Maturitas 115 (2018) 56–63

Contents lists available at ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

# Socioeconomic inequalities in frailty among older adults in six low- and middle-income countries: Results from the WHO Study on global AGEing and adult health (SAGE)

Emiel O. Hoogendijk[a,*], Judith J.M. Rijnhart[a], Paul Kowal[b,c], Mario U. Pérez-Zepeda[d,e], Matteo Cesari[f], Pedro Abizanda[g], Teresa Flores Ruano[g], Astrid Schop-Etman[h,i], Martijn Huisman[a,j], Elsa Dent[k,l]

[a] Department of Epidemiology & Biostatistics, Amsterdam Public Health research institute, VU University Medical Center, Amsterdam, The Netherlands
[b] Research Institute for Health Sciences, Chiang Mai University, Chiang Mai, Thailand
[c] World Health Organization, Geneva, Switzerland
[d] Clinical and Epidemiologic Research Department, Instituto Nacional de Geriatría, Mexico City, Mexico
[e] Instituto de Envejecimiento, Pontificia Universidad Javeriana, Bogotá, Colombia
[f] Geriatric Unit, Fondazione Ca' Granda, IRCCS Ospedale Maggiore Policlinico, Milan, Italy
[g] Department of Geriatrics, Albacete University Hospital, Albacete, Spain
[h] Department of Public Health, Erasmus University Medical Center, Rotterdam, The Netherlands
[i] Erasmus University College, Erasmus University, Rotterdam, The Netherlands
[j] Department of Sociology, VU University, Amsterdam, The Netherlands
[k] Torrens University Australia, Adelaide, Australia
[l] Baker Heart and Diabetes Institute, Melbourne, Australia

ARTICLE INFO

*Keywords:*
Frail older adults
SAGE
Low- and middle-income countries
Socioeconomic position

ABSTRACT

*Objectives:* The aim of this study was to investigate socioeconomic inequalities in frailty among older adults in six low- and middle-income countries (LMICs), and to examine to what extent chronic diseases account for these inequalities.

*Study design:* Data were used from the Study on global AGEing and adult health (SAGE) wave 1 (2007–2010). Nationally representative samples of adults aged 50+ years from China, Ghana, India, Mexico, the Russian Federation and South Africa were analyzed (n = 31,174).

*Main outcome measures:* Educational level and wealth were used as socioeconomic indicators. Frailty was assessed with modified criteria for the frailty phenotype. Self-reported disease diagnoses were used. A relative index of inequality (RII) was calculated to compare socioeconomic inequalities in frailty between countries.

*Results:* People in lower socioeconomic positions had higher prevalence rates of frailty. The largest inequalities in frailty were found in Mexico (RII 3.7, 95% CI 2.1–6.4), and the smallest inequalities in Ghana (RII 1.1, 95% CI 0.7–1.8). Mediation analyses revealed that the chronic diseases considered in this study do not explain the higher prevalence of frailty seen in lower socioeconomic groups.

*Conclusions:* Substantial socioeconomic inequalities in frailty were observed in LMICs, but additional research is needed to find explanations for these. Given that the population of older adults in many LMICs is expanding at a greater rate than in many high-income countries, our results indicate an urgent public health need to address frailty in these countries.

## 1. Introduction

Due to population aging, physical frailty has become a major challenge for public health worldwide [1]. Characterized by a loss of reserve capacity in multiple physiological systems and decreased resistance to stressors, frailty is a leading cause of functional decline and mortality in older people, and associated with the need for healthcare [2,3]. It is often described by diminished strength, reduced gait speed, and exhaustion [4]. Frailty is conceptually different from disability and comorbidity, although related to these factors [5,6].

* Corresponding author at: Department of Epidemiology & Biostatistics, Amsterdam Public Health Research Institute, VU University Medical Center, P.O. Box 7057, 1007MB Amsterdam, The Netherlands.
*E-mail address:* e.hoogendijk@vumc.nl (E.O. Hoogendijk).

https://doi.org/10.1016/j.maturitas.2018.06.011
Received 31 October 2017; Received in revised form 16 May 2018; Accepted 19 June 2018
0378-5122/ © 2018 Elsevier B.V. All rights reserved.

From studies in high income countries, frailty has been shown to be associated with lower socioeconomic position (SEP) in the older population. Older adults with a low SEP (e.g., those with a low educational level or low income) have higher frailty prevalence rates [7,8], about twice as high as older adults with a high SEP [7]. Although frailty has been studied in low- and middle-income countries (LMICs) [9–11], none of the previous studies have focused on socioeconomic inequalities in frailty – specifically, the unequal distribution of frailty across socioeconomic groups. Therefore, it remains unknown if similar patterns of inequalities are present in LMICs.

Besides describing the level of inequalities, gaining insight into pathways leading from SEP to frailty is necessary for the development of intervention strategies aimed at reducing frailty and its negative health consequences, especially in groups with a low SEP. Explanations may be sought in variables that accelerate the development of frailty. Chronic diseases are seen as important risk factors for frailty, as they may reduce the physiologic reserve capacity of a person [2,12]. There is some evidence that social gradients in chronic diseases might be different in LMICs compared to higher income countries [13,14]. Studies in Europe have shown that chronic diseases and the presence of multiple diseases explain between 10% and 20% of socioeconomic inequalities in frailty among older adults, because of higher disease prevalence rates in lower socioeconomic groups [7,15]. Given the possible differences in social gradients in chronic diseases, the role of diseases in explaining socioeconomic inequalities in frailty in LMICs would provide needed information for health promotion and management.

The World Health Organization (WHO) Study on global AGEing and adult health (SAGE) provides a unique opportunity to study socioeconomic inequalities in frailty in LMICs. Using data from SAGE, the aim of this study was to investigate socioeconomic inequalities in frailty among older adults in six LMICs, and to examine to what extent chronic diseases account for these inequalities.

## 2. Methods

### 2.1. Study population and design

Data were used from WHO's SAGE wave 1 (2007–2010). SAGE consists of nationally representative samples of older adults in six LMICs: China, Ghana, India, Mexico, Russian Federation, and South Africa. The SAGE countries represent different geographic regions of the world and different levels of economic development, and include the world's two most populous countries (China and India). The SAGE sampling method was based on the design developed for the World Health Survey. Standardized survey materials and training were provided for teams in each country, with face-to-face interviews used to collect data. The individual response rates were relatively high, but there was variation across countries: China (93%), Ghana (81%), India (68%), Mexico (53%), Russian Federation (83%), and South Africa (75%). The response rates in Mexico were the lowest, mainly because there was limited time for the fieldwork, which did not allow for multiple revisits if the respondent was not at home at the first visit. More details on the sampling and data collection of SAGE have been published elsewhere [16]. The pooled wave 1 six-country sample consisted of 34,124 respondents aged 50+ years. The analytical sample of the current study consisted of 31,174 respondents with valid data on frailty (91.4%). Ethical approval was obtained from local research review boards for each participating SAGE site, in addition to the WHO Ethical Review Committee. All participants provided written informed consent prior to the interview.

### 2.2. Measures

Educational level and wealth were used as indicators of SEP. Highest educational level attained was grouped into five categories (no education, less than primary, primary, secondary and higher) standardized across countries using the UNESCO International Standard Classification of Education [17]. Relative wealth levels were derived using the WHO standard approach to estimate permanent income from household ownership of durable goods, dwelling characteristics (type of floors, walls, and cooking stove), and access to services such as water, sanitation and electricity [18,19]. Wealth levels were transformed into quintiles (country specific), with the lowest quintile (Q1) indicating the poorest households and the highest quintile (Q5) indicating the richest households.

Frailty was assessed with a modified frailty phenotype, based on the criteria proposed by Fried et al. [12], including slow gait speed, weight loss, low grip strength, exhaustion, and low physical activity. Since the original cut-off points of the frailty phenotype have not been validated in low- and middle income countries, we used the lowest quintile approach (country specific) for the items measured on a continuous scale. This method has proven to be a good alternative for pre-defined cut-off points [20]. For each country, the frailty criteria were assessed as follows. Gait speed was measured by recording the time taken in seconds to walk 4 m at a normal pace. Slow gait speed was defined by the lowest quintile, stratified by sex and height. The presence of the weight loss criterion was based on the lowest quintile of body mass index (BMI) [21]. Body height and weight were measured without shoes. Grip strength was assessed with a handheld dynamometer, using the sum of the highest values of two measurements on each hand. The lowest quintile stratified by sex and BMI was applied as cut-off to indicate low grip strength. Exhaustion was measured on a 5-point Likert scale by asking respondents whether they had enough energy for daily activities. This criterion was considered present if participants answered "Not at all" or "A little". Finally, physical activity was assessed using the WHO Global Physical Activity Questionnaire (GPAQ) [22,23]. The GPAQ collects information on frequency, intensity and duration of physical activities in daily life. The low physical activity criterion was present for those who were categorized as "low" according to the GPAQ (activity < 600 MET-minutes a week). See Appendix 1 for more details on the measurement of the five criteria. Participants were classified as pre-frail if one or two criteria were present, and as frail if three or more criteria were present.

The presence of chronic diseases was assessed by self-reported diagnosis, by means of the question "Has a healthcare professional ever told you that you have this disease?" In the current study, six major chronic diseases were considered: angina, osteoarthritis, lung disease (emphysema, bronchitis, chronic obstructive pulmonary diseases or asthma), diabetes, hypertension, and stroke. Multimorbidity was defined as the presence of two or more diseases.

### 2.3. Statistical analysis

Descriptive statistics were calculated for each country to characterize the study population. To compare socioeconomic inequalities in frailty between countries, we calculated a relative index of inequality (RII) for both educational level and wealth. This measure takes into account the population distribution across socioeconomic groups, and is directly comparable between different populations [24]. It is a continuous score between 0 and 1, which is assigned to each person based on their relative position in the cumulative population distribution of each socioeconomic indicator. The RII is an odds ratio (OR) obtained from logistic regression, that expresses the risk of frailty for those at the bottom of the socioeconomic hierarchy compared with those at the top. A higher RII indicates larger SEP inequalities.

To study the association between SEP and frailty, and the explanatory role of chronic diseases and multimorbidity, we performed mediation analyses (Fig. 1). Two logistic regression models were fitted to the data for each chronic disease variable and country. One model was used to estimate the effect of SEP on chronic disease ($a$ coefficient). The other model was used to estimate the direct effect of SEP on frailty

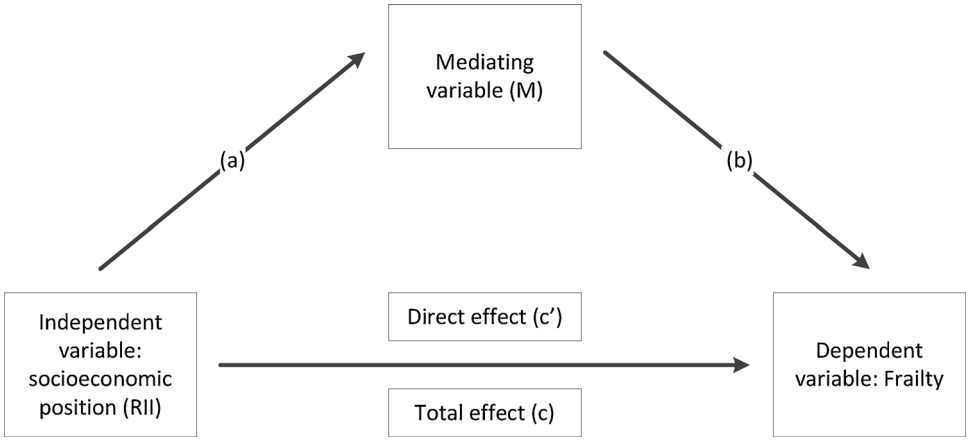



**Fig. 1.** Mediation model.

(*c'* coefficient) and the effect of chronic disease on frailty (*b* coefficient). To cope with the different scales of the coefficients in multiple logistic regression analysis, all coefficients from the logistic regression analyses were fully-standardized before further calculations [25]. Based on the fully-standardized coefficients, the indirect effect of SEP on frailty via chronic disease was calculated using the product of the *a* and *b* coefficients approach. For each indirect effect a 95% percentile bootstrap confidence interval based on 5000 bootstrap resamples was computed [26]. The total effect of SEP on frailty was calculated as the summation of the direct and indirect effect. Analyses were performed in STATA 11 (StataCorp LP, College Station, TX, USA).

## 3. Results

Table 1 shows the characteristics of the study population for each country. The proportion of respondents with no formal education across countries ranged from 1% (Russia) to 55% (Ghana). Frailty prevalence was the highest in South Africa (14.5%) and lowest in Russia (8.4%). Descriptive analyses (Table 2) showed for all countries differences in frailty prevalence by educational level and wealth. The frailty prevalence was the highest in those with no formal education or less than primary education completed, and in those in the lowest wealth quintile.

The RII showed variation between countries for frailty by socioeconomic status (Fig. 2). For educational level as the SEP indicator, inequalities were larger in Mexico (RII 3.7, 95% CI 2.1–6.4), India (RII 3.2, 95% CI 2.3–4.5), China (RII 2.6, 95% CI 2.0–3.3), South Africa (RII 2.2, 95% CI 1.5–3.3), and Russia (RII 2.2, 95% CI 1.5–3.2) than in Ghana (RII 1.10, 95% CI 0.7–1.8). By the same index, instead with wealth as the SEP indicator, the largest inequalities were also found in Mexico (RII 4.0, 95% CI 2.2–7.3), followed by India (RII 3.6, 95% CI 2.7–4.8), South Africa (RII 3.2, 95% CI 2.2–4.6), Russia (RII 2.5, 95% CI 1.9–3.2), and China (RII 2.5, 95% CI 1.9–3.1). The smallest inequalities were again found in Ghana (RII 1.6, 95% CI 1.1–2.3).

Table 3 shows the results of the mediation analyses with the RII of educational level as the independent variable. In most cases, diseases

**Table 1**
Characteristics of the study population.

| | China N = 12,126 | Ghana N = 4,155 | India N = 6,372 | Mexico N = 2,055 | Russia N = 3,494 | South Africa N = 2,972 |
|---|---|---|---|---|---|---|
| Age, mean (SD) | 62.9 (9.2) | 64.2 (10.6) | 61.6 (8.5) | 67.9 (9.1) | 64.8 (10.1) | 62.6 (9.6) |
| Sex, female N (%) | 6,490 (53.5) | 1,982 (47.7) | 3,155 (49.5) | 1,249 (60.8) | 2,248 (64.3) | 1,792 (60.3) |
| Educational level, N (%) | | | | | | |
| No education | 2,971 (24.5) | 2,286 (55.0) | 3,256 (51.1) | 413 (20.1) | 35 (1.0) | 794 (26.7) |
| Less than primary | 2,230 (18.4) | 418 (10.1) | 724 (11.4) | 849 (41.3 | 62 (1.8) | 732 (24.6) |
| Primary | 2,440 (20.1) | 448 (10.8) | 907 (14.2) | 443 (21.6) | 267 (7.6) | 698 (23.5) |
| Secondary | 2,464 (20.3) | 168 (4.0) | 637 (10.0) | 136 (6.6) | 666 (19.1) | 407 (13.7) |
| Higher | 2,021 (16.7) | 835 (20.1) | 848 (13.3) | 214 (10.4) | 2,464 (70.5) | 341 (11.5) |
| Wealth, N (%) | | | | | | |
| Q1 (lowest) | 2,438 (20.2) | 822 (19.8) | 1,029 (16.2) | 443 (21.6) | 621 (17.8) | 557 (18.8) |
| Q2 | 2,448 (20.3) | 818 (19.7) | 1,179 (18.6) | 441 (21.5) | 688 (19.7) | 606 (20.5) |
| Q3 | 2,428 (20.1) | 823 (19.8) | 1,173 (18.5) | 367 (17.9) | 700 (20.1) | 607 (20.5) |
| Q4 | 2,488 (20.6) | 847 (20.4) | 1,372 (21.7) | 417 (20.3) | 716 (20.5) | 599 (20.3) |
| Q5 | 2,271 (18.8) | 840 (20.2) | 1,582 (25.0) | 386 (18.8) | 765 (21.9) | 589 (19.9) |
| Missing (not included in analyses), N | 53 | 5 | 37 | 1 | 4 | 14 |
| Frailty, N (%) | | | | | | |
| Robust (0) | 4,586 (37.8) | 1,450 (34.9) | 2,459 (38.6) | 618 (30.1) | 1,427 (40.8) | 540 (18.2) |
| Pre-frail (1-2) | 6,495 (53.6) | 2,238 (53.9) | 3,070 (48.2) | 1,213 (59.0) | 1,772 (50.7) | 2,000 (67.3) |
| Frail (≥3) | 1,045 (8.6) | 467 (11.2) | 843 (13.2) | 224 (10.9) | 295 (8.4) | 432 (14.5) |
| Chronic diseases, N (%) | | | | | | |
| Angina | 1,062 (8.8) | 137 (3.3) | 309 (4.8) | 42 (2.0) | 1,143 (32.7) | 169 (5.7) |
| Osteoarthritis | 2,709 (22.3) | 543 (13.1) | 1,139 (17.9) | 253 (12.3) | 1,211 (34.7) | 671 (22.6) |
| Lung disease | 1,180 (9.7) | 474 (4.2) | 602 (9.4) | 168 (8.2) | 668 (19.1) | 188 (6.3) |
| Diabetes | 781 (6.4) | 159 (3.8) | 465 (7.3) | 417 (20.3) | 315 (9.0) | 296 (10.0) |
| Hypertension | 3,318 (27.4) | 555 (13.4) | 1,114 (17.5) | 782 (38.1) | 1,965 (56.2) | 916 (30.8) |
| Stroke | 417 (3.4) | 89 (2.1) | 137 (2.2) | 99 (4.8) | 196 (5.6) | 101 (3.4) |
| Multimorbidity, N (%) with two or more diseases | 2,407 (19.8) | 357 (8.6) | 982 (15.4) | 534 (26.0) | 1,750 (50.1) | 617 (20.8) |

**Table 2**
Frailty prevalence by educational level and wealth categories.

| | Frailty prevalence, % | | | | | |
|---|---|---|---|---|---|---|
| | China | Ghana | India | Mexico | Russia | South Africa |
| Educational level | | | | | | |
| No education | 16.6 | 14.8 | 16.6 | 20.1 | 22.9 | 18.0 |
| Less than primary | 7.9 | 6.9 | 15.2 | 11.2 | 27.4 | 17.2 |
| Primary | 6.6 | 7.8 | 11.1 | 6.5 | 18.0 | 14.8 |
| Secondary | 3.8 | 6.0 | 7.1 | 5.11 | 13.1 | 10.8 |
| Higher | 5.9 | 6.5 | 5.7 | 4.7 | 5.5 | 4.7 |
| *p* | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Wealth | | | | | | |
| Q1 (lowest) | 15.1 | 14.6 | 19.0 | 16.9 | 15.5 | 19.2 |
| Q2 | 9.2 | 12.3 | 16.5 | 12.9 | 10.6 | 18.0 |
| Q3 | 6.6 | 10.3 | 13.6 | 12.8 | 8.0 | 14.0 |
| Q4 | 6.4 | 10.5 | 10.9 | 6.2 | 4.9 | 13.4 |
| Q5 | 5.5 | 8.6 | 8.7 | 4.9 | 4.3 | 8.7 |
| *p* | < 0.001 | < 0.01 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |

P-value based on overall Chi-square tests.

were less common among people with lower educational levels (negative *a* coefficients) across countries. The associations between chronic diseases and frailty (*b*) were not consistent. Stroke and multimorbidity were associated with frailty in all countries and in five countries, respectively. However, as individual conditions, diabetes and hypertension were only associated with frailty in Ghana and South Africa. The associations between educational level and frailty (*c'*), showing higher frailty prevalence rates among lower education levels, were statistically significant in all countries, except Ghana.

From the mediation analyses it can be seen that only the indirect effect ($a \times b$) of lung disease in India was in line with our hypotheses. Respondents with lower education levels had higher prevalence rates of lung disease ($\beta = 0.058$, SE = 0.026, $p < 0.05$), lung disease was associated with frailty ($\beta = 0.126$, SE = 0.014, $p < 0.001$), and also the $a \times b$ effect was statistically significant ($\beta = 0.007$, 95% CI = 0.001–0.014). All other statistically significant $a \times b$ effects in Table 3 had a negative *a* coefficient. This means that those with lower levels of education had lower disease prevalence and multimorbidity rates compared to those who were higher educated. Therefore, in these cases chronic diseases do not explain a higher prevalence of frailty among lower educated. Similar patterns were found when performing the analyses with wealth as socioeconomic indicator, except for some small differences in magnitude of associations (Table 4). For example, with wealth as the SEP indicator, the direct effect (c') is also statistically significant in Ghana.

## 4. Discussion

In our study among older adults in six LMICs, substantial socioeconomic inequalities in frailty were observed. In all countries, people in lower socioeconomic groups had a higher risk of frailty. Socioeconomic inequalities in frailty were the largest in Mexico and India, and the smallest in Ghana. Mediation analyses revealed that chronic diseases and multimorbidity did not play a significant role in explaining the association between SEP and frailty. Various diseases were associated with frailty, but disease prevalence rates were in general lower in people with a low SEP compared to those with a high SEP.

Studies into socioeconomic health inequalities in LMICs are relatively scarce [27]. To our knowledge, this was the first study that was solely focused on socioeconomic inequalities in frailty among older adults in LMICs, since previous studies used educational level and income mainly as covariates [28]. For example, a previous study in the six SAGE countries, showed that educational level and income were associated with higher frailty, measured with the frailty index – a multidimensional frailty instrument [11]. However, this previous work did not quantify the level of inequality, nor did it look at explanations for inequalities. The results of the current study in six LMICs are in line with finding from studies in high income countries [7]. Higher frailty prevalence rates were found in older people with a low SEP. Nevertheless, we also found substantial differences between countries in the SEP-frailty relationship. Although descriptive analyses revealed

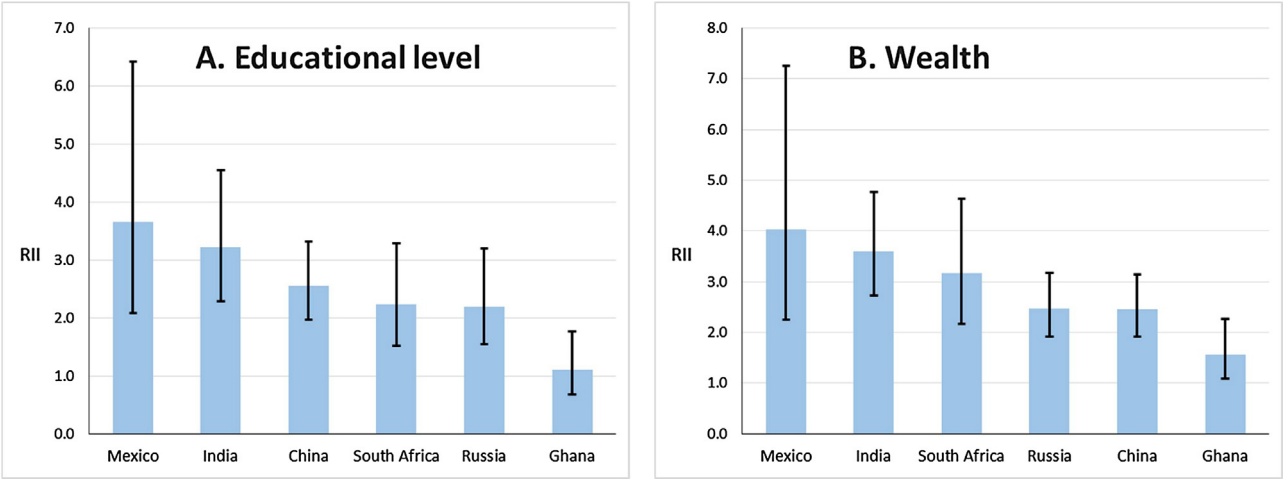



**Fig. 2.** Relative Index of Inequality (RII) and 95% CI for frailty by educational level (A) and wealth (B), adjusted for age and sex.
Sorted from high to low RII. Based on logistic regression analyses, adjusted for age and sex. A higher RII indicates larger socioeconomic inequalities.

**Table 3**
Fully-standardized effect estimates (β) of the mediation analyses of chronic diseases as mediators of educational level (RII) on frailty, adjusted for age and sex.

| Country | Mediating variable (M) | Effect of RII on M (a) | | Effect of M on frailty (b) | | Direct effect (c') | | Indirect effect (a × b) | | Total effect (c) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | β (SE) | p | β (SE) | p | β (SE) | p | β (SE) | 95% CI | β (SE) | p |
| China | Angina | −0.168 (0.018) | < 0.001 | 0.052 (0.013) | < 0.001 | 0.131 (0.018) | < 0.001 | −0.009 | −0.014 to -0.004* | 0.123 (0.017) | < 0.001 |
| | Osteoarthritis | 0.007 (0.013) | 0.56 | −0.004 (0.011) | 0.81 | 0.124 (0.018) | < 0.001 | 0.000 | −0.001 to 0.000 | 0.124 (0.017) | < 0.001 |
| | Lung disease | −0.011 (0.017) | 0.51 | 0.032 (0.013) | < 0.05 | 0.124 (0.018) | < 0.001 | 0.000 | −0.002 to 0.001 | 0.124 (0.017) | < 0.001 |
| | Diabetes | −0.204 (0.021) | < 0.001 | 0.016 (0.017) | 0.27 | 0.126 (0.018) | < 0.001 | −0.003 | −0.009 to 0.003 | 0.122 (0.017) | < 0.001 |
| | Hypertension | −0.125 (0.012) | < 0.001 | −0.010 (0.010) | 0.54 | 0.123 (0.018) | < 0.001 | 0.001 | −0.003 to 0.005 | 0.124 (0.017) | < 0.001 |
| | Stroke | −0.132 (0.027) | < 0.001 | 0.089 (0.017) | < 0.001 | 0.135 (0.018) | < 0.001 | −0.012 | −0.018 to -0.006* | 0.123 (0.017) | < 0.001 |
| | Multimorbidity | −0.128 (0.013) | < 0.001 | 0.048 (0.010) | < 0.01 | 0.131 (0.018) | < 0.001 | −0.006 | −0.010 to -0.002* | 0.124 (0.017) | < 0.001 |
| Ghana | Angina | 0.003 (0.054) | 0.95 | 0.052 (0.030) | < 0.05 | 0.012 (0.031) | 0.70 | 0.000 | −0.006 to 0.007 | 0.012 (0.031) | 0.69 |
| | Osteoarthritis | −0.041 (0.028) | 0.14 | 0.074 (0.017 | < 0.001 | 0.012 (0.031) | 0.69 | −0.003 | −0.008 to 0.001 | 0.009 (0.030) | 0.76 |
| | Lung disease | −0.147 (0.046) | < 0.01 | 0.064 (0.026) | < 0.01 | 0.018 (0.031) | 0.57 | −0.009 | −0.018 to -0.002* | 0.008 (0.031) | 0.79 |
| | Diabetes | −0.312 (0.047) | < 0.001 | 0.049 (0.030) | < 0.05 | 0.018 (0.031) | 0.56 | −0.015 | −0.030 to 0.000* | 0.003 (0.031) | 0.93 |
| | Hypertension | −0.295 (0.027) | < 0.001 | 0.092 (0.017) | < 0.001 | 0.032 (0.031) | 0.30 | −0.027 | −0.041 to -0.013* | 0.005 (0.030) | 0.87 |
| | Stroke | −0.261 (0.062) | < 0.001 | 0.115 (0.031) | < 0.001 | 0.029 (0.031) | 0.34 | −0.030 | −0.048 to -0.014* | −0.001 (0.031) | 0.98 |
| | Multimorbidity | −0.215 (0.033) | < 0.001 | 0.116 (0.018) | < 0.001 | 0.031 (0.031) | 0.31 | −0.025 | −0.037 to -0.015* | 0.006 (0.030) | 0.84 |
| India | Angina | −0.139 (0.034) | < 0.001 | 0.032 (0.022) | 0.06 | 0.155 (0.023) | < 0.001 | −0.004 | −0.010 to 0.001 | 0.151 (0.022) | < 0.001 |
| | Osteoarthritis | −0.031 (0.020) | 0.12 | 0.042 (0.013) | < 0.05 | 0.153 (0.023) | < 0.001 | −0.001 | −0.004 to 0.000 | 0.152 (0.022) | < 0.001 |
| | Lung disease | 0.058 (0.026) | < 0.05 | 0.126 (0.014) | < 0.001 | 0.148 (0.023) | < 0.001 | 0.007 | 0.001 to 0.014* | 0.155 (0.022) | < 0.001 |
| | Diabetes | −0.334 (0.028) | < 0.001 | 0.017 (0.020) | 0.38 | 0.156 (0.023) | < 0.001 | −0,006 | −0.017 to 0.008 | 0.150 (0.022) | < 0.001 |
| | Hypertension | −0.261 (0.020) | < 0.001 | 0.017 (0.013) | 0.38 | 0.156 (0.023) | < 0.001 | −0.004 | −0.014 to 0.006 | 0.152 (0.022) | < 0.001 |
| | Stroke | −0.099 (0.050) | < 0.05 | 0.049 (0.029) | < 0.01 | 0.155 (0.023) | < 0.001 | −0.005 | −0.011 to 0.000 | 0.150 (0.022) | < 0.001 |
| | Multimorbidity | −0.158 (0.021) | < 0.001 | 0.073 (0.013) | < 0.001 | 0.162 (0.023) | < 0.001 | −0.011 | −0.018 to -0.006* | 0.150 (0.021) | < 0.001 |
| Mexico | Angina | −0.097 (0.087) | 0.27 | −0.028 (0.080) | 0.49 | 0.177 (0.038) | < 0.001 | 0.003 | −0.006 to 0.019 | 0.180 (0.037) | < 0.001 |
| | Osteoarthritis | −0.035 (0.037) | 0.35 | 0.040 (0.027) | 0.21 | 0.179 (0.038) | < 0.001 | −0.001 | −0.006 to 0.002 | 0.178 (0.037) | < 0.001 |
| | Lung disease | −0.044 (0.045) | 0.32 | 0.043 (0.032) | 0.17 | 0.180 (0.038) | < 0.001 | −0.002 | −0.008 to 0.003 | 0.178 (0.037) | < 0.001 |
| | Diabetes | 0.012 (0.031) | 0.70 | 0.030 (0.024) | 0.40 | 0.179 (0.038) | < 0.001 | 0.000 | −0.002 to 0.004 | 0.179 (0.037) | < 0.001 |
| | Hypertension | −0.058 (0.025) | < 0.05 | −0.067 (0.021) | 0.07 | 0.173 (0.038) | < 0.001 | 0.004 | 0.000 to 0.011 | 0.176 (0.037) | < 0.001 |
| | Stroke | −0.116 (0.058) | < 0.05 | 0.071 (0.038) | < 0.05 | 0.184 (0.038) | < 0.001 | −0.008 | −0.018 to 0.000* | 0.176 (0.038) | < 0.001 |
| | Multimorbidity | −0.051 (0.028) | 0.07 | 0.065 (0.021) | 0.06 | 0.184 (0.038) | < 0.001 | −0.003 | −0.010 to 0.001 | 0.180 (0.037) | < 0.001 |
| Russia | Angina | −0.049 (0.021) | < 0.05 | 0.107 (0.014) | < 0.001 | 0.088 (0.029) | < 0.01 | −0.005 | −0.011 to -0.001* | 0.082 (0.030) | < 0.01 |
| | Osteoarthritis | 0.032 (0.021) | 0.12 | 0.065 (0.014) | < 0.05 | 0.080 (0.029) | < 0.01 | 0.002 | −0.001 to 0.006 | 0.082 (0.030) | < 0.01 |
| | Lung disease | 0.094 (0.026) | < 0.001 | 0.046 (0.017) | 0.11 | 0.080 (0.029) | < 0.01 | 0.004 | −0.001 to 0.011 | 0.084 (0.030) | < 0.01 |
| | Diabetes | −0.001 (0.034) | 0.97 | −0.029 (0.025) | 0.35 | 0.083 (0.029) | < 0.01 | 0.000 | −0.003 to 0.003 | 0.084 (0.030) | < 0.01 |
| | Hypertension | −0.007 (0.021) | 0.75 | 0.023 (0.015) | 0.49 | 0.083 (0.029) | < 0.01 | 0.000 | −0.002 to 0.002 | 0.083 (0.030) | < 0.01 |
| | Stroke | −0.011 (0.040) | 0.78 | 0.095 (0.022) | < 0.001 | 0.087 (0.029) | < 0.01 | −0.001 | −0.009 to 0.007 | 0.085 (0.030) | < 0.01 |
| | Multimorbidity | −0.006 (0.021) | 0.76 | 0.121 (0.015) | < 0.001 | 0.083 (0.028) | < 0.01 | −0.001 | −0.006 to 0.005 | 0.082 (0.030) | < 0.01 |
| South Africa | Angina | −0.006 (0.044) | 0.89 | 0.055 (0.030) | < 0.05 | 0.119 (0.029) | < 0.001 | 0.000 | −0.005 to 0.005 | 0.118 (0.026) | < 0.001 |
| | Osteoarthritis | −0.078 (0.024) | < 0.01 | 0.151 (0.017) | < 0.001 | 0.130 (0.029) | < 0.001 | −0.012 | −0.021 to -0.004* | 0.118 (0.027) | < 0.001 |
| | Lung disease | 0.034 (0.042) | 0.42 | 0.112 (0.026) | < 0.001 | 0.115 (0.029) | < 0.001 | 0.004 | −0.005 to 0.013 | 0.119 (0.027) | < 0.001 |
| | Diabetes | −0.168 (0.034) | < 0.001 | 0.077 (0.024) | < 0.01 | 0.127 (0.029) | < 0.001 | −0.013 | −0.023 to -0.004* | 0.114 (0.026) | < 0.001 |
| | Hypertension | −0.042 (0.022) | 0.06 | 0.077 (0.016) | < 0.01 | 0.122 (0.029) | < 0.001 | −0.003 | −0.008 to 0.000 | 0.119 (0.026) | < 0.001 |
| | Stroke | −0.074 (0.057) | 0.19 | 0.082 (0.035) | < 0.001 | 0.121 (0.029) | < 0.001 | −0.006 | −0.015 to 0.002 | 0.115 (0.027) | < 0.001 |
| | Multimorbidity | −0.083 (0.025) | < 0.01 | 0.133 (0.018) | < 0.001 | 0.129 (0.029) | < 0.001 | −0.011 | −0.019 to -0.004* | 0.118 (0.027) | < 0.001 |

* $p < 0.05$, based on 5000 bootstraps.

**Table 4**
Fully-standardized effect estimates (β) of the mediation analyses of chronic diseases as mediators of wealth (RII) on frailty, adjusted for age and sex.

| Country | Mediating variable (M) | Effect of RII on M (a) | | Effect of M on frailty (b) | | Direct effect (c') | | Indirect effect (a × b) | | Total effect (c) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | β (SE) | p | β (SE) | p | β (SE) | p | β | 95% CI | β (SE) | p |
| China | Angina | −0.037 (0.017) | < 0.05 | 0.047 (0.013) | < 0.001 | 0.122 (0.017) | < 0.001 | −0.002 | −0.004 to 0.000* | 0.121 (0.017) | < 0.001 |
| | Osteoarthritis | −0.014 (0.012) | 0.25 | −0.003 (0.011) | 0.85 | 0.119 (0.017) | < 0.001 | 0.000 | −0.001 to 0.001 | 0.119 (0.017) | < 0.001 |
| | Lung disease | 0.026 (0.017) | 0.12 | 0.031 (0.013) | < 0.05 | 0.118 (0.017) | < 0.001 | 0.001 | 0.000 to 0.002 | 0.119 (0.017) | < 0.001 |
| | Diabetes | −0.211 (0.021) | < 0.001 | 0.018 (0.017) | 0.23 | 0.121 (0.017) | < 0.001 | −0.004 | −0.010 to 0.003 | 0.118 (0.017) | < 0.001 |
| | Hypertension | −0.125 (0.011) | < 0.001 | −0.010 (0.010) | 0.53 | 0.118 (0.017) | < 0.001 | 0.001 | −0,003 to 0.005 | 0.119 (0.017) | < 0.001 |
| | Stroke | −0.076 (0.026) | < 0.01 | 0.088 (0.017) | < 0.001 | 0.128 (0.017) | < 0.001 | −0.007 | −0.012 to -0.002* | 0.121 (0.017) | < 0.001 |
| | Multimorbidity | −0.088 (0.013) | < 0.001 | 0.046 (0.010) | < 0.01 | 0.124 (0.017) | < 0.001 | −0.004 | −0.007 to -0.001* | 0.120 (0.017) | < 0.001 |
| Ghana | Angina | −0.091 (0.048) | 0.06 | 0.053 (0.032) | < 0.01 | 0.063 (0.026) | < 0.05 | −0.005 | −0.013 to 0.000 | 0.058 (0.026) | < 0.05 |
| | Osteoarthritis | −0.097 (0.025) | < 0.001 | 0.077 (0.018) | < 0.001 | 0.065 (0.026) | < 0.05 | −0.007 | −0.014 to -0.002* | 0.058 (0.026) | < 0.05 |
| | Lung disease | −0.044 (0.043) | 0.30 | 0.065 (0.028) | < 0.01 | 0.063 (0.026) | < 0.05 | −0.003 | −0.010 to 0.002 | 0.060 (0.026) | < 0.05 |
| | Diabetes | −0.309 (0.047) | < 0.001 | 0.053 (0.033) | < 0.05 | 0.067 (0.026) | < 0.05 | −0.016 | −0.031 to -0.002* | 0.050 (0.027) | 0.06 |
| | Hypertension | −0.380 (0.027) | < 0.001 | 0.108 (0.019) | < 0.001 | 0.090 (0.026) | < 0.01 | −0.041 | −0.059 to -0.023* | 0.049 (0.026) | 0.06 |
| | Stroke | −0.168 (0.060) | < 0.01 | 0.116 (0.033) | < 0.001 | 0.072 (0.026) | < 0.01 | −0.020 | −0.036 to -0.005* | 0.052 (0.027) | 0.06 |
| | Multimorbidity | −0.269 (0.031) | < 0.001 | 0.123 (0.020) | < 0.001 | 0.083 (0.026) | < 0.01 | −0.033 | −0.048 to -0.020* | 0.050 (0.026) | 0.06 |
| India | Angina | −0.158 (0.032) | < 0.001 | 0.038 (0.023) | < 0.05 | 0.178 (0.020) | < 0.001 | −0.006 | −0.013 to 0.000* | 0.172 (0.019) | < 0.001 |
| | Osteoarthritis | 0.005 (0.018) | 0.76 | 0.041 (0.013) | < 0.05 | 0.176 (0.020) | < 0.001 | 0.000 | −0.001 to 0.002 | 0.176 (0.019) | < 0.001 |
| | Lung disease | 0.077 (0.023) | < 0.01 | 0.122 (0.015) | < 0.001 | 0.171 (0.020) | < 0.001 | 0.009 | 0.004 to 0.016* | 0.180 (0.019) | < 0.001 |
| | Diabetes | −0.323 (0.028) | < 0.001 | 0.019 (0.021) | 0.31 | 0.178 (0.020) | < 0.001 | −0.006 | −0.019 to 0.007 | 0.172 (0.019) | < 0.001 |
| | Hypertension | −0.258 (0.019) | < 0.001 | 0.026 (0.014) | 0.17 | 0.181 (0.020) | < 0.001 | −0.007 | −0.017 to 0.004 | 0.174 (0.019) | < 0.001 |
| | Stroke | −0.087 (0.047) | 0.06 | 0.049 (0.030) | < 0.01 | 0.177 (0.020) | < 0.001 | −0.004 | −0.011 to 0.000 | 0.172 (0.019) | < 0.001 |
| | Multimorbidity | −0.158 (0.019) | < 0.001 | 0.080 (0.014) | < 0.001 | 0.186 (0.020) | < 0.001 | −0.013 | −0.019 to -0.007* | 0.173 (0.019) | < 0.001 |
| Mexico | Angina | −0.145 (0.088) | 0.10 | −0.028 (0.082) | 0.50 | 0.169 (0.038) | < 0.001 | 0.004 | −0.006 to 0.024 | 0.173 (0.037) | < 0.001 |
| | Osteoarthritis | −0.045 (0.037) | 0.23 | 0.044 (0.027) | 0.17 | 0.173 (0.038) | < 0.001 | −0.002 | −0.008 to 0.002 | 0.171 (0.037) | < 0.001 |
| | Lung disease | −0.030 (0.045) | 0.51 | 0.041 (0.033) | 0.19 | 0.171 (0.038) | < 0.001 | −0.001 | −0.007 to 0.003 | 0.170 (0.037) | < 0.001 |
| | Diabetes | −0.032 (0.031) | 0.30 | 0.033 (0.025) | 0.35 | 0.172 (0.038) | < 0.001 | −0.001 | −0.006 to 0.002 | 0.171 (0.037) | < 0.001 |
| | Hypertension | −0.068 (0.025) | < 0.01 | −0.070 (0.021) | 0.06 | 0.166 (0.038) | < 0.001 | 0.005 | 0.000 to 0.012* | 0.171 (0.037) | < 0.001 |
| | Stroke | −0.078 (0.057) | 0.17 | 0.067 (0.039) | < 0.05 | 0.174 (0.038) | < 0.001 | −0.005 | −0.015 to 0.002 | 0.169 (0.037) | < 0.001 |
| | Multimorbidity | −0.086 (0.028) | < 0.01 | 0.067 (0.022) | < 0.05 | 0.176 (0.038) | < 0.001 | −0.006 | −0.014 to 0.000 | 0.171 (0.037) | < 0.001 |
| Russia | Angina | 0.020 (0.020) | 0.32 | 0.104 (0.017) | < 0.001 | 0.167 (0.033) | < 0.001 | 0.002 | −0.002 to 0.007 | 0.169 (0.035) | < 0.001 |
| | Osteoarthritis | −0.024 (0.020) | 0.24 | 0.071 (0.017) | < 0.05 | 0.170 (0.034) | < 0.001 | −0.002 | −0.006 to 0.001 | 0.168 (0.035) | < 0.001 |
| | Lung disease | −0.015 (0.025) | 0.55 | 0.056 (0.020) | < 0.05 | 0.169 (0.034) | < 0.001 | −0.001 | −0.004 to 0.002 | 0.169 (0.035) | < 0.001 |
| | Diabetes | −0.011 (0.033) | 0.73 | −0.028 (0.030) | 0.37 | 0.169 (0.034) | < 0.001 | 0.000 | −0.002 to 0.004 | 0.169 (0.035) | < 0.001 |
| | Hypertension | −0.017 (0.019) | 0.36 | 0.018 (0.019) | 0.57 | 0.168 (0.034) | < 0.001 | 0.000 | −0.003 to 0.001 | 0.168 (0.035) | < 0.001 |
| | Stroke | −0.026 (0.041) | 0.53 | 0.097 (0.026) | < 0.001 | 0.173 (0.034) | < 0.001 | −0.002 | −0.011 to 0.006 | 0.170 (0.035) | < 0.001 |
| | Multimorbidity | −0.019 (0.019) | 0.32 | 0.124 (0.019) | < 0.001 | 0.170 (0.033) | < 0.001 | −0.002 | −0.008 to 0.002 | 0.168 (0.035) | < 0.001 |
| South Africa | Angina | −0.179 (0.044) | < 0.001 | 0.067 (0.030) | < 0.01 | 0.175 (0.028) | < 0.001 | −0.012 | −0.023 to -0.002* | 0.163 (0.027) | < 0.001 |
| | Osteoarthritis | −0.120 (0.024) | < 0.001 | 0.161 (0.018) | < 0.001 | 0.187 (0.028) | < 0.001 | −0.019 | −0.030 to -0.010* | 0.167 (0.027) | < 0.001 |
| | Lung disease | 0.048 (0.042) | 0.25 | 0.110 (0.026) | < 0.001 | 0.167 (0.028) | < 0.001 | 0.005 | −0.003 to 0.015 | 0.172 (0.027) | < 0.001 |
| | Diabetes | −0.248 (0.035) | < 0.001 | 0.092 (0.024) | < 0.001 | 0.184 (0.029) | < 0.001 | −0.023 | −0.036 to -0.010* | 0.161 (0.027) | < 0.001 |
| | Hypertension | −0.142 (0.022) | < 0.001 | 0.096 (0.017) | < 0.001 | 0.182 (0.029) | < 0.001 | −0.014 | −0.023 to -0.006* | 0.169 (0.027) | < 0.001 |
| | Stroke | 0.041 (0.056) | 0.46 | 0.077 (0.035) | < 0.01 | 0.166 (0.028) | < 0.001 | 0.003 | −0.006 to 0.013 | 0.170 (0.027) | < 0.001 |
| | Multimorbidity | −0.184 (0.025) | < 0.001 | 0.154 (0.018) | < 0.001 | 0.195 (0.029) | < 0.001 | −0.028 | −0.040 to -0.017* | 0.167 (0.027) | < 0.001 |

* $p < 0.05$, based on 5000 bootstraps.

socioeconomic frailty inequalities in all countries, the RII of Ghana for educational level was not statistically significant. This may be explained by the distribution of educational level in Ghana, where more than 75% of the older population has completed only primary education or less.

Our results indicated that chronic diseases were less common in lower socioeconomic groups, a finding which contradicts with evidence from high income countries [7,15]. There may be various explanations for the higher disease prevalence in those with a high SEP. First, socioeconomic patterning of disease prevalence in LMICs may follow the same trajectories linked with economic development as in higher income countries, where the direction of the association between SEP and health has changed over several decades. In these countries, the prevalence rates of non-communicable diseases and behavioral risk factors for diseases were higher in groups with a higher SEP, and this shifted towards people with a lower SEP over time [27]. For example, in countries with a developing economy, such as China, the increasing welfare has led to more unhealthy lifestyles (higher levels of negative risk factors, as the precursors for many diseases) and a higher prevalence of cardiovascular disease and diabetes. It is expected that the negative effects of some changes such as supermarket growth and increasingly sedentary lifestyles will finally affect all socioeconomic groups in China [29]. Indeed, rates of smoking and poor diet have already been found to be significantly higher in lower socioeconomic groups across 48 LMICs [30]. Another explanation may be that our results reflect the limited access to healthcare. People who never visit healthcare professionals may never have been diagnosed with a disease. Previous research in the SAGE countries has shown that chronic diseases are more often undiagnosed or untreated in lower socioeconomic groups [31]. Alternatively, it could be that those with lower SEP are simply dying earlier when they develop a chronic disease – likely because they forgo unaffordable healthcare. Finally, our findings may also be the result of methodological issues. Self-reported measures are sensitive to reporting bias, and this bias may be related to SEP, for example, due to lower health literacy levels among those with a low SEP. Clinical tests or performance tests are not always a solution, as they often have larger number of missing values, and lower feasibility for assessment in the context of large health surveys.

This study provides important information for health policy makers. Given that the population of older adults in many LMICs countries is expanding at a greater rate than in high income countries combined with lower infrastructure, our study provides crucial insights into patterns of socioeconomic inequalities in frailty among older adults in LMICs. The implications of the findings with regard to the mediating role of chronic diseases are less clear. Explanations for socioeconomic inequalities in frailty is indispensable knowledge for country-level health departments to facilitate their development of effective preventive strategies aimed to reduce the development and progression of frailty. However, before any conclusion can be drawn on the explanatory role of chronic diseases and multimorbidity, additional research addressing the limitations of the current study has to be conducted. This research should consider diseases not included in the current study, such as cancer and cardiac disease, and different diagnostic measures.

This study has several strengths. Studies of disparities in health in LMICs rarely include older adults. The present study uses a large sample of older adults in LMICs to study socioeconomic inequalities in frailty, and comprehensively investigates individual-country differences. There are relatively large study samples in each country, with survey sampling methods that allow the results to be extrapolated to the national level. The cross-country comparison showed that the effects are robust, as most effects pointed in the same direction, no matter what SEP indicator was used.

The findings of our study should be contextualized by some limitations. First, the data are measured at only one point in time – longitudinal data from SAGE Wave 2 will become available in the next few years. Second, while self-reporting of disease diagnosis is a standard method to capture this information in health studies, it comes with known concerns about reliability [14]. We did not assess the extent to which health services access or other disease-specific features differed by SEP as possible explanations for differences in self-reported diagnoses. Particularly in countries where access to health services is limited, the under-reporting of disease may be higher, particularly for 'silent killers' like hypertension. Third, although the response rates in the current study were relatively high, it is still possible that there was selective non-response. Previous research has shown that in particular, frail older people are less likely to participate in epidemiological surveys [32]. Fourth, we made a first attempt to explain socioeconomic inequalities in frailty in LMICs. Besides the above-mentioned refined measure of chronic diseases, other explanations should also be investigated. For instance, nutrition, lifestyle factors such as tobacco use, healthcare access, support from family or other network members, and living conditions should be considered [33]. Additional research could also investigate whether there is an effect of geographic location, specifically, latitudes on frailty in LMICs, particularly as frailty renders an older person susceptible to external stressors such as heat and cold. Finally, we were able to compare six LMICs, but a comparison with high income countries is lacking. These countries may be included in future research.

## 5. Conclusion

This study showed that substantial socioeconomic inequalities in frailty exist among older adults in LMICs. The findings suggested that chronic diseases do not play an important role in explaining the higher frailty prevalence rate observed in lower socioeconomic groups. Additional research is needed to confirm our findings and to find alternative explanations for socioeconomic inequalities in frailty among older adults in LMICs.

## Contributors

Emiel O. Hoogendijk designed the study, drafted the manuscript and performed the statistical analysis.

Judith J.M. Rijnhart supported the statistical analysis and was involved in the design of the study.

Paul Kowal was involved in the acquisition of data and was involved in the design of the study.

Elsa Dent was involved in the design of the study.

All authors were involved in the interpretation of data. All authors revised the manuscript for important intellectual content. All authors approved the final version of the manuscript.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Funding

SAGE Wave 1 was supported by the World Health Organization, and the US National Institute on Aging through Interagency Agreements (OGHA 04034785; YA1323-08-CN-0020; Y1-AG-1005-01) and through a research grant (R01-AG034479). Elsa Dent was supported by an Australian National Health and Medical Research Council (NHMRC) Early Career Fellowship (Grant #ID 1112672). Emiel O. Hoogendijk was supported by an NWO/ZonMw Veni fellowship [grant number 91618067].

## Ethical approval

Ethical approval was obtained from local research review boards for each participating SAGE site, in addition to the WHO Ethical Review

Committee. All participants provided written informed consent prior to the interview.

## Provenance and peer review

This article has undergone peer review.

## Appendix 1

See Table A1

**Table A1**
Measurement of the criteria of the frailty phenotype in SAGE.

| Criteria | Measure |
|---|---|
| Slow gait speed | Lowest quintile of gait speed (walking 4 m) stratified by sex and height, country-specific. Cut-offs were derived for the following groups: men ≤173 cm, men > 173 cm, women ≤159 cm, and women > 159 cm. |
| Weight loss | Lowest quintile of BMI, country-specific. |
| Low grip strength | Lowest quintile of grip strength (sum of highest values of two measurements on each hand) stratified by sex and BMI, country-specific. Cut-offs were derived for the following groups: men BMI ≤ 24, men BMI 24-26, men BMI 26-28, men BMI > 28, women BMI ≤ 23, women BMI 23-26, women BMI 26-29, and women BMI > 29. |
| Exhaustion | The following question was asked: "Do you have enough energy for everyday life?" Exhaustion was considered present if people answered "Not at all" or "A little". |
| Low physical activity | Using the WHO Global Physical Activity Questionnaire (GPAQ), low physical activity was present if people were categorized as "low" (activity < 600 MET-minutes a week). |

Participants were classified as pre-frail if one or two criteria were present, and as frail if three or more criteria were present.

## Research data (data sharing and collaboration)

There are no linked research data sets for this paper. Data will be made available on request.

## References


[1] F. Rodriguez-Artalejo, L. Rodriguez-Manas, The frailty syndrome in the public health agenda, J. Epidemiol. Community Health 68 (2014) 703–704.
[2] A. Clegg, J. Young, S. Iliffe, M.O. Rikkert, K. Rockwood, Frailty in elderly people, Lancet 381 (2013) 752–762.
[3] T.M. Gill, E.A. Gahbauer, L. Han, H.G. Allore, Trajectories of disability in the last year of life, N. Engl. J. Med. 362 (2010) 1173–1180.
[4] E. Dent, P. Kowal, E.O. Hoogendijk, Frailty measurement in research and clinical practice: a review, Eur. J. Intern. Med. 31 (2016) 3–10.
[5] L.P. Fried, L. Ferrucci, J. Darer, J.D. Williamson, G. Anderson, Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care, J. Gerontol. A Biol. Sci. Med. Sci. 59 (2004) 255–263.
[6] P. Abizanda, L. Romero, P.M. Sanchez-Jurado, M. Martinez-Reig, S.A. Alfonso-Silguero, L. Rodriguez-Manas, Age, frailty, disability, institutionalization, multimorbidity or co-morbidity. Which are the main targets in older adults? J. Nutr. Health Aging 18 (2014) 622–627.
[7] E.O. Hoogendijk, H.P. van Hout, M.W. Heymans, H.E. van der Horst, D.H. Frijters, M.I. Broese van Groenou, et al., Explaining the association between educational level and frailty in older adults: results from a 13-year longitudinal study in the Netherlands, Ann. Epidemiol. 24 (2014) 538–544 e2.
[8] S.L. Szanton, C.L. Seplaki, R.J. Thorpe Jr., J.K. Allen, L.P. Fried, Socioeconomic status is associated with frailty: the women's health and aging studies, J. Epidemiol. Community Health 64 (2010) 63–67.
[9] J. At, R. Bryce, M. Prina, D. Acosta, C.P. Ferri, M. Guerra, et al., Frailty and the prediction of dependence and mortality in low- and middle-income countries: a 10/66 population-based cohort study, BMC Med. 13 (2015) 138.
[10] D.D. Siriwardhana, S. Hardoon, G. Rait, M.C. Weerasinghe, K.R. Walters, Prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries: a systematic review and meta-analysis, BMJ Open 8 (2018) e018195.
[11] R.B. Biritwum, N. Minicuci, A.E. Yawson, O. Theou, G.P. Mensah, N. Naidoo, et al., Prevalence of and factors associated with frailty and disability in older adults from China, Ghana, India, Mexico, russia and South Africa, Maturitas 91 (2016) 8–18.
[12] L.P. Fried, C.M. Tangen, J. Walston, A.B. Newman, C. Hirsch, J. Gottdiener, et al., Frailty in, J. Gerontol. A Biol. Sci. Med. Sci. 56 (2001) M146–M156.
[13] S. Vellakkal, S.V. Subramanian, C. Millett, S. Basu, D. Stuckler, S. Ebrahim, Socioeconomic inequalities in non-communicable diseases prevalence in India: disparities between self-reported diagnoses and standardized measures, PLoS One 8 (2013) e68219.
[14] S. Vellakkal, C. Millett, S. Basu, Z. Khan, A. Aitsi-Selmi, D. Stuckler, et al., Are estimates of socioeconomic inequalities in chronic disease artefactually narrowed by self-reported measures of prevalence in low-income and middle-income countries? Findings from the WHO-SAGE survey, J. Epidemiol. Community Health 69 (2015) 218–225.
[15] H. Soler-Vila, E. Garcia-Esquinas, L.M. Leon-Munoz, E. Lopez-Garcia, J.R. Banegas, F. Rodriguez-Artalejo, Contribution of health behaviours and clinical factors to socio-economic differences in frailty among older adults, J. Epidemiol. Community Health 70 (2016) 354–360.
[16] P. Kowal, S. Chatterji, N. Naidoo, R. Biritwum, W. Fan, R. Lopez Ridaura, et al., Data resource profile: the world health organization study on global AGEing and adult health (SAGE), Int. J. Epidemiol. 41 (2012) 1639–1649.
[17] UNESCO, International Standard Classification of Education: ISCED 1997, UNESCO, Geneva, 2006.
[18] L.D. Howe, B. Galobardes, A. Matijasevich, D. Gordon, D. Johnston, O. Onwujekwe, et al., Measuring socio-economic position for epidemiological studies in low- and middle-income countries: a methods of measurement in epidemiology paper, Int. J. Epidemiol. 41 (2012) 871–886.
[19] B.D. Ferguson, A. Tandon, E. Gakidou, C.J. Murray, Estimating permanent income using indicator variables, Health Systems Performance Assessment: Debates, Methods and Empiricism, World Health Organization, Geneva, 2003.
[20] K.U. Saum, H. Muller, C. Stegmaier, K. Hauer, E. Raum, H. Brenner, Development and evaluation of a modification of the Fried frailty criteria using population-independent cutpoints, J. Am. Geriatr. Soc. 60 (2012) 2110–2115.
[21] K. Bandeen-Roche, Q.L. Xue, L. Ferrucci, J. Walston, J.M. Guralnik, P. Chaves, et al., Phenotype of frailty: characterization in the women's health and aging studies, J. Gerontol. A Biol. Sci. Med. Sci. 61 (2006) 262–266.
[22] F.C. Bull, T.S. Maslin, T. Armstrong, Global physical activity questionnaire (GPAQ): nine country reliability and validity study, J. Phys. Act Health 6 (2009) 790–804.
[23] P.C. Hallal, L.B. Andersen, F.C. Bull, R. Guthold, W. Haskell, U. Ekelund, Global physical activity levels: surveillance progress, pitfalls, and prospects, Lancet 380 (2012) 247–257.
[24] J.P. Mackenbach, A.E. Kunst, Measuring the magnitude of socio-economic inequalities in health: an overview of available measures illustrated with two examples from Europe, Soc. Sci. Med. 44 (1997) 757–771.
[25] J. Scott Long, Regression Models for Categorical and Limited Dependent Variables. Advanced Quantitative Techniques in the Social Sciences Number 7, Sage Publications, Thousand Oaks, CA, 1997.
[26] A.F. Hayes, M. Scharkow, The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: does method really matter? Psychol. Sci. 24 (2013) 1918–1927.
[27] S. Stringhini, P. Bovet, Socioeconomic status and risk factors for non-communicable diseases in low-income and lower-middle-income countries, Lancet Global Health 5 (2017) e230–e231.
[28] W.K. Gray, J. Richardson, J. McGuire, F. Dewhurst, V. Elder, J. Weeks, et al., Frailty screening in low- and middle-income countries: a systematic review, J. Am. Geriatr. Soc. 64 (2016) 806–823.
[29] K.H. Wagner, H. Brath, A global view on the development of non communicable diseases, Prev. Med. 54 (Suppl) (2012) S38–S41.
[30] A.R. Hosseinpoor, N. Bergen, A. Kunst, S. Harper, R. Guthold, D. Rekve, et al., Socioeconomic inequalities in risk factors for non communicable diseases in low-income and middle-income countries: results from the world health survey, BMC Public Health 12 (2012) 912.
[31] P. Arokiasamy, Uttamacharya, P. Kowal, B.D. Capistrant, T.E. Gildner, E. Thiele, et al., Chronic noncommunicable diseases in 6 low- and middle-income countries: findings from wave 1 of the world health organization's study on global ageing and adult health (SAGE), Am. J. Epidemiol. 185 (2017) 414–428.
[32] K.A. McCaul, O.P. Almeida, P.E. Norman, B.B. Yeap, G.J. Hankey, J. Golledge, L. Flicker, How many older people are frail? Using multiple imputation to investigate frailty in the population, J. Am. Med. Dir. Assoc. 16 (439) (2015) e1–e7.
[33] A. Etman, C.B. Kamphuis, T.J. van der Cammen, A. Burdorf, F.J. van Lenthe, Do lifestyle, health and social participation mediate educational inequalities in frailty worsening? Eur. J. Public Health 25 (2015) 345–350.