Frailty progression in adults aged 40 years and older in rural Burkina Faso: a longitudinal, population-based study

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Summary

Background Little is known about ageing and frailty progression in low-income settings. We aimed to describe frailty changes over time in individuals living in rural Burkina Faso and to assess which sociodemographic, disability, and multimorbidity factors are associated with frailty progression and mortality.

Methods This longitudinal, population-based study was conducted at the Nouna Health and Demographic Surveillance Systems (HDSS) site in northwestern Burkina Faso. Eligible participants were aged 40 years or older and had been primarily resident in a household within the HDSS area for at least the past 6 months before the baseline survey and were selected from the 2015 HDSS household census using a stratified random sample of adults living in unique households within the area. Participants were interviewed in their homes in 2018 (baseline), 2021 (follow-up), or both. We derived the Fried frailty score for each participant at each timepoint using data on grip strength, gait speed, self-reported weight loss, self-reported exhaustion, and physical activity, and described changes in frailty status (no frailty, pre-frailty, or frailty) between 2018 and 2021. We used multivariate regression models to assess factors (ie, sex, age, marital status, educational attainment, wealth quintile, WHO Disability Assessment Schedule (WHODAS) score, and multimorbidity) associated with frailty progression (either worsening frailty status or dying, compared with frailty status remaining the same or improving) and with mortality, and developed sequential models: unadjusted, adjusting for sociodemographic factors (sex, age, marital status, educational attainment, and wealth quintile), and adjusting for sociodemographic factors, disability, and multimorbidity.

Findings Between May 25 and July 19, 2018, and between July 1 and Aug 22, 2021, 5952 individuals were invited to participate: 1709 (28·7%) did not consent, 1054 (17·8%) participated in 2018 only and were lost to follow-up, 1214 (20·4%) participated in 2021 only, and 1975 (33·2%) were included in both years or died between years. Of 1967 participants followed up with complete demographic data, 190 (9·7%) were frail or unable to complete the frailty assessment in 2018, compared with 77 (3·9%) in 2021. Between 2018 and 2021, frailty status improved in 567 (28·8%) participants and worsened in 327 (16·6%), and 101 (5·1%) participants died. The relative risk of frailty status worsening or of dying (compared with frailty improving or no change) increased with age and WHODAS score, whereas female sex appeared protective. After controlling for all sociodemographic factors, multimorbidity, and WHODAS score, odds of mortality were 1·07 (odds ratio 2·07, 95% CI 1·05–4·09) times higher among pre-frail individuals and 1·1 (2·21, 0·90–5·41) times higher among frail individuals than among non-frail individuals.

Interpretation Frailty status was highly dynamic in this low-income setting and appears to be modifiable. Given the rapid increase in the numbers of older adults in low-income or middle-income countries, understanding the behaviour of frailty in these settings is of high importance for the development of policies and health systems to ensure the maintenance of health and wellbeing in ageing populations. Future work should focus on designing context-appropriate interventions to improve frailty status.

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Introduction

By 2030, approximately 80% of the world's older people (aged ≥60 years) will live in low-income or middle-income countries (LMICs).[1] Yet, although the global community has recognised the need to invest in ageing studies in lower-income settings, most research on ageing still takes place in high-income settings.[2]

Understanding the trajectory of ageing in lower-income settings is essential to ensure the appropriate use of limited resources to effectively support healthy ageing.

Frailty, an important component of ageing, is a state characterised by a loss of homoeostatic reserve and increased vulnerability to stressors, such that even a minor illness or injury can cause major loss of function.[3]

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Research in context

Evidence before this study
We searched PubMed for articles in English using the keywords "frailty progression" OR "frailty trajectory" AND "older adults" from database inception to July 31, 2023. We found two relevant categories of study: one evaluating interventions to slow frailty progression and another describing frailty prevalence. However, most studies were done in high-income settings and were cross-sectional. We found no longitudinal studies that included individuals living in low-income countries, where greater exposure to poor nutrition, infectious diseases, and physical labour might lead to different frailty trajectories compared with trajectories observed in higher-income settings. The progression of frailty among older adults in low-income settings therefore remains unclear.

Added value of this study
To our knowledge, this is the first longitudinal study of frailty in a population living in a low-income country and contributes to a growing body of work on ageing populations in resource-limited settings. We provide insight into the plasticity of frailty, risk factors for its progression, and its association with mortality. Compared with other studies, we show a reduced magnitude of association between frailty and mortality, as well as improved frailty status in a large proportion of participants, compared with high-income countries, suggesting that older people in Nouna, Burkina Faso might show greater improvements in frailty status than older people living in higher-income settings.

Implications of all the available evidence
Several primary care interventions have been shown to delay and reverse the progression of frailty, but such work has been based primarily in high-income settings. These interventions might be transferable to resource-limited settings; however, future studies are required to investigate how such interventions might reverse the progression of frailty in settings such as rural Burkina Faso.

Frailty, whether operationalised by a phenotype model or by a frailty score or index,[4] strongly predicts adverse outcomes for older people, including increased morbidity and mortality,[3,5,6] disability,[7] dependency, and the need for social care. An emerging body of work has supported the applicability of the phenotype measure of frailty in LMICs.[8] The Fried frailty phenotype,[9] for example, has been used to characterise frailty in older people in South Africa,[10] Tanzania,[11] and Burkina Faso.[12]

There is a growing body of literature on frailty progression using longitudinal[13] and retrospective[14] cohorts in high-income settings. A systematic review and meta-analysis[6] found that, in the USA, Europe, Canada, and China, the frailty index is a significant predictor of mortality. In South Africa, a locally adapted version of the Fried frailty index was shown to strongly predict mortality over a 2-year time window.[15] Unfortunately, frailty progression is less studied in low-income settings: a 2021 systematic review[16] found 25 articles on frailty trajectories, none of which reported on studies done in low-income countries. However, the socioeconomic (lower individual earnings and lower national gross domestic product), employment (more people employed in manual occupations), nutritional (greater food insecurity or lower dietary diversity), and disease (higher prevalence of infectious disease) status in low-income countries could lead to a different progression of frailty in these settings to that observed in high-income or even middle-income countries.[17,18]

In this study we primarily aimed to describe the longitudinal progression of frailty, from 2018 to 2021, among a cohort of older adults living in a low-income setting (Burkina Faso) and the baseline factors associated with frailty progression. We additionally explored how baseline factors, including frailty, are associated with mortality.

Methods

Study setting
This longitudinal, population-based study was conducted at the Nouna Health and Demographic Surveillance Systems (HDSS) site in Kossi province in the Boucle du Mouhoun region, northwestern Burkina Faso. The HDSS has been running this site since 1993, which comprises the town of Nouna and 58 surrounding villages with a total population of around 107 000. This setting was selected because it is in a low-income country where longitudinal studies of ageing are neglected and it is a poor area within Burkina Faso, providing further insights into the trajectories of frailty in locations of poverty. The site is predominantly rural and primary economic activities include subsistence farming and cattle raising. This area has lower annual per-capita income (averaging US$400 per year) and school attendance (1·2 years per person) than the national averages for Burkina Faso.[12]

Study population and survey
Data were collected as part of the Centre de Recherche en Santé de Nouna (CRSN) Heidelberg Aging Study (CHAS). CHAS is a longitudinal study of health conditions of adults aged 40 years and older. The sample for the 2018 baseline study was drawn from the 2015 HDSS household census using a stratified random sample of adults living in unique households within the census area. To reach a target of 3000 responses, field staff sampled 4000 potential participants, expecting a 25% non-response rate due to, for example, mortality since the last census, inadequate mobility to participate, or individuals declining to participate. The present study is a secondary analysis of CHAS data; all outcomes included in analyses were predefined in the protocol. Participants were interviewed in their homes in 2018

(baseline), 2021 (follow-up), or both. The sample size available in CHAS was calculated to be sufficient to provide power to detect prevalence ratios of 2·0 (5% level of significance, 80% power, two-sided test) for health conditions prevalent in the setting (hypertension and diabetes) across key reporting domains (eg, sex, age tertiles, and major ethnic and religious groupings).

The age of 40 years and older was selected to define older adults in CHAS. Because life expectancy at birth in Burkina Faso is 59·73 years,[19] populations older than 60 or 65 years—the cutoff used to define older age in many countries—are small. Adopting a life course approach to understanding frailty requires assessing people as they age rather than only when they are old, and people older than 40 years in Burkina Faso are conceptualised as older. Additionally, our previous work[12,20] has shown that people older than 40 years in LMICs have similar frailty prevalence compared with older adults in higher-income countries, suggesting that biological ageing might affect people at younger chronological ages in this setting.

Eligible participants were aged 40 years or older, resided primarily in a household within the Nouna HDSS area for at least 6 months before the start of the study, and provided written informed consent to participate. There were no exclusion criteria. In six villages with fewer than 50 adults aged 40 years or older, all eligible adults in households were selected. In the remaining communities, households containing one or more people aged 40 years or older were randomly selected, and one respondent within this age group was randomly selected from each household. Methods are described in full elsewhere.[12,20] All participants from whom data were collected in the baseline survey in 2018 were followed up, if possible, in the 2021 survey. Deaths were recorded using CRSN census data. Oral assent for the study was sought from village elders and written informed consent was obtained from each participant; if participants were illiterate, a literate witness assisted.

Ethical approval for the first wave of CHAS was obtained from Ethics Commission I of the Medical Faculty Heidelberg (S-120/2018), the Burkina Faso Comité d'Ethique pour la Recherche en Santé (CERS) in Ouagadougou (2018-4-045), and the Institutional Ethics Committee of the CRSN (2018-04). Ethical approval for the second wave was obtained from the Ethical Committee of the Ministry of Health, Burkina Faso (2018-5-053) and the University of Birmingham, Birmingham, UK (ERN_21-0867).

Data collection and variables

Data were collected between May 25 and July 19, 2018 (baseline), and between July 1 and Aug 22, 2021 (follow-up), using tablet computers at respondents' houses. Interviews were either conducted in French or translated into Dioula or Mooré, the most frequently spoken local languages, by trained local fieldworkers. Translation practice was included in fieldworker training.

Baseline interviews included questions on socio-demographic factors—age (in years), sex (male or female), highest level of education completed (with the options of no formal schooling, less than primary, primary complete, some secondary, secondary complete, high school complete, or college/university, and dichotomised as no formal education versus any education), and marital status (dichotomised as married or cohabitating versus divorced, single, or widowed)—and 37 questions on household assets and dwelling characteristics. Wealth quintiles were derived from household assets using the method described by Filmer and Pritchett.[21]

Disability status was measured as a continuous variable using the 12-item WHO Disability Assessment Schedule, version 2 (WHODAS 2.0).[22] The Generalised Anxiety Disorder two-item (GAD-2) questionnaire was used to assess anxiety symptoms[23] and the Patient Health Questionnaire (PHQ-9)[24] was used to assess depressive symptoms. Cognitive functioning was measured using the Community Screening Instrument for Dementia (CSI-D).[25]

Multimorbidity was defined as two or more of hypertension, diabetes, hypercholesterolaemia, heart disease, stroke, chronic pulmonary obstructive disease, asthma, cancer, HIV, possible or probable cognitive impairment, symptoms of depression, or symptoms of anxiety. Disease status was self-reported for cancer, HIV, chronic respiratory disease, stroke, and heart disease, via the question "Have you ever been told by a health worker that you have [disease of interest]?". To ascertain hypertension, blood pressure was measured in the left arm after 15 min of rest using Omron Series 7 portable blood pressure machines (Omron Healthcare; Kyoto, Japan). Three measurements were taken with the participant in a seated position, with at least 5 min between the final two measurements, which were averaged for use in the analysis. BMI was computed from weight and height as kg/m². Capillary blood was drawn by a trained phlebotomist; samples were analysed using SD CodeFree point-of-care testing strips (SD Biosensor; Gyeonggi-do, South Korea) for blood glucose and the Pictus 400 (Diatron Assembly Systems; Norwich, UK) for cholesterol.

Diseases to be included were selected considering the morbidities that were found to be important in other populations living in low-income or middle-income countries.[20] The derivation of hypertension, diabetes, hypercholesterolaemia, possible or probable cognitive impairment, symptoms of depression, or symptoms of anxiety is described in the appendix (p 1).

See **Online** for appendix

Frailty assessment

Frailty was assessed in 2018 (baseline) and at the follow-up visit (2021). We used the Fried frailty phenotype to derive frailty status. Although numerous other tools are available, this measure was chosen because it is easy to apply and has been validated extensively in LMIC

settings.[10,12,20,26] Scores were determined using five domains: weight loss, low grip strength, low walk speed, self-reported exhaustion, and low activity levels. Thresholds for each domain were selected to be as close to those used in the original Fried derivation as possible.[9–12] Weight loss was defined as a self-reported loss of more than 4 kg over the past year. Handgrip strength was measured using a Jamar Plus Digital Hand Dynamometer (Lafayette Instrument Company, Lafayette, IN, USA).[27] Measurements were taken with the participant seated, the arm at 90° elbow flexion, and the shoulder and wrist in the neutral position. Two measurements were recorded from each hand, and the maximum value was used in this analysis. Low grip strength was defined as the lowest quintile of BMI-adjusted grip for each sex. Walk speed was measured over a 4-m course, with participants asked to walk the course at their usual walking pace. Two measures were obtained, with the second in the reverse direction to the first, and the fastest time taken to complete the course was used to derive walk speed in metres per second.[28] Low walk speed was defined as the lowest quintile of height-adjusted walk speed over a 4-m course for each sex. Low physical activity was defined as the highest quintile of self-reported hours of sitting per week for each sex. Self-reported exhaustion was measured using two questions from the eight-item Center for Epidemiologic Studies Depression (CES-D) scale: "Everything I did in the last week was an effort" or "I could not get going";[29] a positive response was defined as either question answered as applying for at least 3–4 days per week. Scores ranged from 0 to 5 points, with 0 categorised as non-frail, 1–2 as pre-frail, and 3 or more points as frail. Individuals with missing data in one or both domains of physical measurement (grip strength or low walk speed; n=44) were grouped with frail individuals in the primary scoring system, because previous research has shown that those with missing data have a prognosis similar to or worse than those who are classed as frail.[10]

Statistical analysis

Descriptive statistics for continuous variables are presented using mean and SD, or median and IQR if not normally distributed. Normality was assessed using Shapiro–Wilk and quantile–quantile plots. Categorical variables were described using count and proportion. To assess differences between groups, Kruskal–Wallis tests were used for continuous variables and χ² tests for categorical variables. χ² tests were used to assess whether attrition between surveys might be related to frailty or sociodemographic characteristics, WHODAS score, and presence of multimorbidity, in total and stratified by sex.

Changes in frailty status between 2018 and 2021—including individuals who had died between study visits in the 2021 category—were shown by Sankey diagrams, prepared using SankeyMATIC.

We used modified Poisson regression with robust standard error to assess factors associated with worsening frailty category or with mortality between 2018 and 2021, compared with frailty status remaining the same or improving. These models were chosen because the outcome was a non-rare event (22%). Covariables were sex, age, marital status, educational attainment, wealth quintile, WHODAS score, and presence of multimorbidity. Two sequential models were created: one adjusting for all sociodemographic factors and another adjusting for all sociodemographic factors, WHODAS score, and multimorbidity. In a further model, WHODAS score and multimorbidity were added individually. These models were used to explore whether a change in frailty status is conditional on each variable while controlling for all others as possible confounding factors, because of the hypothesised associations between these variables and frailty.[10,12]

For models investigating the association between baseline frailty status and death, where the outcome occurred in only 5% of our study population, we conducted logistic regression. Three sequential models were created: unadjusted; adjusting for all sociodemographic factors; and adjusting for all sociodemographic factors, WHODAS score, and multimorbidity. In a further model, WHODAS score and multimorbidity were added individually. In all models, age was included as a continuous variable and using regression splines.

We conducted an exploratory analysis to investigate which factors at baseline were associated with an improvement in frailty category (compared with worsening or remaining unchanged).

We conducted five sensitivity analyses to ensure robustness of our results. The first was an exploration of potential confounding and overadjustment informed by a directed acyclic graph (appendix p 2), in which we investigated the association between baseline frailty
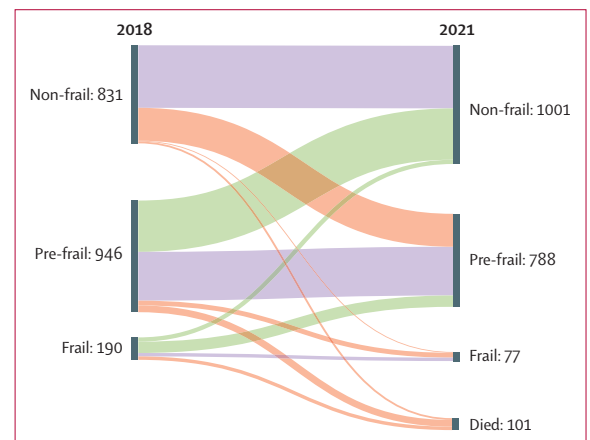

Figure: Sankey diagram showing change in frailty status among 1970 participants from 2018 to 2021
Green indicates improved frailty status, purple indicates no change in frailty status, and orange indicates a worsening frailty status. Prepared using SankeyMATIC.

status and mortality using a logistic regression model that adjusted for age, sex, WHODAS score, and multimorbidity. Directed acyclic graphs are useful tools to explore potential causal pathways and potential biases from confounding or overadjustment for intermediate variables on a causal path from exposure to outcome.[30]

The second analysis involved expanding the 2021 population to include the 170 individuals who did not complete the follow-up in 2021 for reasons that might be related to frailty (ie, hospitalisation, being "too old", or being incapacitated). We classified these individuals as being frail in 2021. We tabulated the changes in frailty using this new population and included these individuals in all models to investigate whether results remained unchanged.

The third analysis aimed to ascertain whether a polytomous outcome would affect the significance or directionality of our findings. We used multinomial regression comparing improving frailty status, worsening frailty status, and death to the referent category: frailty status remaining unchanged.

The fourth analysis was conducted to assess whether the primary analysis was affected by classifying individuals with missing data on the physical measurement frailty domain as being frail. In this analysis, we used an alternative scoring methodology for frailty, whereby individuals with no response for each of the physical measurement domains were scored 0 for the domain that was missing.[10,12] The aforementioned Sankey diagram, logistic regression models, and multinomial regression analysis were repeated for this new population.

For the fifth sensitivity analysis, we aimed to investigate whether loss to follow-up affected our results by calculating the inverse probability of response weights using sex-specific logistic models for follow-up visit participation given sample selection. These models comprised baseline frailty status, education, age, marital status, educational attainment, WHODAS score, wealth

	Overall (n=1967)	Improved (n=567)	No change (n=972)	Worsened (n=327)	Died (n=101)
Fried frailty categorisation*					
Non-frail (0)	831 (42·2%)	··	530 (54·5%)	286 (87·5%)	15 (14·9%)
Pre-frail (1–2)	946 (48·1%)	435 (76·7%)	413 (42·5%)	41 (12·5%)	57 (56·4%)
Frail or unable to complete assessment (3+)	190 (9·7%)	132 (23·3%)	29 (3·0%)	··	29 (28·7%)
Age group, years					
40–50	873 (44·4%)	254 (44·8%)	456 (46·9%)	143 (43·7%)	20 (19·8%)
51–60	554 (28·2%)	166 (29·3%)	270 (27·8%)	99 (30·3%)	19 (18·8%)
61–70	344 (17·5%)	91 (16·0%)	173 (17·8%)	61 (18·7%)	19 (18·8%)
71–80	158 (8·0%)	47 (8·3%)	62 (6·4%)	21 (6·4%)	28 (27·7%)
≥81	38 (1·9%)	9 (1·6%)	11 (1·1%)	3 (0·9%)	15 (14·9%)
Age, years	52 (45–62)	52 (45–61)	52 (45–61)	53 (46–61)	65 (53–76)
Sex					
Female	1019 (51·8%)	284 (50·1%)	543 (55·9%)	151 (46·2%)	41 (40·6%)
Male	948 (48·2%)	283 (49·9%)	429 (44·1%)	176 (53·8%)	60 (59·4%)
Marital status					
Married or cohabiting	1490 (75·7%)	415 (73·2%)	764 (78·6%)	256 (78·3%)	55 (54·5%)
Widowed, divorced, or single	477 (24·3%)	152 (26·8%)	208 (21·4%)	71 (21·7%)	46 (45·5%)
Educational attainment					
No formal education	1635 (83·1%)	467 (82·4%)	806 (82·9%)	271 (82·9%)	91 (90·1%)
Any formal education	332 (16·9%)	100 (17·6%)	166 (17·1%)	56 (17·1%)	10 (9·9%)
Wealth quintile					
1 (lowest)	392 (19·9%)	110 (19·3%)	185 (19·0%)	66 (20·2%)	31 (30·7%)
2	387 (19·7%)	107 (18·8%)	192 (19·8%)	72 (22·0%)	16 (15·8%)
3	364 (18·5%)	128 (22·6%)	166 (17·1%)	55 (16·8%)	15 (14·9%)
4	400 (20·3%)	94 (16·5%)	225 (23·1%)	64 (19·6%)	17 (16·8%)
5 (highest)	424 (21·6%)	128 (22·6%)	204 (21·0%)	70 (21·4%)	22 (21·8%)
WHODAS score, points†	10·4 (2·1–22·9)	12·5 (2·1–25·0)	8·3 (2·1–20·8)	10·4 (2·1–22·9)	27·1 (12·5–50·0)
Multimorbidity‡	433/1662 (26·1%)	144/460 (31·3%)	195/850 (22·9%)	57/270 (21·1%)	37/82 (45·1%)

Data are n (%) or median (IQR). WHODAS=WHO Disability Assessment Schedule. *Fried frailty categories were determined using five domains (weight loss, low grip strength, low walk speed, self-reported exhaustion, and low activity levels). Each domain scored one point so scores ranged from 0 to 5. Participants with missing values for physical measurements were categorised as unable to score (with frail). †WHODAS score ranged from 0 to 100 where 0 is no disability and 100 is the worst disability. ‡Multimorbidity is defined as two or more of the following conditions: hypertension, diabetes, hypercholesterolaemia, heart disease, stroke, chronic pulmonary obstructive disease, asthma, cancer, HIV, possible or probable cognitive impairment, symptoms of depression, or symptoms of anxiety. 305 participants were missing data on multimorbidity.

Table 1: Baseline characteristics of the study population by change in frailty status

	Model 1*		Model 2†	
	RR (95% CI)	p value	RR (95% CI)	p value
Age	1·02 (1·01–1·02)	<0·0001	1·01 (1·00–1·02)	0·040
Sex				
Male	1·0 (ref)	..	1·0 (ref)	..
Female	0·68 (0·58–0·82)	<0·0001	0·65 (0·53–0·81)	<0·0001
Marital status				
Married or cohabitating	1·0 (ref)	..	1·0 (ref)	..
Widowed, divorced, or single	1·13 (0·90–1·41)	0·29	1·18 (0·92–1·50)	0·20
Educational attainment				
No formal education	1·0 (ref)	..	1·0 (ref)	..
Any education	0·90 (0·70–1·15)	0·39	0·86 (0·65–1·12)	0·26
Wealth quintile	..	0·60‡	..	0·36‡
1 (lowest)	1·0 (ref)	..	1·0 (ref)	..
2	1·00 (0·78–1·29)	0·92	0·91 (0·70–1·20)	0·52
3	0·83 (0·63–1·09)	0·18	0·79 (0·58–1·06)	0·11
4	0·88 (0·68–1·15)	0·36	0·77 (0·57–1·02)	0·071
5 (highest)	0·95 (0·74–1·22)	0·67	0·88 (0·67–1·16)	0·36
WHODAS score	..	..	1·01 (1·00–1·01)	0·012
Multimorbidity§	..	..	0·91 (0·73–1·14)	0·40

RR=relative risk. WHODAS=WHO Disability Assessment Schedule. *Model 1 adjusted for age, sex, marital status, education level, and wealth quintile. †Model 2 adjusted for age, sex, marital status, education level, wealth quintile, disability, and multimorbidity. ‡Results for global p value when covariable has more than two levels. §Multimorbidity is defined as two or more of the following conditions: hypertension, diabetes, hypercholesterolaemia, heart disease, stroke, chronic pulmonary obstructive disease, asthma, cancer, HIV, possible or probable cognitive impairment, symptoms of depression, or symptoms of anxiety.

Table 2: Multivariable associations from modified Poisson models between change in frailty status and baseline sociodemographic factors, disability, and multimorbidity

index, and multimorbidity. A random effect at the village level was also included to account for any clustering. We then calculated the predicted probability of retention for each sampled individual on the basis of their characteristics. These weights were then normalised and applied to the described frailty and mortality models.

We conducted analyses using STATA 17.0. All statistical tests were done after checking that necessary assumptions had been met.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Between May 25 and July 19, 2018, and July 1 and Aug 22, 2021, 5952 individuals were approached to participate: 1709 (28·7%) did not consent, 1054 (17·7%) participated in 2018 only and were lost to follow-up, 1214 (20·4%) participated in 2021 only, and 1975 (33·2%) were included in both years or died between years (appendix p 2). Eight individuals were excluded from the analyses as they were missing baseline data on frailty, age, sex, marital status, or wealth quintile. In 2018, 66 individuals were categorised as frail as they were unable to score

on physical measurement domains. Fewer than four participants (<0·3%) had missing data for each of the baseline covariates of interest (education, age, sex, marital status, educational attainment, WHODAS score, and wealth index). For baseline multimorbidity, 305 (16%) participants were missing data.

Baseline characteristics of the 1967 participants included in this analysis and the 1054 participants lost to follow-up are shown in the appendix (pp 2–5). The median follow-up time between visits was 36·9 months (IQR 36·6–37·5). Among participants included in both study waves, 190 (9·7%) of 1967 were frail or unable to complete the frailty assessment in 2018, compared with 77 (3·9%) in 2021. Of the 1967 participants included in both study waves, frailty status improved in 567 (28·9%) participants and worsened in 327 (16·6%) participants between 2018 and 2021; 101 (5·1%) participants died between visits. Changes in frailty status and progression to death are shown in the figure and the appendix (p 6). Most participants whose frailty status did not change were non-frail or pre-frail. The most common changes were between non-frail and pre-frail, in both directions. Of the 946 participants who were pre-frail at baseline, 57 (6·0%) died, while 29 (15·3%) died of the 190 participants who were frail at baseline. Frailty progression by sex is shown in the appendix (p 6).

Baseline characteristics by change in frailty status among all participants included in both study visits are given in table 1. The relative risk (RR) of either frailty status worsening or of dying (compared with frailty improving or no change) increased with increasing age and increasing WHODAS score (table 2), whereas female sex appeared to be protective. Models adjusting for WHODAS score and multimorbidity separately did not change the association between change in frailty status or mortality and sociodemographic factors (results not shown).

Improving frailty status (compared with no change or worsening) was associated with baseline marital status, sex, education, and wealth quintile 3 (compared with the lowest quintile; appendix p 7). Although significant, the RR and corresponding 95% CIs for the associations of age and WHODAS score with improving frailty status suggest that the associations were fairly weak (RR for age 0·99 [0·99–1·00]; RR for WHODAS score 1·00 [1·00–1·01]). Adjusting for WHODAS score and multimorbidity attenuated the association between improving frailty category and marital status from an RR of 1·16 (95% CI 1·06–1·27) to 1·11 (1·01–1·22).

Both pre-frailty and frailty, compared with being non-frail, were associated with mortality in the unadjusted model and the model adjusting for sociodemographic factors (table 3). Sequential model adjustments attenuated the relationship between frailty status at baseline and eventual death. After controlling for all sociodemographic factors, multimorbidity, and WHODAS score, the odds of death were higher for pre-frail individuals (odds ratio

	Model 1*		Model 2†		Model 3‡		Model 4§	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Frailty status	..	<0·0001¶	..	0·0060¶	..	..	..	0·10¶
Non-frail	1·0 (ref)	..	1·0 (ref)	..	1·0 (ref)	..	1·0 (ref)	..
Pre-frail	3·41 (1·95–5·97)	<0·0001	2·30 (1·26–4·20)	0·0070	2·16 (1·10–4·25)	0·025	2·07 (1·05–4·09)	0·036
Frail	10·38 (5·39–19·99)	<0·0001	3·38 (1·56–7·32)	0·0020	2·66 (1·12–6·35)	0·027	2·21 (0·90–5·41)	0·084
Age	..	..	1·05 (1·03–1·08)	<0·0001	1·04 (1·02–1·07)	<0·0001	1·03 (1·01–1·06)	0·0090
Sex								
Male	..	..	1·0 (ref)	..	1·0 (ref)	..	..	..
Female	..	..	0·39 (0·24–0·63)	<0·0001	0·50 (0·31–0·81)	0·0048	0·35 (0·20–0·62)	<0·0001
Marital status								
Married or cohabiting	..	..	1·0 (ref)	..	..	..	1·0 (ref)	..
Widowed, divorced, or single	..	..	1·81 (1·06–3·06)	0·027	..	..	1·94 (1·08–3·50)	0·028
Educational attainment								
No formal education	..	..	1·0 (ref)	..	..	..	1·0 (ref)	..
Any education	..	..	0·69 (0·34–1·38)	0·29	..	..	0·69 (0·32–1·47)	0·34
Wealth quintile	..	..	..	0·92¶	..	..	..	0·38¶
1 (lowest)	..	..	1·0 (ref)	..	..	..	1·0 (ref)	..
2	..	..	0·81 (0·42–1·57)	0·53	..	..	0·73 (0·36–1·49)	0·38
3	..	..	0·76 (0·39–1·48)	0·41	..	..	0·50 (0·23–1·09)	0·081
4	..	..	0·81 (0·42–1·55)	0·52	..	..	0·55 (0·26–1·17)	0·12
5 (highest)	..	..	0·91 (0·50–1·67)	0·77	..	..	0·80 (0·42–1·54)	0·51
WHODAS score	..	..	..	..	1·03 (1·01–1·04)	<0·0001	1·03 (1·01–1·04)	<0·0001
Multimorbidity‖	..	..	..	..	1·19 (0·70–2·02)	0·52	1·24 (0·73–2·13)	0·42

OR=odds ratio. WHODAS=WHO Disability Assessment Schedule. *Model 1 did not adjust for any covariables. †Model 2 adjusted for age, sex, marital status, education level, and wealth quintile. ‡Model 3 adjusted for age, sex, WHODAS score, and multimorbidity (sensitivity analysis 1). §Model 4 adjusted for age, sex, marital status, education level, wealth quintile, WHODAS score, and multimorbidity. ¶Results for global p value presented when covariable has more than two levels. ‖Multimorbidity is defined as two or more of the following conditions: hypertension, diabetes, hypercholesterolaemia, heart disease, stroke, chronic pulmonary obstructive disease, asthma, cancer, HIV, possible or probable cognitive impairment, symptoms of depression, or symptoms of anxiety.

Table 3: Multivariable associations between mortality and baseline frailty status, sociodemographic factors, and multimorbidity

2·07 [95% CI 1·05–4·09]) than for non-frail individuals. Associations were also found between odds of death and increasing age; male sex; being single, widowed or divorced; and increasing WHODAS score. Adjusting separately for WHODAS score and multimorbidity did not change associations (results not shown).

The first sensitivity analysis adjusting for age, sex, multimorbidity, and WHODAS score showed similar results to the primary analyses, with both pre-frailty and frailty associated with mortality (table 3). The second sensitivity analysis (appendix pp 8–9)—in which the 170 individuals who were lost to follow-up were classified as frail in 2021—did not change the results. The main findings were supported by the multinomial regression conducted in the third sensitivity analysis (appendix p 10). The fourth sensitivity analysis, in which the alternative scoring methodology for frailty was applied to the 44 individuals with missing data on physical domains of frailty, resulted in 27 individuals who were previously classified as frail being re-classified as pre-frail, while 17 remained classified as frail. Using this scoring method for classifying frailty status did not change the results substantially (appendix pp 11–13). Finally, in the fifth sensitivity analysis, weighting models to account for non-participation in the follow-up visit did

not substantially change the results of the main analysis (appendix pp 14–15).

Discussion

This is, to our knowledge, the first longitudinal study of frailty in a population living in a low-income country. Frailty status was highly dynamic. Pre-frail status increased the risk of death in all models whereas frailty was not associated with increased risk in the fully adjusted model; most deaths occurred among participants who were categorised as pre-frail at baseline. Associations between mortality and frailty status were attenuated by sociodemographic factors, multimorbidity, and disability.

Our results suggest that, despite different economic, physical activity, and disease contexts, frailty trajectories in low-income settings might operate in a similarly dynamic way to trajectories observed in high-income settings.[31,32] However, in our study population, frailty status improved in a much larger proportion of individuals than has been shown in high-income countries. We know of no health system strengthening intervention in Burkina Faso that could have contributed to this improvement. However, given that the improvement was associated with baseline WHODAS

score or multimorbidity, one explanation for the greater improvement in this setting, compared with high-income country settings, might be that, at the time of the first survey, participants had an acute or chronic condition that was cured or improved over time. Additionally, the subsistence farming activities in the region, which might encourage greater physical engagement and performance, could mean that frailty is more reversible and that respondents have a greater ability to improve from illness than those in other settings. Given that the two waves of the survey were conducted at similar times of year, this finding is unlikely to be due to a seasonal effect.[33] Nevertheless, our observation that frailty is plastic—and therefore, modifiable—in this population is encouraging. Several approaches—such as increasing physical exercise, health education, and counselling for older people—have been previously established as effective to delay and reverse frailty in higher-income settings;[34] these approaches could be transferable to resource-limited settings.

The relationship between frailty status and mortality, which has been extensively shown in high-income settings[6] and in a cohort from South Africa (an upper-middle-income country), was substantiated in our study.[10,15] Although our method of calculating frailty was different from that used in the meta-analysis in 2018,[6] our analysis suggests that frailty, compared with non-frail status, was associated with a higher risk of mortality in this low-income setting. A study of rural South African adults older than 40 years found that both pre-frailty and frailty were associated with a higher risk of death;[10] similar to our analysis, this previous study showed that adjustment for age, sex, household wealth, marital status, and individual comorbidities reduced the effect size. However, the study in South Africa did not include multimorbidity or disability in the fully adjusted models. Although differences in methods make it challenging to draw comparisons, our results showed a lower magnitude of associations between frailty and mortality, which suggest that people in Nouna seem to improve frailty status more than individuals in higher-income settings.

Previous studies in high-income or middle-income settings have typically shown higher mortality with increasing frailty status.[16,17,34,35] We observed numerically more deaths among participants who were pre-frail than among those who were frail at baseline—possibly because our study included more frail women than frail men, and women are known to have greater longevity than men. Three of our four sequentially adjusted regression models found that the odds of mortality were higher among those in the frail than in the pre-frail category (compared with those who were non-frail). Our results therefore suggest, overall, that both pre-frail and frail states are important indicators of future outcomes in this population.

Several other studies in Burkina Faso have shown that, in all age groups, women have a lower health status than men.[20,36] However, these studies have been predominantly cross-sectional. The results of our longitudinal study differ from these previous findings in that men had a higher risk of both mortality and worsening frailty status (compared with improving frailty or no change) than women. This finding could be due to differential attrition, as more men than women were lost to follow-up, which might have resulted in the men included in both study waves being less healthy, thereby obscuring sex differences in health status that have been observed in other studies done in similar settings. However, our analyses showed no difference in baseline frailty status or multimorbidity among men who were lost to follow-up compared with those included in both study visits, suggesting low levels of differential attrition. Our findings also remained unchanged after accounting for missingness using inverse probability weighting.

Considered together, our findings suggest that frailty is a more dynamic state in this population than in other previously studied settings. Frailty might therefore be more reversible and more amenable to interventions in this population, which is encouraging given the projected growth in the population of older people in Burkina Faso and in low-income and middle-income countries more generally.

Our study has several limitations. Loss to follow-up was substantial, with 35% of the 2018 population not included in the 2021 visit. However, given that being frail or non-frail at baseline did not affect loss to follow-up and that two sets of sensitivity analyses focused on loss to follow-up did not affect the findings substantially, we believe that frailty status probably did not affect loss to follow-up. Next, considering the associations between frailty, other confounders, and death, as noted in our directed acyclic graph, adjusting for marital status, wealth, and education might result in overadjustment, as the effects of these factors are potentially mediated through intermediate phenotypes, including frailty, disability, and multimorbidity. However, the phenotypes through which these factors might act and the strength and directionality of this mediation are complex and poorly defined. Additionally, the relationships between disability, multimorbidity, and frailty are complex, with some elements of bidirectionality. We have therefore included multiple models to facilitate understanding of these effects. However, the confounders explored might not be causally related to frailty. Additionally, our age threshold for inclusion in the study (ie, 40 years) was lower than that of most recognised thresholds for defining old age (ie, 60 or 65 years). However, this lower threshold is used in much research done in LMICs, in accordance with the age distributions in these countries and given the small number of people older than the standard thresholds. The age cutoff used in our study allows comparison of our findings with those of other studies that have used the same cutoff. Additionally, other studies have shown that components of the ageing phenotype (frailty and multimorbidity) are prevalent in

people older than 40 years in LMICs, which might suggest that biological ageing can occur in younger populations in these settings. We chose to use age as a continuous variable in our models, showing the change in outcome per each 1-year increment in age (noting that the linearity assumption was met). Including age in groups as determined by regression splines did not substantially change the strength or directionality of the results (data not shown).

In this epidemiological study, we were not able to use standard clinical guidelines to classify people with hypertension. However, given that access to health care for non-communicable diseases is poor in Burkina Faso, requiring a clinical diagnosis for classification would likely result in high under-reporting of hypertension in our study. We therefore followed the same protocol as previous epidemiological field studies.[37] Participants with test results suggesting hypertension, diabetes, hyperlipidaemia, or anaemia were provided with a referral to the appropriate level of care, with costs of care and travel provided. This referral system could have influenced frailty status in 2021, although field staff have reported that many people who were provided with these services chose not to use them (Sie A, unpublished). Multimorbidity conditions were identified using a combination of self-reporting and biomarker-based definitions, and therefore self-reporting could have led to under-reporting of conditions. Self-reporting was also used for assessing weight loss in the derivation of the Fried frailty index; however, our previous work has validated this method.[10] Furthermore, potential measurement errors in confounders such as wealth index, multimorbidity, and disability result in a risk of unmeasured confounding and residual confounding. We did not have access to causes of death and could therefore not exclude deaths from trauma or injury that might not be related to frailty. Finally, our study was restricted to only one area of Burkina Faso, and therefore our results might not generalise to other communities.

Despite these limitations, this study contributes to a growing body of work on ageing populations in low-resource settings and provides insight into the plasticity of frailty in these populations. Together, our findings suggest that investment in social and care systems is needed to ensure that the growing older population—and their families, who are traditionally their caretakers—can continue to contribute to the societies in which they live. Future work should focus on designing tailored interventions that can effectively improve frailty status at an early stage.

Contributors
CG, SA-B, MDW, CFP, MB, BC, PG, GH, MI, JM-G, LO, AS, and JID conceptualised and designed the study. DG-P, GH, and SA-B cleaned the data. DG-P, JID, MDW, and GH analysed and interpreted the data. DG-P, JID, and CG wrote the initial draft of the Article, which was critically revised by all authors. DG-P and JID developed the figure and tables. DG-P and JID accessed and verified the data. All authors had full access to all the data in the study and accept final responsibility for the decision to submit for publication.

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