Socioeconomic inequalities in physical, psychological, and cognitive multimorbidity in middle-aged and older adults in 33 countries: a cross-sectional study

Yujie Ni, Yaguan Zhou*, Mika Kivimäki, Ying Cai, Rodrigo M Carrillo-Larco, Xin Xu, Xiaochen Dai, Xiaolin Xu*

Summary

Background Many physical, psychological, and cognitive disorders are highly clustered among populations with low socioeconomic status. However, the extent to which socioeconomic status is associated with different combinations of these disorders is unclear, particularly outside high-income countries. We aimed to evaluate these associations in 33 countries including high-income countries, upper-middle-income countries, and one lower-middle-income country.

Methods This cross-sectional multi-region study pooled individual-level data from seven studies on ageing between 2017 and 2020. Education and total household wealth were used to measure socioeconomic status. Physical disorder was defined as having one or more of the self-reported chronic conditions. Psychological and cognitive disorders were measured by study-specific instruments. The outcome included eight categories: no disorders, physical disorder, psychological disorder, cognitive disorder, and their four combinations. Multivariable-adjusted logistic regression models were used to estimate odds ratios (ORs) and 95% CIs for the associations of socioeconomic status with these outcomes separately for high-income countries, upper-middle-income countries, and the lower-middle-income country.

Findings Among 167 376 individuals aged 45 years and older, the prevalence of multimorbidity was 24·5% in high-income countries, 33·9% in upper-middle-income countries, and 8·1% in the lower-middle-income country (India). Lower levels of education, household wealth, and a combined socioeconomic status score were strongly associated with physical, psychological, and cognitive multimorbidity in high-income countries and upper-middle-income countries, with ORs (low *vs* high socioeconomic status) for physical–psychological–cognitive multimorbidity of 12·36 (95% CI 10·29–14·85; p<0·0001) in high-income countries and of 23·84 (18·85–30·14; p<0·0001) in upper-middle-income countries. The associations in the lower-middle-income country were mixed. Participants with both a low level of education and low household wealth had the highest odds of multimorbidity (eg, OR for physical-psychological–cognitive multimorbidity 21·21 [15·95–28·19; p<0·0001] in high-income countries, 37·07 [25·66–53·56; p<0·0001] in upper-middle-income countries, and 54·96 [7·66–394·38; p<0·0001] in the lower-middle-income country).

Interpretation In study populations from high-income countries, upper-middle-income countries, and the lower-middle-income country, the odds of multimorbidity, which included physical, psychological, and cognitive disorders, were more than ten times greater in individuals with low socioeconomic status. Equity-oriented policies and programmes that reduce social inequalities in multimorbidity are urgently needed to achieve Sustainable Development Goals.

Funding Zhejiang University, Fundamental Research Funds for the Central Universities, The Key Laboratory of Intelligent Preventive Medicine of Zhejiang Province, Wellcome Trust, Medical Research Council, National Institute on Aging, and Academy of Finland.

Lancet Healthy Longev 2023; 4: e618–28

For the Chinese translation of the abstract see Online for appendix 1

*Contributed equally

School of Public Health, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, China (Y Ni MSc, Y Zhou BMed, Xin Xu PhD, Xiaolin Xu PhD); **The Key Laboratory of Intelligent Preventive Medicine of Zhejiang Province, Hangzhou, China** (Y Ni, Y Zhou, Xin Xu, Xiaolin Xu); **UCL Brain Sciences, University College London, London, UK** (Prof M Kivimäki FMedSci); **Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China** (Y Cai PhD); **Emory Global Diabetes Research Center** (R M Carrillo-Larco PhD) **and Hubert Department of Global Health, Rollins School of Public Health** (R M Carrillo-Larco), **Emory University, Atlanta, GA, USA; Department of Health Metrics Sciences, School of Medicine** (X Dai PhD) **and Institute for Health Metrics and Evaluation** (X Dai), **University of Washington, Seattle, WA, USA; School of Public Health, Faculty of Medicine, The University of Queensland, Brisbane, QLD, Australia** (Xiaolin Xu)

Correspondence to:
Dr Xiaolin Xu, School of Public Health, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou 310058, China
xiaolin.xu@zju.edu.cn

Introduction

Population ageing is contributing to increases in chronic diseases, imposing a substantial burden on global health-care systems.[1] The leading contributors to the global disease burden in ageing populations are cardiovascular diseases, malignant neoplasms, chronic respiratory diseases, musculoskeletal diseases, and neurological and mental disorders.[1] The co-occurrence of these conditions—multimorbidity—has also become a global challenge.[2] There is an inverse association between socioeconomic status, such as level of education, social class, and household wealth, and multimorbidity.[3,4] For instance, a longitudinal study from the UK found that socioeconomically disadvantaged individuals experienced an earlier onset and a more rapid accumulation of diseases and multimorbidity than socioeconomically

Research in context

Evidence before this study

Global analyses of differences in multimorbidity between socioeconomic groups could increase understanding of health inequalities and provide insights to reduce chronic disease burden more efficiently. We searched PubMed and Google Scholar on March 25, 2022, using the terms "socioeconomic inequalities in health", "health inequalities", "physical and mental multimorbidity", "cognitive impairment", "mental and cognitive condition", "education", "wealth", "income", "multimorbidity and socioeconomic status", "high-income countries", and "middle- and low- income countries". We searched for systematic reviews, crossover studies, and cohort studies from inception to March 25, 2022, with language restricted to English, and found approximately ten studies from high-income countries. In contrast, very few analyses originated from middle-income and low-income countries. In addition, most studies used a simplistic summation of chronic conditions to define multimorbidity. Some studies distinguished physical and mental conditions in multimorbidity, and others focused on specific psychological and cognitive diseases. Absent, however, were compilations of global data on physical, psychological, and cognitive multimorbidity.

Added value of this study

We used harmonised data from seven studies on ageing across 33 high-income, upper-middle-income, and lower-middle-income countries to examine the extent to which socioeconomic status is associated with physical, psychological, and cognitive disorders and their multimorbidity, and whether these associations vary across different country types. Our analysis included a total of 167 376 individuals aged 45 years and older. When examining distinct indicators of socioeconomic status, such as education and household wealth, we observed more consistent associations with physical, psychological, and cognitive disorders, and multimorbidity, in high-income countries and upper-middle-income countries compared with the lower-middle-income country. Across all types of countries, education showed an inverse association with physical–cognitive, psychological–cognitive, and physical–psychological–cognitive multimorbidity. However, the most substantial gradients in multimorbidity were observed among participants with both low education and low household wealth. Irrespective of the country's classification, this specific group had odds of multimorbidity—encompassing physical, psychological, and cognitive disorders—that were more than ten times higher compared with individuals with high socioeconomic status.

Implications of all the available evidence

The UN's 2030 Sustainable Development Goals (SDGs) include specific objectives to address health disparities at national and global levels. WHO has created guidelines for monitoring these disparities and facilitating SDG attainment. Highlighting the importance and timeliness of these initiatives, this study provides global-level evidence, showing substantially increased odds of multimorbidity of physical, psychological, and cognitive disorders in socioeconomically disadvantaged people living in high-income and middle-income countries. This evidence supports equity-oriented policies and health intervention programmes that place particular emphasis on socioeconomically deprived groups.

For the **Program on Global Aging, Health, and Policy** see https://g2aging.org

For the **US Health and Retirement Study (HRS)** see https://hrs.isr.umich.edu

For the **English Longitudinal Study on Ageing (ELSA)** see https://www.elsa-project.ac.uk

For the **Survey of Health, Ageing and Retirement in Europe (SHARE)** see https://share-eric.eu

For the **Korean Longitudinal Study of Aging (KLoSA)** see https://survey.keis.or.kr/eng/klosa/klosa01.jsp

For the **China Health and Retirement Longitudinal Study (CHARLS)** see https://charls.pku.edu.cn/en

For the **Mexican Health and Aging Study (MHAS)** see https://www.mhasweb.org/Home/index.aspx

For the **Longitudinal Aging Study in India (LASI)** see https://lasi-india.org

advantaged individuals.[3] In a meta-analysis of 24 cross-sectional studies, people with lower educational attainment had 1·6 times higher odds of multimorbidity than people with higher education level.[4] Regarding the definition of multimorbidity, these studies included physical, psychological (eg, depression), or cognitive disorders (eg, dementia), or a combination of them, although the specific list of diseases varied between the studies. Not one of them, however, characterised multimorbidity in terms of different combinations of physical, psychological, and cognitive disorders. This limitation is crucial because socioeconomic disadvantages might be linked to specific patterns of multimorbidity. Another concern is that most of the studies were conducted in high-income countries, leaving the association between socioeconomic status and multimorbidity in countries with lower income levels poorly understood.[5]

This multi-region study aimed to investigate the associations between socioeconomic status (eg, education and household wealth) and different multimorbidity patterns in countries with diverse income levels, including four cohort studies from high-income countries, two from upper-middle-income countries, and one from a lower-middle-income country.

Methods

Study design and population

This cross-sectional multi-region study used individual-level data from seven well-characterised studies on ageing in the Program on Global Aging, Health, and Policy: the US Health and Retirement Study (HRS); the English Longitudinal Study on Ageing (ELSA); the Survey of Health, Ageing and Retirement in Europe (SHARE); the Korean Longitudinal Study of Aging (KLoSA); the China Health and Retirement Longitudinal Study (CHARLS); the Mexican Health and Aging Study (MHAS); and the Longitudinal Aging Study in India (LASI). They are HRS-family studies with the same biennial longitudinal design and comparable survey protocols, sharing consistent measures of economic status, lifestyle, and health among nationally representative samples of middle-aged and older adults (aged ≥45 years). According to the World Bank definition,[6]

the cohorts are from a total of 33 high-income countries (HRS, ELSA, KloSA, and SHARE, except for Bulgaria), upper-middle income countries (CHARLS, MHAS, and Bulgaria from SHARE), and a lower-middle-income country (India; LASI).

The latest wave for each study was selected to use the most updated data and maintain consistency of the time period across studies (table 1). Our study included adults (aged ≥45 years) as physical, psychological, and cognitive disorders are increasingly prevalent among middle-aged and older adults. After single-value imputation (appendix 2 p 3), participants with non-missing information on level of education, total household wealth, and physical, psychological, and cognitive disorders were included (appendix 2 p 2).

This study is a secondary analysis based on publicly available datasets. All participating studies were approved by Institutional Review Boards and the respondents provided written informed consent. Ethical approval was not required for the analysis of the anonymised data.

Procedures

Data on level of education and total household wealth of participants were extracted from each study by YN on Dec 16, 2022. Level of education was country-specific categorised into tertiles based on years of schooling (low, middle, and high). Total household wealth was defined as the net value of all financial assets and was also country-specific categorised into tertiles (low, middle, and high). Data was harmonised for education and total household wealth using specific cutoff values of tertiles across different countries (appendix 2 p 4).

Previous studies have employed various measurements of socioeconomic status, including summed scores of different socioeconomic status indicators and combining different categories of these indicators into groups. Additionally, some studies have suggested that education and wealth might not be interchangeable.[7] This study measured socioeconomic status in two ways: (1) by using the summed score of education and total household wealth tertiles, which ranged from 2 to 6; and (2) by combining the categories of education and total household wealth, resulting in nine groups ($3 \times 3 = 9$).

Outcomes

The outcomes were physical, psychological, and cognitive disorders, and their co-occurrence (multimorbidity). Participants were identified as having a physical disorder if they self-reported at least one of the following seven chronic conditions: hypertension, diabetes, cancer, lung disease, heart disease, stroke, and arthritis. The presence of a psychological disorder was ascertained by study-specific psychological assessments (eg, Center for Epidemiologic Studies Depression score), using the same cutoff values as in previous studies (appendix 2 p 4). The presence of a cognitive disorder was assessed through study-specific cognitive tests (eg, Mini-Mental State Examination), and the cutoff values were adapted from previous studies or determined empirically (appendix 2 p 4). Considering that the included physical disorders are chronic, and the

	Country type*	Selected study phase	Year	Number of participants (total/women)	Age (years) at the survey (mean [SD])
US Health and Retirement Study (HRS)					
USA	High income	Wave 14	2018–20	12 087/7059	69·53 (11·64)
English Longitudinal Study on Ageing (ELSA)					
England	High income	Wave 9	2018–20	7428/4160	67·96 (10·16)
Survey of Health, Ageing and Retirement in Europe (SHARE)					
Austria	High income	Wave 8	2018–20	1562/945	72·33 (8·88)
Belgium	High income	Wave 8	2018–20	1998/1111	70·04 (9·64)
Bulgaria	Upper–middle-income	Wave 8	2018–20	899/544	68·38 (9·34)
Croatia	High income	Wave 8	2018–20	1188/671	68·37 (8·81)
Cyprus	High income	Wave 8	2018–20	537/328	72·64 (9·99)
Czech Republic	High income	Wave 8	2018–20	2701/1652	71·58 (7·93)
Denmark	High income	Wave 8	2018–20	2160/1171	69·40 (9·26)
Estonia	High income	Wave 8	2018–20	3025/1102	71·73 (9·63)
Finland	High income	Wave 8	2018–20	1154/618	68·45 (9·31)
France	High income	Wave 8	2018–20	2477/1450	71·01 (9·80)
Germany	High income	Wave 8	2018–20	2871/1535	69·71 (9·09)
Greece	High income	Wave 8	2018–20	2993/1725	69·55 (9·80)
Hungary	High income	Wave 8	2018–20	775/472	70·26 (7·70)
Israel	High income	Wave 8	2018–20	929/551	73·18 (8·74)
Italy	High income	Wave 8	2018–20	2146/1207	70·63 (9·64)
Latvia	High income	Wave 8	2018–20	788/497	68·32 (9·96)
Lithuania	High income	Wave 8	2018–20	1432/901	68·33 (10·47)
Luxembourg	High income	Wave 8	2018–20	949/520	68·18 (8·76)
Malta	High income	Wave 8	2018–20	794/436	68·54 (8·80)
Netherlands	High income	Wave 8	2018–20	1926/1048	70·78 (8·25)
Poland	High income	Wave 8	2018–20	2074/1163	68·01 (9·49)
Romania	High income	Wave 8	2018–20	1268/729	67·06 (9·29)
Slovakia	High income	Wave 8	2018–20	992/549	63·46 (8·19)
Slovenia	High income	Wave 8	2018–20	2493/1466	70·97 (9·12)
Spain	High income	Wave 8	2018–20	2120/1207	73·54 (9·83)
Sweden	High income	Wave 8	2018–20	2355/1271	73·28 (8·41)
Switzerland	High income	Wave 8	2018–20	1900/1040	71·60 (9·04)
Korean Longitudinal Study of Aging (KLOSA)					
South Korea	High income	Wave 7	2018–19	6828/3944	69·48 (9·93)
China Health and Retirement Longitudinal Study (CHARLS)					
China	Upper–middle-income	Wave 4	2018–19	14 036/6829	60·91 (9·39)
Mexican Health and Aging Study (MHAS)					
Mexico	Upper–middle-income	Wave 5	2018–19	15 889/9226	64·43 (11·11)
The Longitudinal Aging Study in India (LASI)					
India	Lower–middle-income	Wave 1	2017–19	64 602/34 586	59·62 (10·54)

*Defined by The World Bank (2019 calendar year).

Table 1: **Included cohort studies, data waves, and study populations**

See Online for appendix 2

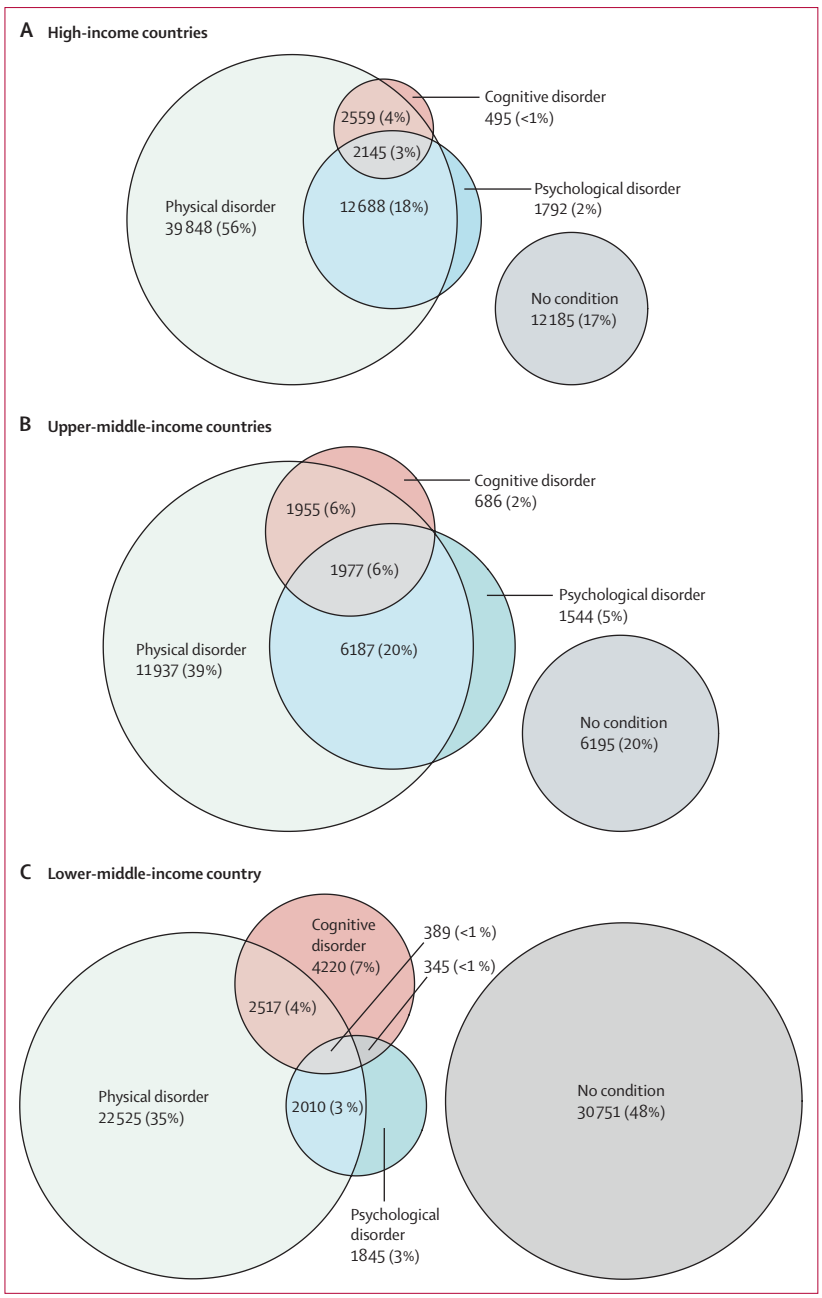

Figure 1: **Proportional Venn diagrams of outcomes by country types**
High-income countries included the USA (US Health and Retirement Study; HRS), England (English Longitudinal Study on Ageing; ELSA), South Korea (Korean Longitudinal Study of Aging; KLOSA), and European countries (Survey of Health, Ageing and Retirement in Europe; SHARE) except for Bulgaria; upper-middle-income countries included China (China Health and Retirement Longitudinal Study; CHARLS), Mexico (Mexican Health and Aging Study; MHAS), and Bulgaria (SHARE); and the lower-middle-income country was India (The Longitudinal Aging Study in India; LASI). The size of the circles was proportional to the prevalence of physical, psychological, and cognitive conditions in each country type. Full prevalence results can be found in the appendix (p 2).

measurement of psychological and cognitive disorders involved current conditions, the assessment of multimorbidity in this study mainly relates to the simultaneous co-occurrence of these three types of disorders in the same individual.

Eight outcomes were constructed: (1) physical disorder; (2) psychological disorder; (3) cognitive disorder; (4) physical–psychological multimorbidity; (5) physical–cognitive multimorbidity; (6) psychological–cognitive multimorbidity; (7) physical–psychological–cognitive multimorbidity; and (8) no above-mentioned disorders (reference group).

In each study, covariates were assessed at the selected wave of the survey. In addition to age (45–64 years and ≥65 years), sex (self-reported with two options of male *vs* female), and countries, we selected lifestyle factors, including BMI, alcohol consumption, smoking, and physical activity as they can act as confounders in the association between socioeconomic status and multimorbidity.[8,9] BMI was calculated as weight (kg) divided by the square of the height (m²) and was categorised into underweight (<18·5 kg/m²), normal weight (18·5–24·9 kg/m²), and overweight (≥25kg/m²). Alcohol consumption (less frequent than drinking weekly, and equal or more frequent than drinking weekly), smoking (whether being a current smoker), and physical activity (whether being physically active at least once a week) were also harmonised as categorical variables (appendix 2 p 4). No race or ethnicity data were available due to participant confidentiality.

Statistical analysis

The characteristics of the participants from high-income countries, upper-middle-income countries, and the lower-middle-income country were summarised by socioeconomic status and outcomes. Between-group differences were explored using the χ^2 test. The distribution of outcomes among the study population from the three income country groups was described using a proportional Venn diagram.

Multivariable adjusted logistic regressions were conducted to estimate odds ratios (ORs) and 95% CIs for the association of socioeconomic status with outcomes in different income countries (high-income countries, upper- middle-income countries and lower-middle-income country). Independent associations of education and total household wealth with different outcomes were examined, followed by the association of categorised summed scores of socioeconomic status with different outcomes. In addition, we investigated the association of different combinations of education and total household wealth with different outcomes and visualised ORs using heat maps. For each analysis, we ran: (1) a crude model that included socioeconomic status; (2) a partially adjusted model with the covariates of country, age, and sex; and (3) a fully adjusted model that controlled for country, age, sex, smoking, alcohol consumption, physical activity, and BMI.

A series of additional analyses were conducted to test the robustness of the results. Subgroup analyses were used to explore variation in the socioeconomic status-morbidity associations by age and sex, as suggested by previous

studies.[10] Sensitivity analysis using different definitions of education and total household income (appendix 2 p 4) to measure socioeconomic status was conducted. To minimise confounding arising from the differences in the ability to take cognitive assessments between the educated population and non-educated population, we performed another sensitivity analysis, in which only educated participants (years of schooling >0 years) were included. Additionally, quasi-Poisson regression mixed effects models were used to examine the association between socioeconomic status and the number of physical conditions among those with physical-related outcomes. All tests in this study were two-sided with a significance level of p<0·05. Statistical analyses were implemented using SAS (version 9.4) and R (version 4.2.2).

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.

	Physical disorders		Psychological disorders		Cognitive disorders		Physical–psychological multimorbidity		Physical–cognitive multimorbidity		Psychological–cognitive multimorbidity		Physical–psychological–cognitive multimorbidity	
	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)
High-income countries*														
Education level†														
Low	11 290	1·53 (1·44–1·63)‡	393	1·25 (1·09–1·44)§	222	4·49 (3·47–5·79)‡	4837	2·11 (1·96–2·28)‡	1251	4·56 (3·96–5·26)‡	104	4·32 (2·98–6·25)‡	1170	5·21 (4·44–6·11)‡
Middle	10 782	1·23 (1·16–1·30)‡	519	1·08 (0·95–1·23)	95	1·83 (1·38–2·44)‡	3478	1·36 (1·27–1·47)‡	453	2·01 (1·72–2·34)‡	44	1·79 (1·19–2·70)§	368	2·16 (1·81–2·58)‡
High	11 280	1 (ref)	710	1 (ref)	121	1 (ref)	2987	1 (ref)	350	1 (ref)	59	1 (ref)	249	1 (ref)
Total household wealth														
Low	9994	1·36 (1·28–1·45)‡	520	1·48 (1·29–1·69)‡	175	2·15 (1·66–2·78)‡	4812	2·11 (1·96–2·28)‡	920	2·23 (1·95–2·56)‡	96	2·66 (1·84–3·85)‡	966	3·00 (2·58–3·49)‡
Middle	11 547	1·17 (1·11–1·24)‡	520	1·11 (0·98–1·27)	152	1·39 (1·08–1·80)¶	3637	1·34 (1·25–1·44)‡	706	1·45 (1·27–1·66)‡	63	1·30 (0·88–1·92)	528	1·45 (1·24–1·70)‡
High	11 811	1 (ref)	582	1 (ref)	111	1 (ref)	2853	1 (ref)	428	1 (ref)	48	1 (ref)	293	1 (ref)
Socioeconomic status**														
Low	4633	2·05 (1·87–2·24)‡	177	1·89 (1·57–2·29)‡	107	7·90 (5·86–10·66)‡	2576	4·09 (3·70–4·52)‡	631	8·05 (6·83–9·49)‡	51	9·41 (6·04–14·68)‡	698	12·36 (10·29–14·85)‡
Lower-middle	7283	1·52 (1·43–1·63)‡	306	1·39 (1·20–1·61)‡	114	3·57 (2·70–4·72) ‡	2899	2·30 (2·12–2·49)‡	633	4·14 (3·56–4·81)‡	58	4·40 (2·92–6·63)‡	482	4·51 (3·78–5·38)‡
Higher-middle	8730	1·28 (1·20–1·35) ‡	430	1·21 (1·06–1·38)§	101	1·95 (1·48–2·57) ‡	2799	1·59 (1·47–1·71)‡	434	2·16 (1·86–2·52)‡	51	2·34 (1·55–3·51)‡	385	2·81 (2·36–3·36)‡
High	12 706	1 (ref)	709	1 (ref)	116	1 (ref)	3028	1 (ref)	356	1 (ref)	47	1 (ref)	222	1 (ref)
Upper-middle-income countries*														
Education level														
Low	2401	1·31‡ (1·18–1·44)	307	1·74 (1·47–2·06)‡	336	13·35 (9·99–17·84)‡	1697	2·28 (2·04–2·54)‡	1062	14·34 (11·76–17·49)‡	184	12·29 (8·22–18·35)‡	1101	15·91 (12·85–19·71)‡
Middle	3493	1·02 (0·94–1·10)	467	1·27 (1·10–1·46)‖	131	2·46 (1·81–3·35) ‡	1870	1·43 (1·30–1·57)‡	294	2·17 (1·76–2·68)‡	54	2·00 (1·27–3·13)§	312	2·73 (2·18–3·42)‡
High	4193	1 (ref)	511	1 (ref)	64	1 (ref)	1532	1 (ref)	150	1 (ref)	31	1 (ref)	120	1 (ref)
Total household wealth														
Low	2867	1·05 (0·96–1·15)	490	1·62 (1·39–1·89)‡	194	1·29 (1·02–1·64)¶	1956	1·77 (1·60–1·96)‡	642	1·55 (1·32–1·82)‡	138	2·75 (1·94–3·89)‡	798	2·63 (2·22–3·11)‡
Middle	3449	1·09 (1·01–1·19)¶	398	1·11 (0·95–1·30)	200	1·33 (1·05–1·68)¶	1753	1·41 (1·28–1·56)‡	508	1·31 (1·11–1·54)§	84	1·65 (1·14–2·38)§	478	1·70 (1·42–2·03) ‡
High	3771	1 (ref)	397	1 (ref)	137	1 (ref)	1390	1 (ref)	356	1 (ref)	47	1 (ref)	257	1 (ref)
Socioeconomic status														
Low	836	1·28 (1·11–1·47)‖	144	2·56 (2·05–3·21)‡	131	10·21 (7·49–13·91)‡	781	3·24 (2·78–3·77)‡	483	14·88 (11·94–18·54)‡	106	20·34 (13·37–30·96)‡	596	23·84 (18·85–30·14)‡
Lower-middle	1920	1·21 (1·10–1·34)‖	270	1·82 (1·53–2·16)‡	171	5·65 (4·27–7·46)‡	1218	2·14 (1·91–2·39)‡	447	6·22 (5·10–7·59)‡	75	6·27 (4·11–9·57)‡	495	9·28 (7·47–11·52)‡
Higher-middle	2958	1·13 (1·04–1·23)§	396	1·47 (1·27–1·70)‡	144	2·88 (2·18–3·81)‡	1563	1·68 (1·52–1·85)‡	399	3·63 (2·99–4·41)‡	55	2·79 (1·80–4·34)‡	313	3·90 (3·13–4·86)‡
High	4373	1 (ref)	475	1 (ref)	85	1 (ref)	1537	1 (ref)	177	1 (ref)	33	1 (ref)	129	1 (ref)

(Table 2 continues on next page)

	Physical disorders		Psychological disorders		Cognitive disorders		Physical–psychological multimorbidity		Physical–cognitive multimorbidity		Psychological–cognitive multimorbidity		Physical–psychological–cognitive multimorbidity	
	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)
(Continued from previous page)														
Lower-middle-income country*														
Education level														
Low	7638	0·76 (0·72–0·80) ‡	879	1·30 (1·14–1·49)‖	3369	30·73 (22·03–42·85)‡	816	1·05 (0·92–1·19)	1858	15·76 (11·60–21·40)‡	275	18·43 (6·79–50·01)‡	271	10·25 (5·19–20·24)‡
Middle	5688	0·98 (0·93–1·03)	456	1·26 (1·09–1·45)§	360	8·08 (5·72–11·41)‡	520	1·24 (1·09–1·41)§	284	5·78 (4·19–7·98)‡	20	3·72 (1·27–10·91)¶	31	2·86 (1·35–6·03)§
High	7222	1 (ref)	382	1 (ref)	36	1 (ref)	486	1 (ref)	44	1 (ref)	4	1 (ref)	9	1 (ref)
Total household wealth														
Low	5576	0·77 (0·73–0·80)‡	650	1·09 (0·96–1·23)	1843	1·36 (1·23–1·49)‡	585	0·89 (0·79–1·00)	856	1·05 (0·93–1·17)	142	1·37 (1·01–1·86)¶	139	1·56 (1·15–2·12)§
Middle	6753	0·85 (0·81–0·89)‡	605	1·05 (0·92–1·19)	1146	0·97 (0·88–1·07)	584	0·84 (0·75–0·95)§	728	0·92 (0·82–1·04)	97	1·07 (0·77–1·48)	110	1·31 (0·96–1·80)
High	8219	1 (ref)	462	1 (ref)	776	1 (ref)	653	1 (ref)	602	1 (ref)	60	1 (ref)	62	1 (ref)
Socioeconomic status														
Low	2707	0·62 (0·59–0·66)‡	372	1·29 (1·11–1·50)§	1685	12·78 (10·60–15·56)‡	318	0·94 (0·81–1·09)	733	6·84 (5·57–8·39)‡	130	32·56 (10·31–102·85)‡	120	11·45 (6·11–21·46)‡
Lower-middle	4265	0·72 (0·69–0·76)‡	481	1·30 (1·13–1·50)‖	1155	7·40 (6·08–9·02)‡	457	1·02 (0·89–1·16)	735	5·47 (4·46–6·70)‡	97	21·00 (6·63–66·51)‡	111	8·51 (4·54–15·94)‡
Higher-middle	5574	0·84 (0·80–0·88)‡	470	1·26 (1·10–1·45)§	811	5·68 (4·65–6·94)‡	495	1·01 (0·89–1·15)	602	4·46 (3·63–5·47)‡	69	16·73 (5·25–53·26)‡	69	5·37 (2·83–10·20)‡
High	8002	1 (ref)	394	1 (ref)	114	1 (ref)	552	1 (ref)	116	1 (ref)	3	1 (ref)	11	1 (ref)

The results were fully adjusted for country, age, sex, BMI, drinking, smoking, and physical activity. *High-income countries included the USA (US Health and Retirement Study; HRS), England (English Longitudinal Study on Ageing; ELSA), South Korea (Korean Longitudinal Study of Aging; KLOSA), and European countries (Survey of Health, Ageing and Retirement in Europe; SHARE) except for Bulgaria; upper-middle-income countries included China (China Health and Retirement Longitudinal Study; CHARLS), Mexico (Mexican Health and Aging Study; MHAS), and Bulgaria (SHARE); and the lower-middle-income country was India (The Longitudinal Aging Study in India; LASI). †Education and total household wealth were included in the same model. ‡Test significance p<0·0001. §Test significance p<0·01. ¶Test significance p<0·05. ‖Test significance p<0·001. **Socioeconomic status was constructed as the summed score (ranging from 2 to 6) of education tertiles (1, 2, or 3) and total household wealth tertiles (1, 2, or 3), and categorised into four classes: low (summed score of 2), lower-middle (summed score of 3), upper-middle (summed score of 4), and high (summed score of 5 or 6).

Table 2: **Levels of education, total household wealth, and composite socioeconomic status score in relation to seven health outcomes**

Results

Of the 167 376 participants (aged ≥45 years) included in this study, 43·0% (71 950 of 167 376) were from high-income countries, 18·4% (30 824) from upper-middle-income countries, and 38·6% (64 602) from the lower-middle-income country (appendix 2 p 6). The prevalence of multimorbidity was 24·5% for high-income countries, 33·9% for upper-middle-income countries, and 8·1% for the lower-middle-income country (figure 1).

In general, compared with individuals with a higher level of education or wealth, participants with a lower level of education or wealth had higher odds of disorders in most of the outcomes, specifically in high-income countries and upper-middle-income countries (table 2). In the lower-middle-income country (India), the associations of education and household wealth were weaker for physical–psychological multimorbidity, and reversed for physical disorders alone. In addition, education presented a greater gradient across tertiles than household wealth in most of the outcomes.

Socioeconomic status had a consistent dose–response relationship with having physical, psychological, or cognitive disorders, and multimorbidity in high-income countries and upper-middle-income countries (table 2). For example, in upper-middle-income countries, low socioeconomic status was associated with 3·24 (95% CI 2·78–3·77; p<0·0001) times higher odds of having physical–psychological multimorbidity, 14·88 (11·94–18·54; p<0·0001) times higher odds of physical–cognitive multimorbidity, and 20·34 (13·37–30·96; p<0·0001) times higher odds of psychological–cognitive multimorbidity. In addition, the gradient from low to high socioeconomic status class was significantly higher in upper-middle-income countries and in the lower-middle-income country than the high-income countries. In India, this dose–response relationship was not found in physical–psychological multimorbidity and was reversed in having physical disorders alone. However, irrespective of the country type, the odds of having physical–psychological–cognitive multimorbidity were more than ten times higher in individuals with low socioeconomic status than those with high socioeconomic status. The odds were 12·36 (95% CI 10·29–14·85; p<0·0001) in high-income countries, 23·84 (18·85–30·14;

p<0·0001) in upper-middle-income countries, and 11·45 (6·11–21·46; p<0·0001) in India. Unadjusted and partially adjusted ORs can be found in the appendix 2 (pp 12–14).

Different combinations of education and household wealth had varied associations with health outcomes (figure 2, appendix 2 p 15). In high-income countries and upper- middle-income countries, participants with both a low level of education and low level of household wealth had the highest ORs in all of the outcomes. ORs were 21·21 (95% CI 15·95–28·19; p<0·0001) for physical–psychological–cognitive multimorbidity in high-income countries, and 37·07 (25·66–53·56; p<0·0001) in upper-middle-income countries. This pattern was also found in the lower-middle-income country for most of the outcomes, but attenuated or reversed in the physical-related outcomes. Across all income country groups, education showed a particularly marked gradient in cognitive-related outcomes.

Within each subgroup by age and sex in the three income country groups, the associations between socioeconomic status and the outcomes remained in most of the outcomes (appendix 2 pp 17–20). In addition, the associations were more pronounced in middle-aged participants than in older participants in upper-middle-income countries and the lower-middle-income country, whereas the associations were more pronounced in women than men in high-income countries and upper-middle-income countries.

In high-income countries and upper-middle-income countries, there was a dose–response relationship between socioeconomic status and the number of physical conditions in participants with at least one physical condition (appendix 2 p 21). In the lower-middle-income country, the observed dose–response relationship was exclusively identified in individuals with physical–psychological–cognitive multimorbidity and physical–cognitive multimorbidity. In addition, it was less pronounced in relation to physical–psychological multimorbidity, and was in reverse for those with physical conditions alone.

The sensitivity analysis based on the total household income-constructed socioeconomic status category indicator showed similar results to those from primary analyses in all income country groups (appendix 2 p 23). The sensitivity analysis with a subgroup of educated participants (years of schooling >0 year) showed consistent associations with the health outcomes in all country types (appendix 2 p 24).

Discussion

Our study analysed data from 167 376 individuals aged 45 years and older from seven studies on ageing across 33 countries to explore socioeconomic inequalities in physical, psychological, and cognitive disorders, and multimorbidity. Lower socioeconomic status was consistently associated with higher odds of all seven morbidity outcomes in high-income countries and

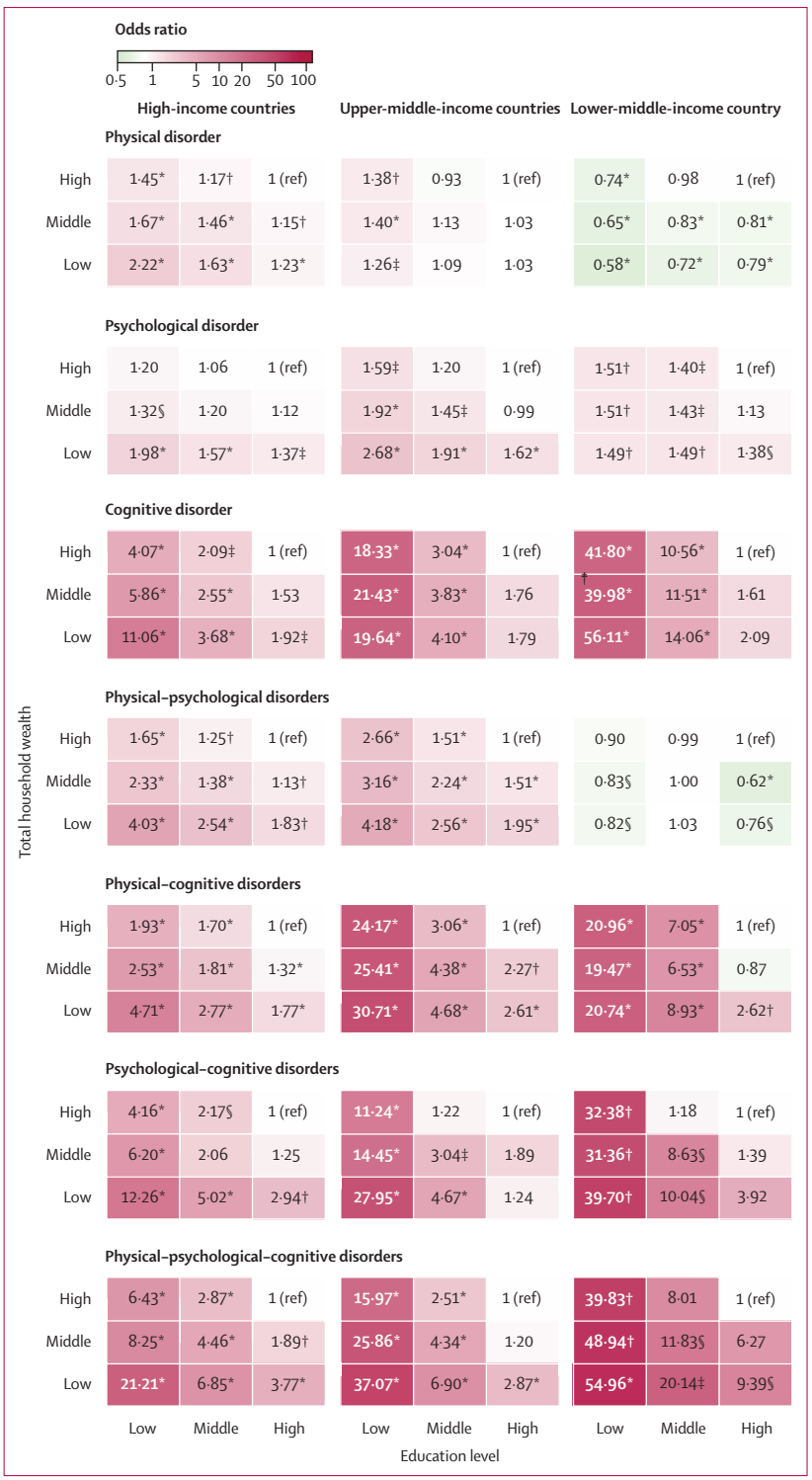

Figure 2: **Heat maps based on the associations (odds ratios) of the combinations of level of education and total household wealth with the outcomes**

A darker colour in a gradient from white to red shows higher odds of corresponding outcomes. A darker colour in a gradient from white to green shows lower odds of corresponding outcomes. The results were fully adjusted for country, age, sex, BMI, smoking, drinking, and physical activity. Detailed odds ratios and 95% CIs can be found in the appendix (p 2). *Test significance p<0·0001. †Test significance p<0·001. ‡Test significance p<0·01. §Test significance p<0·05.

upper- middle-income countries, whereas the corresponding associations with some disorders were attenuated in the lower-middle-income country. However, the odds of physical–psychological–cognitive multimorbidity were more than ten times greater in individuals with low socioeconomic status compared with those with high socioeconomic status across all income country groups.

Although previous studies have suggested the adverse associations between socioeconomic status and health, disorders, and multimorbidity,[11,12] there has been a shortage of research on specific patterns of multimorbidity by the nature of the disorders. In a longitudinal study based on ELSA, lower socioeconomic status (defined by wealth) was associated with accelerated decline between 6 years to 8 years in 16 outcomes from physical, physiological, cognitive, and emotional domains, independently of diagnosed health conditions, self-rated health, education, and other factors.[13] This study adds to those findings by providing population-based evidence on the dose–response relationship of socioeconomic status with physical, psychological, and cognitive disorders, and their multimorbidity in high-income countries, upper-middle-income countries, and a lower-middle-income country. Potential contributors to these inequalities include poorer health-care access, greater environmental exposures, lower neighbourhood safety, increased prevalence of unhealthy behaviours, and chronic stress in those experiencing social disadvantage than those who were socially advantaged.[14] Individuals with lower socioeconomic status are more likely to be exposed to social and environmental stressors than individuals with high socioeconomic status (eg, crowding, crime, noise pollution, and discrimination), leading to negative psychological consequences.[15] In addition, we observed stronger associations in cognitive-related multimorbidity than the rest of the outcomes, with the sharpest socioeconomic gradient found in physical–psychological–cognitive multimorbidity in high-income countries and upper-middle-income countries, and psychological–cognitive multimorbidity in the lower-middle-income country. These findings highlight the need for wide-ranging prevention of multimorbidity among middle-aged and older adults, especially for those with a low socioeconomic status.

We observed a prevalence of multimorbidity in the lower-middle-income country at 8·1%, notably lower than in high-income countries (24·5%) and upper-middle-income countries (33·9%). This finding could be attributed to the average age of participants from the lower-middle-income country (59·6 years), which was lower than in studies from high-income countries and upper-middle-income countries (60·9–73·5 years) and possibly reduced the prevalence of age-related conditions. Health-care services being less robust in lower-middle-income countries may also have led to lower disease detection rates compared with high-income countries,[11] contributing to under-reported multimorbidity cases. In addition, the lower life expectancy in lower-middle-income countries might reduce the prevalence of late-onset age-related conditions, attenuating more multimorbidity prevalence in LASI compared with other studies.[12]

At the global level, we found the gradient of socioeconomic inequalities in multimorbidity was more marked in upper-middle-income countries than in high-income countries, especially in cognitive-related outcomes. Previous quantitative evidence regarding cross-country comparison is very limited. A study that used data from 41 low-income and middle-income countries found that wealth and educational inequalities were more pronounced in the low-income country group. Both wealth and education were inversely associated with angina, arthritis, asthma, depression, and comorbidity prevalence.[16] In this study, individuals with lower socioeconomic status in the lower-middle-income country experienced lower odds of having physical disorders alone than individuals with higher socioeconomic status, and this disparity has also been noticed by various studies. Although evidence from high-income countries revealed higher risks of multiple physical chronic conditions in people with low socioeconomic status,[17,18] a previous multinational study from middle-income settings showed protective effects of low socioeconomic status on obesity and diabetes.[19] A systematic review of low-income and lower-middle-income countries has suggested a higher prevalence of diabetes among wealthier and more educated people, especially in low-income countries.[17] According to the nutrition transition hypothesis, increasing wealth is often associated with shifts in dietary and physical activity patterns.[20] Specifically, groups from a high socioeconomic status were less physically active and consumed more fats, salt, and processed foods compared with groups from a low socioeconomic status, leading to the predominance of nutrition-related diseases (eg, diabetes and cancer).[20] The reverse relationship between socioeconomic status class and physical disorders could also partially explain the absence of association between low socioeconomic status and physical–psychological multimorbidity. Future studies including more lower-middle-income countries and low-income countries are needed to further compare health inequalities in multimorbidity across the globe.

We found that level of education and total household wealth had varied associations with the outcomes. Level of education was a more robust indicator than total household wealth in most of the outcomes, which is in agreement with previous evidence. A study of 29 lower-middle-income countries showed that higher educational attainment was more strongly associated with an elevated risk of incident diabetes, compared with household wealth.[21] Some European studies found low educational level to be a more important risk factor

for depressive symptoms than low household income or low occupational position among older adults.[22,23] Furthermore, education remained a robust correlate of cognitive-related outcomes after considering its potential effect on the ability to take cognitive assessments. A previous study[24] has suggested that in addition to improving vocabulary, literacy, and numeracy, education might attenuate age-associated declines in cognition. Additionally, education was obtained at the early adulthood stage and had a fundamental influence on the ability to work, nature of occupation, level of income and, to some extent, area-based deprivation, all of which could influence morbidity.[4] Therefore, improving the level of education nationwide can be beneficial for achieving health equity, especially in lower-middle-income countries.

The main findings were replicated in subgroup analyses by age and sex. Socioeconomic gradients in almost all health outcomes were more pronounced in middle-aged adults than older adults in upper-middle-income countries and the lower-middle-income country. In these countries, underdiagnosis of medical conditions among older people could partially explain this finding.[25] In high-income countries and upper-middle-income countries, socioeconomic gradients in health outcomes were also greater in women than men and in the lower-middle-income country where a dose–response relationship between socioeconomic status and psychological conditions was observed in women but not men. This study added to the evidence that socioeconomic inequalities in chronic health exist not only across and within regions but also within age and sex subgroups.

There is a pressing need for increased investments in integrated strategies for managing multimorbidity in primary care with the aim of reducing social inequalities in multimorbidity.[11] A *Lancet* Health Policy[26] highlights the presence of an inverse care law characterising health care in many low-income and middle-income countries where socially disadvantaged individuals receive less and lower-quality health care despite having greater needs than those advantaged. Furthermore, a disproportionate care law persists in high-income countries where socially disadvantaged individuals receive more health care, but of worse quality and insufficient quantity to meet their additional needs.

The observed strong dose–response relationships between socioeconomic status and physical, psychological, and cognitive multimorbidity indicate the need for social and fiscal policies to reduce health inequalities. National programmes should be implemented to protect vulnerable middle-aged and older populations with little economic and educational resources, and groups (including women) likely to be further disadvantaged during events that worsen their frail socioeconomic and health status. Providing health benefits to the entire population could inadvertently increase inequalities as individuals with higher socioeconomic status or education tend to benefit more from such resources.

Recommended actions to decrease socioeconomic inequalities in multimorbidity: (1) implementing resource redistribution measures (eg, affordable housing, taxes, and social security); (2) targeting health resources and interventions towards less advantaged populations, addressing unhealthy behaviours, and improving engagement with health care;[27] and (3) emphasising international collaboration to tackle substantial socioeconomic inequalities in middle-income countries, tailoring care models for specific chronic conditions, and aligning efforts with UN's Sustainable Development Goals and WHO guidelines.[28]

Our study represents a pioneering effort to access the association between socioeconomic status and multimorbidity, considering the distinct effects on physical, psychological, and cognitive disorders. Data from large population-based cohorts in 33 high-income countries and middle-income countries further enhanced the generalisability of the evidence across different settings. Additionally, the robustness of the findings was confirmed by employing various measures of socioeconomic status and conducting subgroup and sensitivity analyses.

There are several limitations to this study. First, the cross-sectional nature of the study precluded us from assessing the longitudinal influence of socioeconomic status. Future longitudinal studies are thus warranted to consider the temporal and potentially reciprocal influences of socioeconomic status on different types of multimorbidity. Additionally, lifestyle factors were incorporated into the multivariable-adjusted analyses, but the confounding or mediating effect of these factors could not be evaluated due to the cross-sectional nature of the data. Second, although we focused on individual physical conditions rather than disease categories, as recommended by a recent Delphi consensus study,[29] the number of included conditions was limited, potentially leading to an underestimation of multimorbidity prevalence. Furthermore, the symptoms, subtypes, and severity of disorders were not accounted for, especially in measuring psychological and cognitive conditions, considering the proportion of imputed values from the previous wave. Third, physical, psychological, and cognitive disorders were self-reported by respondents, potentially introducing recall bias and overlooking undiagnosed conditions. Considering that the availability of health care often varies inversely with the needs of the population served,[26] this limitation could contribute to an underestimation of socioeconomic inequalities in multimorbidity. However, it is worth noting that previous studies have shown a high correlation between self-reported medical history on physical disorders and electronic health records.[30,31] Fourth, due to the inconsistency of socioeconomic factors across studies, only level of education, total household wealth, and

income were used for the socioeconomic status measurement. Other factors such as area of living (neighbourhood socioeconomic status, and urban or rural) and occupation (nature and hierarchy) that have previously been recognised should be explored in future studies. Fifth, due to data availability limitations and population differences among the cohorts, the measurement of depressive and cognitive impairment symptoms relied on study-specific multi-item instruments. Although cutoffs were predefined and all instruments were validated,[32,33] the variations in measurement tools across cohorts could increase heterogeneity in cohort-specific results. Future research can use consistent instruments and cutoff thresholds to confirm the validity of the findings. Sixth, our study included only high-income countries and middle-income countries, with only one country (India) falling into the lower-middle-income country category. Further research with available data from lower-middle-income countries and low-income countries is warranted to capture the global health inequity. Seventh, despite the overall large sample size, certain groups still had limited numbers due to the low prevalence of outcome cases, leading to sparse data bias. Estimates from these comparisons exhibit wide 95% CIs and should be interpreted cautiously.[34] Finally, the bias from measurement errors in confounders (eg, smoking, alcohol consumption, and physical activity) and some unmeasured confounding (eg, family history of physical, psychological, and cognitive disorders) could also have influenced our results.

This multi-region study found strong associations between socioeconomic status and physical, psychological, and cognitive disorders, and their multimorbidity, although the strength varied. Particularly, the association with multimorbidity, involving all three disorder types, showed a significant correlation as individuals with low socioeconomic status faced odds of this type of multimorbidity more than ten times greater than those with high socioeconomic status. Our findings emphasise the urgent need for action and enhanced efforts to address health inequalities at national and global levels. Policy makers and health professionals should prioritise socioeconomically disadvantaged groups in multimorbidity prevention and management strategies.

Contributors

XiaoX conceptualised the study and supervised the project. YN and XiaoX created the analysis plan and YN conducted the statistical analyses. YZ and XiaoX validated and verified the data and statistical analyses. YN and YZ contributed to the visualisation of the study and wrote the initial draft of the manuscript. MK, YC, RMC-L, XD, and XinX provided valuable advice on writing revisions of the manuscript and statistical methods. All authors contributed to and approved the final manuscript and had full access to the data in the study and final responsibility for the decision to submit for publication. The corresponding author had full access to all data in the study and had the final responsibility for the decision to submit for publication.

Declaration of interests

XiaoX was supported by Zhejiang University, Fundamental Research Funds for the Central Universities, and The Key Laboratory of Intelligent Preventive Medicine of Zhejiang Province. MK was supported by the Wellcome Trust (grant number 221854/Z/20/Z), the Medical Research Council (grant numbers R024227 and S011676), the National Institute on Aging (grant numbers R01AG056477 and R01AG062553), and Academy of Finland (grant number 350426). All other authors declare no competing interests.

Data sharing

The original data for this study are available on their respective websites: The Health and Retirement Study (HRS; https://hrs.isr.umich.edu), the English Longitudinal Study on Ageing (ELSA; https://www.elsa-project.ac.uk), the Survey of Health, Ageing and Retirement in Europe (SHARE; https://share-eric.eu), the Korean Longitudinal Study of Aging (KLoSA; https://survey.keis.or.kr/eng/klosa/klosa01.jsp), the China Health and Retirement Longitudinal Study (CHARLS; http://charls.pku.edu.cn/index/en.html), the Mexican Health and Aging Study (MHAS; https://www.mhasweb.org/Home/index.aspx), and the Longitudinal Aging Study in India (LASI; https://lasi-india.org).

Acknowledgments

We thank all team members who have contributed to the HRS, ELSA, SHARE, KLoSA, CHARLS, MHAS, and LASI studies. This analysis used data or information from the Harmonized HRS, ELSA, SHARE, KLoSA, CHARLS, MHAS, and LASI datasets, and Codebooks developed by the Gateway to Global Aging Data, supported by the National Institute on Aging (grant numbers R01 AG030153, RC2 AG036619, and 1R03AG043052). For more information, please refer to https://g2aging.org. HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan. Funding for ELSA is provided by the National Institute of Aging (grants 2RO1AG7644–01A1 and 2RO1AG017644) and a consortium of UK Government departments coordinated by the Office for National Statistics. SHARE data collection has been funded by European Union (under grant agreement number 101102412) and the European Union's Horizon 2020 research and innovation programme (under grant agreement numbers 870628 and 101015924), and various national funding sources gratefully acknowledged (https://share-eric.eu/infrastructure/funding). KLoSA is organised by the Korea Employment Information Service. CHARLS is supported by the Behavioral and Social Research division of the National Institute on Aging of the National Institute of Health (grants 1-R21-AG031372–01, 1-R01-AG037031–01, and 3-R01AG037031–03S1); the Natural Science Foundation of China (grants 70773002, 0910107022, and 71130002), the World Bank (contracts 7145915 and 7159234), and is conducted by Peking University. The Mexican Health and Aging Study is partly sponsored by the National Institutes of Health and National Institute on Aging (grant number NIH R01AG018016) in the USA and the Instituto Nacional de Estadísticay Geografía in Mexico. LASI is supported by the National Institute on Aging (R01AG042778).

References

1 Prince MJ, Wu F, Guo Y, et al. The burden of disease in older people and implications for health policy and practice. *Lancet* 2015; **385:** 549–62.

2 Barnett K, Mercer SW, Norbury M, Watt G, Wyke S, Guthrie B. Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet* 2012; **380:** 37–43.

3 Khanolkar AR, Chaturvedi N, Kuan V, et al. Socioeconomic inequalities in prevalence and development of multimorbidity across adulthood: a longitudinal analysis of the MRC 1946 National Survey of Health and Development in the UK. *PLoS Med* 2021; **18**: e1003775.

4 Pathirana TI, Jackson CA. Socioeconomic status and multimorbidity: a systematic review and meta-analysis. *Aust N Z J Public Health* 2018; **42**: 186–94.

5 Xu X, Mishra GD, Jones M. Mapping the global research landscape and knowledge gaps on multimorbidity: a bibliometric study. *J Glob Health* 2017; **7**: 010414.

6 The World Bank. The world by income and region. 2023. https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html#:~:text=The%20World%20Bank%20classifies%20economies,%2Dmiddle%2C%20and%20high%20income (accessed Feb 13, 2023).

7 Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc* 2007; **99**: 1013–23.

8 Fortin M, Haggerty J, Almirall J, Bouhali T, Sasseville M, Lemieux M. Lifestyle factors and multimorbidity: a cross sectional study. *BMC Public Health* 2014; **14**: 686.

9 House JS, Kessler RC, Herzog AR. Age, socioeconomic status, and health. *Milbank Q* 1990; **68**: 383–411.

10 Jin Y, Hong C, Luo Y. Sex differences in cognitive aging and the role of socioeconomic status: evidence from multi-cohort studies. *Psychiatry Res* 2023; **321:** 115049.

11 The Lancet. 50 years of the inverse care law. *Lancet* 2021; **397:** 767.

12 Foreman KJ, Marquez N, Dolgert A, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories. *Lancet* 2018; **392:** 2052–90.

13 Steptoe A, Zaninotto P. Lower socioeconomic status and the acceleration of aging: an outcome-wide analysis. *Proc Natl Acad Sci USA* 2020; **117:** 14911–7.

14 Kivimäki M, Bartolomucci A, Kawachi I. The multiple roles of life stress in metabolic disorders. *Nat Rev Endocrinol* 2023; **19:** 10–27.

15 Baum A, Garofalo JP, Yali AM. Socioeconomic status and chronic stress. Does stress account for SES effects on health? *Ann N Y Acad Sci* 1999; **896:** 131–44.

16 Hosseinpoor AR, Bergen N, Mendis S, et al. Socioeconomic inequality in the prevalence of noncommunicable diseases in low- and middle-income countries: results from the World Health Survey. *BMC Public Health* 2012; **12**: 474.

17 Williams J, Allen L, Wickramasinghe K, Mikkelsen B, Roberts N, Townsend N. A systematic review of associations between non-communicable diseases and socioeconomic status within low- and lower-middle-income countries. *J Glob Health* 2018; **8:** 020409.

18 Xu Y, Wu Q. Prevalence trend and disparities in rheumatoid arthritis among US adults, 2005–2018. *J Clin Med* 2021; **10:** 3289.

19 McEniry M, Samper-Ternent R, Flórez CE, Pardo R, Cano-Gutierrez C. Patterns of SES health disparities among older adults in three upper middle- and two high-income countries. *J Gerontol B Psychol Sci Soc Sci* 2019; **74:** e25-e37.

20 Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. *Int J Obes Relat Metab Disord* 2004; **28**: S2–9.

21 Seiglie JA, Marcus ME, Ebert C, et al. Diabetes prevalence and its relationship with education, wealth, and BMI in 29 low- and middle-income countries. *Diabetes Care* 2020; **43:** 767–75.

22 Chlapecka A, Kagstrom A, Cermakova P. Educational attainment inequalities in depressive symptoms in more than 100,000 individuals in Europe. *Eur Psychiatry* 2020; **63:** e97.

23 Domènech-Abella J, Mundó J, Leonardi M, et al. The association between socioeconomic status and depression among older adults in Finland, Poland and Spain: a comparative cross-sectional study of distinct measures and pathways. *J Affect Disord* 2018; **241:** 311–8.

24 Livingston G, Huntley J, Sommerlad A, et al. Dementia prevention, intervention, and care: 2020 report of the *Lancet* Commission. *Lancet* 2020; **396:** 413–46.

25 Peters DH, Garg A, Bloom G, Walker DG, Brieger WR, Rahman MH. Poverty and access to health care in developing countries. *Ann N Y Acad Sci* 2008; **1136:** 161–71.

26 Cookson R, Doran T, Asaria M, Gupta I, Mujica FP. The inverse care law re-examined: a global perspective. *Lancet* 2021; **397:** 828–38.

27 Wang D, Dai X, Mishra SR, Lim C, Carrillo-Larco RM, Gakidou E, Xu X. Socioeconomic inequality in health behavior changes before and after noncommunicable diseases onset in older adults: a multi-cohort study from 17 countries. *The Lancet Public Health* 2022; **7:** e670–82.

28 Abebe F, Schneider M, Asrat B, Ambaw F. Multimorbidity of chronic non-communicable diseases in low- and middle-income countries: a scoping review. *J Comorb* 2020; **10**: 2235042x20961919.

29 Ho ISS, Azcoaga-Lorenzo A, Akbari A, et al. Measuring multimorbidity in research: Delphi consensus study. *BMJ Medicine* 2022; **1:** e000247.

30 Glymour MM, Avendano M. Can self-reported strokes be used to study stroke incidence and risk factors?: evidence from the health and retirement study. *Stroke* 2009; **40:** 873–9.

31 Ning M, Zhang Q, Yang M. Comparison of self-reported and biomedical data on hypertension and diabetes: findings from the China Health and Retirement Longitudinal Study (CHARLS). *BMJ Open* 2016; **6:** e009836.

32 Prince MJ, Reischies F, Beekman ATF, et al. Development of the EURO–D scale – a European Union initiative to compare symptoms of depression in 14 European centres. *Brit J Psychiat* 1999; **174:** 330–8.

33 Boey KW. Cross-validation of a short form of the CES-D in Chinese elderly. *International Journal of Geriatric Psychiatry* 1999; **14:** 608–17.

34 Greenland S, Mansournia MA, Altman DG. Sparse data bias: a problem hiding in plain sight. *BMJ* 2016; **352:** i1981.