good	3
		Fair	2
		Poor	1

Part 3- Social activity and social support

Now I am going to ask few questions about your living arrangements, participation in social activities, and social support.

3.1	Who do you live with?	With spouse (husband, wife, partner)	1
		With children/other family	2
		Alone	3
		With carer	4
		Other (please specify)	5

3.2	**Social activity scale of the Leisure Participation Questionnaire** (How often do you do the following activity? 5-Everyday 4-Almost every day 3-Atleast once a week 2-At least once a month 1-Once in several months 0-Never						
	Social Activity	5	4	3	2	1	0
a	Meeting or visiting friends or other family members						
b	Involving community activities (Volunteers, association, politics)						
c	Involving religious activities (going to temple, observing sil)						
d	Having conversations while relaxing						
e	Spending time with grand children						

3.3	**Oslo-3 item social support scale**		
	How many people are so close to you that you can count on them if you have serious problems?	None	1
		1 or 2	2
		3–5	3
		6 or more	4
	How much concern do people show in what you are doing?	A lot of concern and interest	5
		Some concern and interest	4
		Uncertain	3
		Little concern and interest	2
		No concern and interest	1
	How easy can you get practical help from neighbours if you should need it?	Very easy	5
		Easy	4
		Possible	3
		Difficult	2
		Very difficult	1

Part 4- Lifestyle factors

Now I am going to ask some questions about your lifestyle. This includes smoking, drinking alcohol and diet.

	Smoking		
4.1	Have you ever-smoked? *(If **no** go to question **4.9**.* *If **yes** go to question **4.2**)*	No	0
		Yes	1
4.2	Have you smoked at least 100 cigarettes in your entire life?	No	0
		Yes	1
4.3	How frequently do you now smoke cigarettes?	Every day	3
		Some days	2
		Not at all	1
4.4	If "yes" to question 4.1 ask the type of product he/she use/used. *(Mark the most frequently use/used product)*	Manufactured cigarette	1
		Bidi	2
		Suruttu	3
		Pipes of full tobacco	4
		Other (please specify)	5
4.5	During the past 30 days, have you smoked?	No	0
		Yes	1

4.6	If you smoke daily, on average, **how many** of following do you smoke each day?	Manufactured cigarette	
		Bidi	
		Suruttu	
		Pipes of full tobacco	
		Other (please specify)	
4.7	How old were you when you start smoking?		
4.8	How old were you when you quit smoking (if applicable)		
	Alcohol consumption		
4.9	Have you ever consumed any alcohol such as beer, wine, arrack, toddy etc.? *(If **no** go to question **4.15)*** *If **yes** go to question **4.10**)*	No	0
		Yes	1
4.10	Have you consumed any alcohol within the **past 12 months**? *(If **no** go to question **4.15)*** *If **yes** go to question **4.11**)*	No	0
		Yes	1
4.11	During the past 12 months, **how frequently** have you had at least one standard alcoholic drink?	Daily	1
		5-6 days per week	2
		3-4 days per week	3
		1-2 days per week	4
		1-3 days per month	5
		Less than once a month	6

4.12	Have you consumed any alcohol within the **past 30 days**? *(If **no** go to question **4.15)*** *If **yes** go to question **4.13**)*	No	0
		Yes	1
4.13	During the past 30 days, on how many occasions did you have at least one standard alcoholic drink? (Use show card 1 on standard drink)		
4.14	During the past 30 days, when you drank alcohol, how many standard drinks on average did you have during one drinking occasion? (Use show card 1 on standard drink)		
	Diet		
	A typical week means a "normal" week when the diet is not affected by cultural, religious, or other events. Ask the participant to not report an average over a period. When determining the serving size, ask the participant to think of one day he/she can recall easily. Refer to the show card 2 for serving sizes.		
4.15	In a typical week how many days do you eat **fish, poultry, meat, egg, dried fish**?	Number of days	
4.16	How many servings of fish, poultry, meat, egg, dried fish do you eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size
4.17	In a typical week how many days do you eat **pulses**?	Number of days	

4.18	How many servings of pulses do you eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size
4.19	In a typical week how many days do you drink **milk** and/or eat **dairy products**?	Number of days	
4.20	How many servings of milk/dairy products do you drink/ eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size
4.21	In a typical week how many days do you eat **vegetables**?	Number of days	
4.22	How many servings of vegetables do you eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size
4.23	In a typical week how many days do you eat **green leafy vegetables**?	Number of days	
4.24	How many servings of green leafy vegetables do you eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size

4.25	In a typical week how many days do you eat **fruits**?	Number of days	
4.26	How many servings of fruits do you eat on **one** of those days? (Use show card 2 on serving size)	Type of food	Serving size

End of the questionnaire

Appendix 7 A standard drink for different types of alcohol in Sri Lanka

Show Card 1- Calculation of the number of units of different types of alcohol in Sri Lanka

(Reference Table)

Type of Alcohol	Pure alcohol % by volume	A single unit in ml	1 unit in conventional measurements
Arrack	34-36	30	One drink
Illicit spirits*	20 (approx.)	50	Two shots/drinks
Beer	4.5-5	200-250	Half a pint
Toddy	5	200-250	Half a pint
Whisky	40-43	25	One drink
Wine	11-12	175	One small glass

*Includes 'Kassippu' (Moon shine/homemade alcohol)

Appendix 8 Serving sizes for food

Show card 2- Serving sizes for food

Food item	Serving size=1
Cooked fish, poultry, meat	30 g
Cooked pulses	3 tbsp
Eggs	1
Dried fish	15 g
Milk	1 cup (200 ml)
Yogurt/curd	100 ml
Milk powder	30 g (2 tbsp)
Cooked vegetables (Fruit vegetables, leafy vegetables)	3 tbsp (½ cup)
Raw vegetable salad/green leafy vegetables	1 cup
Medium size fruit	1 (1 banana, 1 orange, etc.)
Cut fruit/ Fruit salad	½ cup
Dried fruits	2 tbsp (20-30 g)

tbsp- table spoon
1 cup= 200 ml tea cup

Appendix 9 Showcard used to display the answers to OPQOL-35 questionnaire

Show card 3

Strongly agree

Agree

Neither agree or disagree

Disagree

Strongly disagree

Appendix 10 Assessment of internal consistency of the study instruments

Methodology

Internal consistency is a measure of scale reliability. It measures to what extent the different items in an instrument measures the same concept.[61] Cronbach's alpha was used to evaluate the internal consistency of the study instruments and alpha values between 0.70 and 0.95 indicate good internal consistency.[61] All the interviews were conducted in Sinhala language but in few occasions participants were given a copy of Tamil questionnaire to explain certain questions if their first language is Tamil. Therefore, the scale reliability was assessed with both effective sample and sample belong to Sinhalese ethnicity only.

Results

Internal consistency of all study instruments was good with this study sample except the 'Oslo 3-items social support scale' (Cronbach's alpha=0.61) and 'Social activity participation scale' (Cronbach's alpha=0.27). Hence, the latter was excluded from the study. There was no difference of the results of the entire sample and between the sample that only constitutes participants belong to Sinhalese ethnicity only. Please refer to Table A (next page).

Table A Internal consistency of the study instruments

Study instrument	**Cronbach's alpha**	
	Entire study sample (N)	**Sample belong to Sinhalese ethnicity (N)**
Short Falls Efficacy Scale- International (Short FES-I)	0.95 (734)	0.95 (711)
Barthel index	0.92 (746)	0.92 (723)
Lawton Instrumental Activities of Daily Living scale (Lawton IADL scale)	0.92 (723)	0.92 (702)
Montreal Cognitive Assessment (MoCA)	0.85 (741)	0.85 (718)
Older People's Quality of Life Scale (OPQOL)	0.85 (739)	0.86 (716)
The 15-item Geriatric Depression Scale (GDS-15 scale)	0.83 (742)	0.84 (719)
The Oslo 3-items social support scale	0.61 (742)	0.60 (719)
Social activity participation scale	0.27 (743)	0.28 (720)

Appendix 11 Assessment of intra-rater reliability of anthropometric measurements and physical performance tests

Methodology

Intra-rater reliability shows the variation of data measured by one rater across two or more trials.[337] The same rater (research assistant) measures participants' height, weight, grip strength in both left and right hands in three trials and time taken to walk 15 feet was measured in two trials. Intraclass correlation (ICC) was computed to assess the intra-rater reliability of these anthropometric measurements and physical performance tests. ICC value less than 0.5 implies poor reliability, 0.50-0.75 moderate, 0.75-0.90 good, and greater than 0.90 excellent reliability.[337]

Results

The intra-rater reliability of anthropometric measurements (height and weight) and physical performance tests (grip strength and walking time) as assessed by the ICC was excellent with all five research assistants. Please refer to Table B (next page).

Table B Intra-rater reliability of anthropometric measurements and physical performance tests

Measurement	Rater A		Rater B		Rater C		Rater D		Rater E	
	Effective sample	ICC (95% CI)	Effective sample	ICC (95% CI)	Effective sample	ICC (95% CI)	Effective sample	ICC (95% CI)	Effective sample	ICC (95% CI)
Height	139	0.99 (0.99, 0.99)	148	0.99 (0.99, 0.99)	151	0.99 (0.99, 0.99)	150	0.99 (0.99, 0.99)	149	0.99 (0.99, 0.99)
Weight	139	0.99 (0.99,1.00)	148	0.99 (0.99, 0.99)	151	0.99 (0.99, 0.99)	150	1.00 (1.00, 1.00)	150	1.00 (0.99, 1.00)
Grip strength, right hand	140	0.94 (0.91, 0.95)	150	0.93 (0.91, 0.95)	151	0.95 (0.93, 0.96)	149	0.95 (0.94, 0.96)	150	0.93 (0.91, 0.95)
Grip strength, left hand	137	0.94 (0.92, 0.96)	149	0.95 (0.93, 0.96)	151	0.95 (0.94, 0.97)	148	0.95 (0.94, 0.96)	149	0.95 (0.94, 0.96)
Walking time	138	0.94 (0.86, 0.97)	148	0.96 (0.93, 0.98)	150	0.97 (0.90, 0.99)	150	0.97 (0.91, 0.98)	149	0.94 (0.81, 0.97)

An ICC value of <0.5 (poor), 0.50-0.75 (moderate), 0.75-0.90 (good), and >0.90 (excellent) reliability.

Appendix 12 Assessment of inter-rater reliability of data

Methodology

Inter-rater reliability (IRR) indicates the variation between two or more raters who assess the same group of individuals.[337] In order to assess the inter-rater reliability, I again collected data for selected questions from interviewer-administered questionnaire Appendix 6 (page 435) and complete Lawton IADL scale from 12.0% of the effective sample. I identified the questions used to test inter-rater reliability in consultation with Sri Lankan supervisor (MCW). These questions covered different types of data such as ordinal (e.g. "how would you rate your general health?") and interval ("how many times did you fall during last year?") with different reference time periods (e.g. past week, last year, and in general) (Table C, page 460). Initially, research assistants (5 raters) administered the entire questionnaire and performed the physical assessments with participants. After a gap of 2.5 to 3 hours, I (DDS) administered selected questions with the same participants. Therefore, each participant in this sub-sample has been assessed by two raters (A/B/C/D/E and DDS (myself) as the second rater).

IRR between each research assistant (rater) and DDS was calculated. IRR of ordinal scale responses was assessed using weighted percentage agreement coefficient, weighted Cohen's kappa, and weighted Gwet's AC_2 agreement. Ordinal weights were used; ordinal scale categories that are one unit apart in the natural ordering are assigned smaller weights than categories that are more units apart. ICC was

computed to evaluate the agreement of questions that have continuous responses.

All the agreement coefficients and ICCs were computed using *kappaetc* user written Stata programme.[338] Single rating, absolute agreement, two-way mixed effects model was used when computing the ICCs of intra-rater and inter-rater reliability.[337] Values of Cohen's kappa, Gwet's AC_2 agreement were interpreted using criteria proposed by Landis and Koch.[336] Values between 0 and 0.20, between 0.21 and 0.40, between 0.41 and 0.60, between 0.61 and 0.80, and >0.80 are indicative of slight, fair, moderate, substantial, and excellent agreement respectively. ICC value less than 0.5 implies poor reliability, 0.50-0.75 moderate, 0.75-0.90 good, and greater than 0.90 excellent reliability.[337] When reporting the findings, Guidelines for Reporting Reliability and Agreement Studies (GRRAS) proposed by Kottner et al were followed.[339]

Table C The list of questions used to test the inter-rater reliability

Question number/Description	**Question**	**Type of data**
1.16	How well would you say you are managing financially these days?	Ordinal
Fried phenotype (Self-reported exhaustion)	How often you have felt this way during the past week?; "I could not get going"	Ordinal
2.20	How would you rate your general health?	Ordinal
3.3 Oslo-3 item social support scale	a. How many people are so close to you that you can count on them if you have serious problems?	Ordinal
Lawton Instrumental Activities of daily living scale (All the items)		Ordinal/Interval
2.9	How many times did you fall during last year?	Interval
Fried phenotype (Low physical activity) IPAQ-Short Form questionnaire	a. Number of days engaged in vigorous physical activities during last 7 days	Interval
	b. Time spent doing vigorous physical activities roughly per day (minutes)	Interval
	e. Number of days walked at least 10 minutes at a time during last 7 days	Interval

Results

The inter-rater reliability of the responses for below questions (comparing the rater/research assistant with DDS) was ranged from moderate to excellent according to the Gwet's AC_2 agreement. The percentage agreements were also high (Table D, next page). The inter-rater reliability of Lawton IADL scale-Sinhala version is presented in Chapter 5 (page 213).

Table D Inter-rater reliability of questions with ordinal responses

Questions and raters	Effective sample	Percentage agreement coefficient	Cohen's weighted kappa	Gwet's AC
Perceived financial strain				
DDS-A	14	0.88	0.64	0.70
DDS-B	18	0.83	0.43	0.62
DDS-C	19	0.93	0.76	0.83
DDS-D	17	0.75	**0.01**	0.49
DDS-E	21	0.84	0.43	0.65
How would you rate your general health?				
DDS-A	14	0.94	0.57	0.87
DDS-B	18	0.83	**0.13**	0.57
DDS-C	19	0.89	**0.24**	0.76
DDS-D	17	0.90	0.51	0.74
DDS-E	21	0.92	0.57	0.80
Oslo-3 item social support scale; a. How many people are so close to you that you can count on them if you have serious problems?				
DDS-A	14	0.74	**0.08**	0.58
DDS-B	17	0.78	**0.14**	0.57
DDS-C	19	0.89	0.48	0.72
DDS-D	17	0.76	**0.16**	0.54
DDS-E	21	0.83	**0.11**	0.66
How often you have felt this way during the past week?; "I could not get going"				
DDS-A	14	0.88	0.62	0.78
DDS-B	18	0.73	**-0.00**	0.54
DDS-C	19	0.91	0.65	0.83
DDS-D	17	0.94	0.81	0.90
DDS-E	21	0.87	**0.40**	0.82

Non-significant agreement coefficients ($p>0.05$) and zero agreement coefficients are displayed in bold.

The ICC values for below questions were ranged from moderate to excellent except in five occasions (Table E, below). The inter-rater reliability for total Lawton IADL scale-Sinhala version is presented in Chapter 5 (page 213).

Table E Inter-rater reliability of questions with interval or ratio scale responses

Questions and raters	Effective sample	ICC (95% CI)
How many times did you fall during last year?		
DDS-A	14	0.71 (0.32, 0.90)
DDS-B	18	0.84 (0.63, 0.94)
DDS-C	19	0.71 (0.39, 0.88)
DDS-D	17	0.95 (0.87, 0.98)
DDS-E	21	**0.19 (0.00, 0.57)**
IPAQ-Short a. Number of days engaged in vigorous physical activities during last 7 days		
DDS-A	14	**0.18 (0.00, 0.64)**
DDS-B	18	**0.27 (0.00, 0.64)**
DDS-C	19	0.57 (0.18, 0.81)
DDS-D	17	0.71 (0.37, 0.88)
DDS-E	21	0.47 (0.09, 0.74)
IPAQ-Short b. Time spent doing vigorous physical activities roughly per day (minutes)		
DDS-A	14	0.55 (0.06, 0.83)
DDS-B	18	0.71 (0.39, 0.88)
DDS-C	19	**0.30 (0.00, 0.67)**
DDS-D	17	0.85 (0.65, 0.94)
DDS-E	21	0.67 (0.29, 0.86)
IPAQ-Short e. Number of days walked at least 10 minutes at a time during last 7 days		
DDS-A	14	**0.00 (0.00, 0.13)**
DDS-B	18	0.85 (0.67, 0.95)
DDS-C	19	0.64 (0.29, 0.85)
DDS-D	17	0.50 (0.06, 0.78)
DDS-E	21	0.61 (0.27, 0.83)

Non-significant agreement coefficients (p>0.05) and zero agreement coefficients are displayed in bold.

Appendix 13 Invitation letter for the study participants

Invitation to take part in the Survey of Health and Wellbeing of the Older People in Kegalle District, Sri Lanka

We would like to invite you to take part in a study about the "Health and Wellbeing of the Older People in Kegalle District". A survey like this has never been done in Sri Lanka before. This is an important study as the Sri Lankan population is ageing rapidly. The findings of this research will inform better care services for older people.

This study will take place in selected Grama Niladhari divisions in Kegalle district. We will interview older people aged 60 years and above.

If you decided to participate you have to spend some time with the research assistant answering some questions and taking part in a short physical assessment (e.g. walking). There is more information about the study in the information sheet we have attached.

Thank you for taking time to read this invitation.

_____

Ms. Deepani Siriwardhana

Appendix 14 Information sheet for the study participants

INFORMATION SHEET

(Version 1.1, 01st June, 2016)

Original Research Title: The epidemiology of frailty, its association with quality of life and disability among community-dwelling rural older adults in a selected district of Sri Lanka

Short Title: Survey of Health and Wellbeing of the Older People in Kegalle District

This research has been approved by the;

UCL Research Ethics Committee (Project ID Number): 8155/001

Ethics Review Committee, Faculty of Medicine, University of Colombo, Sri Lanka (Application Reference Number): (Protocol No. EC-16-071)

We would like to invite you to participate in this research project. Before you decide to participate, it is important to know about this research and what it involves. Please read this information sheet carefully and discuss it with your family members if you wish. If there is anything that is not clear or if you need more information please ask the research assistant or contact the members of the research team mentioned at the end of this document.

This research will be carried out in selected Grama Niladhari divisions in the Kegalle district. We are inviting people aged 60 years and above who are permanently living in the district to take part. We aim to involve people during home visits in selected Grama Niladhari divisions.

1. **Why are we doing the research?**

We are conducting this research to identify the number of people aged over 60 who are affected by problems of feeling lacking in energy, weak or slowed up or being under-weight or having low activity levels, what factors are related to it and how it affects the quality of life and disability. We are looking at people who live at home in the community in Kegalle district.

2. **Do I have to take part?**

It is up to you if you want to take part or not. You can withdraw from the study at any time. You do not need to give reasons for your withdrawal. There will be no loss of medical care or any other available treatment for your illness or condition to which you are otherwise entitled.

3. **What is involved?**

If you take part in the research it will involve an interview with a research assistant for about 1½ to 2 hours. There are two parts: a physical assessment and answering a set of questionnaires. The physical assessments include measuring your height, weight, grip strength, and time taken to walk 15 feet. The weight and height will be measured without shoes and in light clothing. The grip strength will be measured three times when you are in the sitting position. You will not be asked to perform the test if you have problems with your hands affecting your grip. You will be asked to perform the walking test two times but only if you are comfortable. The research assistant will walk by you to minimise the risk of falling. The questionnaires cover information about your circumstances, activity level,

information on physical health and symptoms, memory, mood, social interactions, social support, lifestyle factors, quality of life, and disability. When completing the questionnaires you will be asked to share your medical records (information about your medical diagnoses and drug prescriptions) to check if you have any chronic health conditions like heart problems or diabetes that might be related. You can request breaks in between the assessments or questionnaires if you feel tired.

4. **What are the advantages of taking part?**

This research will provide really important information on the health and wellbeing of older people in Kegalle District. The Sri Lankan population is ageing rapidly and this research will influence policy makers and authorities on what care they need to provide for people who may be becoming easily tired or weak or low in weight or physically inactive, to improve their health and keep them active and independent for longer. A survey like this has never been done in Sri Lanka before. If you have a serious health concern identified in the survey, you will be directed to appropriate care.

5. **What are the disadvantages of taking part?**

We do not expect any risk to people taking part during the research. The walking test carries a small risk of falling, but the research assistant will be walking next to you to minimise this risk. It may be tiring to complete the assessments, and you can take breaks when needed. A few of the questions are of a personal nature, for example on your mood and feelings. You can miss any question that you do not want to answer.

6. **Will my information be kept confidential?**

Personal identifiable information such as name, address and contact details of people who take part will not be collected. Each questionnaire (participant) will be given a code. This code will be entered into the database. The questionnaires will be kept in a locked place. The access to database and the questionnaires will be restricted to the members of the research team only. The data will be collected and stored in accordance with the United Kingdom's Data Protection Act, 1998. The databases will be stored in University College London's secure computer network and encrypted laptop. Hence, the privacy of the participants and the confidentiality of data will be protected. The results of this research will published in PhD thesis, conference proceedings, and journal articles. No information by which you can be identified will be released or published. These data will never be used in such a way that you could be identified in any way in any public presentation or publication. This data may use for subsequent research of the investigators and may share anonymously with other researchers.

7. **If you have any questions**

If you have questions about the research or any of the tests/procedures you can ask now or later. If you have a question later, please feel free to ask any of the persons listed below.

Name: Ms. Dhammika Deepani Siriwardhana

Work Address:

Contact Details:

Name: Dr. Manuj C. Weerasinghe

Work Address:

Contact Details:

If you decide to take part you will be given this information sheet to keep with you and be asked to sign a consent form.

Thank you for taking time for read this information sheet.

Appendix 15 Consent form for the study participants

CONSENT FORM

(Version 1.1, 01st June, 2016)

Original Research Title: The epidemiology of frailty, its association with quality of life and disability among community-dwelling rural older adults in a selected district of Sri Lanka

Short Title: Survey of Health and Wellbeing of the Older People in Kegalle District

To be completed by the participant

The participant should complete the whole of this sheet himself/herself.

1. Have you read the information sheet? (Please keep a copy for yourself)

   YES/NO

2. Have you had an opportunity to discuss this study and ask any questions?

   YES/NO

3. Have you had satisfactory answers to all your questions?

   YES/NO

4. Have you received enough information about the study?

   YES/NO

5. Who explained the study to you?

   ……

6. Do you understand that you are free to withdraw from the study at any time, without having to give a reason and without affecting your future medical care?

   YES/NO

7. Relevant sections of your medical records may be looked at by members of research team. Do you give permission for members of research team to have access to your records?

   YES/NO

8. Do you understand that collected data may use for subsequent research of the investigators and may share anonymously with other researchers?

   YES/NO

9. Do you understand that information collected about you will contribute to reports, presented in scientific conferences and journals? The confidentiality and anonymity of the information will be protected and it will not able to identify you from any publication.

   YES/NO

10. Do you understand that personal information is treated as strictly confidential and handled in accordance with the provisions of the United Kingdom's Data Protection Act 1998?

    YES/NO

11. Have you had sufficient time to come to your decision?

    YES/NO

12. Do you agree to take part in this study?

    YES/NO

Participant's signature……Date…….

Name (BLOCK CAPITALS)……

To be completed by the investigator

I have explained the research to the above volunteer and he/ she has indicated her willingness to take part.

Signature of investigator……..……..Date…….

Name (BLOCK CAPITALS)……

Appendix 16 Ethical approval letter from University College London

UCL RESEARCH ETHICS COMMITTEE
ACADEMIC SERVICES

7 March 2016

Dr Katherine Walters
Principal Researcher
Department of Primary Care and Population Health
UCL

Dear Dr Walters

Notification of Ethical Approval
Project ID: 8155/001: The epidemiology of frailty, its association with quality of life and disability amongst community dwelling rural older adults in a selected district of Sri Lanka

I am pleased to confirm in my capacity as Chair of the UCL Research Ethics Committee that I have approved your study for the duration of the project i.e. until **27th September 2018.**

Approval is subject to the following conditions:

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form': http://ethics.grad.ucl.ac.uk/responsibilities.php

2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

   For non-serious adverse events the Chair or Vice-Chair of the Ethics Committee should again be notified via the Ethics Committee Administrator (ethics@ucl.ac.uk) within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

On completion of the research you must submit a brief report of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

Academic Services, 1-19 Torrington Place (9th Floor),
University College London
Tel: +44 (0)20 3108 8216
Email: ethics@ucl.ac.uk
http://ethics.grad.ucl.ac.uk/

Yours sincerely

Appendix 17 Ethical approval letter from Faculty of Medicine, University of Colombo, Sri Lanka

Ethics Review Committee
Faculty of Medicine
University of Colombo
P O Box 271, Kynsey Road, Colombo 8, Sri Lanka
Telephone: +94-11-2695300 ext 240 Fax: +94-11-2691581
Email: ethicscommitteemfc@gmail.com

REFERENCE: EC-16-071

13th June 2016.

Dr. Manuj C. Weerasinghe,
Senior Lecturer,
Department of Community Medicine,
Faculty of Medicine,
University of Colombo.

Dear Dr. Weerasinghe,

RE : **Protocol No EC-16-071**

Title : **The Epidemiology of Frailty, its Association with Quality of Life and Disability among Community Dwelling Rural Older Adults in a Selected District of Sri Lanka**

Investigators : **Dr. Manuj C. Weerasinghe**
Miss. Dhammika Deepani Siriwardhana
Dr. Katherine Walters
Dr. Greta Rait
Dr. Sarah Hardoon

Thank you for submitting the above research proposal, which was considered by the Ethics Review Committee, at its special meeting on 07.06.2016. Approval is granted to proceed.

This approval relates to the following:

- Research Proposal (Version 1.1)
- Information sheets (Version 1.1)
- Consent forms (Version 1.1)
- Data collection form (Version 1.0)

Ethics Review Committee
Faculty of Medicine
University of Colombo
P O Box 271, Kynsey Road, Colombo 8, Sri Lanka
Telephone: +94-11-2695300 ext 240 Fax: +94-11-2691581
Email: ethicscommitteemfc@gmail.com

The following members of the ERC were present at the meeting:

Prof. Hemantha Senanayake, Dr. Panduka Karunanayake, Dr. Nilakshi Samaranayake, Prof.Anuja Abayadeera, , Dr. G R Constantine Dr. S.Benaragama, Dr. Enoka Corea, Dr. Dinithi Fernando, Prof. P.Galappatthy, Prof. Ariaranee Gnanathasan, Mrs. Kumudini Hettiarachchi, Dr. Sharmila Jayasena, Dr. Nazima Kamardeen, Ms. Kantha Lankathilake, Dr. Kamal Perera, Dr. Samanthi Premarathne, Dr. Priyanga Ranasinghe, Ms. Oshadee de Silva, Dr. S.Sivaganesh, Dr. Jithangi Wanigasinghe, Dr. Sepalika Welikala, Mrs. Nirmali Wickramasinghe

You are asked to note the following,

- This approval is valid for one year, and the commitee requires that you furnish a final report.
- This approval relates to the ethical content of this study only, and you are responsible for the following:
    - Negotiating individual arrangements with the heads of service departments in those situations where the use of their resources is involved.
    - If appropriate, informing the study sponsor that the membership and procedures of the Faculty of Medicine ,University of Colombo Ethics Review Committee comply with approprate guidelines of the Forum of Ethics Review Committees in Sri Lanka (FERCSL).

Yours sincerely,

Appendix 18 The Lawton Instrumental Activities of Daily Living (IADL) scale-Sinhala version

ප්‍රාථමික නොවන දෛනික වැඩ කටයුතු කර ගැනීමේ හැකියාව මැන බැලීමේ ප්‍රශ්නාවලිය

උපදෙස්: සමීක්ෂණයට සහභාගී වන පුද්ගලයාගෙන්, පහත සඳහන් කාර්යයන් එදිනෙදා කිරීමට ඇති හැකියාව විමසා බලන්න. ඔහුට/ඇයට වඩාත් අදාල වන පිළිතුර ඉදිරියෙන් ඇති ලකුණ රවුම් කරන්න.

A. දුරකථනය භාවිත කිරීමේ හැකියාව

තනිවම දුරකථනය භාවිතා කළ හැක; ඕනෑම දුරකථන අංකයකට ඇමතුමක් ලබා ගත හැක. 1

හොඳින්ම දන්නා දුරකථන අංක කීපයකට පමණක් ඇමතුම් ලබා ගත හැක. 1

දුරකථනයට ලැබෙන ඇමතුම් වලට පිළිතුරු දීමට හැකි වුවත් තනිවම දුරකථන ඇමතුමක් ලබා ගැනීමට නොහැක. 1

දුරකථනය කිසිසේත්ම භාවිතා කළ නොහැක. 0

B. කඩයකට ගොස් නිවසට අවශ්‍ය භාණ්ඩ මිලදී ගැනීමේ හැකියාව

තනිවම කඩයකට ගොස් නිවසට අවශ්‍ය ඕනෑම දෙයක් මිලදී ගත හැක. 1

තනිවම කඩයකට ගොස් නිවසට අවශ්‍ය සුළු දෙයක් මිලදී ගත හැක. 0

කඩයකින් බඩු ගැනීමට යාමේදී වෙනත් අයකුද තමා සමඟ යා යුතුය. 0

භාණ්ඩ මිලදී ගැනීමට යාමට කිසිසේත්ම නොහැක. 0

C. ආහාර පිළියෙල කිරීම

ස්වාධීනව ප්‍රමාණවත් ආහාර වේලක් සැලසුම් කර, පිළියෙල කර, පරිභෝජනය දක්වා සකස් කර ගත හැක. 1

අවශ්‍ය කරන අමුද්‍රව්‍ය ලබා දුන්නහොත් ප්‍රමාණවත් ආහාර වේලක් පිළියෙල කළ හැක. 0

ආහාර රත් කිරීමට, පරිභෝජනය දක්වා සකස් කර ගැනීමට හැකි වුවත් ප්‍රමාණවත් ආහාර වේලක් පිළියෙල කළ නොහැක. 0

වෙනත් කෙනෙකු විසින් ආහාර පිළියෙල කර පිළිගැන්විය යුතුයි. 0

D. ගේ දොර වැඩ කටයුතු කිරීම

ගේ දොර වැඩ කටයුතු තනිවම කිරීමට පුළුවන, කලාතුරකින් ඉතා අසීරු කාර්යයන් සඳහා වෙනත් අයගේ සහයෝගය අවශ්‍යය වේ. 1

ගේ දොර එදිනෙදා සිදු කරන සැහැල්ලු වැඩ කටයුතු තනිවම කළ හැක, උදා. පිඟන් කෝප්ප සේදීම, ඇඳන් අස් පස් කිරීම. 1

ගේ දොර එදිනෙදා සිදු කරන සැහැල්ලු වැඩ කටයුතු තනිවම කළ හැකි නමුත් එම වැඩ කටයුතු වල පිරිසිදු බව පිළිබඳව සෑහීමකට පත් විය නොහැක. 1

ගේ දොර සෑම වැඩ කටයුත්තක් සඳහාම වෙනත් අයගේ සහයෝගය අවශ්‍ය වේ. 1

ගේ දොර එදිනෙදා කිසිම වැඩ කටයුත්තකට සහභාගී නොවේ. 0

E. ඇඳුම් සෝදා ගැනීම

තමන්ගේ සියලුම ඇඳුම් තනිවම සෝදා ගත හැක. 1

කුඩා ඇඳුමක් පමණක් තනිවම සෝදා ගත හැක, උදා. ලේන්සුවක්, කුඩා තුවායක්

වැනි. 1

තමන්ගේ සියලුම ඇඳුම් වෙනත් අය විසින් සෝදා දිය යුතුයි. 0

F. ගමන් බිමන් යාම

පොදු ප්‍රවාහන සේවා භාවිතා කරමින් හෝ වාහනයක් පදවාගෙන තනිවම ගමන් බිමන් යා හැක. 1

කුලී රථයක තනිවම ගමන් බිමන් යා හැකි වුවත් පොදු ප්‍රවාහන සේවා භාවිතා කරමින් ගමන් බිමන් යා නොහැකිය. 1

තව කවුරුන්ගේ හෝ සහය ඇතිව පොදු ප්‍රවාහන සේවා භාවිතා කරමින් ගමන් බිමන් යා හැක. 1

තව කවුරුන් හෝ සමඟ කුලී රථයක ගමන් බිමන් යා හැක. 0

ගමන් බිමන් යාමට නොහැකිය. 0

G. තමා ගත යුතු ඖෂධ තනිවම ගැනීමේ හැකියාව

නියමිත වේලාවට නියමිත මාත්‍රාවට අනුව ඖෂධ තනිව ලබා ගත හැක. 1

නියමිත මාත්‍රාවට අනුව වෙන කවුරුන් හෝ කලින් ඖෂධ පිළියෙල කර තබා ඇත්නම් ඒවා ලබා ගත හැක. 0

තමා ගත යුතු ඖෂධ තනිවම ගැනීමට නොහැක. 0

H. මුදල් හැසිරවීමට ඇති හැකියාව

මුදල් සම්බන්ධ කාරණා තනිවම කළමනාකරණය කල හැක (උදා. විදුලි බිල්පත්, ජල බිල්පත් ආදිය ගෙවීම, බැංකුවට යාම) 1

එදිනෙදා අවශ්‍ය සුළු දේවල් මිලදී ගත හැකි නමුත් බැංකු කටයුතු වලදී හෝ විශාල මිලදී ගැනීම් වලදී උදව් අවශ්‍යය වේ. 1

මුදල් හැසිරවීමට නොහැක. 0

සම්පූර්ණ ලකුණ.....

මෙම ප්‍රශ්නාවලිය මෙතැනින් අවසන්. ඔබ දැක්වූ සහයෝගයට ස්තූතියි.

Appendix 19 Prevalence of total number of IADL and BADL limitations in the overall sample and by frailty status

Disability	Unweighted sample, N (%)				Weighted sample, %			
	All	Non-frail	Pre-frail	Frail	All	Non-frail	Pre-frail	Frail
No of IADL limitations								
0	474	221	237	16				
	(65.7)	(86.6)	(67.3)	(13.9)	67.2	86.6	68.7	15.6
1	112	26	73	13				
	(15.5)	(10.2)	(20.7)	(11.3)	14.9	10.2	19.9	10.1
2	45	4	23	18				
	(6.2)	(1.6)	(6.5)	(15.7)	6.3	1.8	6.0	18.2
3	30	3	10	17				
	(4.2)	(1.2)	(2.9)	(14.8)	4.2	1.2	3.0	15.1
4	14	1	4	9				
	(1.9)	(0.4)	(1.1)	(7.8)	1.7	0.2	0.9	8.2
5	11	0	1	10				
	(1.5)	(0.0)	(0.3)	(8.7)	1.2	0.0	0.3	7.1
6	18	0	3	15				
	(2.5)	(0.0)	(0.9)	(13.0)	2.4	0.0	1.0	12.5
7	8	0	1	7				
	(1.1)	(0.0)	(0.3)	(6.1)	1.0	0.0	0.2	5.7
8	10	0	0	10				
	(1.4)	(0.0)	(0.0)	(8.7)	1.1	0.0	0.0	7.5
No of BADL limitations								
0	683	261	352	70				
	(91.7)	(100.0)	(97.0)	(57.8)	92.8	100.0	97.3	61.3
1	21	0	9	12				
	(2.8)	(0.0)	(2.4)	(9.9)	2.5	0.0	2.2	9.7
2	11	0	1	10				
	(1.5)	(0.0)	(0.3)	(8.2)	1.2	0.0	0.3	6.6
3	9	0	1	8				
	(1.2)	(0.0)	(0.3)	(6.6)	1.1	0.0	0.2	6.5
4	6	0	0	6				
	(0.8)	(0.0)	(0.0)	(5.0)	0.7	0.0	0.0	4.3
5	3	0	0	3				
	(0.4)	(0.0)	(0.0)	(2.5)	0.3	0.0	0.0	2.2
6	2	0	0	2				
	(0.3)	(0.0)	(0.0)	(1.7)	0.2	0.0	0.0	1.4
7	2	0	0	2				
	(0.3)	(0.0)	(0.0)	(1.7)	0.2	0.0	0.0	1.5
8	5	0	0	5				
	(0.6)	(0.0)	(0.0)	(4.1)	0.7	0.0	0.0	4.5
9	2	0	0	2				
	(0.3)	(0.0)	(0.0)	(1.7)	0.2	0.0	0.0	1.3
10	1	0	0	1				
	(0.1)	(0.0)	(0.0)	(0.8)	0.1	0.0	0.0	0.7

Appendix 20 Distribution of BADL limitations among 11 participants who were not frail in the present study sample

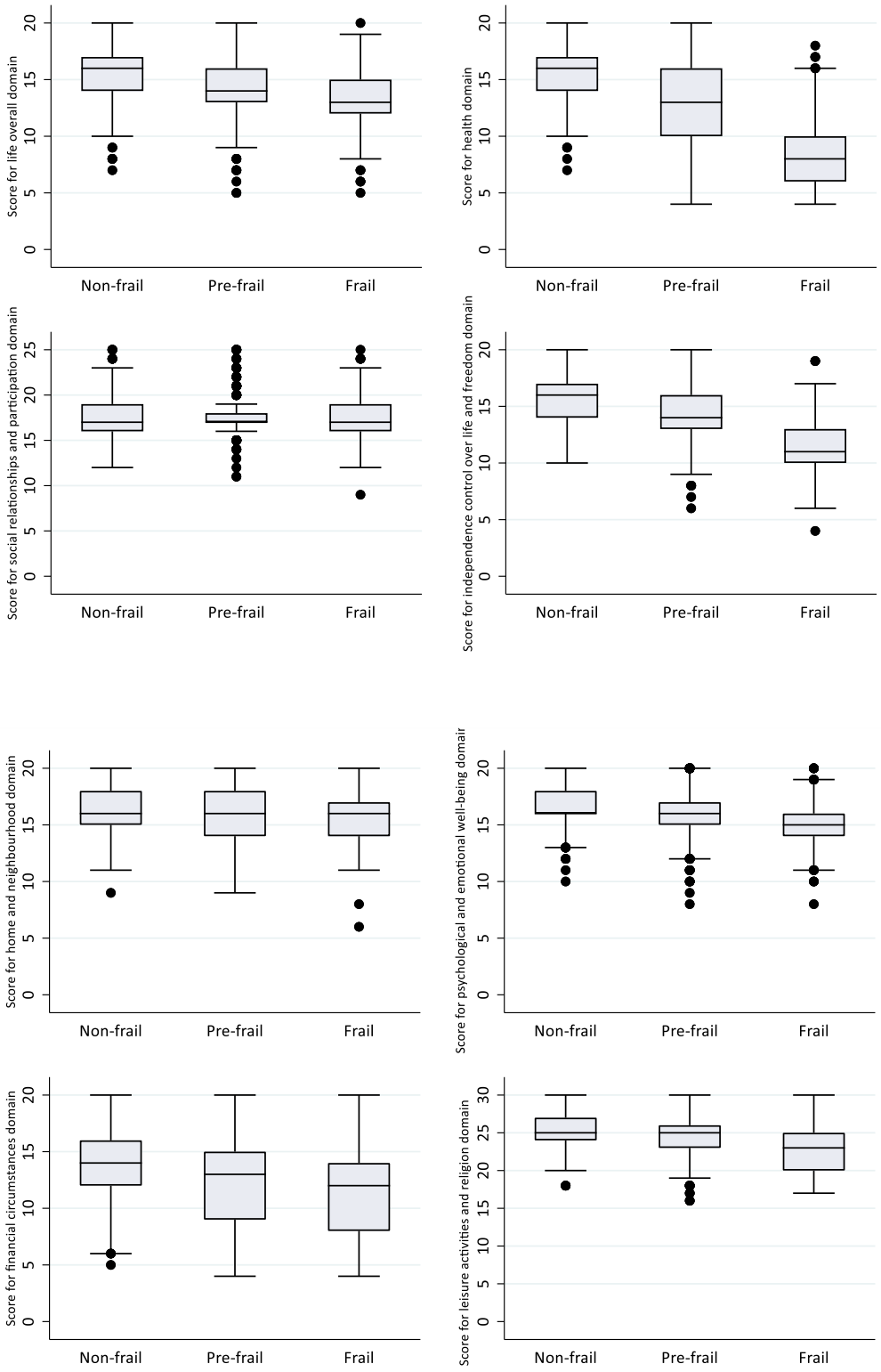
BADL limitations	Number of participants
Feeding	3
Bathing	2
Dressing	3
Toilet use	1
Grooming	0
Transfers	1
Stairs	1
Mobility	1
Bladder	0
Bowels	2

Nine participants were dependent on one basic activities of daily living.

One participant was dependent on feeding and toilet use.

One participant was dependent on bathing, dressing, and bowels.

Appendix 21 Distribution of raw domain-specific QoL scores according to frailty status



The subsequent pages include four scientific articles based on the findings of my PhD thesis published in peer-reviewed journals.

Paper 1

Open Access Research

BMJ Open

Prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries: a systematic review and meta-analysis

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ABSTRACT

Objective To systematically review the research conducted on prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries (LMICs) and to estimate the pooled prevalence of frailty and prefrailty in community-dwelling older adults in LMICs.

Design Systematic review and meta-analysis. PROSPERO registration number is CRD42016036083.

Data sources MEDLINE, EMBASE, AMED, Web of Science, CINAHL and WHO Global Health Library were searched from their inception to 12 September 2017.

Setting Low-income and middle-income countries.

Participants Community-dwelling older adults aged ≥60 years.

Results We screened 7057 citations and 56 studies were included. Forty-seven and 42 studies were included in the frailty and prefrailty meta-analysis, respectively. The majority of studies were from upper middle-income countries. One study was available from low-income countries. The prevalence of frailty varied from 3.9% (China) to 51.4% (Cuba) and prevalence of prefrailty ranged from 13.4% (Tanzania) to 71.6% (Brazil). The pooled prevalence of frailty was 17.4% (95% CI 14.4% to 20.7%, I^2=99.2%) and prefrailty was 49.3% (95% CI 46.4% to 52.2%, I^2=97.5%). The wide variation in prevalence rates across studies was largely explained by differences in frailty assessment method and the geographic region. These findings are for the studies with a minimum recruitment age 60, 65 and 70 years.

Conclusion The prevalence of frailty and prefrailty appears higher in community-dwelling older adults in upper middle-income countries compared with high-income countries, which has important implications for healthcare planning. There is limited evidence on frailty prevalence in lower middle-income and low-income countries.

PROSPERO registration number CRD42016036083.

Strengths and limitations of this study

- This is the first systematic review and meta-analysis of the prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries.
- We conducted a comprehensive literature search in six electronic databases with a comprehensive search strategy, including WHO Global Health Library to capture studies published regionally.
- No language restriction was imposed.
- Subgroup analysis of prevalence of frailty and prefrailty was performed with substantial number of studies, and meta-regression technique was used to identify the sources of heterogeneity between the studies.
- We did not include grey literature in this review.

INTRODUCTION

Population ageing is not confined to high-income countries (HICs). People in low-income and middle-income countries (LMICs) have increasing life expectancy with the advancement of healthcare services.[1] The pace of population ageing is faster in LMICs compared with HICs.[2] This creates an additional burden for these countries with growing economies as they have to tackle health, social and welfare issues associated with ageing populations.

Frailty is a health problem of older age with no universally agreed conceptual or operational definition. However, there is a common agreement that frailty is an important clinically identifiable state that increases the vulnerability to adverse outcomes due to the decline in reserve and functions in multiple physiological systems.[3] The Fried phenotype of frailty, comprising five phenotypic criteria (unintentional weight loss, self-reported exhaustion, weakness, slowness and low physical activity),[4] and the frailty index (comprising a list of deficits)[5] are the most

frequently used frailty assessment methods in the literature.[6] Longitudinal studies have identified several negative outcomes associated with frailty which can have a huge impact on individual lives and society as a whole. These include falls, worsening mobility, disability, hospitalisation and increased risk of mortality.[4 5 7 8]

Prefrailty is an intermediate state between frailty and non-frailty/robust that has higher risk of progressing to frailty.[9] Since frailty status is assessed using different assessment methods, most of the assessment methods have its own cut-off for prefrailty status. For instance, having one to two criteria of five is considered as prefrail for the Fried's phenotype.[4] Like frailty, prefrailty is also associated with adverse health outcomes. Findings from a recent meta-analysis based on six prospective cohort studies suggested increased risk for faster onset of any type of cardiovascular diseases in prefrail versus robust.[10] Another longitudinal study also showed that prefrail individuals are more likely to show persistent and new depressive symptoms.[11] Evidence is emerging that frailty as a dynamic state with transitions between frailty statuses; frailty, prefrailty and non-frailty;[12–14] and there is potential for interventions to improve the health and well-being of both frail and prefrail older adults.

A substantial amount of research on frailty has been conducted in HICs. According to a systematic review conducted in 2012, the weighted prevalence of frailty in HICs is 10.7% and prefrailty is 41.6%.[15] There is some suggestion of a socioeconomic gradient in frailty between HICs; one study from 15 European countries reported a lower mean frailty index in North and Western Europe compared with lower income countries in South and Eastern Europe.[16] In addition, the survival of frail older people was higher in countries with a higher relative income within Europe.[16] It is possible that the prevalence of frailty in LMICs is higher than HICs, given a steeper gradient in income. Alternatively, the prevalence may be lower with a reduced life expectancy of older people in LMICs. A narrative review published in 2015 on frailty in developing countries found limited availability of studies and suggested that frailty occurs more frequently in developing countries.[17] However, no studies are available up-to-date collating all the epidemiological findings available from LMICs to examine the burden of frailty in these countries. This is important to inform healthcare planning in these countries in the context of world-wide population ageing. The aim of this study was to conduct a systematic review and meta-analysis on prevalence of frailty and prefrailty among community-dwelling older adults in LMICs.

METHODS

Search strategy and selection criteria

We performed a comprehensive structured search in six electronic bibliographic databases. MEDLINE, EMBASE and AMED databases using OvidSP interface, Web of Science Core Collection, CINAHL Plus databases and WHO Global Health Library were searched from their inception to 12 September 2017. Two concepts 'frailty' and 'LMICs' were used to develop the electronic search strategy. The example LMIC filters developed by the Cochrane organisation in 2012 was used with slight modifications.[18] The World Bank country classification issued on 1 July 2017,[19] based on 2016 economic data was used to identify the countries that switched from LMICs to HICs in 2017 or vice versa. Studies in these countries were included only if the country belongs to low-income and middle-income category during the time of data collection. The electronic search strategy was first developed for MEDLINE (online supplementary appendix A) and then adapted accordingly to other databases. The electronic search strategy was developed with the support of specialist librarian (SP). Additionally reference lists of the selected articles were scanned and citation searches were performed in the Web of Science. The search was limited to full-text articles as study quality assessment requires a detailed description on the methodology. No language restriction was imposed on the search.

The condition studied was frailty measured by any assessment method. The review was restricted to studies with community-dwelling older adults aged ≥60 years living in the LMICs. This age cut-off is in line with the United Nations's definition of older populations.[20] Studies with institutionalised or hospitalised adults, nursing home residents, outpatients of primary or secondary care clinics, or older adults belonging to specific disease groups were excluded. Cross-sectional studies conducted to assess the prevalence and associated factors of frailty, prospective follow-up studies that have baseline prevalence of frailty, cross-sectional studies conducted to explore the association of frailty with some other health variable or disease (eg, haemoglobin level and cardiovascular risk factors) were included in this review.

Identified citations were exported into EndNote X8 and duplicates were removed. In the first stage, the title and abstracts of the citations were screened against inclusion and exclusion criteria to identify potentially eligible citations. In the second stage, full texts of potentially eligible articles were retrieved. Two reviewers (DDS and SH) independently reviewed the full-text articles to identify the articles meeting eligibility criteria. If multiple studies were available from the same cohort, the study with the largest sample and most information was included in the review. The agreement between the two raters was high with a kappa value of 0.84 (95% CI 0.72 to 0.90). Disagreement between the reviewers was resolved through discussions and consulting senior researchers in the research team (KRW, GR and MCW).

Study quality assessment and data extraction

Selected articles were subjected to a quality assessment. Methodological rigour of the articles was assessed using eight criteria proposed by Loney *et al*[21] for the critical appraisal of the prevalence literature. If a study achieved three criteria or less, it was excluded from the review.

Study quality of all selected articles (61) was assessed by the first reviewer (DDS). The second reviewer (SH) assessed the study quality of a random 10% of articles to check for discrepancies.

Data extraction included information on study background (authors and year of publication, data source, study setting and study period), characteristics of the population (percentage of women in the study population, mean age, age range, number of frail and prefrail participants in the total sample, and by sex and age), study methodology (study design, effective sample, sampling technique and frailty assessment method) and study strengths and limitations. Authors were contacted requesting additional data required for subgroup analysis.

Data analysis

The results of the systematic review are presented in tabular format and narratively synthesised. All statistical analyses were performed in Stata V.14 (StataCorp, College Station, Texas, USA). A random-effects meta-analysis with 95% CI was performed to calculate the pooled prevalence of frailty and prefrailty. A random-effects model was chosen as there is a variation in the true effect from one study to another. And also, there was considerable heterogeneity of the study characteristics including geography, frailty assessment method, frailty cut-offs and recruitment age. When a study has used multiple assessment methods of frailty, the prevalence presented using Fried phenotype was used for the meta-analysis as it was the most commonly used assessment method in the literature.[22] The analysis was performed on Freeman-Tukey double arcsine transformed proportions to stabilise the variance. We used *metaprop random fit* command.[23] Results were presented using forest plots. The main meta-analysis and subgroup analysis excluded three studies, two studies with minimum recruitment age of ≥80 years and another study with minimum recruitment age of ≥90 years as those based on much older populations with expected higher prevalence rates for frailty. The findings from these studies were reported separately.

Cochran's Q statistic was used to assess heterogeneity between the studies. P<0.05 was considered as evidence of heterogeneity. The I^2 statistic was further used to quantify the magnitude of the heterogeneity. I^2 values of 25%, 50% and 75% were considered as of low, moderate and high heterogeneity, respectively.[24] Funnel plots generated by *metafunnel* command was used to visually inspect the existence of reporting biases and/or between study heterogeneity. In the absence of biases and/or between study heterogeneity, funnel plot will be a symmetrical inverted funnel in shape.[25] However, this eye ball test is subjective. Hence, we used Egger's weighted regression test to measure the degree of funnel plot asymmetry. The null hypothesis for Egger's test is that symmetry exists in the funnel plot.[26 27] Stata *metabias* command was used.

Subgroup analysis of frailty and prefrailty prevalence was performed according to the frailty assessment method (Fried phenotype with five criteria where weakness and slowness assessed objectively using grip strength and gait speed, Fried phenotype with five criteria where weakness and slowness assessed using self-reported questions (subjective), Fried phenotype with four criteria, Edmonton Frail Scale (EFS), frailty index and FRAIL scale). If the same cohort of participants had been assessed using different frailty assessment methods, we used that information in the subgroup analysis. However, studies that have used different frailty assessment methods to that mentioned above were excluded from the frailty and prefrailty subgroup analysis as they cannot be grouped into a particular category that is Study of Osteoporotic Fractures (SOF) index and Cuban frailty criteria, Brief Frailty Instrument for Tanzania (B-FIT). Further subgroup analyses by sex, age group (60–64, 65–69, 70–74, 75–79, 80–84, 85+ years), age and sex were performed with studies which had employed the Fried phenotype with five criteria where weakness and slowness assessed using objective tests. A two-sample proportion test was used to compare the prevalence of frailty and prefrailty by sex.

We performed a supplementary analysis to compare our findings with HICs. We used published data from a systematic review on prevalence of frailty which includes HICs only.[15] This review included 14 studies which had used Fried's phenotype of frailty assessment method. We estimated the random-effects pooled prevalence of frailty and prefrailty only with the studies that have used the Fried phenotype with five criteria where weakness and slowness assessed using objective tests (10 studies). Minimum recruitment age of the participants included in this review was 65 years. For a fair comparison we calculated the random-effects pooled prevalence of frailty and prefrailty only with the studies of minimum recruitment age 65 years that have used same assessment method included in our review.

Random-effects univariable and multivariable meta-regression were performed using *metareg* command to identify the potential sources of heterogeneity between the studies (demographic, geographical and methodological).[28] Three studies which used SOF index, Cuban frailty criteria and Brief Frailty Instrument for Tanzania (B-FIT) were excluded from the analysis. The following explanatory variables were included in the models; mean age, percentage of women in the study sample, study quality assessment score, World Bank region classification (Latin America and the Caribbean, East Asia and Pacific, Europe and Central Asia, and South Asia) and frailty assessment method. All the variables were included in the multivariable model irrespective of their significance (P value) in univariable analysis. Variables with P<0.05 were considered as significant. The systematic review protocol of this study is registered in PROSPERO and the number is CRD42016036083. This systematic review and meta-analysis have been reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2009 checklist is attached separately).[29]

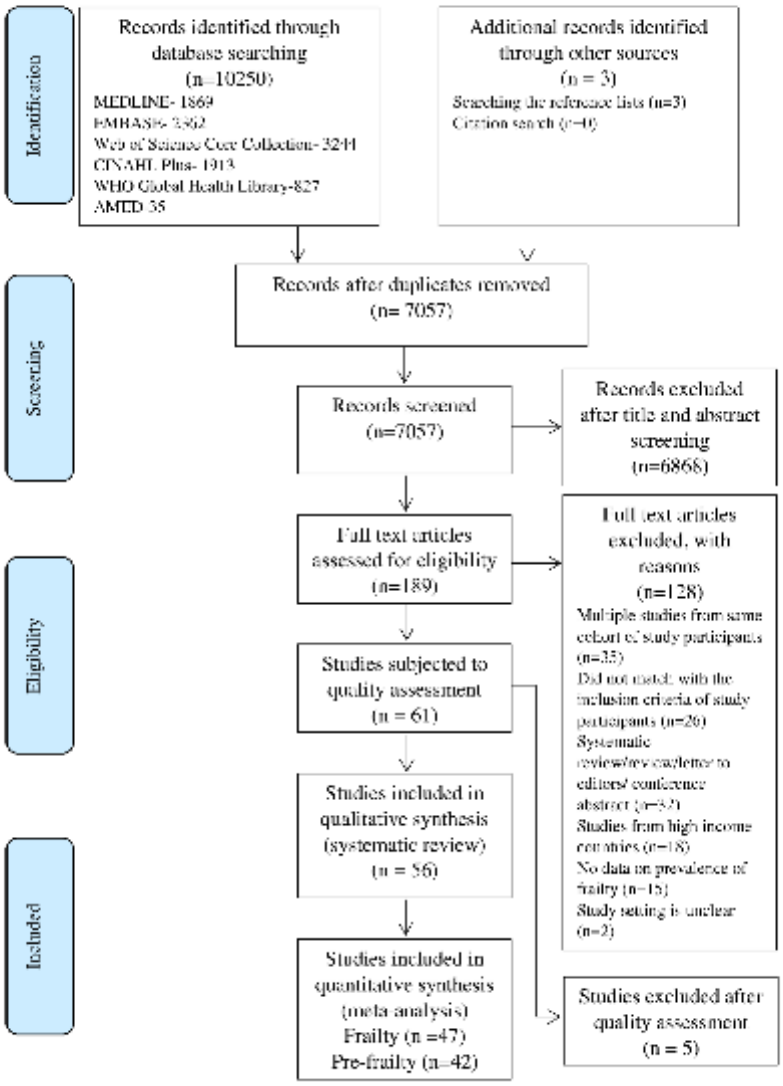

Figure 1 Study selection.

RESULTS

Study characteristics

The search yielded 10 253 records, with 7057 records left after removing duplicates. Fifty-six studies meeting all eligibility criteria were included in the systematic review (figure 1). Forty-seven and 42 studies were included in the meta-analysis of frailty and prefrailty, respectively.

The study quality assessment score of the studies included ranged from 3.5 to 7.5, with a mean score of (SD) 6.0 (1.07). Quality assessment results of the studies are presented in the online supplementary appendix B.

The characteristics of included studies are described in the online supplementary appendix C. Fifty studies have been published between 2012 and 2017. The majority of the studies were from the Latin America and the Caribbean region, predominantly from Brazil (n=24). Most of the studies had used data from large population-based cross-sectional or longitudinal studies on ageing.

The sample size of the studies varied (range 54–12 373) and the minimum recruitment age of the study participants varied from 60 to 90 years. The minimum age at recruitment of the study participants was 60 years in 30

studies, 65 years in 19 studies, 70 years in 4 studies, 80 years in 2 studies and 90 years in 1 study. Fifty-two studies had reported the percentage of women in the study samples and it varied from 48.1% to 100.0%, with more than half of participants being women in all except three studies. Forty-two studies reported the mean age (42/56) of the participants, which ranged from 68.2 to 77.2 years after excluding three studies with minimum recruitment age ≥80 years (two studies) and ≥90 years (one study).

Studies used various frailty assessment methods. The Fried phenotype was the most extensively used method. Researchers had operationalised the Fried phenotype differently. We identified three broad categories based on the number of phenotypic criteria used and measures used to operationalise those criteria. Those are Fried phenotype with five criteria—weakness and slowness assessed using objective tests, Fried phenotype with five criteria—weakness and slowness assessed using self-reported questions (subjective) and Fried phenotype with only four criteria.

Prevalence of frailty and prefrailty

Irrespective of the frailty assessment method, the prevalence of frailty varied from 3.9% in China (Fried phenotype with five criteria—weakness and slowness assessed using objective tests) to 51.4% in Cuba (Cuban frailty criteria) and prevalence of prefrailty ranged from 13.4% in Tanzania (Brief Frailty Instrument for Tanzania, B-FIT) to 71.6% in Brazil (Fried phenotype with five criteria—weakness and slowness measured objectively) for the studies with minimum recruitment age 60, 65 and 70 years. There was one study in those aged ≥90 years, reporting 61.8% participants as frail using the frailty index (not reported prefrailty). Another study with aged ≥80 years had not reported a cut-off value for the frailty index to define frail participants. Instead, authors had reported six levels based on the value of the frailty index and the percentage of participants belongs to each level. The other study with aged ≥80 years reported 14.8% and 63.8% participants as frail and prefrail, respectively, using Fried phenotype with five criteria—weakness and slowness assessed using objective tests. When restricting to the studies that used Fried phenotype with five criteria and assessed the weakness and slowness objectively, the prevalence of frailty varied from 3.9% (China) to 26.0% in India. The prevalence of prefrailty varied from 40.7% to 71.6% in Brazil.

Pooled prevalence of frailty and prefrailty

Descriptions of included studies in the meta-analysis are presented in table 1. Sixty-nine prevalence estimates (47 studies), corresponding to a total of 75 133 community-dwelling older adults, were included in the frailty meta-analysis. The random-effects pooled prevalence of frailty in community-dwelling older adults was 17.4% (95% CI 14.4% to 20.7%). Cochran's Q and I^2 indicated a high heterogeneity between included studies (Q=8756.8, df=68, P<0.001; I^2=99.2%) (figure 2). Funnel plot asymmetry (figure 3) revealed evidence of reporting biases and/or between study heterogeneity. Results of Egger'sweighted regression test further confirmed the funnel plot asymmetry (P=0.042).

Fifty four prevalence estimates (42 studies) corresponding to 47 302 participants were included in the prefrailty meta-analysis. The random-effects pooled prevalence of prefrailty in community-dwelling older adults was 49.3% (95% CI 46.4% to 52.2%). High heterogeneity was observed between included studies (Q=2082.6, df=53, P<0.001; I^2=97.5%) (figure 4). Asymmetric funnel plot (figure 5) suggested the existence of reporting biases and/or between study heterogeneity. However, results of Egger's weighted regression test was insignificant indicating no funnel plot asymmetry (P=0.817).

Subgroup analyses

The pooled prevalence varied by the assessment method and the highest prevalence of frailty was reported for the EFS, 35.9% (95% CI 31.7% to 40.2%, I^2=61.9%, P=0.022). The lowest prevalence of frailty was reported for the FRAIL scale, 12.4% (95% CI 8.4% to 17.1%). The pooled prevalence of frailty for the Fried phenotype with five criteria—weakness and slowness assessed using objective tests was 12.7% (95% CI 10.9% to 14.5%, I^2=94.8%, P<0.001) (online supplementary appendix D). Results for pooled prevalence of prefrailty stratified by the frailty assessment method is presented in the online supplementary appendix D.

Twenty-four prevalence estimates were available from 24 studies using the same assessment method (Fried Phenotype with objective tests) for sex-stratified analysis of prevalence of frailty and prefrailty. In total, there were 10 507 and 15 458 male and female participants, respectively. The pooled prevalence of frailty in men was 11.1% (95% CI 8.9% to 13.4%, I^2=91.4%, P<0.001) compared with 15.2% (95% CI 12.5% to 18.1%, I^2=95.2%, P<0.001) in women. Frailty prevalence was significantly higher in women compared with men (Z=−7.38, P<0.001). The pooled prevalence of prefrailty in men was 53.8% (95% CI 51.3% to 56.3%, I^2=80.9%, P<0.001) and women was 56.3% (95% CI 54.0% to 58.7%, I^2=86.2%, P<0.001). Similar to frailty, there was a statistically significant sex difference in prefrailty (Z=−3.51, P<0.001).

The prevalence of frailty increased gradually with advancing age (online supplementary appendix E). The prevalence considerably increased after age of 75 years. The prevalence of prefrailty also slightly increased with advancing age and was >50% in all age groups. An age-related incremental rise in frailty was evident even after stratification by sex (online supplementary appendix F). Prevalence of frailty was higher in women in all 5-year age bands. There was no age-related trend for prefrailty after stratification by sex (online supplementary appendix G).

Supplementary analysis

Ten prevalence estimates (10 studies), corresponding to a total of 27 660 community-dwelling older adults from

Table 1 Descriptions of the studies included in the meta-analysis of prevalence of frailty and prefrailty

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Fraility assessment method	Effective sample	Prevalence (%)	
							Frailty	Prefrailty
Tribess *et al*, 2012[45]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	622	19.9	49.8
Reis Júnior *et al*, 2014[46]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	286	23.8	58.7
Pegorari and Tavares, 2014[47]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	958	12.8	54.5
Santos *et al*, 2015[48]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	136	16.9	61.8
Closs *et al*, 2016[49]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	521	21.5	51.1
Mello *et al*, 2017[50]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	137	12.4	61.3
Sousa *et al*, 2012[51]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	391	17.1	60.1
Amaral *et al*, 2013[52]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	295	18.6	55.3
Moreira and Lourenço, 2013[53]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	754	9.5	47.5
Neri *et al*, 2013[54] (Belem)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	720	10.8	48.2
Neri *et al*, 2013[54] (Parnaiba)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	431	9.7	55.5
Neri *et al*, 2013[54] (Campina Grande)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	395	8.9	51.4
Neri *et al*, 2013[54] (Poco de Caldas)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	388	9.3	53.4
Neri *et al*, 2013[54] (Ermelino Matarazzo)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	384	8.1	54.9
Neri *et al*, 2013[54] (Campinas)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	898	7.7	52.2
Neri *et al*, 2013[54] (Ivoti)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	197	8.6	47.7
Vieira *et al*, 2013[55]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	601	8.7	48.3
Ricci *et al*, 2014[56]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	761	9.7	48.0

Continued

Table 1 Continued

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Prefrailty
Silveira *et al*, 2015[57]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	54	11.1	48.2
Calado *et al*, 2016[58]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	385	9.1	49.6
Augusti *et al*, 2017[59]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	306	21.5	71.6
Ferrioli *et al*, 2017[60] (Recife)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	556	12.1	68.9
Ferrioli *et al*, 2017[60] (Juiz de Fora)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	412	15.5	63.1
Ferrioli *et al*, 2017[60] (Fortaleza)	Brazil	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype*	461	10.4	63.6
Ocampo-Chaparro *et al*, 2013[61]	Colombia	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	314	12.7	71.3
Curcio *et al*, 2014[62]	Colombia	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	1878	12.2	53.0
Samper-Ternent *et al*, 2016[63]	Colombia	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype *	1442	9.4	52.4
Sánchez-García *et al*, 2017[64]	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype*	1252	11.2	50.3
Moreno-Tamayo *et al*, 2017[65]	Mexico	Latin America and the Caribbean	Upper middle income	≥70	Fried phenotype*	667	11.9	51.9
Chen *et al*, 2015[66]	China	East Asia and Pacific	Upper middle income	≥60	Fried phenotype*	604	12.7	58.5
Wu *et al*, 2017[67]	China	East Asia and Pacific	Upper middle income	≥60	Fried phenotype*	5290	6.3	51.3
Dong *et al*, 2017[68]	China	East Asia and Pacific	Upper middle income	≥60	Fried phenotype*	1188	3.9	45.9
Wang *et al*, 2015[69]	China	East Asia and Pacific	Upper middle income	≥65	Fried phenotype*	316	14.2	49.1
Badrasawi *et al*, 2017[70]	Malaysia	East Asia and Pacific	Upper middle income	≥60	Fried phenotype*	473	8.9	61.7
Kashikar and Nagarkar, 2016[32]	India	South Asia	Lower middle income	≥65	Fried phenotype*	250	26.0	63.6
Gurina *et al*, 2011[71]	Russia	Europe and Central Asia	Upper middle income	≥65	Fried phenotype*	611	21.1	63.0
Alvarado *et al*, 2008[33] (SABE wave 1)	Barbados	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1446	26.7	54.4

Continued

Table 1 Continued

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Prefrailty
Alvarado *et al*, 2008[33] (SABE wave 1)	Brazil	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1879	40.6	48.8
Alvarado *et al*, 2008[33] (SABE wave 1)	Chile	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1220	42.6	51.4
Alvarado *et al*, 2008[33] (SABE wave 1)	Cuba	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1726	39.0	51.6
Alvarado *et al*, 2008[33] (SABE wave 1)	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	1063	39.5	49.0
Aguilar-Navarro *et al*, 2015[72] (MHAS wave 1)	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype†	5644	37.2	51.3
Avila-Funes *et al*, 2016[73]	Mexico	Latin America and the Caribbean	Upper middle income	≥70	Fried phenotype†	927	14.1	37.3
Sánchez-García *et al*, 2014[74]	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Fried phenotype‡	1933	15.7	33.3
Akin *et al*, 2015[75] (KEHES)	Turkey	Europe and Central Asia	Upper middle income	≥60	Fried phenotype‡	848	27.8	34.8
Zhu *et al*, 2016[76]	China	East Asia and Pacific	Upper middle income	≥70	Fried phenotype‡	1478	12.0	42.9
Jotheeswaran *et al*, 2015[31]	China (urban)	East Asia and Pacific	Upper middle income	≥65	Fried phenotype‡	989	7.8	–
Jotheeswaran *et al*, 2015[31]	China (rural)	East Asia and Pacific	Upper middle income	≥65	Fried phenotype‡	1002	8.7	–
Jotheeswaran *et al*, 2015[31]	Cuba (urban)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	2637	21.0	–
Jotheeswaran *et al*, 2015[31]	Dominican Republic (urban)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	1706	34.6	–
Jotheeswaran *et al*, 2015[31]	India (urban)	South Asia	Lower middle income	≥65	Fried phenotype‡	748	11.4	–
Jotheeswaran *et al*, 2015[31]	Mexico (urban)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	909	10.1	–
Jotheeswaran *et al*, 2015[31]	Mexico (rural)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	933	8.5	–
Jotheeswaran *et al*, 2015[31]	Peru (urban)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	1245	25.9	–
Jotheeswaran *et al*, 2015[31]	Peru (rural)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	507	17.2	–
Jotheeswaran *et al*, 2015[31]	Venezuela (urban)	Latin America and the Caribbean	Upper middle income	≥65	Fried phenotype‡	1697	11.0	–

Continued

Table 1 Continued

Authors and year of publication	Country	World Bank region classification	World Bank income classification	Age (years)	Frailty assessment method	Effective sample	Prevalence (%)	
							Frailty	Prefrailty
Rhon *et al*, 2012[77]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	240	39.2	24.6
Agrell *et al*, 2013[78]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	103	30.1	22.3
Duarte *et al*, 2013[79]	Brazil	Latin America and the Caribbean	Upper middle income	≥60	EFS	166	39.2	21.7
Del Brutto *et al*, 2016[80]	Ecuador	Latin America and the Caribbean	Upper middle income	≥60	EFS	298	31.2	22.0
Fabricio-Wehbe *et al*, 2009[81]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	EFS	137	31.4	20.4
Carneiro *et al*, 2016[82]	Brazil	Latin America and the Caribbean	Upper middle income	≥65	EFS	511	41.3	-
Woo *et al*, 2015[42]	China	East Asia and Pacific	Upper middle income	≥65	Frailty index	6320 (urban) 978 (rural)	17.0 5.2	- -
Sathasivam *et al*, 2015[43]	Malaysia	East Asia and Pacific	Upper middle income	≥60	Frailty index	789	5.7	67.7
Pérez-Zepeda *et al*, 2016[44]	Mexico	Latin America and the Caribbean	Upper middle income	≥60	Frailty index	7108	45.2	-
Galbán *et al*, 2009[83]	Cuba	Latin America and the Caribbean	Upper middle income	≥60	Cuban frailty criteria	541	51.4	-
Boulos *et al*, 2016[84]	Lebanon	Middle East and North Africa	Upper middle income	≥65	SOF frailty index	1120	36.4	30.4
Gray *et al*, 2017[30]	Tanzania	Sub-Saharan Africa	Low income	≥70	B-FIT	941	4.6	13.4

*Fried Phenotype with five criteria—weakness and slowness assessed using objective tests.
†Fried Phenotype with five criteria—weakness and slowness assessed using self-reported questions (subjective).
‡Fried phenotype with four criteria.
B-FIT, Brief Frailty Instrument for Tanzania; EFS, Edmonton Frail Scale; KEHES, Kayseri Elderly Health Study; MHAS, Mexican Health and Aging Study; SABE-Health, Wellbeing and Ageing Study; SOF, Study of Osteoporotic Fractures frailty index.

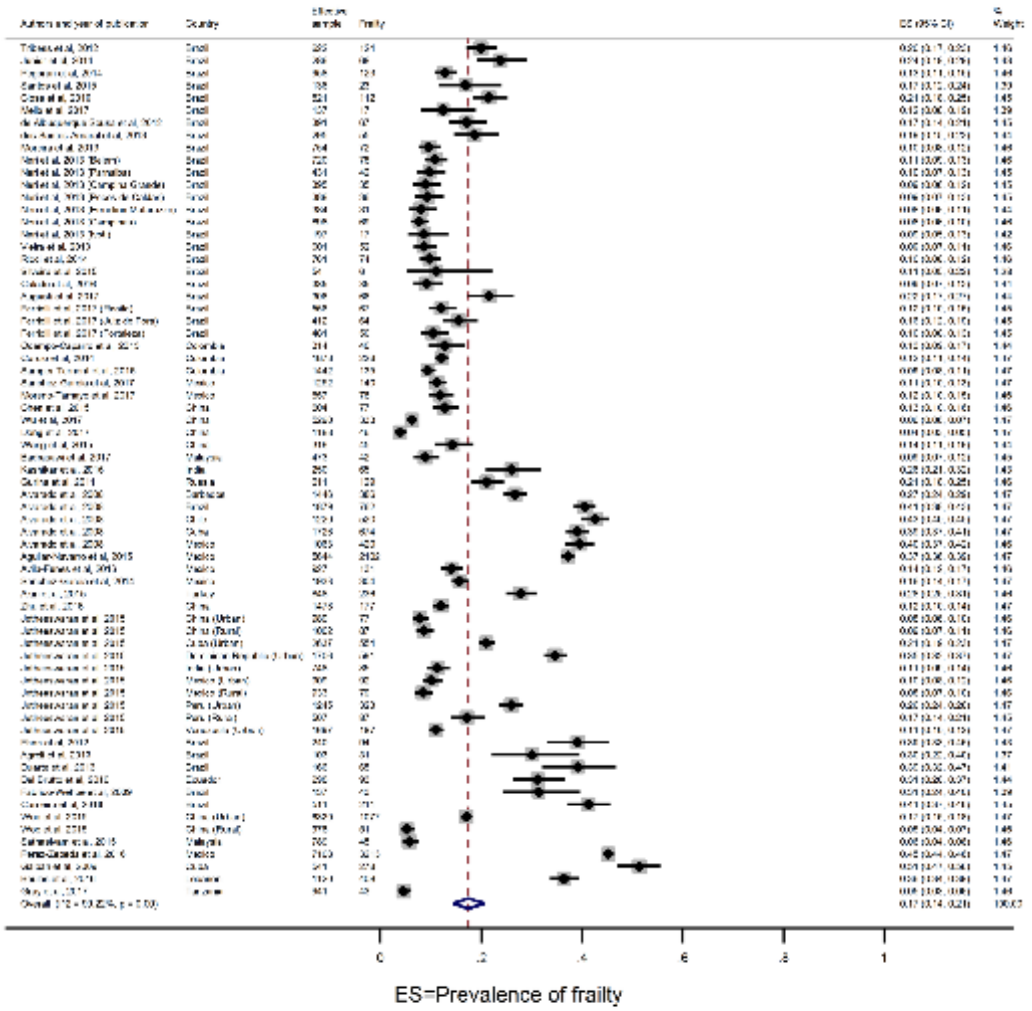

Figure 2 Random-effects pooled prevalence of frailty among community-dwelling older adults in LMICs. ES, effect size; LMICs, low-income and middle-income countries.

HICs and 21 prevalence estimates (13 studies), corresponding to a total of 9586 community-dwelling older adults from middle-income countries, were included in the frailty meta-analysis. The random-effects pooled prevalence of frailty in community-dwelling older adults in HICs and middle-income countries were 8.2% (95% CI 5.7% to 11.2%) (online supplementary appendix H) and 12.3% (95% CI 10.4% to 14.4%) (online supplementary appendix I), respectively. The prevalence of frailty in older adults from middle-income countries was significantly higher compared with the older adults residing in HICs, (Z=−8.86, P<0.001). However, it is also of note that studies included in the meta-analysis of HICs were predominantly from the USA whereas studies included in the middle-income countries meta-analysis were predominantly from Brazil and all the countries belong to upper middle-income category except one study from India. The pooled prevalence of frailty except the study from India was 11.8% (95% CI 10.0% to 13.6%) and still significantly higher compared with HICs.

The random-effects pooled prevalence of prefrailty in community-dwelling older adults in HICs and middle-income countries were correspondingly 43.9% (95% CI 40.9% to 46.9%) (online supplementary appendix J) and 55.3% (95% CI 52.0% to 58.6%) (online supplementary appendix K). Like frailty, prevalence of prefrailty also

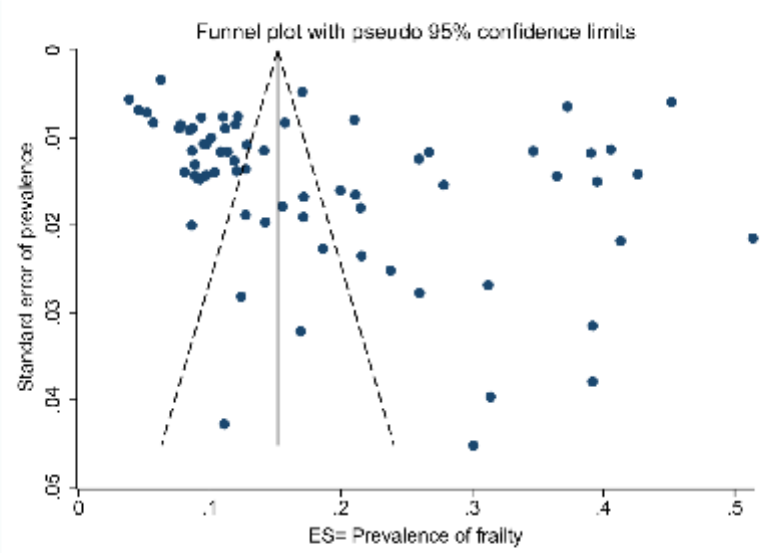

Figure 3 Funnel plot for assessing publication or other types of biases in meta-analysis of prevalence of frailty. ES, effect size.

significantly higher among the older adults in middle-income countries compared with the higher income countries (Z=−17.14, P<0.001).

Meta-regression

After adjusting for all the other study characteristics in a multivariable meta-regression model, there remained statistically significant differences in frailty prevalence between different assessment methods. Use of EFS, frailty index and Fried phenotype (five criteria, weakness and slowness assessed using self-reported questions (subjective)) was associated with a frailty prevalence approximately 20% higher than the reference method (Fried phenotype five criteria with objective tests). Geographic region was also a statistically significant predictor of frailty. The variables included in the multivariable model (mean age, % of women in the sample, study quality assessment score, geographic region and frailty assessment method) explained 58.4% of variability between the studies included in the analysis (table 2).

DISCUSSION

Summary of main findings

Only one epidemiological study on frailty was found from countries with low-income economies[30] (≤US$1005) according to World Bank Classification, 2017.[19] Of countries with lower middle-income economies (US$1006–US$3955) we only found two studies both from India. One was a study site of a multicountry study[31] and the other one was a small community-based cross-sectional study.[32] All the other studies have been conducted in countries with upper middle-income economies (US$3956–US$12 235) indicating income inequality in frailty research.

The random-effects pooled prevalence of frailty and prefrailty in community-dwelling older adults were 17.4% (95% CI 14.4% to 20.7%) and 49.3% (95% CI 46.4% to 52.2%), respectively. Frailty was significantly higher in women compared with men and as expected increased with age. This finding is consistent with previous research.[15 33–36] Interestingly, the prevalence of prefrailty was also slightly increasing across all age groups at around half the participants. Both the prevalence of frailty and prefrailty appeared significantly higher in community-dwelling older adults in upper middle-income countries compared with HICs.

Comparison with the existing literature

The pooled prevalence of frailty and prefrailty in LMICs in this review appeared to be higher than the weighted prevalence in HICs reported previously (10.7%, (95% CI 10.5% to 10.9%) and 41.6% (95% CI 41.2% to 42.0%), respectively).[15] However, it is also of note that the participants in HICs included people aged ≥65 years, whereas 50% of studies in our meta-analysis included participants aged ≥60 years. Given that prevalence of frailty increases with age, when participants of a higher age group are selected, a higher prevalence would be expected. Our meta-analysis included 18 studies (36 estimates) with a population aged ≥65 years. The prevalence of frailty of this subsample was 14.6% (95% CI 11.9% to 17.4%) and still higher compared with HICs. In the review of frailty in HICs, most studies were from Europe and North America.

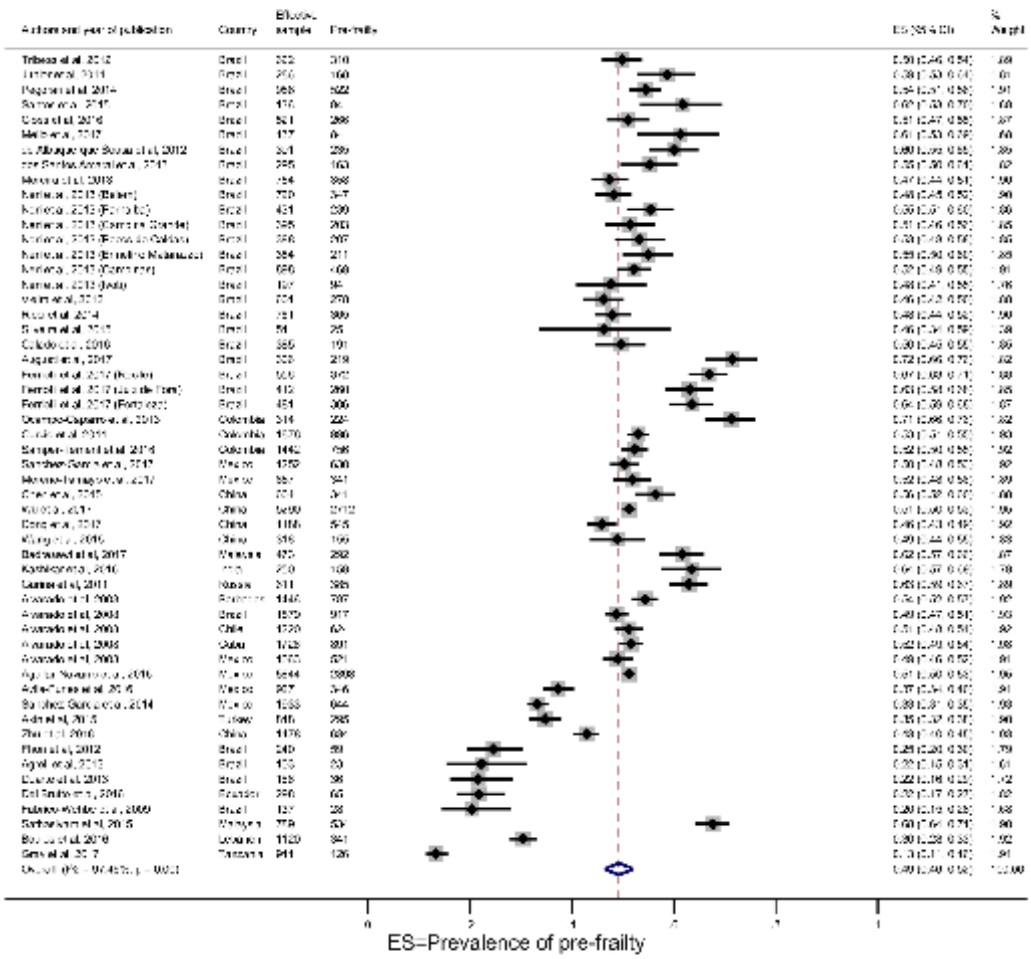

Figure 4 Random-effects pooled prevalence of prefrailty among community-dwelling older adults in LMICs. ES, effect size; LMICs, low-income and middle-income countries.

Studies included in our review were predominantly from Latin America and the Caribbean and belong to the countries with upper middle-income economies, with little representation of lower middle-income and low-income countries. A recent meta-analysis in Latin America and Caribbean showed consistent findings to our study, with nearly one out of five older adult defined as frail.[37]

We found lower prevalence rates when we restricted the meta-analysis only to the Fried phenotype with five criteria, including objective measures of weakness and slowness. This found a pooled prevalence of frailty of 12.7% and prefrailty of 55.2%. The review on frailty and prefrailty which included only HICs has simply reported the weighted prevalence of frailty and prefrailty.[15] Given the heterogeneity of the studies along with the actual differences of frailty estimates in different populations, we performed a supplementary analysis for a fair comparison of frailty estimates between HICs and middle-income countries (no studies were available from low-income countries using the same frailty assessment method). Results indicated significantly higher prevalence of frailty and prefrailty among community-dwelling older adults in middle-income countries compared with the HICs. Another review of the prevalence of frailty measured by the Fried phenotype based on community-dwelling older adults ≥ 65 years in nationally representative samples reported lower prevalence to our estimate except in the countries of Southern Europe (France, Italy, Greece and Spain).[38] Lower prevalence of frailty is also observed in high-income Asian countries (Japan, Singapore and Taiwan).[36 39–41]

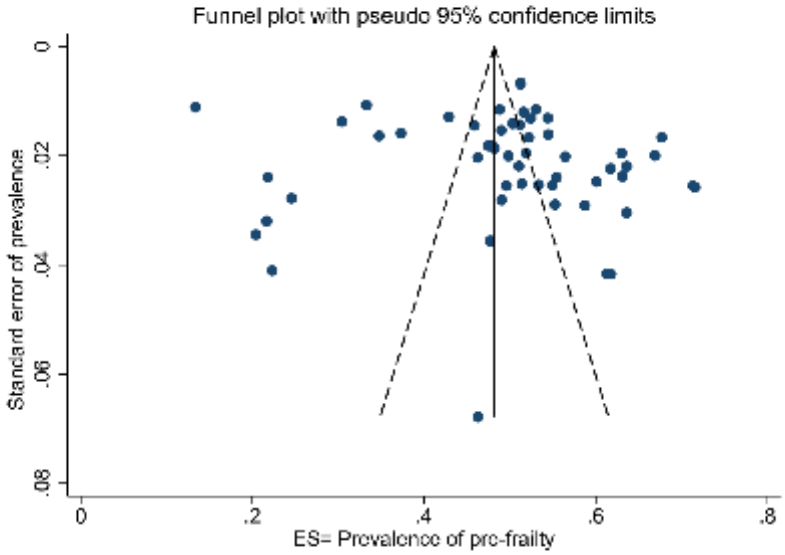

Figure 5 Funnel plot for assessing publication or other types of biases in meta-analysis of prevalence of prefrailty. ES, effect size.

In contrast to these findings, a single multicountry study conducted with data from 14 HICs in Europe and six LMICs (China, Ghana, India, Mexico, Russian Federation and South Africa) reported higher frailty level (high mean frailty index) in HICs compared with the low-income countries.[34] This study included nationally representative samples of adults aged ≥50 years. They also found an inverse association between level of frailty and income and education in both HICs and low-income countries. Individuals with poor education and low income were more likely to be frail. Higher levels of frailty in HICs could be due to the higher survival rate of participants with advanced healthcare and social protection. On the other hand, as the frailty index is based on a list of deficits including diagnosed diseases, many medical conditions could be under reported/diagnosed in the participants in LMICs. Similarly, in most LMICs where access to continued care is lacking, maintenance of medical records are poor making it difficult to use cumulative deficit models.

In our study, even among the studies using Fried phenotype with objective criteria, there was considerable variation in operationalising the five phenotypic criteria. Furthermore, the approach to deriving frail cut-offs for weakness, slowness and physical activity criteria were varied. Of thirty studies, 17 have calculated their population specific cut-offs based on the anthropometry of their own study populations. Eight studies have used the cut-offs developed by Fried *et al* in the Cardiovascular Health Study (CHS).[4] The pooled prevalence of frailty is higher with the studies that used CHS cut-offs compared with the studies that used own population specific cut-offs. However, the pooled prevalence of prefrailty was similar in both groups. Similarly, the number of deficits used in frailty index and cut-off points for defining frailty and prefrailty status were inconsistent.[42–44] A further meta-analysis with all available studies including both higher and the lower and middle-income countries would be valuable, controlling for frailty assessment method, sex and age composition of the sample. In addition, methodologically comparable studies across countries are required to study the true population difference of frailty.

Strengths and weaknesses

This is the first systematic review and meta-analysis on prevalence of frailty and prefrailty among community-dwelling older adults in LMICs. The strengths of our study include we conducted a comprehensive literature search in six electronic databases with a comprehensive search strategy, including WHO Global Health library to capture studies published regionally. No language restriction, subgroup analysis of prevalence of frailty and prefrailty with substantial number of studies, and using a meta-regression technique to identify the sources of heterogeneity between the studies, contacting authors to get the additional information of the studies required for subgroup analyses were also strengths.

Both funnel plot asymmetry and the results of the Egger's weighted regression test indicated the presence of reporting biases and/or between study heterogeneity in the random-effects meta-analysis of frailty. The nature of our study effect (prevalence) is unlikely to be affected by publication bias. However, publication bias could also be affected by study size, funding source or research

Table 2 Univariable and multivariable meta-regression results

Characteristic	Univariable analysis				Multivariable analysis			
	No of estimates	β (95% CI)	P value	Adjusted R^2 (%)	No of estimates	β (95% CI)	P value	Adjusted R^2 (%)
Mean age, years (per unit increase)	41	0.003 (−0.012 to 0.018)	0.665	−2.48	41	0.003 (−0.009 to 0.017)	0.570	58.41
Percentage of women in the sample (per unit increase)	53	0.002 (−0.001 to 0.007)	0.190	0.96	41	−0.000 (−0.004 to 0.004)	0.962	
Study quality assessment score (per unit increase)	53	−0.007 (−0.046 to 0.031)	0.697	−1.77	41	0.015 (−0.020 to 0.051)	0.379	
World Bank region classification (*Reference: Latin America and the Caribbean*)	38			19.96	29			
East Asia and Pacific	11	−0.138 (−0.212 to −0.063)	0.001		8	−0.105 (−0.177 to −0.033)	0.005	
Europe and Central Asia	2	0.014 (−0.144 to 0.173)	0.856		2	0.068 (−0.051 to 0.189)	0.252	
South Asia	2	−0.051 (−0.217 to −0.114)	0.535		2	0.001 (−0.129 to 0.132)	0.982	
Frailty assessment method (Reference: frailty phenotype with five criteria, weakness and slowness assessed using objective tests)	23			47.11	20			
EFS	6	0.222 (0.124 to 0.319)	0.000		6	0.215 (0.120 to 0.309)	0.000	
Frailty index	4	0.053 (−0.041 to 0.149)	0.264		2	0.171 (0.056 to 0.286)	0.005	
Fried phenotype with four criteria	13	0.026 (−0.037, to 0.089)	0.410		12	0.032 (−0.035 to 0.100)	0.342	
Fried phenotype with five criteria, weakness and slowness assessed using self-reported questions (subjective)	7	0.206 (0.129 to 0.283)	0.000		1	0.223 (0.065 to 0.382)	0.007	

EFS, Edmonton Frail Scale.

group.[27] We noted that majority of the studies included in our meta-analysis have large samples. Multiple sources have been identified that could affect funnel plot asymmetry including reporting biases (publication bias, selective outcome reporting and selective analysis reporting), poor methodological quality, true heterogeneity, artefactual and chance.[25 26] In our case, we believe that the funnel plot asymmetry is mainly due to the true heterogeneity between the studies mainly because of the use of different frailty assessment methods. And also, it is possible to have a true underlying difference of frailty prevalence in different populations. Another limitation of this study was non-inclusion of grey literature.

Implications for practice

The findings of the study suggest that the prevalence of frailty appears higher among community-dwelling older adults in upper middle-income countries compared with HICs. One study was identified from low-income countries and two studies from a lower middle-income country. Despite evidence that populations are rapidly ageing in many of these countries, we do not currently know the prevalence of frailty in these populations to inform health and social care planning. Research is required from low-income and lower middle-income countries with rapidly ageing populations to estimate burden of frailty and to understand how frailty affects the day-to-day lives of older people. Furthermore, a consensus is required on methods of assessing frailty to allow for more robust comparisons across populations.

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Contributors DDS, KRW and GR: conceived the idea of this systematic review. DDS: designed, conducted the study and drafted the manuscript. SH: was the secondary reviewer of the systematic review and involved with screening, data extraction, study quality assessment, data analysis and provided important intellectual facts to revise the manuscript. KRW, GR and MCW: provided important feedback at various stages of the study; devised the protocol, resolved the disagreements between DDS and SH at the study selection process, clarified the issues related to study quality assessment and interpreted the findings and provided important intellectual facts to revise the manuscript.

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Paper 2

PLOS ONE

RESEARCH ARTICLE

Cross-cultural adaptation and psychometric evaluation of the Sinhala version of Lawton Instrumental Activities of Daily Living Scale

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Abstract

Introduction

Instrumental activities of daily living (IADL) are cognitively complex activities related to independent living in the community. Robust IADL scales are needed, however the psychometric properties of instruments have been little evaluated. There is no validated instrument for Sri Lankan older populations. Sri Lanka has the highest proportion of older people in South Asia with rapid population ageing. Therefore, it is essential to have standard instruments to assess activity limitations. We aimed to cross-culturally adapt the original Lawton Instrumental Activities of Daily Living Scale from English to Sinhala and evaluate the psychometric properties of the Sinhala version.

Methods

Cross-cultural adaptation of the instrument was performed. The instrument was validated in a sample of 702 community-dwelling older adults aged 60 years and above in Sri Lanka. Reliability (internal consistency and inter-rater reliability) was assessed. Construct validity of the scale was evaluated by performing exploratory and confirmatory factor analysis and testing convergent and divergent validity.

Results

The Lawton IADL scale was successfully adapted to Sri Lankan context. Internal consistency of the scale was very high (Cronbach's alpha = 0.91). Very good inter-rater reliability was observed with very good agreement for all items. Inter-class correlations for overall IADL score ranged from 0.57 to 0.91. Results of the exploratory and confirmatory factor analyses supported the unidimensionality of the scale. Goodness of fit indices in confirmatory factor analysis were in acceptable range (CFI = 0.98, SRMR = 0.06, NNFI = 0.97).

Strength of associations were significant and in the expected direction. Results of the known group validity were also significant, confirming the convergent and divergent validity.

Conclusion

The Lawton IADL scale was successfully translated and culturally adapted to Sinhala language. The Sinhala version demonstrated excellent reliability and construct validity. Given good psychometric properties, this scale would be recommended for use in future research.

Introduction

'Activities of daily living' measurement instruments are commonly used to assess the activity limitations. Two types of activities are assessed; Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL). BADL are cognitively less complex self-maintaining tasks which include feeding, dressing, bathing, toileting, etc. They do not require attentional processes. Conversely, IADL are more complex and require higher level cognitive functions such as memory, attention and executive functions [1, 2]. Example IADL tasks are food preparation, housekeeping tasks, taking own medication, handling finances etc. These activities are important to lead an independent life [3]. IADL limitations often present with mild cognitive impairment and early dementia [4].

A number of questionnaires are available to assess IADL [3, 5], however, no gold standard exists [5]. One of the most widely used is the Lawton Instrumental Activities of Daily Living Scale developed in 1969 [2, 6]. A few modifications to the original scale are also available in the literature; modified Lawton- Brody scale proposed in 1988 [7], Lawton IADL scale in MFA (Multidimentional Functional Assessment of Older Adults) [8] and Lawton IADL scale in MAI (Multilevel Assessment Instrument) [9]. At present no agreement on the quality of IADL questionnaires exists. Moreover, the psychometric properties of commonly used IADL questionnaires are either unavailable or do not meet the standard quality [3].

Cultural adaptability, reliability and validity of the original [10–13] and Lawton IADL scale in MAI [14] have been tested in older populations (aged ≥60 or ≥65 years) in studies conducted in Iran, Spain, Greece, Singapore and Hong Kong. Study populations included patients with dementia [10], outpatients of memory clinics [12], patients who attended emergency rooms in with a hip or wrist fracture due to a fall [11], institutionalized older adults [14] and community living older adults [13].

We found three studies reporting IADL in Sri Lankan older adults [15–17]. However, none of the studies reported use of standard questionnaire to assess IADL, and instead used a few selected IADL tasks. Only four IADL tasks have been assessed in two studies [15, 16] and six in the remaining study [17]. We could not identify any culturally adapted, psychometrically tested instrument available to assess instrumental activities of daily living in Sri Lanka. It is important to have a standard instrument for this purpose as Sri Lanka has the highest proportion of older adults among South Asian countries [18] and considered as one of the fastest ageing populations in the South East Asia [19]. IADL limitations are associated with both poor quality of life [20] and increased healthcare costs [21]. Understanding the current IADL limitations of older adults in Sri Lanka using a robust standardised measure will inform planning of health and social care services with anticipated rapid population ageing. Therefore, the objective of this study was to cross culturally adapt the original Lawton Instrumental Activities of

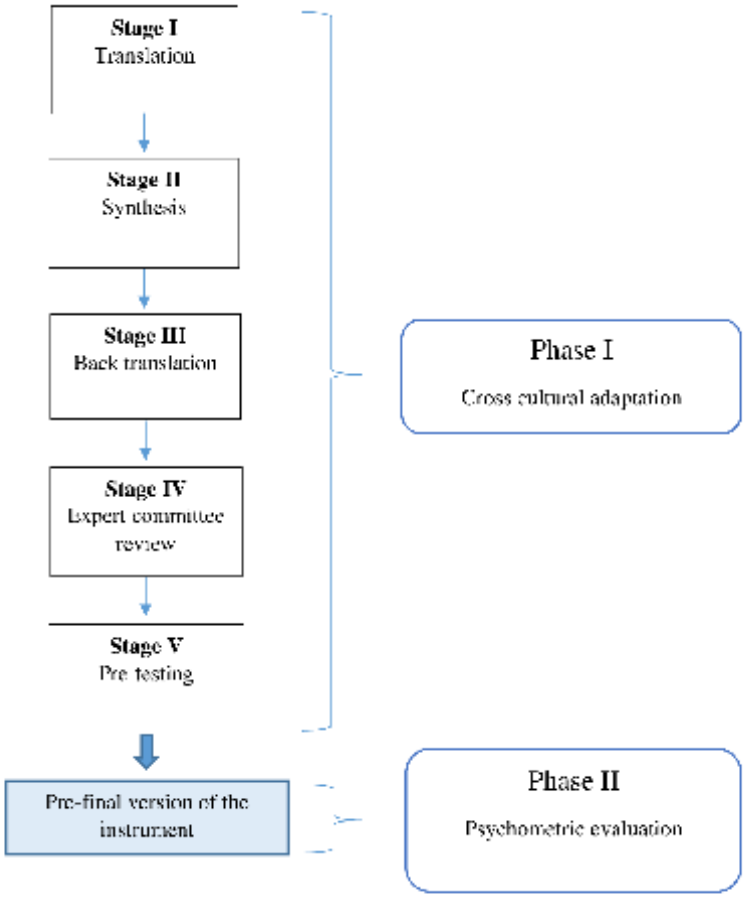

Fig 1. Study methodology.

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Daily Living scale from English to Sinhala and to evaluate the psychometric properties of the Sinhala version.

Materials and methods

The methodology of this study comprised of two phases. Phase one involved cross cultural adaptation of the Lawton IADL scale. Phase two was evaluating the psychometric properties of the scale which included testing the reliability (internal consistency and inter-rater reliability) and validity (cross-cultural validity, structural validity, convergent and divergent validity). Fig 1 illustrates the study methodology.

Lawton Instrumental Activities of Daily Living Scale

We choose the original Lawton IADL scale for this study [2] (please see S1 File). It is a widely used instrument to measure IADL of older adults in different settings; community, clinics or hospitals [6]. Moreover, it is easy to administer (within 10–15 minutes). Most newer scales have also been derived from the original Lawton IADL scale [5]. The scale encompasses eight activities which includes ability to use telephone, shopping, food preparation, housekeeping, laundry, transport, ability to handle finances and responsibility for own medication. Each activity has varying number of response options indicating participant's degree of ability to perform each activity starting from completely independent status to completely dependent status. Despite having number of responses under each activity, participants are classified into two categories as 1 (independent) and 0 (dependent) during the scoring. The total score of the scale ranges from 0 (dependent) to 8 (independent). Historically women were scored on all the items of the scale and men were scored for only five items of the scale excluding the food preparation, housekeeping and laundering activities. However, the current recommendation is to assess all activities with both sexes [22].

The original scale uses the self-repot/surrogate report 'actual performance' question stem, and later versions offered options of assessing self-repot/surrogate report 'actual performance' and 'capacity'. We decided to use the self-reported 'capacity' question stem with the items and response structure of the original scale as in the Sri Lankan cultural context older adults are often supported by their own children and relatives. According to the recent census 17% of adults aged 60 years and above live with their own children [23]. Hence, some are not fully engaged doing certain IADL activities like housekeeping, shopping, preparing meals, handling finances even though they are fully capable of those. Sri Lanka is a country with good gender equality and we therefore used all the items in the scale with both males and females. Permission was granted from Oxford University Press to translate and republish the original scale in Sinhala language.

Phase I- Cross cultural adaptation process

We used the systematic method proposed by Beaton and colleagues [24] for the cross cultural adaptation of self-reported measures.

Stage 1- Forward translation: Two independent bilingual translators who have a background in public health (DDS) and community medicine (MCW) translated the English version of entire instrument into Sinhala. The mother tongue of the both translators were Sinhala. They independently recorded the issues they had while translating the instrument.

Stage 2- Synthesis of the translations: A common Sinhala version of the instrument was created using the two independent translated versions.

Stage 3-Back translation: The synthesis version created at the second stage was used for back translation process. Two translators (TW, SJ different to stage 1 translators) who are fluent in both English and Sinhala languages conducted the back translations independently. Both were blind to the original instrument or original independent translated versions. Two back translated versions were compared with the original English version of the instrument for a validity check.

Stage 4- Expert committee review: A panel of experts from medical, allied health science, sociological backgrounds and translators (forward and backward) reviewed the two forward translations, two backward translations with the original scale. Consultations were conducted in person or using digital technology. MCW coordinated this stage. Semantic,

idiomatic, experiential and conceptual equivalence of the instrument were discussed at these meetings. Any issues raised were addressed and a preliminary version of the instrument was created and circulated among the review members.

Stage 5- Pre-test: The preliminary version of the instrument was pre-tested with five male and female older adults in different age categories living in the district where the psychometric testing was planned. The pre-final version of the instrument was created to use in the psychometric evaluation.

Phase II- Psychometric evaluation

Study design and participants. Psychometric evaluation; reliability and validity testing of the instrument was carried out as part of a large population based cross sectional study conducted in a district of Sri Lanka (Kegalle). The study population was community dwelling older adults, aged 60 years and above permanently residing in the rural sector of the district. Older adults who were unable to give the informed consent; older adults with severe dual hearing and vision impairment, aphasia following a stroke, severe stages of dementia, and those with unstable severe mental illnesses and terminally ill were excluded. The estimated sample size was 750 participants. Three-stage area probability sampling was utilized to recruit the participants. Fifty clusters were selected using probability proportionate to size technique covering entire district. Fifteen participants were recruited from each cluster based on the population demographics of rural sector of Sri Lanka [25]. According to the scale of sample size adequacy by Comrey and Lee (1992) sample of 500 considered as very good where 1000 or more considered as excellent in Exploratory Factor Analysis (EFA) [26] Five nursing graduates collected the data from the entire sample. They were given a comprehensive training on all aspects of the study. Participation for the study was voluntary and informed written consent was obtained from all the participants prior to collect data. The ethical clearance for this study was obtained from two ethics review committees at University College London (Project ID: 8155/001) and Faculty of Medicine, University of Colombo, Sri Lanka (Protocol No. EC-16-071).

Data analyses: Participants' characteristics and distribution of Lawton IADL scale-Sinhala version scores. The characteristics of the study sample was described with descriptive statistics. The eight items of the scale were coded to preserve the original response structure as they do not have uniform response structure (ability to use telephone (1–4), shopping (1–4), food preparation (1–4), housekeeping (1–5), laundry (1–3), transport (1–5), responsibility for own medication (1–3) and ability to handle finances (1–3). The minimum number represents the response indicating complete dependent status for each item whilst the maximum number represent the response indicating highest independent status. However, when assigning scores according to the guidelines of the scale, response for each item was coded either as 0 (dependent) or 1 (independent). Hence, the total score of the scale ranges from 0 to 8.

Reliability testing. We assessed internal consistency (the extent to which different items measured the same construct [27, 28]) using standardized Cronbach's alpha (as scale items do not have uniform response structure) and interpreted the same using the criteria proposed by Nunnally [29].

We assessed inter-rater reliability (IRR) [28] in a randomly selected 12% of the total sample (n = 89), representing 26 clusters. The number of participants recruited from each cluster varied from 1–5 with the modes of 3 and 4. Research assistants (5 raters) administered the IADL scale. After a gap of 2.5 to 3 hours the primary investigator (PI- DDS) re-administered the scale with the same participants. Therefore, each participant has been assessed by two raters (A/B/C/D/E and DDS).

We assessed the IRR of the each individual item considering its original response structure (ordinal) and after scoring (binary). Participants with missing values were excluded. For ordinal case, inter-rater reliability was calculated using unweighted percentage agreement coefficient, quadratic weighted Cohen's kappa and Gwet's AC_2 with quadratic weights [30]. For binary case unweighted percentage agreement coefficient, Cohen's kappa and Gwet's AC_1 were used. Both Gwet's AC_1 and AC_2 agreement coefficients are corrected for chance agreement and adjusted for misclassification errors. Moreover, they are consistent with the percentage agreement [31]. Values of Cohen's kappa, Gwet's AC_1 and AC_2 were interpreted using criteria proposed by Landis and Koch [32]. Intra Class Correlation (ICC) was used to assess the agreement of the overall score of the scale between each rater and the PI. Single rating, absolute agreement, two way mixed effects model was used [33]. All the agreement coefficients and ICCs were computed using *kappaetc* user written Stata programme. Stata version 14 (StataCorp, College Station, Texas, USA) was used for the analyses. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) proposed by Kottner et al were followed [34].

Validity testing. We assessed the construct validity of the IADL scale, including cross cultural validation (as above), structural validation (using factor analysis [28, 35]) and hypothesis testing [36] to establish the convergent and divergent validity of the scale [37, 38].

Exploratory factor analysis (EFA) explores the underlying factor structure of a construct [39, 40]. We performed EFA with 702 participants to test the hypothesis that the scale is unidimensional i.e. the 8 items in the scale represents one construct (instrumental activities of daily living). Original response structure of the scale was used in the analysis. Parallel analysis (PA) was run to determine the number of factors to retain in the model. PA was carried out on polychoric (two step) correlations with permuted samples, using principal component estimation and mean eigenvalue criterion [41]. Principal axis factoring was chosen as the factor extraction method because our data is ordinal and it violates the assumption of multivariate normality [40]. Principal axis factoring is also capable of detecting weak factors [42]. The Kaiser-Meyer-Olkin (KMO) statistic and Bartlett's test of sphericity were used to determine the appropriateness of running the factor analysis. KMO values varies from 0 to 1 and values >0.5 are acceptable [43]. Bartlett's test requires to yield significant result ($p<0.05$). Communalities $\geq$0.4 and factor loadings $\geq$ 0.5 were considered as satisfactory [39]. The analysis was performed on the polychoric (two step) correlations using SPSS R-menu v2.0 [44].

Confirmatory factor analysis (CFA) was performed to explore whether the observed data fit hypothesised factor structure of the IADL scale. Analysis was performed with the original response structure. To accommodate the ordinal response structure of the scale items, CFA was performed on asymptotic covariance matrix that calculated using the polychoric correlations. Diagonally weighted least square technique was used as the estimation method, recommended use when fitting structural equation model with ordinal variables [45]. Several goodness of fit indices were evaluated to determine the model fit. Evaluated fit indices include chi-square value (Satorra-Bentler scaled chi-square) with its degrees of freedom and associated p value, Relative/normed (χ^2/df) chi-square, Root Mean Square Error of Approximation (RMSEA), Non-Normed Fit Index (NNFI)/ Tucker Lewis Index (TLI), Comparative Fit Index (CFI), Standardised Root Mean Residual (SRMR) and Parsimonious Normed Fit Index (PNFI). Insignificant chi square at a threshold of 0.05 is indicative of good model fit [46]. No consensus is available for the acceptable ratio of relative chi-square. Wheaton et al suggested a value of 5.0 [47]. For RMSEA Tuker and Lewis [48] suggested a cut-off of 0.06 whereas Steiger [49] proposed a strict upper limit as 0.07. For NNFI and CFI cut-off value of $\geq$ 0.95 accepted as good model fit [48, 50]. For SRMR a value of $\leq$ 0.08 considered as appropriate [50]. No threshold level has been specified for PNFI. CFA was performed on LISREL 9.30 student edition.

Historically Lawton et al (1969) proposed using the full scale (8 items) with females and five items (excluding food preparation, housekeeping and laundry) for males [2]. However, they had not checked the structural validity of IADL scale on this aspect. Therefore, we performed both EFA and CFA for females and males separately including all items.

The Barthel index of daily living measures the disability or dependence in basic activities of daily living, which are cognitively less complex tasks than IADL. [51]. Mild cognitive impairment is also associated with impairments in IADL [52]. Montreal cognitive assessment (MoCA) is a brief screening tool for mild cognitive impairment [53]. To assess the convergent validity, we hypothesised that IADL score is positively correlated with Barthel index score and MoCA score. Spearman's correlation coefficient was used to quantify the magnitude of the correlation. We used following criteria to interpret the size of the correlation coefficients; (0 to ±0.3) negligible, (±0.3 to ±0.5) low, (±0.5 to ±0.7) moderate, (±0.7 to ±0.9) high and (±0.9 to 1.0) as very high correlation [54].

We used known group validity method to assess the divergent validity of the IADL scale. Advanced age is associated with the limitations of IADL [55]. Therefore, we hypothesised lower IADL scores for older age groups. The participants of this study were divided into two groups based on the median age of the sample. Median IADL score of the two groups were tested using Mann-Whitney U non-parametric test since our IADL score does not follow a normal distribution. The significance level was set as 0.05. Both analyses performed using IBM SPSS 24 software (SPSS INc., Chicago, IL, USA).

Results

Cross cultural adaptation of Lawton IADL scale

Stage 1- Forward translation was performed as planned. Both forward translators encountered following issues. The last response for the item 1- 'Ability to use telephone', in the original scale is 'does not use telephone at all'. We felt that this response can be interpreted in different ways. A person could be not using a telephone at all since he/she does not have a one or incapable of using it. Incapability could be due to an impairment or the person has never used it before and have no skills to use it. The same issue was noted for the last response of item 6-'Mode of transportation'. Both translators were uncertain about the identical Sinhala word to 'instrumental'.

Stage 2- PI prepared the synthesis version with the aid of both Sinhala versions.

Stage 3- Backward translation was also carried out as planned. Both backward translated versions showed good agreement with the original English version.

Stage 4- By considering the issues raised in the forward translation process (stage 1), panel of experts agreed to replace the last response of item 1 with the meaning of 'incapable of using the telephone at all' in Sinhala. However, they acknowledged that still the response could not be applicable to a person who has never used a telephone. Hence, the suggestion was to ask whether they have ever used a telephone if their response is 'incapable of using the telephone at all' and make a note in the questionnaire. Similarly the last response for item 6 ('does not travel at all') was replaced from 'incapable of travelling at all'. Example apparels used in the second response of item 5-'Laundry' were replaced from 'socks' and 'stockings' to 'small hanker chief' and 'small towel', as more relevant to Sri Lankan older adults living in tropical climate. Example activities used in the final item-'ability to handle finances' were 'budgets, writes checks, pays rent, bills, goes to bank'. They were replaced from making a payment for electricity or water bill and doing bank transactions. We could not find an

identical Sinhala word for the word 'instrumental'. Therefore, we substituted that word to 'non-basic' in Sinhala.

Stage 5- No difficulties were encountered in pre-testing and the IADL Sinhala version and showed good acceptability.

Psychometric evaluation of Lawton IADL scale-Sinhala version

Socio-demographic characteristics of the study participants. Data collection was conducted from 03rd October to 23rd December 2016. Seven hundred forty six participants were recruited for the study. Twenty three participants were excluded as they are not fully conversant in Sinhala language. Twenty one participants were excluded as they had never used a telephone and/or were completely unaware of how to cook. Five males and eight females had never used a telephone. Seven males were unaware of how to cook. One male participant was excluded for both reasons. Therefore, the effective sample was 702.

A sub sample from Sinhala speaking participants was invited to test the IRR. Six participants invited were excluded when testing for IRR. Of the six, two had not used a telephone ever and response for one item in the scale was missing for four participants in the PI's dataset. Fig 2 demonstrates the study flow chart.

Table 1 presents the socio-demographic characteristics of study sample (n = 702) and the sub sample used to test IRR (n = 83). The percentage of the females in the study sample was 53.7%. The median (IQR) age of the sample was 67 (63, 75) years. The age of the participants ranged from 60 years to 94 years. The median (IQR) age of the sub sample used to test IRR was 68 (63, 73) years. The age of the participants was ranged from 60 years to 91 years.

Distribution of Lawton IADL scale-Sinhala version scores. The frequency distribution of the responses for each item and overall score are presented in S1 and S2 Figs respectively. A negatively skewed distribution was observed for responses of all the items and overall score. Table 2 presents the median and inter quartile range for the scores of each item. None of the items' or total score distributed normally.

Internal consistency and Inter-rater reliability. The internal consistency of the scale with 8 items assessed by Cronbach's alpha was 0.918. Cronbach's alpha if an item deleted is presented in the Table 3.

Table 4 presents the unweighted percentage agreement coefficient, weighted Cohen's kappa and Gwet's AC_2 agreement coefficient for each item according to the responses in the original scale. Relatively low absolute percentage agreement was observed for the 'Housekeeping' item between PI and all five raters compared with the other items. However, for all the items primary investigator had a satisfactory absolute/unweighted percentage agreement coefficient ranged from 0.62 to1.00, poor to excellent weighted Cohen's kappa (0.00 to 1.00) and substantial to almost perfect Gwet's AC_2 (0.62 to 1.00) agreement coefficient with all raters. Interestingly, weighted Cohen's kappa was not computed when the percentage agreement too high or too low indicating the 'kappa paradox'[56]. Please refer S1 Table for IRR for each item after scoring as binary. Rater A, C, and D showed ICC values above 0.8 indicating an excellent reliability. In overall, ICC values for all the raters were above 0.5 and indicate moderate to excellent reliability [33].

Exploratory factor analysis. Kaiser-Meyer-Olkin measure of sampling adequacy was 0.898 which is considered a 'very good' value [57]. The Significance value of Bartlett's test of sphericity was <0.001, indicating that the correlations between the items were significantly different from zero. Results of the parallel analysis suggested to extract one factor (Fig 3), indicating the unidimensionality of the scale. The first factor explained 79.4% of the total variance. As

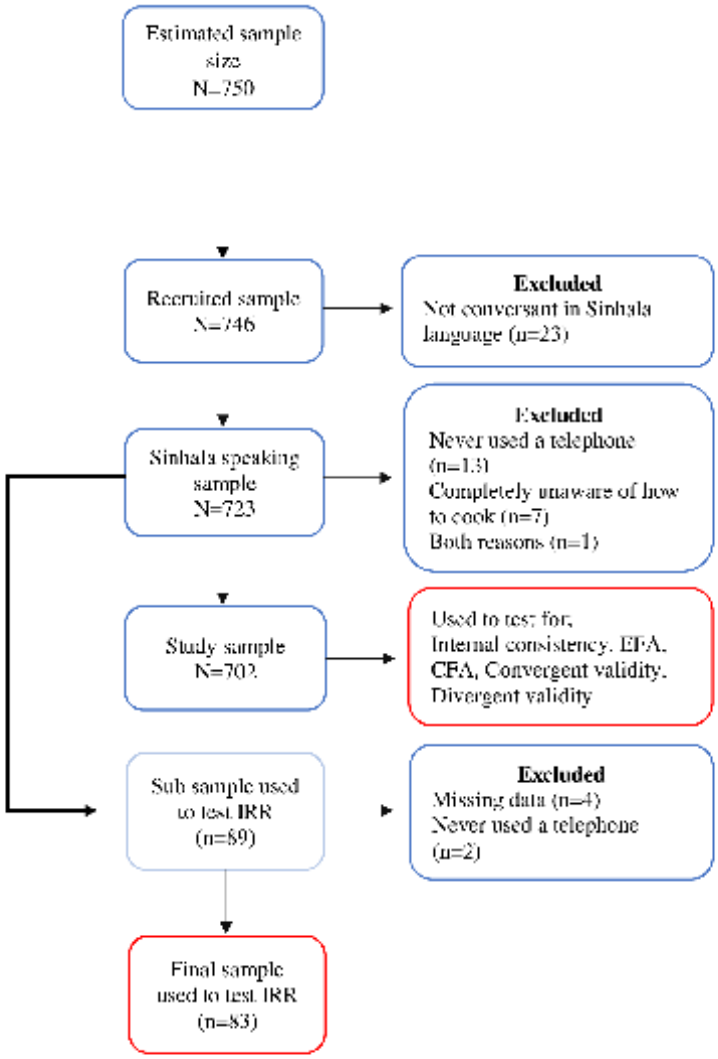

Fig 2. Study flow chart.

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shown in Table 5, the communalities of 8 items varied from 0.392 to 0.903 and factor loadings were varied from 0.626 to 0.950. Item scale correlation (corrected) for all the items were above 0.7 except for item 1. The polychoric (two step) correlations matrix is available in S2 Table.

EFA results by sex also showed a stable item structure (8 items) across both females and males. Parallel analysis suggested to extract one factor in both cases (S3 and S4 Figs). The

Table 1. Socio-demographic characteristics of the study participants.

Characteristics		Study sample n (%)	Sub sample used to test IRR n (%)
Sex	Male	325 (46.3)	30 (36.1)
	Female	337 (53.7)	53 (63.9)
Age category (years)			
	60–64	238 (33.9)	28 (33.7)
	65–69	189 (26.9)	22 (26.5)
	70–74	91 (13.0)	15 (18.1)
	75–79	91 (13.0)	6 (7.2)
	≥80	93 (13.2)	12 (14.5)
Marital status			
	Never married	33 (4.7)	7 (8.4)
	Married	427 (60.8)	43 (51.8)
	Separated	12 (1.7)	2 (2.4)
	Divorced	5 (0.7)	1 (1.2)
	Widowed	223 (31.8)	30 (36.2)
	Cohabiting	2 (0.3)	-
Living arrangement			
	With spouse	79 (11.3)	11 (13.3)
	With children/other family	580 (82.6)	65 (78.3)
	Alone	43 (6.1)	7 (8.4)
Educational status			
	Never schooled; unable to read and write	31 (4.4)	2 (2.4)
	Never schooled; able to read and write	3 (0.4)	1 (1.2)
	Passed Grade 1–5 (1–5 years)	163 (23.2)	22 (26.5)
	Passed Grade 6–10 (6–10 years)	246 (35.0)	29 (35.0)
	Passed G.C.E. O/L (11 years)	181 (25.8)	24 (28.9)
	Passed G.C.E. A/L (13 years)	60 (8.6)	5 (6.0)
	Higher education (16 years minimum)	18 (2.6)	-
Perceived financial status*			
	Finding it difficult/very difficult	140 (20.0)	15 (18.1)
	Just about getting by	380 (54.1)	48 (57.8)
	Living comfortably	182 (25.9)	20 (24.1)

*Using a question of Weich and Lewis (1998) (Weich S, Lewis G. Poverty, unemployment, and common mental disorders: population based cohort study. BMJ. 1998;317(7151):115.)

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percentage of variance explained by the first factor was 80.2% for females and 81.5% for males. The communalities of 8 items varied from 0.357 to 0.934 and 0.421 to 0.925 for females and males respectively. The factor loadings were varied from 0.598 to 0.966 for females and from 0.649 to 0.962 for males. The polychoric (two step) correlations matrixes by sex are available in S3 and S4 Tables. Please refer S5 Table for additional results.

Confirmatory factor analysis. CFA results are presented in Table 6. The measurement model with standard factor loadings and uniquenesses are presented in S5 Fig. Standardized factor loadings were ranged from 0.660 to 0.958. Values of goodness of fit indices; NNFI, CFI and SRMR were in acceptable range indicating an excellent model fit. However, the chi-square value was significant, χ^2 (20, 702) = 144.42, p <0.001. The value of relative chi-square (χ^2/df) was 7.22 and not in the acceptable range. Similarly, RMSEA value was too high and neither in acceptable range.

Table 2. Item descriptive statistics of IADL scale-Sinhala version.

Item	Item description	Min, Max	Median (IQR)	Dependent n (%)	Independent n (%)
Item 1	Ability to use telephone	1,4	4 (2,4)	73 (10.4)	629 (89.6)
Item 2	Shopping	1,4	4 (4,4)	146 (20.8)	556 (79.2)
Item 3	Food preparation	1,4	4 (4,4)	139 (19.8)	563 (80.2)
Item 4	Housekeeping	1,5	5 (5,5)	39 (5.6)	663 (94.4)
Item 5	Laundry	1,3	3 (3,3)	36 (5.1)	666 (94.9)
Item 6	Mode of transportation	1,5	5 (5,5)	56 (8.0)	646 (92.0)
Item 7	Responsibility of own medication	1,3	3 (3,3)	90 (12.8)	612 (87.2)
Item 8	Ability to handle finances	1,3	3 (2,3)	55 (7.8)	647 (92.2)
	Overall IADL score	0,8	8 (7,8)		

IQR- Inter quartile range

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In CFA by sex, standardized factor loadings were ranged from 0.645 to 0.973 and from 0.673 to 0.981 for females and males respectively. All the goodness of fit indices except chi-square, and RMSEA were in the acceptable range for both sexes. Please refer S6 and S7 Tables for additional results.

Item 1 (ability to use telephone) consistently demonstrated low communality, factor loading and item-scale correlation in EFA and low standardized factor loading in CFA. Furthermore, Cronbach's alpha was slightly higher when item 1 was deleted from the scale (see Table 3). This finding was consistent even in the sex stratified analysis.

Convergent validity. The Spearman's correlation coefficients between Lawton IADL score and the scores of Barthel index and MoCA were 0.61 and 0.41, indicating a moderate and low strength of association respectively. Both correlation coefficients were significant at $p<0.001$.

Divergent validity. The median age of the sample was 67 years. Therefore, the sample divided into two groups as age ≤67 years and >68 years. The median (IQR) IADL scores for both groups were 8 (0) and 7 (1) (Mann-Whitney U = 37,974, $p<0.001$) demonstrating a lower IADL score in older group as hypothesised.

Discussion

Summary of main findings

The Lawton Instrumental Activities Daily Living scale was successfully translated and culturally adapted to Sri Lankan context. The Sinhala version of the scale demonstrated excellent

Table 3. Cronbach's alpha if an item deleted in IADL scale-Sinhala version.

Item	Item description	Cronbach's alpha if an item deleted
Item 1	Ability to use telephone	0.928
Item 2	Shopping	0.899
Item 3	Food preparation	0.910
Item 4	Housekeeping	0.897
Item 5	Laundry	0.907
Item 6	Mode of transportation	0.902
Item 7	Responsibility of own medication	0.908
Item 8	Ability to handle finances	0.903

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Table 4. Item wise inter-rater reliability with original response structure for Lawton IADL scale-Sinhala version and ICC for overall IADL score.

Item	Item description	PI-A (n = 13)			PI-B (n = 15)			PI-C (n = 17)			PI-D (n = 17)			PI-E (n = 21)		
		p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2	p	κ_w	Gwet's AC_2
Item 1	Ability to use telephone	0.92	0.77	0.87	0.93	0.81	0.90	0.94	0.97	0.98	0.88	0.96	0.96	0.90	0.72	0.92
Item 2	Shopping	0.92	0.75	0.89	0.73	0.70	0.92	0.71	0.50	0.87	0.88	0.93	0.97	0.90	**-0.05**	0.90
Item 3	Food preparation	0.85	0.82	0.93	0.67	**0.00**	0.70	0.71	0.72	0.86	0.82	**0.00**	0.89	0.95	0.64	0.94
Item 4	Housekeeping	0.62	0.32	0.89	0.67	0.65	0.88	0.71	0.51	0.84	0.71	0.20	0.82	0.76	**0.00**	0.91
Item 5	Laundry	Not computed[‡]			0.80	**0.51**	0.85	0.88	0.77	0.96	0.82	**-0.06**	0.89	0.81	**0.00**	0.92
Item 6	Mode of transportation	0.77	0.85	0.88	0.73	0.62	0.81	0.76	0.82	0.89	0.82	0.84	0.92	0.90	**0.48**	0.87
Item 7	Responsibility of own medication	0.92	0.78	0.97	0.93	0.78	0.98	0.94	0.91	0.98	1.00	1.00	1.00	0.95	0.79	0.98
Item 8	Ability to handle finances	0.77	**0.41**	0.62	0.67	0.46	0.84	0.82	0.78	0.91	0.65	0.63	0.81	0.76	0.46	0.91
	Intra Class Correlation (95% CI)	0.91 (0.74, 0.97)			0.62 (0.20, 0.85)			0.89 (0.73, 0.96)			0.88 (0.64, 0.96)			0.57 (0.20, 0.80)		

p- Unweighted percentage agreement coefficient, κ_w—Cohen's weighted kappa. Non-significant agreement coefficients (p > 0.05) and zero agreement coefficients are displayed in bold.

Not computed[‡], since ratings do not vary.

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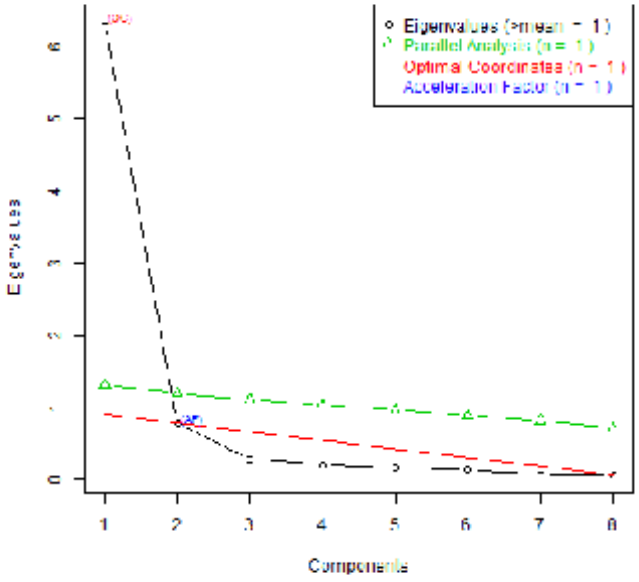

Fig 3. Parallel analysis based on permuted data.

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Table 5. Results of the exploratory factor analysis.

Items	Item description	Exploratory factor analysis*		
		Communality	Factor loading	Item-scale correlation†
Item 1	Ability to use telephone	0.392	0.626	0.503
Item 2	Shopping	0.892	0.944	0.865
Item 3	Food preparation	0.724	0.851	0.724
Item 4	Housekeeping	0.903	0.950	0.883
Item 5	Laundry	0.782	0.884	0.771
Item 6	Mode of transportation	0.848	0.921	0.819
Item 7	Responsibility of own medication	0.787	0.887	0.745
Item 8	Ability to handle finances	0.819	0.905	0.825

†Item total correlation with its own Lawton IADL scale corrected for overlap.

*Fit indices: GFI (ULS) = 0.980, RMSR = 0.063

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reliability and construct validity. Internal consistency of the scale was very high. Satisfactory agreement was observed between PI and the raters for all the items in the scale. With regard to the overall score, ICC values were between 0.57 and 0.91 which is indicative of moderate to very good agreement. Findings of EFA and CFA strongly supported the unidimensionality of the scale. In EFA, communalities and factor loadings for all the items were well above the cut-off values. Similarly all the goodness of fit indices in CFA were in the acceptable range except chi-square and RMSEA. Eight item structure scale was stable across both females and males. Results of the sex stratified EFA and CFA were also consistent with the main analysis. We observed moderate and low positive correlations between IADL score and scores of Barthel index and MoCA respectively. The scale was capable of detecting the difference of overall IADL score between age groups.

Reliability

In line with other studies, Lawton IADL-Sinhala version has demonstrated an excellent internal consistency. Cronbach's alpha coefficient was 0.91. Of all studies Spanish version has demonstrated the highest alpha value of 0.94 [11] whilst 0.86, 0.84 in Hong Kong Chinese (Lawton IADL-CV) and Greek versions respectively [12, 14]. The lowest was observed in the Persian version (Lawton IADL-PV) [10].

Table 6. Results of confirmatory factor analysis.

Items	Item description	Confirmatory factor analysis‡	
		Standardized factor loading	Standard error
Item 1	Ability to use telephone	0.660	0.034
Item 2	Shopping	0.938	0.012
Item 3	Food preparation	0.871	0.021
Item 4	Housekeeping	0.958	0.008
Item 5	Laundry	0.926	0.017
Item 6	Mode of transportation	0.911	0.014
Item 7	Responsibility of own medication	0.873	0.023
Item 8	Ability to handle finances	0.918	0.013

‡Fit indices: RMSEA (90% CI) = 0.283 (0.270–0.297), NNFI/TLI = 0.977, CFI = 0.984, SRMR = 0.06, PNFI = 0.701

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We found ICC values ranging from 0.57 to 0.91 for five raters, with three raters having values above 0.8, in a relatively large sample of 83 participants. The inter-rater reliability of the original scale was 0.85, however this study was with a small sample (n = 12), interviewed by one interviewer in the presence of the second rater who did not participate in the interviewing process [2]. Two further studies have reported the inter-rater reliability, with ICCs of 0.96 [10] and 0.99 [14] in similarly small studies. In the latter, inter-rater reliability was assessed with 9 participants on video-taped IADL abilities, and this method (videos) has been shown to produce higher inter-rater reliability [58].

Unlike our study, none of the prior studies have reported the item-wise inter-rater reliability of the scale. In those studies, ICC was computed based on the total score of the scale. It does not reflect how each rater marked the response for each item based on participant's response.

Validity

EFA results of our study strongly supported the unidimensionality of the scale and corroborate with the existing literature [11, 14]. In our study first factor explained 79.4% variance whilst 70.6% and 50.1% variances explained by the Hong Kong Chinese and Spanish versions correspondingly. Eight item structure has an excellent factorial validity across both sexes [11]. We excluded 8 male participants from the analysis since they were completely unaware of how to cook. However, this was only 2.4% of total males in the sample. In contrast, Ng et al (2006) found two strong factors underlying physical and cognitive domains of IADL in a multi-ethnic Asian population in Singapore [13]. Two factors explained 87.5% of variance. Interestingly, physical IADL domain included 5 items (grocery shopping, getting to places outside the house, doing housework/handyman work, doing laundry and preparing meals) and cognitive domain included remaining three items (using the telephone, taking medications and managing finances).

All the reported goodness of fit indices of CFA (RMSEA, TLI, and CFI) were satisfactory and all factor loadings were significant in the Spanish version [11]. Similarly all the factor loadings were significant in Sinhala version and values of TLI, CFI, and SRMR were in the acceptable range. However, our RMSEA value was not in the acceptable range. One possible explanation could be use of diagonally weighted least square technique estimation. Nye et al showed that RMSEA appears to be affected by sample size [59]. With a sample of 400, they have observed increase of cut-off value for RMSEA whilst SRMR seems to be performing relatively well which is similar to our case. While the chi-square value of our model was significant, this may often be the case with large sample sizes [60] and when data deviate from multivariate normality [61].

We observed a substantially low communality and factor loading for the first item; 'ability to use the telephone' in EFA and relatively low standardized factor loading in CFA. Item one has demonstrated a relatively low inter-item correlation with item 3, 4, and 5. This pattern was consistent across both sexes. Interestingly, we observed the same results for EFA with the Spanish version [11]. A possible reason could be transition of use of land/fixed telephones to the mobile devices. At present, most of the households in Sri Lanka use mobile phones. According to the statistics of Telecommunications Regulatory Commission of Sri Lanka, 12.1 and 122 fixed access and cellular mobile subscriptions per 100 inhabitants were reported respectively in 2016 [62]. Using a telephone does not only require a reasonable cognitive function. It is also affected by the sensory function and fine motor skills particularly when using the mobile phones. Therefore, the patterns of activity limitations assessing here is slightly different to other IADLs. However, it is still measuring something different than the other items as it represents the ability to communicate with the outside world, an important part of ageing well.

The Spearman's correlation coefficient between the scores of Barthel index and Lawton IADL Spanish version was above 0.4 and mean IADL score was significantly different by age [11]. In our study, value of the same correlation was 0.61 and the median IADL scores were significantly different by age. Known group validity results of the Singapore study has also shown significantly different mean IADL scores across different age groups and gradual decrease of the mean IADL score values with increasing age [13]. In line with our findings studies conducted in Greece and Hong Kong also supported the convergent and/or divergent validity of the Lawton IADL scale by means of the strength of associations or known group validity [12, 14].

Strengths of the study

The main strengths of this study were following a comprehensive and rigorous methodology, and using advanced statistical techniques to address the structure and distribution of the data. We performed the psychometric evaluation with a large random sample of Sinhala speaking community dwelling rural older adults. According to the recent census, 99% of Sri Lankan older adults live in the community [23]. In the original validation study, Lawton and Brody (1969) had not explored the factor structure of the IADL scale [2]. Therefore, we performed both EFA and CFA. We adhered to set of guidelines and best practices available in the literature when performing and reporting cross cultural adaptation of instrument, reliability testing, EFA and CFA [24, 33, 34, 39, 63, 64].

Study limitations and recommendations

We excluded 21 participants (<2%) from the study population who reported they had never used a telephone or were completely unaware of how to cook. We could not assess the test-retest reliability and responsiveness of the scale due to inadequate resources available. The limitation of the scale itself is absence of a reference point of time. However, no guidelines exists as to the appropriate choice of reference point of time either [5].

We used the participant's self-reported capacity of performing each activity in our Lawton IADL-Sinhala version as a measure of self-reported efficacy or capacity in performing activities. Some people may over or underestimate their true capacity and this may therefore not reflect the actual performance of these activities. Alternatively a researcher can also use the self-reported 'actual performance' question stem and make notes about not applicable items (where the participant may be capable but does not regularly perform the activity). In our study we used an interviewer-administered questionnaire with the respondent only. In future research self-reported and a key informant reported abilities of performing IADL tasks could also be compared. We have also not specified a reference point of time, instead the scale asks the general ability of performing each activity in day-to-day life.

Conclusions

The Lawton IADL scale was successfully translated and culturally adapted to Sinhala language. The Sinhala version demonstrated an excellent reliability and construct validity with a large representative sample of Sinhala speaking community dwelling older adults. Given good psychometric properties, it is recommended to monitor the limitations of instrumental activities of daily living of community dwelling older adults in Sri Lanka. Lawton IADL-Sinhala version can be found in S2 File.

Supporting information

S1 File. The Lawton Instrumental Activities of Daily Living (IADL) Scale.
(PDF)

S2 File. The Lawton Instrumental Activities of Daily Living (IADL) Scale-Sinhala version.
(PDF)

S1 Fig. The frequency distribution of the responses for each item of the Lawton IADL-Sinhala version.
(PDF)

S2 Fig. The frequency distribution of the overall Lawton IADL score-Sinhala version.
(PDF)

S3 Fig. Parallel analysis results for females.
(PDF)

S4 Fig. Parallel analysis results for males.
(PDF)

S5 Fig. Confirmatory factor analysis model with standardized factor loadings.
(PDF)

S1 Table. Item wise inter-rater reliability when original responses for Lawton IADL-Sinhala version coded as binary.
(PDF)

S2 Table. Polychoric (two step) correlation matrix used in EFA (entire sample).
(PDF)

S3 Table. Polychoric (two step) correlation matrix used in EFA for females.
(PDF)

S4 Table. Polychoric (two step) correlation matrix used in EFA for males.
(PDF)

S5 Table. Results of exploratory factor analysis by sex.
(PDF)

S6 Table. Results of the confirmatory factor analysis by sex.
(PDF)

S7 Table. Goodness of fit indices of confirmatory factor analysis by sex.
(PDF)

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Paper 3

BMJ Open

Prevalence of frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka: a population-based cross-sectional study

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ABSTRACT

Objective Our main objective was to describe the prevalence and associated sociodemographic factors of frailty and pre-frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka.

Design Community-based cross-sectional study.

Setting The study was conducted in rural areas of Kegalle district in Sri Lanka.

Participants A total of 746 community-dwelling older adults aged ≥60 years were included in the study.

Results The prevalence of frailty and pre-frailty in rural Kegalle district was 15.2% (95% CI 12.3% to 18.6%) and 48.5% (95% CI 43.8% to 53.2%), respectively. We found a strong association between age and both frailty and pre-frailty. There were strong associations between longest-held occupation and frailty and education level and pre-frailty.

Conclusions The prevalence of frailty in this rural Sri Lankan older population was high compared with high-income and upper middle-income countries. The profile of health and social care services in Sri Lanka needs to address frailty and its consequences.

Strengths and limitations of this study

- We conducted the first population-based prevalence study on frailty using a representative sample of community-dwelling older adults in rural areas of Kegalle district of Sri Lanka.
- We employed a rigorous methodology and measures were taken to ensure the validity and reliability of data.
- We compared age-adjusted prevalence of frailty in rural Sri Lanka with other Asian countries, and other middle-income countries worldwide.
- Sample only comprised rural older adults and the majority belonged to Sinhalese ethnicity.
- We excluded participants who could not give informed consent (eg, advanced stages of dementia) and were terminally ill. This might have underestimated the true frailty prevalence.

INTRODUCTION

Ageing involves physiological, psychological and social changes that directly affect the health and well-being of older adults. Frailty is an important age-related clinical syndrome commonly defined as a state of increased vulnerability to external stressors as a consequence of cumulative decline in many physiological systems during a lifetime.[1 2] It is widely recognised as a key issue for ageing populations worldwide, as it is associated with multiple adverse outcomes including hospitalisation, institutionalisation/dependency and premature mortality.[3]

Asia is home for the dominant share of the world's population[4] and will become the region with the largest population of older adults in the coming decades. According to recent statistics, Thailand, DPR Korea and Sri Lanka have the highest proportion of older persons (aged ≥60 years) among the 11 member states that belong to WHO South-East Asia region.[5] In 2012, the percentage of older adults aged ≥60 years in Sri Lanka was 12.4%.[6] One out of every four persons is predicted to be an older person aged 60 years or above in Sri Lanka by 2041.[7] Thus, Sri Lanka is considered as one of the fastest growing ageing populations in South-East Asia.[8]

A recent meta-analysis on prevalence of frailty in low-income and middle-income countries (LMICs) reported a higher prevalence of frailty (12.3%) and pre-frailty (55.3%) in middle-income countries compared with high-income countries (8.2%, 43.9%).[9] Few studies were found from Asia in general, particularly from WHO South-East Asia and low-income and lower middle-income countries.[9] The pooled prevalence of frailty was 19.6% (95% CI 15.4% to 24.3%), in Latin America and the Caribbean with a range of 7.7% to 42.6% in the studies reviewed in another systematic review and

meta-analysis.[10] As a lower middle-income country with per capita gross domestic product of US$3857 (2016),[11] Sri Lanka needs to consider efficient and effective strategies to tackle the health, social and welfare issues of older adults. However, Sri Lanka, as with many LMICs that are ageing, has made little preparation to address the issues related to increased longevity. Moreover, there is a lack of underpinning empirical research to inform policy-makers on the emerging issues and the needs of the growing older population. Therefore, the main objective of this study was to describe the prevalence and associated sociodemographic factors of frailty and pre-frailty in community-dwelling older adults in rural areas of Kegalle district of Sri Lanka. We further explored how these compared with findings from other Asian countries and with other middle-income countries worldwide.

METHODS

Study setting and study population

We conducted a population-based cross-sectional study in rural areas of Kegalle district of Sri Lanka. Sri Lanka is divided into nine provinces encompassing 25 districts. The Kegalle district includes 4.1% of the Sri Lankan population.[6] In addition to this administrative division, Sri Lanka has been categorised into three sectors (urban, rural and estate) on the basis of geographical location and availability of infrastructure facilities.[6] Of the total population, 77.4%, 18.2% and 4.4% live in the rural, urban and estate sectors, respectively.[6] In Kegalle district, the majority of people live in the rural sector (91.3%) and the rest in the urban (1.9%) and estate (6.8%) sectors.[6] The ethnic distribution of the district is 85.5% Sinhalese followed by Sri Lankan Moor (7.1%), Indian Tamil (5.2%), Sri Lankan Tamil (2.1%) and other ethnicities (0.1%).[6]

Study inclusion criteria were being an older adult aged ≥60 years permanently residing in the rural areas. Older adults who were unable to give informed consent were excluded. This included people with severe dual hearing and vision impairment, aphasia, severe stages of dementia and those with unstable severe mental illness. Terminally ill older adults were also excluded.

Sampling strategy and recruitment

The sample size was calculated using the standard formula for prevalence studies.[12] No published literature was found on the prevalence of frailty in Sri Lanka. We therefore used the prevalence of frailty in an Indian study of 11.4%[13] to estimate the expected prevalence of frailty in rural Sri Lanka as 11%. The absolute precision required on either side of the prevalence estimate was set as 3.5% and the z statistics for the 95% level of confidence was 1.96. To account for the multistage probability sampling technique, we inflated the estimated sample size by a design effect of 2.4,[14] giving a minimum sample of 737 participants. We used a complex sampling design: a three-stage probability sampling to recruit older adults representing the rural areas of the entire district (online supplementary appendix I). The final sample required was estimated as 750 participants.

Data collection

Data collection was conducted from 3 October to 23 December 2016. Five trained research assistants (nursing graduates) collected data, assisted by six field assistants. A pre-tested interviewer administered questionnaire collected data on sociodemographic, health-related, social activity and social support and lifestyle factors. The questionnaire was available in Sinhala and Tamil languages.

Definition and assessment of frailty syndrome

We used the Fried phenotype to define frailty status.[2] All five phenotypic components proposed in the original study were retained, with small modifications to operationalise the shrinking and low physical activity components. Shrinking was defined as a body mass index (BMI) <18.5 kg/m^2. Poor endurance and energy as indicated by self-reported exhaustion was assessed using two questions: 'I felt that everything I did was an effort' and 'I could not get going' from the Center for Epidemiologic Studies–Depression Scale.[15 16] If the answer was three or more days in the last week to either of these two questions, the respondent was considered as frail for this component. Falling in the lowest quintile of grip strength after adjusting for sex and BMI quartiles of the study population was considered as indicative of weakness. Participants' walking time in the highest time quintile after adjusting for sex and median standing height of the study population was considered as indicative of slowness. Individuals unable to perform the walking test were also considered as frail for this component. Low physical activity level was measured using the International Physical Activity Questionnaire (IPAQ) Short Form.[17 18] Participants in the lowest quintile of weekly kilocalorie expenditure adjusted for sex were considered as frail for this component. A detailed description of how we measured the phenotypic components is provided in online supplementary appendix II. As recommended previously,[2] participants were classified as frail if they had three or more frailty components, pre-frail (1–2 components) and robust/non-frail (0 components).

Covariates

Sociodemographic covariates of participants included sex, age at last birthday, ethnicity, marital status, living arrangements, education level (according to the International Standard Classification of Education[19]), longest-held income generation activity and subjective financial strain.[20] We used the Sri Lanka Standard Classification of Occupation,[21] based on the International Standard Classification of Occupations 2008,[22] to classify income generation activities.

Statistical analyses

Data were double entered by two independent operators and checked for discrepancies using EpiData software V.3.1 and, if necessary, corrected with reference to the original questionnaires. All analyses were performed in Stata V.14 accounting for the complex survey design.[23] Design weights were computed as the inverse of the inclusion probability of each participant to the sample. Subsequently, post-stratification weights were obtained by adjusting the design weights to match the population age and sex distribution of the district. Post-strata (n=10) were defined by 5-year age categories (60–64; 65–69; 70–74; 75–79; ≥80 years) by sex using the information available from the latest census.[6]

We estimated the prevalence and corresponding 95% CI of frailty, pre-frailty and robust groups overall and by sociodemographic characteristics. The main outcome of interest in our study was ordinal (robust, pre-frail and frail). We initially fitted a multivariable ordinal logistic regression model to estimate the association between sociodemographic factors and frailty status. However, the proportional odds assumption underlying this model was not valid for our data, and we therefore used a multinomial logistic regression instead. Robust was chosen as the reference category. Unadjusted, age-adjusted and sex-adjusted, and multivariable-adjusted relative risk ratios and their corresponding 95% CIs were derived. All statistical tests were two sided with a significance level set at 0.05.

Exploratory cross-country comparison

The age-specific prevalence of frailty and pre-frailty in our weighted sample was compared with the random-effects pooled prevalence of frailty and pre-frailty obtained from meta analyses of studies in upper middle-income Asian countries (n=7555; three studies from China and one study from Malaysia), Japan—a higher income Asian country (n=10 912; three studies)—and upper middle-income Latin American countries (n=15 773; 11 studies from Brazil, 3 from Colombia and 2 studies from Mexico). The data required for these meta analyses were obtained from two published papers.[9 24] Studies that used the Fried phenotype of frailty with five components where weakness and slowness components were measured objectively using grip strength and gait speed were included, as a valid comparison with our study assessment methods. The details of the included studies are presented in online supplementary appendix III.

Patient and public involvement

We did not include involvement of Sri Lankan older adults in the study design, as the study was developed in the UK as part of a Commonwealth Scholarship, with limited resources. We used standard study instruments and physical assessment tests, which had been developed elsewhere, and most of these have been cross-culturally adapted and validated for Sri Lankan population. Prior to our main study, we obtained feedback from 10 Sri Lankan older adults (from a different location) on the study processes, including how to phrase certain questions and order of administering the instruments. A plain language summary of overall study results will be produced in English and translated into Sinhala and Tamil languages, and we will discuss with public representatives the best way to present and disseminate this information.

Participation was voluntary and no incentives were provided.

This manuscript was written according to the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) statement.[25]

RESULTS

Sociodemographic characteristics

Data were collected from 746 out of 750 older adults approached (response rate 99.5%). The age range of the participants was 60 to 94 years. The median (IQR) age was 68 (64–75) years in both the weighted and unweighted samples. In the weighted sample, 56.7% were women, 97.4% participants belonged to the Sinhalese ethnicity and 63.8% of participants had an education level below upper secondary. Table 1 presents the sociodemographic characteristics of the unweighted and weighted samples overall and by sex.

Fried phenotypic frailty components

Of all participants in the unweighted sample, nine did not have measurements of height and weight (needed for obtaining BMI) due to medical conditions (they could not stand independently). For these participants, we also could not use their grip strength data as BMI is required for calculating the grip strength cut-offs. Overall, out of the five phenotypic components, only unintentional weight loss and weakness were missing for nine participants. However, eight of them met the frailty criteria on all three available frailty components, so they were classified as frail. The other participant was excluded from subsequent analyses as with the partial information available we could not assign a frailty status with certainty.

For simplicity, from here onwards we will only present the results based on the weighted sample. The most prevalent frailty component in the overall sample was self-reported exhaustion (37.5%) followed by weakness (23.6%) (table 2).

Overall prevalence of frailty and pre-frailty

The prevalences of frailty, pre-frailty and robust among rural community-dwelling older adults in Kegalle district in 2016 were 15.2% (95% CI 12.3% to 18.6%), 48.5% (95% CI 43.8% to 53.2%) and 36.3% (95% CI 32.4% to 40.2%), respectively.

Prevalence of frailty and pre-frailty by sociodemographic characteristics

The prevalence of frailty status by sociodemographic characteristics is presented in table 3. The prevalence of frailty increased steeply with advancing age. Moreover, 3.8% of

Table 1 Sociodemographic characteristics of the unweighted and weighted study samples

Covariate	Unweighted sample, N (%)			Weighted sample (%)		
	All n=746	Men n=349 (46.8 %)	Women n=397 (53.2 %)	All	Men (43.3 %)	Women (56.7%)
Age category (years)						
60–64	248 (33.2)	100 (28.7)	148 (37.3)	35.7	37.4	34.3
65–69	199 (26.7)	99 (28.4)	100 (25.2)	25.3	25.5	25.2
70–74	100 (13.4)	50 (14.3)	50 (12.6)	17.0	17.2	16.8
75–79	100 (13.4)	50 (14.3)	50 (12.6)	11.2	10.2	11.9
≥80	99 (13.3)	50 (14.3)	49 (12.3)	10.8	9.7	11.8
Ethnicity						
Sinhalese	723 (96.9)	338 (96.9)	385 (97.0)	97.4	97.3	97.5
Other	23 (3.1)	11 (3.1)	12 (3.0)	2.6	2.7	2.5
Marital status						
Never married/widowed/ separated/divorced	289 (38.7)	45 (12.9)	244 (61.5)	40.4	11.3	62.6
Married/cohabiting	457 (61.3)	304 (87.1)	153 (38.5)	59.6	88.7	37.4
Living arrangement						
Children/other family	617 (82.7)	284 (81.4)	333 (83.9)	83.0	82.1	83.6
With spouse only	84 (11.3)	54 (15.5)	30 (7.6)	10.7	15.1	7.4
Alone	45 (6.0)	11 (3.1)	34 (8.5)	6.3	2.8	9.0
Education level						
No formal education/primary	214 (28.7)	87 (24.9)	127 (32.0)	28.6	23.3	32.7
Lower secondary	262 (35.1)	129 (37.0)	133 (33.5)	35.2	37.6	33.3
Upper secondary/post-secondary non-tertiary/tertiary	270 (36.2)	133 (38.1)	137 (34.5)	36.2	39.1	34.0
Longest-held occupation						
Never employed/skill level 1	316 (42.3)	83 (23.8)	233 (58.7)	43.7	24.7	58.2
Skill level 2	293 (39.3)	188 (53.9)	105 (26.4)	38.5	53.1	27.3
Skill level 3/4	137 (18.4)	78 (22.3)	59 (14.9)	17.8	22.2	14.5
Perceived financial strain						
Finding it difficult/very difficult	152 (20.4)	68 (19.5)	84 (21.2)	20.3	18.9	21.4
Just about getting by	406 (54.4)	191 (54.7)	215 (54.1)	55.0	56.8	53.6
Living comfortably	188 (25.2)	90 (25.8)	98 (24.7)	24.7	24.3	25.0

older adults aged 60–64 years were classified as frail while nearly half (47.9%) of those aged 80 years or older were considered as frail. The prevalence of frailty by sex did not vary markedly, though more women than men were pre-frail. A higher prevalence of frailty was observed in older adults with low education, those who have had low skilled occupations or never had employment and those who reported higher financial strain.

Sociodemographic characteristics associated with frailty and pre-frailty

Table 4 presents the results from the unadjusted, age-adjusted and sex-adjusted, and fully adjusted multinomial logistic regression models.

Frailty versus robust

In the fully adjusted model, the relative risk of being frail compared with being robust increased with advancing age. Similarly, the relative risk of being frail compared with being robust was 3.4 times higher in older adults who have never been employed or who had an occupation in the lowest skill level rather than the highest skill level.

Pre-frailty versus robust

In the fully adjusted model, the relative risk of being pre-frail compared with being robust was two-thirds lower for participants aged 60–64 years relative to those aged 70–74 years. Conversely, older adults in the lowest education group compared with those in the highest education

Table 2 Prevalence of Fried phenotype frailty components and the total number of frailty components in the overall sample and by sex

	Total (%)	Men (%)	Women (%)
Fried's phenotype of frailty component			
Shrinking (low BMI)	18.2	20.2	16.6
Self-reported exhaustion	37.5	31.9	41.7
Weakness (low grip strength)	23.6	19.6	26.6
Slowness (low gait speed)	19.6	18.7	20.3
Low physical activity	19.2	17.4	20.5
Total no of frailty components			
0	36.2	41.3	32.3
1	30.8	29.7	31.6
2	17.8	14.7	20.2
3	10.5	10.4	10.6
4	4.2	3.0	5.0
5	0.5	0.8	0.3

BMI, body mass index.

group had an approximately 2.4 times higher risk of being pre-frail compared with being robust.

Supplementary exploratory analysis: cross-country comparison of prevalence of frailty and pre-frailty

Figure 1 compares the age-specific prevalence of frailty in the rural areas of Kegalle district of Sri Lanka with the pooled prevalence of frailty in other comparable countries with data available: upper middle-income Asian countries (China and Malaysia), high-income Asian country (Japan) and upper middle-income Latin American countries (Brazil, Colombia and Mexico). Except for the age group 60–64 years, prevalence of frailty across all the other age groups was higher in the rural areas of Kegalle district of Sri Lanka. The prevalence was higher in the older 75–79 years and ≥80 years age categories. With regard to pre-frailty, the prevalence rates were relatively similar across countries (figure 2).

DISCUSSION

Summary of main findings

To our knowledge, this is the first study conducted in Sri Lanka to investigate the epidemiology of frailty using the Fried frailty phenotype.[2] The prevalence of frailty and pre-frailty among rural community-dwelling older adults aged ≥60 years in Kegalle district in 2016 was estimated as 15.2% (95% CI 12.3% to 18.6%) and 48.5% (95% CI 43.8% to 53.2%), respectively. Nearly half of those aged ≥80 years were frail. We found no evidence of an association between sex and being frail or pre-frail in any regression model. In the multivariable-adjusted model, increasing age and having never been employed or having had a low-skilled occupation increased the relative risk of being frail compared with being robust. Being in the lowest education level increased the relative risk of being pre-frail compared with robust. In exploratory analyses, the prevalence of frailty appeared to be higher in Sri Lanka across all the age categories except 60–64 years when compared with the pooled prevalence of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

Comparison with existing literature

Frailty is an important clinical syndrome which predicts numerous adverse health outcomes in later life; however, there is a paucity of epidemiological research from Asian countries compared with the West. The majority of Asian studies are from high-income economies with few from WHO South-East Asia. India was a study site of two multicountry studies[13 26] and there were three small studies from Pune, India,[27] Nepal[28] and Nakhon Pathom, Thailand.[29] The reported prevalence of frailty in these studies ranged from 56.9% (frailty index)[26] to 11.4% (Fried phenotype with four components).[13] The use of different frailty assessment methods and heterogeneity in the minimum recruitment age make it difficult to compare the prevalence of frailty between studies. A small community-based study of older adults (≥65 years) in Pune, India[27] used Fried phenotype, a similar assessment method to ours but with Cardiovascular Health Study (CHS) cut-offs[2] for grip strength and gait speed, and found a prevalence of frailty and pre-frailty of 26.0% and 63.6%, respectively.[27] The corresponding prevalence of frailty and pre-frailty in our study after restricting the sample to those aged ≥65 years and after applying the same CHS grip strength and gait speed cut-offs was 34.6% (95% CI 29.3% to 40.4%) and 49.7% (95% CI 44.6% to 54.9%). This difference may be due to the shorter life expectancy in India[30] compared with Sri Lanka[31] and more highly educated people living in an urbanised area in the Indian study.[27]

In our study, the prevalence of frailty in older adults aged ≥65 years in Sri Lanka was 21.5% using population-specific grip strength and gait speed cut-offs. This is similar to a small study in Thailand (22.7%),[29] but much higher than the pooled prevalence of frailty reported in high-income (8.2%) and upper middle-income (11.8%) countries using the same frailty assessment method and the same minimum recruitment age.[9] This finding supports existing literature showing a strong relationship between national economic indicators and a country's level of frailty and fitness.[32]

We conducted our study in rural areas of Kegalle district. However, in Sri Lankan context, rural classification is itself problematic to some extent since semi-urban areas where people have access to many facilities and good infrastructure are also classified as rural. This applies to Kegalle district too. Lower prevalence of frailty

Table 3 Distribution of frailty statuses across sociodemographic characteristics

Covariates	Prevalence (95% CI), %		
	Robust	Pre-frail	Frail
Sex			
Male	41.3 (36.2 to 46.6)	44.4 (39.3 to 49.5)	14.3 (10.9 to 18.3)
Female	32.4 (26.9 to 38.2)	51.6 (44.0 to 59.0)	16.0 (11.8 to 21.1)
Age group (years)			
60–64	55.0 (45.2 to 64.4)	41.1 (32.3 to 50.5)	3.8 (1.7 to 7.9)
65–69	38.9 (27.6 to 51.5)	51.0 (39.6 to 62.2)	10.0 (5.6 to 17.2)
70–74	25.6 (16.4 to 37.7)	58.4 (47.7 to 68.2)	15.9 (8.6 to 27.4)
75–79	12.4 (6.3 to 22.9)	56.9 (43.0 to 69.7)	30.7 (19.3 to 44.9)
≥80	9.3 (4.2 to 19.3)	42.7 (28.4 to 58.3)	47.9 (33.1 to 63.0)
Marital status			
Married/cohabiting	42.6 (37.1 to 48.3)	45.9 (41.3 to 50.5)	11.5 (7.9 to 16.2)
Never married/widowed/separated/divorced	26.8 (20.6 to 34.0)	52.4 (44.4 to 60.1)	20.8 (14.8 to 28.4)
Living arrangement			
Children/other family	36.0 (32.0 to 40.3)	47.9 (42.9 to 52.6)	16.1 (12.7 to 20.1)
With spouse	42.9 (27.5 to 59.7)	45.9 (30.4 to 62.1)	11.2 (4.7 to 24.0)
Alone	26.8 (14.6 to 43.9)	62.2 (38.1 to 81.4)	11.0 (2.1 to 41.3)
Education level			
No formal education/primary	21.0 (14.0 to 30.0)	55.4 (46.8 to 63.7)	23.6 (16.4 to 32.6)
Lower secondary	35.8 (29.5 to 42.5)	49.3 (42.1 to 56.3)	14.9 (9.9 to 21.8)
Upper secondary/post-secondary non-tertiary/ tertiary)	48.8 (41.9 to 55.7)	42.2 (34.7 to 50.1)	8.9 (5.4 to 14.2)
Longest-held occupation			
Never employed/skill level 1	29.5 (23.5 to 36.3)	49.4 (43.3 to 55.4)	21.1 (16.2 to 26.8)
Skill level 2	38.5 (31.5 to 46.0)	49.1 (41.5 to 56.6)	12.4 (8.2 to 18.2)
Skill level 3/4	47.9 (39.2 to 56.7)	45.1 (35.8 to 54.6)	7.0 (3.3 to 14.1)
Perceived financial strain			
Finding it difficult/very difficult	26.7 (18.8 to 36.2)	54.0 (44.1 to 63.6)	19.3 (13.3 to 27.0)
Just about getting by	36.1 (31.0 to 41.5)	48.7 (42.6 to 54.7)	15.2 (11.7 to 19.3)
Living comfortably	44.5 (35.7 to 53.5)	43.5 (32.6 to 54.9)	12.0 (6.4 to 21.3)

was found among three studies conducted in rural areas of coffee-growing zones of the Colombian Andes mountains (12.2%),[33] Mexico (10.7%)[34] and Turkey (7.1%)[35] compared with our study with similar frailty assessment method. However, both the Colombian and Turkish studies used non-probability sampling techniques (voluntary participation and convenience sampling). Voluntary participation might have underestimated the true prevalence, particularly if people with mobility limitations were less likely to take part in the study. The minimum recruitment age of the participants of these studies were ≥60,[33] ≥70[34] and ≥65[35] years, respectively.

In addition to the true variation of frailty prevalence rates across different populations, and differences in setting (urban/rural), these differences could also depend on methodological issues, for example, how phenotypic components are operationalised, which cut-offs are used, inclusion and exclusion criteria used to define the study population, and the way missing data of frailty components are handled. In keeping with many studies using the Fried phenotype,[36] we used BMI <18.5 kg/m^2 to operationalise 'shrinking', as we did not have access to serial weight measurements to objectively assess weight loss. For physical activity, we used the culturally adapted IPAQ as suitable for a Sri Lankan population unlike the original measure.[37] The instrument used could be sensitive to cultural effects when translated into different languages and interpretation.[38] Many studies included in the Latin American upper middle-income countries meta-analyses of this paper applied more restrictive inclusion criteria, which might have underestimated the true prevalence rates.

Age and female sex are two well-known biological risk factors of frailty[39]; however, we found an age but no sex difference in frailty or pre-frailty. A recent systematic review of longitudinal studies also found both an

Table 4 Unadjusted, age-adjusted and sex-adjusted, and multivariable adjusted multinomial logistic regression results

Covariates	Relative risk ratio (95% CI)					
	Pre-frailty vs robust			Frailty vs robust		
	Unadjusted	Age and sex adjusted	Multivariable*	Unadjusted	Age and sex adjusted	Multivariable*
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.48 (1.00 to 2.18)	1.45 (0.98 to 2.20)	1.31 (0.80 to 2.15)	1.43 (0.91 to 2.23)	1.34 (0.77 to 2.35)	0.96 (0.48 to 1.89)
Age group (years)						
60–64	**0.32 (0.16 to 0.66)**	**0.32 (0.16 to 0.66)**	**0.33 (0.16 to 0.71)**	**0.11 (0.02 to 0.41)**	**0.11 (0.02 to 0.41)**	**0.10 (0.02 to 0.43)**
65–69	0.57 (0.27 to 1.20)	0.57 (0.27 to 1.21)	0.59 (0.27 to 1.30)	0.41 (0.11 to 1.45)	0.41 (0.11 to 1.45)	0.38 (0.09 to 1.50)
70–74	1.00	1.00	1.00	1.00	1.00	1.00
75–79	2.01 (0.87 to 4.64)	1.99 (0.86 to 4.60)	2.05 (0.86 to 4.87)	**3.98 (1.46 to 10.84)**	**3.94 (1.44 to 10.79)**	**4.07 (1.43 to 11.56)**
≥80	1.99 (0.69 to 5.74)	1.96 (0.67 to 5.71)	1.81 (0.55 to 5.94)	**8.20 (2.24 to 30.00)**	**8.09 (2.20 to 29.76)**	**7.42 (1.79 to 30.67)**
Living arrangement						
Children/other family	1.00	1.00	1.00	1.00	1.00	1.00
With spouse	0.80 (0.37 to 1.73)	0.87 (0.38 to 1.98)	0.80 (0.39 to 1.64)	0.58 (0.18 to 1.82)	0.75 (0.20 to 2.78)	0.75 (0.24 to 2.39)
Alone	1.75 (0.74 to 4.13)	1.58 (0.66 to 4.49)	1.32 (0.42 to 4.11)	0.91 (0.17 to 4.75)	0.90 (0.18 to 4.54)	0.72 (0.13 to 3.89)
Education level						
Upper secondary/post-secondary non-tertiary/tertiary)	1.00	1.00	1.00	1.00	1.00	1.00
Lower secondary	**1.59 (1.02 to 2.47)**	1.57 (0.96 to 2.52)	1.49 (0.78 to 2.83)	**2.28 (1.13 to 4.60)**	**2.30 (1.09 to 4.86)**	1.38 (0.56 to 3.42)
No formal education/primary	**3.05 (1.71 to 5.42)**	**2.63 (1.51 to 4.56)**	**2.36 (1.19 to 4.79)**	**6.15 (2.66 to 14.23)**	**4.04 (1.67 to 9.77)**	2.12 (0.73 to 6.18)
Longest-held occupation						
Skill level 3/4	1.00	1.00	1.00	1.00	1.00	1.00
Skill level 2	1.35 (0.83 to 2.18)	1.48 (0.89 to 2.46)	0.87 (0.42 to 1.76)	2.20 (0.84 to 5.70)	**2.92 (1.12 to 7.62)**	1.69 (0.54 to 5.24)
Never employed/skilllevel 1	**1.77 (1.04 to 3.02)**	**1.77 (1.07 to 2.94)**	0.96 (0.48 to 2.00)	**4.88 (2.27 to 10.48)**	**6.33 (2.84 to 14.13)**	**3.43 (1.31 to 8.98)**
Perceived financial strain						
Living comfortably	1.00	1.00	1.00	1.00	1.00	1.00
Just about getting by	1.37 (0.80 to 2.36)	1.54 (0.93 to 2.54)	1.35 (0.83 to 2.21)	1.55 (0.74 to 3.22)	2.11 (0.85 to 5.23)	1.61 (0.62 to 4.18)
Finding it difficult/very difficult	**2.07 (1.08 to 3.96)**	**2.23 (1.16 to 4.28)**	1.70 (0.89 to 3.26)	**2.66 (1.24 to 5.73)**	**3.53 (1.35 to 9.19)**	2.27 (0.77 to 6.67)

The reference category is 1.00.
Significant estimates are displayed in bold.
*Adjusted for sex, age group, living arrangement, education level, longest-held occupation and perceived financial strain.

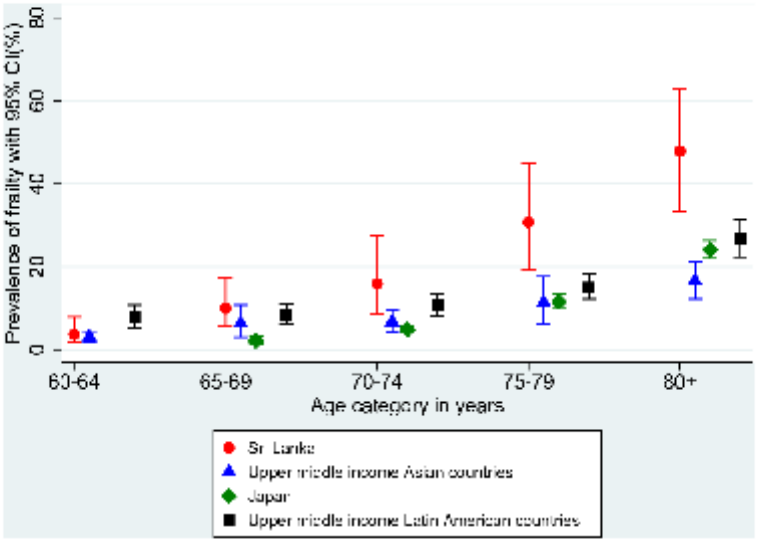

Figure 1 Comparison of age-specific prevalence of frailty in Sri Lanka with the pooled prevalence estimates of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

association and no association between sex and incident or increased risk of frailty.[39] In this review, two studies reported female sex as a risk factor for frailty[40 41] while two studies reported no association.[42 43] A strong association between longest-held occupation and frailty and education level and pre-frailty was found in our study. Aforementioned systematic review based on longitudinal studies found studies reporting both positive and no association between level of education and frailty.[39]

Strengths and limitations

We conducted the first large population-based study on frailty with a regional representative sample of rural community-dwelling older adults in Kegalle district of Sri

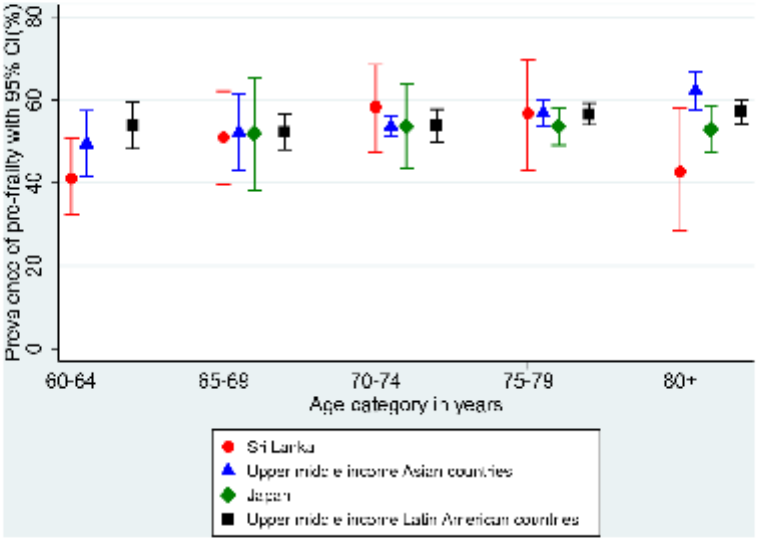

Figure 2 Comparison of age-specific prevalence of pre-frailty in Sri Lanka with the pooled prevalence estimates of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

Lanka. We followed rigorous methodology and measures were taken to improve the validity and reliability of data. The intra-rater reliability of anthropometric measurements (height and weight) and physical performance tests (grip strength and walking time) were excellent (intraclass correlation>0.9). The response rate was extremely high (99.5%). Our analyses involved a cross-country comparison of frailty across income classification and geographical regions. Limitations include that the sample only comprised rural older adults and the majority belonged to Sinhalese ethnicity. Therefore, the results are likely not generalisable to urban and estate sectors and other ethnicities. The prevalence of frailty could be underestimated in our study as we excluded participants who could not give informed consent and those who were terminally ill. However, the number of excluded participants was very small and we were less restrictive than other studies. Some questions, for example, physical activity and self-reported exhaustion, could be affected by recall bias.

With regard to our cross-country comparison, it should be noted that our findings are based on a rural sample, and while the population of Sri Lanka is predominantly rural, this may not reflect the prevalence of frailty in urban and estate sectors in Sri Lanka. Furthermore, in the comparator country samples, it would be ideal if we had representative country-level data on the prevalence of frailty for this analysis. However, with the exception China, we were unable to find any nationally representative samples, and we therefore calculated pooled estimates of frailty and pre-frailty from studies conducted with regional samples. Moreover, studies included in this comparison have used both urban and rural samples. We have indicated the exact study setting and whether the sample is urban/rural/both/uncertain in online supplementary appendix III. We performed this analysis for exploratory purposes only and hence needs to be interpreted cautiously.

Implications for public health

The Sri Lankan health system is a well-known example of the provision of good healthcare at low cost.[44] Around 70% of the disease burden in the country is due to non-communicable diseases (NCDs).[45] The rapidly ageing population is contributing to increases in the prevalence of NCDs which is a huge challenge to the country's health system. Frailty and multimorbidity (multiple coexisting NCDs) are closely linked. Recently, guidelines have been introduced for the management of frailty in Asia-Pacific.[46] Therefore, findings of this study are important to healthcare planners to quantify the extent of frailty and be prepared for establishing appropriate health and social services for older adults with frailty and multiple NCDs. The existing profile of health and social care services in Sri Lanka needs adjustments to meet the needs of age-related illness and care. Further improvements in geriatrics and gerontology disciplines are an urgent need. Investing in elderly health is important to mitigate the medical and social implications of ageing.

CONCLUSION

The prevalence of frailty in this rural Sri Lankan older population was high in comparison with both higher-income and upper middle-income countries. There has been little research conducted on frailty in low-income and lower middle-income countries. Identifying the scale of the problem will help these growing economies to prepare and respond to the challenges associated with increasing longevity.

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Contributors DDS, KRW, MCW and GR conceived and designed the study. DDS and MCW collected the data. DDS, MF and SS analysed the data. DDS drafted the manuscript. KRW, MCW, GR, MF and SS critically revised the manuscript.

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Patient consent for publication Obtained.

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