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Prevalence of frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka: a population-based cross-sectional study

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ABSTRACT

Objective Our main objective was to describe the prevalence and associated sociodemographic factors of frailty and pre-frailty in rural community-dwelling older adults in Kegalle district of Sri Lanka.

Design Community-based cross-sectional study.

Setting The study was conducted in rural areas of Kegalle district in Sri Lanka.

Participants A total of 746 community-dwelling older adults aged ≥60 years were included in the study.

Results The prevalence of frailty and pre-frailty in rural Kegalle district was 15.2% (95% CI 12.3% to 18.6%) and 48.5% (95% CI 43.8% to 53.2%), respectively. We found a strong association between age and both frailty and pre-frailty. There were strong associations between longest-held occupation and frailty and education level and pre-frailty.

Conclusions The prevalence of frailty in this rural Sri Lankan older population was high compared with high-income and upper middle-income countries. The profile of health and social care services in Sri Lanka needs to address frailty and its consequences.

INTRODUCTION

Ageing involves physiological, psychological and social changes that directly affect the health and well-being of older adults. Frailty is an important age-related clinical syndrome commonly defined as a state of increased vulnerability to external stressors as a consequence of cumulative decline in many physiological systems during a lifetime.[1 2] It is widely recognised as a key issue for ageing populations worldwide, as it is associated with multiple adverse outcomes including hospitalisation, institutionalisation/dependency and premature mortality.[3]

Asia is home for the dominant share of the world's population[4] and will become the region with the largest population of older adults in the coming decades. According to recent statistics, Thailand, DPR Korea and Sri Lanka have the highest proportion of

Strengths and limitations of this study

► We conducted the first population-based prevalence study on frailty using a representative sample of community-dwelling older adults in rural areas of Kegalle district of Sri Lanka.

► We employed a rigorous methodology and measures were taken to ensure the validity and reliability of data.

► We compared age-adjusted prevalence of frailty in rural Sri Lanka with other Asian countries, and other middle-income countries worldwide.

► Sample only comprised rural older adults and the majority belonged to Sinhalese ethnicity.

► We excluded participants who could not give informed consent (eg, advanced stages of dementia) and were terminally ill. This might have underestimated the true frailty prevalence.

older persons (aged ≥60 years) among the 11 member states that belong to WHO South-East Asia region.[5] In 2012, the percentage of older adults aged ≥60 years in Sri Lanka was 12.4%.[6] One out of every four persons is predicted to be an older person aged 60 years or above in Sri Lanka by 2041.[7] Thus, Sri Lanka is considered as one of the fastest growing ageing populations in South-East Asia.[8]

A recent meta-analysis on prevalence of frailty in low-income and middle-income countries (LMICs) reported a higher prevalence of frailty (12.3%) and pre-frailty (55.3%) in middle-income countries compared with high-income countries (8.2%, 43.9%).[9] Few studies were found from Asia in general, particularly from WHO South-East Asia and low-income and lower middle-income countries.[9] The pooled prevalence of frailty was 19.6% (95% CI 15.4% to 24.3%), in Latin America and the Caribbean with a range of 7.7% to 42.6% in the studies reviewed in another systematic review and

meta-analysis.[10] As a lower middle-income country with per capita gross domestic product of US$3857 (2016),[11] Sri Lanka needs to consider efficient and effective strategies to tackle the health, social and welfare issues of older adults. However, Sri Lanka, as with many LMICs that are ageing, has made little preparation to address the issues related to increased longevity. Moreover, there is a lack of underpinning empirical research to inform policy-makers on the emerging issues and the needs of the growing older population. Therefore, the main objective of this study was to describe the prevalence and associated sociodemographic factors of frailty and pre-frailty in community-dwelling older adults in rural areas of Kegalle district of Sri Lanka. We further explored how these compared with findings from other Asian countries and with other middle-income countries worldwide.

METHODS
Study setting and study population
We conducted a population-based cross-sectional study in rural areas of Kegalle district of Sri Lanka. Sri Lanka is divided into nine provinces encompassing 25 districts. The Kegalle district includes 4.1% of the Sri Lankan population.[6] In addition to this administrative division, Sri Lanka has been categorised into three sectors (urban, rural and estate) on the basis of geographical location and availability of infrastructure facilities.[6] Of the total population, 77.4%, 18.2% and 4.4% live in the rural, urban and estate sectors, respectively.[6] In Kegalle district, the majority of people live in the rural sector (91.3%) and the rest in the urban (1.9%) and estate (6.8%) sectors.[6] The ethnic distribution of the district is 85.5% Sinhalese followed by Sri Lankan Moor (7.1%), Indian Tamil (5.2%), Sri Lankan Tamil (2.1%) and other ethnicities (0.1%).[6]

Study inclusion criteria were being an older adult aged ≥60 years permanently residing in the rural areas. Older adults who were unable to give informed consent were excluded. This included people with severe dual hearing and vision impairment, aphasia, severe stages of dementia and those with unstable severe mental illness. Terminally ill older adults were also excluded.

Sampling strategy and recruitment
The sample size was calculated using the standard formula for prevalence studies.[12] No published literature was found on the prevalence of frailty in Sri Lanka. We therefore used the prevalence of frailty in an Indian study of 11.4%[13] to estimate the expected prevalence of frailty in rural Sri Lanka as 11%. The absolute precision required on either side of the prevalence estimate was set as 3.5% and the z statistics for the 95% level of confidence was 1.96. To account for the multistage probability sampling technique, we inflated the estimated sample size by a design effect of 2.4,[14] giving a minimum sample of 737 participants. We used a complex sampling design: a three-stage probability sampling to recruit older adults representing the rural areas of the entire district (online supplementary appendix I). The final sample required was estimated as 750 participants.

Data collection
Data collection was conducted from 3 October to 23 December 2016. Five trained research assistants (nursing graduates) collected data, assisted by six field assistants. A pre-tested interviewer administered questionnaire collected data on sociodemographic, health-related, social activity and social support and lifestyle factors. The questionnaire was available in Sinhala and Tamil languages.

Definition and assessment of frailty syndrome
We used the Fried phenotype to define frailty status.[2] All five phenotypic components proposed in the original study were retained, with small modifications to operationalise the shrinking and low physical activity components. Shrinking was defined as a body mass index (BMI) <18.5 kg/m^2. Poor endurance and energy as indicated by self-reported exhaustion was assessed using two questions: 'I felt that everything I did was an effort' and 'I could not get going' from the Center for Epidemiologic Studies–Depression Scale.[15 16] If the answer was three or more days in the last week to either of these two questions, the respondent was considered as frail for this component. Falling in the lowest quintile of grip strength after adjusting for sex and BMI quartiles of the study population was considered as indicative of weakness. Participants' walking time in the highest time quintile after adjusting for sex and median standing height of the study population was considered as indicative of slowness. Individuals unable to perform the walking test were also considered as frail for this component. Low physical activity level was measured using the International Physical Activity Questionnaire (IPAQ) Short Form.[17 18] Participants in the lowest quintile of weekly kilocalorie expenditure adjusted for sex were considered as frail for this component. A detailed description of how we measured the phenotypic components is provided in online supplementary appendix II. As recommended previously,[2] participants were classified as frail if they had three or more frailty components, pre-frail (1–2 components) and robust/non-frail (0 components).

Covariates
Sociodemographic covariates of participants included sex, age at last birthday, ethnicity, marital status, living arrangements, education level (according to the International Standard Classification of Education[19]), longest-held income generation activity and subjective financial strain.[20] We used the Sri Lanka Standard Classification of Occupation,[21] based on the International Standard Classification of Occupations 2008,[22] to classify income generation activities.

Statistical analyses

Data were double entered by two independent operators and checked for discrepancies using EpiData software V.3.1 and, if necessary, corrected with reference to the original questionnaires. All analyses were performed in Stata V.14 accounting for the complex survey design.[23] Design weights were computed as the inverse of the inclusion probability of each participant to the sample. Subsequently, post-stratification weights were obtained by adjusting the design weights to match the population age and sex distribution of the district. Post-strata (n=10) were defined by 5-year age categories (60–64; 65–69; 70–74; 75–79; ≥80 years) by sex using the information available from the latest census.[6]

We estimated the prevalence and corresponding 95% CI of frailty, pre-frailty and robust groups overall and by sociodemographic characteristics. The main outcome of interest in our study was ordinal (robust, pre-frail and frail). We initially fitted a multivariable ordinal logistic regression model to estimate the association between sociodemographic factors and frailty status. However, the proportional odds assumption underlying this model was not valid for our data, and we therefore used a multinomial logistic regression instead. Robust was chosen as the reference category. Unadjusted, age-adjusted and sex-adjusted, and multivariable-adjusted relative risk ratios and their corresponding 95% CIs were derived. All statistical tests were two sided with a significance level set at 0.05.

Exploratory cross-country comparison

The age-specific prevalence of frailty and pre-frailty in our weighted sample was compared with the random-effects pooled prevalence of frailty and pre-frailty obtained from meta analyses of studies in upper middle-income Asian countries (n=7555; three studies from China and one study from Malaysia), Japan—a higher income Asian country (n=10 912; three studies)—and upper middle-income Latin American countries (n=15 773; 11 studies from Brazil, 3 from Colombia and 2 studies from Mexico). The data required for these meta analyses were obtained from two published papers.[9 24] Studies that used the Fried phenotype of frailty with five components where weakness and slowness components were measured objectively using grip strength and gait speed were included, as a valid comparison with our study assessment methods. The details of the included studies are presented in online supplementary appendix III.

Patient and public involvement

We did not include involvement of Sri Lankan older adults in the study design, as the study was developed in the UK as part of a Commonwealth Scholarship, with limited resources. We used standard study instruments and physical assessment tests, which had been developed elsewhere, and most of these have been cross-culturally adapted and validated for Sri Lankan population. Prior to our main study, we obtained feedback from 10 Sri Lankan older adults (from a different location) on the study

processes, including how to phrase certain questions and order of administering the instruments. A plain language summary of overall study results will be produced in English and translated into Sinhala and Tamil languages, and we will discuss with public representatives the best way to present and disseminate this information.

Participation was voluntary and no incentives were provided.

This manuscript was written according to the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) statement.[25]

RESULTS

Sociodemographic characteristics

Data were collected from 746 out of 750 older adults approached (response rate 99.5%). The age range of the participants was 60 to 94 years. The median (IQR) age was 68 (64–75) years in both the weighted and unweighted samples. In the weighted sample, 56.7% were women, 97.4% participants belonged to the Sinhalese ethnicity and 63.8% of participants had an education level below upper secondary. Table 1 presents the sociodemographic characteristics of the unweighted and weighted samples overall and by sex.

Fried phenotypic frailty components

Of all participants in the unweighted sample, nine did not have measurements of height and weight (needed for obtaining BMI) due to medical conditions (they could not stand independently). For these participants, we also could not use their grip strength data as BMI is required for calculating the grip strength cut-offs. Overall, out of the five phenotypic components, only unintentional weight loss and weakness were missing for nine participants. However, eight of them met the frailty criteria on all three available frailty components, so they were classified as frail. The other participant was excluded from subsequent analyses as with the partial information available we could not assign a frailty status with certainty.

For simplicity, from here onwards we will only present the results based on the weighted sample. The most prevalent frailty component in the overall sample was self-reported exhaustion (37.5%) followed by weakness (23.6%) (table 2).

Overall prevalence of frailty and pre-frailty

The prevalences of frailty, pre-frailty and robust among rural community-dwelling older adults in Kegalle district in 2016 were 15.2% (95% CI 12.3% to 18.6%), 48.5% (95% CI 43.8% to 53.2%) and 36.3% (95% CI 32.4% to 40.2%), respectively.

Prevalence of frailty and pre-frailty by sociodemographic characteristics

The prevalence of frailty status by sociodemographic characteristics is presented in table 3. The prevalence of frailty increased steeply with advancing age. Moreover, 3.8% of

Table 1 Sociodemographic characteristics of the unweighted and weighted study samples

Covariate	Unweighted sample, N (%)			Weighted sample (%)		
	All n=746	Men n=349 (46.8 %)	Women n=397 (53.2 %)	All	Men (43.3 %)	Women (56.7%)
Age category (years)						
60–64	248 (33.2)	100 (28.7)	148 (37.3)	35.7	37.4	34.3
65–69	199 (26.7)	99 (28.4)	100 (25.2)	25.3	25.5	25.2
70–74	100 (13.4)	50 (14.3)	50 (12.6)	17.0	17.2	16.8
75–79	100 (13.4)	50 (14.3)	50 (12.6)	11.2	10.2	11.9
≥80	99 (13.3)	50 (14.3)	49 (12.3)	10.8	9.7	11.8
Ethnicity						
Sinhalese	723 (96.9)	338 (96.9)	385 (97.0)	97.4	97.3	97.5
Other	23 (3.1)	11 (3.1)	12 (3.0)	2.6	2.7	2.5
Marital status						
Never married/widowed/separated/divorced	289 (38.7)	45 (12.9)	244 (61.5)	40.4	11.3	62.6
Married/cohabiting	457 (61.3)	304 (87.1)	153 (38.5)	59.6	88.7	37.4
Living arrangement						
Children/other family	617 (82.7)	284 (81.4)	333 (83.9)	83.0	82.1	83.6
With spouse only	84 (11.3)	54 (15.5)	30 (7.6)	10.7	15.1	7.4
Alone	45 (6.0)	11 (3.1)	34 (8.5)	6.3	2.8	9.0
Education level						
No formal education/primary	214 (28.7)	87 (24.9)	127 (32.0)	28.6	23.3	32.7
Lower secondary	262 (35.1)	129 (37.0)	133 (33.5)	35.2	37.6	33.3
Upper secondary/post-secondary non-tertiary/tertiary	270 (36.2)	133 (38.1)	137 (34.5)	36.2	39.1	34.0
Longest-held occupation						
Never employed/skill level 1	316 (42.3)	83 (23.8)	233 (58.7)	43.7	24.7	58.2
Skill level 2	293 (39.3)	188 (53.9)	105 (26.4)	38.5	53.1	27.3
Skill level 3/4	137 (18.4)	78 (22.3)	59 (14.9)	17.8	22.2	14.5
Perceived financial strain						
Finding it difficult/very difficult	152 (20.4)	68 (19.5)	84 (21.2)	20.3	18.9	21.4
Just about getting by	406 (54.4)	191 (54.7)	215 (54.1)	55.0	56.8	53.6
Living comfortably	188 (25.2)	90 (25.8)	98 (24.7)	24.7	24.3	25.0

older adults aged 60–64 years were classified as frail while nearly half (47.9%) of those aged 80 years or older were considered as frail. The prevalence of frailty by sex did not vary markedly, though more women than men were pre-frail. A higher prevalence of frailty was observed in older adults with low education, those who have had low skilled occupations or never had employment and those who reported higher financial strain.

Sociodemographic characteristics associated with frailty and pre-frailty

Table 4 presents the results from the unadjusted, age-adjusted and sex-adjusted, and fully adjusted multinomial logistic regression models.

Frailty versus robust

In the fully adjusted model, the relative risk of being frail compared with being robust increased with advancing age. Similarly, the relative risk of being frail compared with being robust was 3.4 times higher in older adults who have never been employed or who had an occupation in the lowest skill level rather than the highest skill level.

Pre-frailty versus robust

In the fully adjusted model, the relative risk of being pre-frail compared with being robust was two-thirds lower for participants aged 60–64 years relative to those aged 70–74 years. Conversely, older adults in the lowest education group compared with those in the highest education

Table 2 Prevalence of Fried phenotype frailty components and the total number of frailty components in the overall sample and by sex

	Total (%)	Men (%)	Women (%)
Fried's phenotype of frailty component			
Shrinking (low BMI)	18.2	20.2	16.6
Self-reported exhaustion	37.5	31.9	41.7
Weakness (low grip strength)	23.6	19.6	26.6
Slowness (low gait speed)	19.6	18.7	20.3
Low physical activity	19.2	17.4	20.5
Total no of frailty components			
0	36.2	41.3	32.3
1	30.8	29.7	31.6
2	17.8	14.7	20.2
3	10.5	10.4	10.6
4	4.2	3.0	5.0
5	0.5	0.8	0.3

BMI, body mass index.

group had an approximately 2.4 times higher risk of being pre-frail compared with being robust.

Supplementary exploratory analysis: cross-country comparison of prevalence of frailty and pre-frailty

Figure 1 compares the age-specific prevalence of frailty in the rural areas of Kegalle district of Sri Lanka with the pooled prevalence of frailty in other comparable countries with data available: upper middle-income Asian countries (China and Malaysia), high-income Asian country (Japan) and upper middle-income Latin American countries (Brazil, Colombia and Mexico). Except for the age group 60–64 years, prevalence of frailty across all the other age groups was higher in the rural areas of Kegalle district of Sri Lanka. The prevalence was higher in the older 75–79 years and ≥80 years age categories. With regard to pre-frailty, the prevalence rates were relatively similar across countries (figure 2).

DISCUSSION
Summary of main findings
To our knowledge, this is the first study conducted in Sri Lanka to investigate the epidemiology of frailty using the Fried frailty phenotype.[2] The prevalence of frailty and pre-frailty among rural community-dwelling older adults aged ≥60 years in Kegalle district in 2016 was estimated as 15.2% (95% CI 12.3% to 18.6%) and 48.5% (95% CI 43.8% to 53.2%), respectively. Nearly half of those aged ≥80 years were frail. We found no evidence

of an association between sex and being frail or pre-frail in any regression model. In the multivariable-adjusted model, increasing age and having never been employed or having had a low-skilled occupation increased the relative risk of being frail compared with being robust. Being in the lowest education level increased the relative risk of being pre-frail compared with robust. In exploratory analyses, the prevalence of frailty appeared to be higher in Sri Lanka across all the age categories except 60–64 years when compared with the pooled prevalence of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

Comparison with existing literature
Frailty is an important clinical syndrome which predicts numerous adverse health outcomes in later life; however, there is a paucity of epidemiological research from Asian countries compared with the West. The majority of Asian studies are from high-income economies with few from WHO South-East Asia. India was a study site of two multi-country studies[13 26] and there were three small studies from Pune, India,[27] Nepal[28] and Nakhon Pathom, Thailand.[29] The reported prevalence of frailty in these studies ranged from 56.9% (frailty index)[26] to 11.4% (Fried phenotype with four components).[13] The use of different frailty assessment methods and heterogeneity in the minimum recruitment age make it difficult to compare the prevalence of frailty between studies. A small community-based study of older adults (≥65 years) in Pune, India[27] used Fried phenotype, a similar assessment method to ours but with Cardiovascular Health Study (CHS) cut-offs[2] for grip strength and gait speed, and found a prevalence of frailty and pre-frailty of 26.0% and 63.6%, respectively.[27] The corresponding prevalence of frailty and pre-frailty in our study after restricting the sample to those aged ≥65 years and after applying the same CHS grip strength and gait speed cut-offs was 34.6% (95% CI 29.3% to 40.4%) and 49.7% (95% CI 44.6% to 54.9%). This difference may be due to the shorter life expectancy in India[30] compared with Sri Lanka[31] and more highly educated people living in an urbanised area in the Indian study.[27]

In our study, the prevalence of frailty in older adults aged ≥65 years in Sri Lanka was 21.5% using population-specific grip strength and gait speed cut-offs. This is similar to a small study in Thailand (22.7%),[29] but much higher than the pooled prevalence of frailty reported in high-income (8.2%) and upper middle-income (11.8%) countries using the same frailty assessment method and the same minimum recruitment age.[9] This finding supports existing literature showing a strong relationship between national economic indicators and a country's level of frailty and fitness.[32]

We conducted our study in rural areas of Kegalle district. However, in Sri Lankan context, rural classification is itself problematic to some extent since semi-urban areas where people have access to many facilities and good infrastructure are also classified as rural. This applies to Kegalle district too. Lower prevalence of frailty

Table 3 Distribution of frailty statuses across sociodemographic characteristics

Covariates	Prevalence (95% CI), %		
	Robust	**Pre-frail**	**Frail**
Sex			
Male	41.3 (36.2 to 46.6)	44.4 (39.3 to 49.5)	14.3 (10.9 to 18.3)
Female	32.4 (26.9 to 38.2)	51.6 (44.0 to 59.0)	16.0 (11.8 to 21.1)
Age group (years)			
60–64	55.0 (45.2 to 64.4)	41.1 (32.3 to 50.5)	3.8 (1.7 to 7.9)
65–69	38.9 (27.6 to 51.5)	51.0 (39.6 to 62.2)	10.0 (5.6 to 17.2)
70–74	25.6 (16.4 to 37.7)	58.4 (47.7 to 68.2)	15.9 (8.6 to 27.4)
75–79	12.4 (6.3 to 22.9)	56.9 (43.0 to 69.7)	30.7 (19.3 to 44.9)
≥80	9.3 (4.2 to 19.3)	42.7 (28.4 to 58.3)	47.9 (33.1 to 63.0)
Marital status			
Married/cohabiting	42.6 (37.1 to 48.3)	45.9 (41.3 to 50.5)	11.5 (7.9 to 16.2)
Never married/widowed/separated/divorced	26.8 (20.6 to 34.0)	52.4 (44.4 to 60.1)	20.8 (14.8 to 28.4)
Living arrangement			
Children/other family	36.0 (32.0 to 40.3)	47.9 (42.9 to 52.6)	16.1 (12.7 to 20.1)
With spouse	42.9 (27.5 to 59.7)	45.9 (30.4 to 62.1)	11.2 (4.7 to 24.0)
Alone	26.8 (14.6 to 43.9)	62.2 (38.1 to 81.4)	11.0 (2.1 to 41.3)
Education level			
No formal education/primary	21.0 (14.0 to 30.0)	55.4 (46.8 to 63.7)	23.6 (16.4 to 32.6)
Lower secondary	35.8 (29.5 to 42.5)	49.3 (42.1 to 56.3)	14.9 (9.9 to 21.8)
Upper secondary/post-secondary non-tertiary/tertiary)	48.8 (41.9 to 55.7)	42.2 (34.7 to 50.1)	8.9 (5.4 to 14.2)
Longest-held occupation			
Never employed/skill level 1	29.5 (23.5 to 36.3)	49.4 (43.3 to 55.4)	21.1 (16.2 to 26.8)
Skill level 2	38.5 (31.5 to 46.0)	49.1 (41.5 to 56.6)	12.4 (8.2 to 18.2)
Skill level 3/4	47.9 (39.2 to 56.7)	45.1 (35.8 to 54.6)	7.0 (3.3 to 14.1)
Perceived financial strain			
Finding it difficult/very difficult	26.7 (18.8 to 36.2)	54.0 (44.1 to 63.6)	19.3 (13.3 to 27.0)
Just about getting by	36.1 (31.0 to 41.5)	48.7 (42.6 to 54.7)	15.2 (11.7 to 19.3)
Living comfortably	44.5 (35.7 to 53.5)	43.5 (32.6 to 54.9)	12.0 (6.4 to 21.3)

was found among three studies conducted in rural areas of coffee-growing zones of the Colombian Andes mountains (12.2%),[33] Mexico (10.7%)[34] and Turkey (7.1%)[35] compared with our study with similar frailty assessment method. However, both the Colombian and Turkish studies used non-probability sampling techniques (voluntary participation and convenience sampling). Voluntary participation might have underestimated the true prevalence, particularly if people with mobility limitations were less likely to take part in the study. The minimum recruitment age of the participants of these studies were ≥60,[33] ≥70[34] and ≥65[35] years, respectively.

In addition to the true variation of frailty prevalence rates across different populations, and differences in setting (urban/rural), these differences could also depend on methodological issues, for example, how phenotypic components are operationalised, which cut-offs are used, inclusion and exclusion criteria used to define the study population, and the way missing data of frailty components are handled. In keeping with many studies using the Fried phenotype,[36] we used BMI <18.5 kg/m^2 to operationalise 'shrinking', as we did not have access to serial weight measurements to objectively assess weight loss. For physical activity, we used the culturally adapted IPAQ as suitable for a Sri Lankan population unlike the original measure.[37] The instrument used could be sensitive to cultural effects when translated into different languages and interpretation.[38] Many studies included in the Latin American upper middle-income countries meta-analyses of this paper applied more restrictive inclusion criteria, which might have underestimated the true prevalence rates.

Age and female sex are two well-known biological risk factors of frailty[39]; however, we found an age but no sex difference in frailty or pre-frailty. A recent systematic review of longitudinal studies also found both an

Table 4 Unadjusted, age-adjusted and sex-adjusted, and multivariable adjusted multinomial logistic regression results

	Relative risk ratio (95% CI)					
	Pre-frailty vs robust			Frailty vs robust		
Covariates	Unadjusted	Age and sex adjusted	Multivariable*	Unadjusted	Age and sex adjusted	Multivariable*
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.48 (1.00 to 2.18)	1.45 (0.96 to 2.20)	1.31 (0.80 to 2.15)	1.43 (0.91 to 2.23)	1.34 (0.77 to 2.35)	0.96 (0.48 to 1.89)
Age group (years)						
60–64	**0.32 (0.16 to 0.65)**	**0.32 (0.16 to 0.66)**	**0.33 (0.16 to 0.71)**	**0.11 (0.02 to 0.41)**	**0.11 (0.02 to 0.41)**	**0.10 (0.02 to 0.43)**
65–69	0.57 (0.27 to 1.20)	0.57 (0.27 to 1.21)	0.59 (0.27 to 1.30)	0.41 (0.11 to 1.45)	0.41 (0.11 to 1.45)	0.38 (0.09 to 1.50)
70–74	1.00	1.00	1.00	1.00	1.00	1.00
75–79	2.01 (0.87 to 4.64)	1.99 (0.86 to 4.60)	2.05 (0.86 to 4.87)	**3.98 (1.46 to 10.84)**	**3.94 (1.44 to 10.75)**	**4.07 (1.43 to 11.56)**
≥80	1.99 (0.69 to 5.74)	1.96 (0.67 to 5.71)	1.81 (0.55 to 5.94)	**8.20 (2.24 to 30.00)**	**8.09 (2.20 to 29.75)**	**7.42 (1.79 to 30.67)**
Living arrangement						
Children/other family	1.00	1.00	1.00	1.00	1.00	1.00
With spouse	0.80 (0.37 to 1.73)	0.87 (0.38 to 1.98)	0.80 (0.39 to 1.64)	0.58 (0.18 to 1.82)	0.75 (0.20 to 2.78)	0.75 (0.24 to 2.33)
Alone	1.75 (0.74 to 4.13)	1.58 (0.56 to 4.49)	1.32 (0.42 to 4.11)	0.91 (0.17 to 4.75)	0.90 (0.18 to 4.54)	0.72 (0.13 to 3.89)
Education level						
Upper secondary/post-secondary non-tertiary/tertiary)	1.00	1.00	1.00	1.00	1.00	1.00
Lower secondary	**1.59 (1.02 to 2.47)**	1.57 (0.98 to 2.52)	1.49 (0.78 to 2.83)	**2.28 (1.13 to 4.60)**	**2.30 (1.09 to 4.88)**	1.38 (0.56 to 3.42)
No formal education/primary	**3.05 (1.71 to 5.42)**	**2.63 (1.51 to 4.56)**	**2.38 (1.19 to 4.79)**	**6.15 (2.66 to 14.23)**	**4.04 (1.67 to 9.77)**	2.12 (0.73 to 6.18)
Longest-held occupation						
Skill level 3/4	1.00	1.00	1.00	1.00	1.00	1.00
Skill level 2	1.35 (0.83 to 2.18)	1.48 (0.89 to 2.46)	0.87 (0.42 to 1.76)	2.20 (0.84 to 5.70)	**2.92 (1.12 to 7.62)**	1.69 (0.54 to 5.24)
Never employed/skill level 1	**1.77 (1.04 to 3.02)**	**1.77 (1.07 to 2.94)**	0.96 (0.46 to 2.00)	**4.88 (2.27 to 10.46)**	**6.33 (2.84 to 14.13)**	**3.43 (1.31 to 8.98)**
Perceived financial strain						
Living comfortably	1.00	1.00	1.00	1.00	1.00	1.00
Just about getting by	1.37 (0.80 to 2.36)	1.54 (0.93 to 2.54)	1.35 (0.83 to 2.21)	1.55 (0.74 to 3.22)	2.11 (0.85 to 5.23)	1.61 (0.62 to 4.18)
Finding it difficult/very difficult	**2.07 (1.08 to 3.96)**	**2.23 (1.16 to 4.28)**	1.70 (0.89 to 3.26)	**2.66 (1.24 to 5.73)**	**3.53 (1.35 to 9.19)**	2.27 (0.77 to 6.67)

The reference category is 1.00
Significant estimates are displayed in bold.
*Adjusted for sex, age group, living arrangement, education level, longest-held occupation and perceived financial strain.
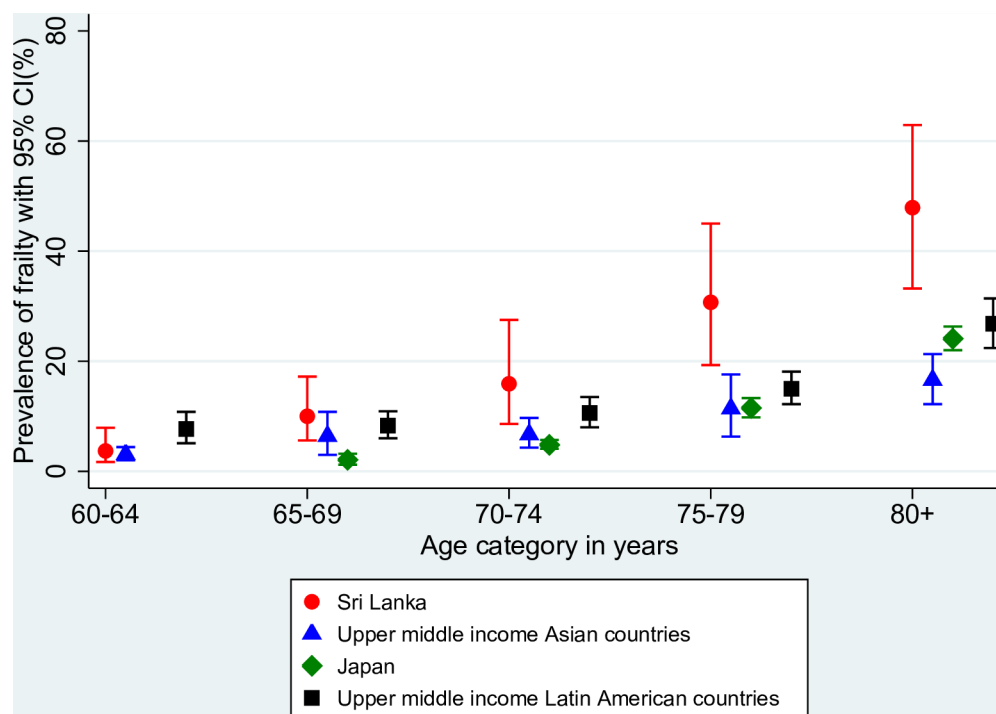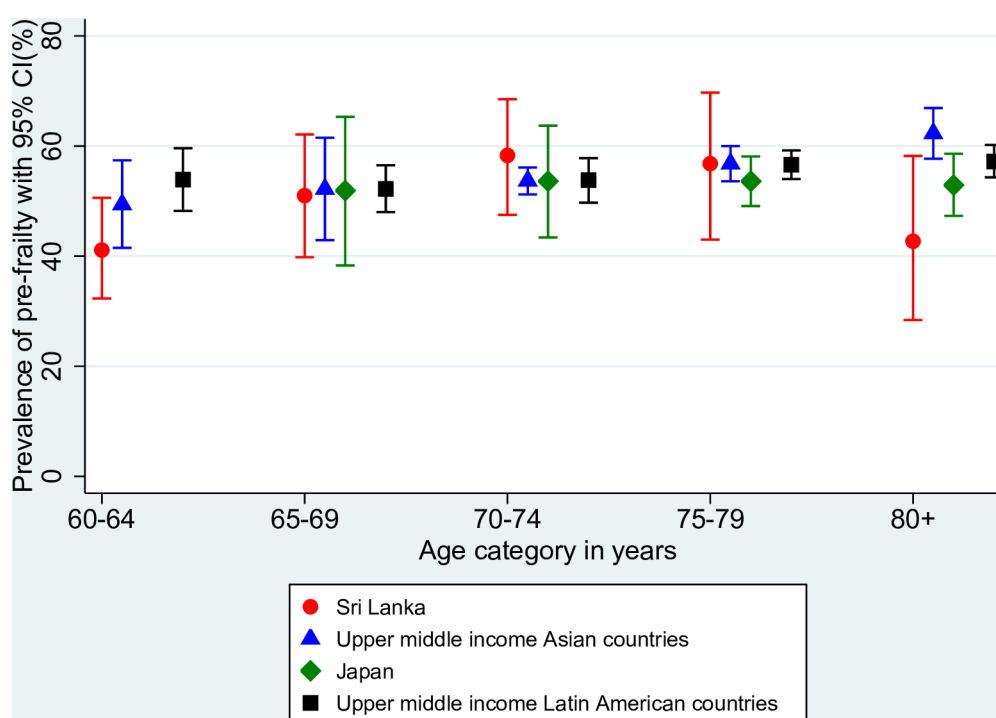
Figure 1 Comparison of age-specific prevalence of frailty in Sri Lanka with the pooled prevalence estimates of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

association and no association between sex and incident or increased risk of frailty.[39] In this review, two studies reported female sex as a risk factor for frailty[40 41] while two studies reported no association.[42 43] A strong association between longest-held occupation and frailty and education level and pre-frailty was found in our study. Aforementioned systematic review based on longitudinal

studies found studies reporting both positive and no association between level of education and frailty.[39]

Strengths and limitations

We conducted the first large population-based study on frailty with a regional representative sample of rural community-dwelling older adults in Kegalle district of Sri

Figure 2 Comparison of age-specific prevalence of pre-frailty in Sri Lanka with the pooled prevalence estimates of upper middle-income Asian countries, Japan and upper middle-income Latin American countries.

Lanka. We followed rigorous methodology and measures were taken to improve the validity and reliability of data. The intra-rater reliability of anthropometric measurements (height and weight) and physical performance tests (grip strength and walking time) were excellent (intraclass correlation>0.9). The response rate was extremely high (99.5%). Our analyses involved a cross-country comparison of frailty across income classification and geographical regions. Limitations include that the sample only comprised rural older adults and the majority belonged to Sinhalese ethnicity. Therefore, the results are likely not generalisable to urban and estate sectors and other ethnicities. The prevalence of frailty could be underestimated in our study as we excluded participants who could not give informed consent and those who were terminally ill. However, the number of excluded participants was very small and we were less restrictive than other studies. Some questions, for example, physical activity and self-reported exhaustion, could be affected by recall bias.

With regard to our cross-country comparison, it should be noted that our findings are based on a rural sample, and while the population of Sri Lanka is predominantly rural, this may not reflect the prevalence of frailty in urban and estate sectors in Sri Lanka. Furthermore, in the comparator country samples, it would be ideal if we had representative country-level data on the prevalence of frailty for this analysis. However, with the exception China, we were unable to find any nationally representative samples, and we therefore calculated pooled estimates of frailty and pre-frailty from studies conducted with regional samples. Moreover, studies included in this comparison have used both urban and rural samples. We have indicated the exact study setting and whether the sample is urban/rural/both/uncertain in online supplementary appendix III. We performed this analysis for exploratory purposes only and hence needs to be interpreted cautiously.

Implications for public health

The Sri Lankan health system is a well-known example of the provision of good healthcare at low cost.[44] Around 70% of the disease burden in the country is due to non-communicable diseases (NCDs).[45] The rapidly ageing population is contributing to increases in the prevalence of NCDs which is a huge challenge to the country's health system. Frailty and multimorbidity (multiple coexisting NCDs) are closely linked. Recently, guidelines have been introduced for the management of frailty in Asia-Pacific.[46] Therefore, findings of this study are important to healthcare planners to quantify the extent of frailty and be prepared for establishing appropriate health and social services for older adults with frailty and multiple NCDs. The existing profile of health and social care services in Sri Lanka needs adjustments to meet the needs of age-related illness and care. Further improvements in geriatrics and gerontology disciplines are an urgent need. Investing in elderly health is important to mitigate the medical and social implications of ageing.

CONCLUSION

The prevalence of frailty in this rural Sri Lankan older population was high in comparison with both higher-income and upper middle-income countries. There has been little research conducted on frailty in low-income and lower middle-income countries. Identifying the scale of the problem will help these growing economies to prepare and respond to the challenges associated with increasing longevity.

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