Sleep duration and sarcopenia in adults aged ≥ 65 years from low and middle-income countries

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ABSTRACT

Background

Sleep duration may infuence risk for sarcopenia but studies on this topic are scarce, especially from low and- middle-income countries (LMICs). Thus, the aim of the present study was to investigate the association between sleep duration and sarcopenia among adults aged≥65 years from fve LMICs (China, Ghana, India, Russia, South Africa).

Methods

Cross-sectional, community-based data from the WHO study on global ageing and adult health (SAGE) were analysed. Sarcopenia was defned as having low skeletal muscle mass (SMM) and weak handgrip strength, while severe sarcopenia was defned as having low SMM, weak handgrip strength, and slow gait speed. Self-reported sleep duration in the past two nights were averaged and classifed as≤6,>6 to≤9, and≥9 h/day. Multivariable logistic regression analysis was conducted.

Results

Data on 13,210 adults aged≥65 years [mean (SD) age 72.6 (11.3) years; 55.0% females] were analyzed. In the overall sample, compared to>6 to≤9 h/day of sleep duration,>9 h/day was associated with 1.70 (95% CI 1.15–2.51) and 1.75 (95% CI 1.08–2.84) times higher odds for sarcopenia and severe sarcopenia, respectively. No signifcant associations were observed among males, but associations were particularly pronounced among females [i.e., OR=2.19 (95% CI 1.26–3.81) for sarcopenia, and OR=2.26 (95% CI 1.20–4.23) for severe sarcopenia].

Conclusions

Long sleep duration was associated with an increased odds of sarcopenia and severe sarcopenia in LMICs, particularly in females. Future studies should investigate whether addressing long sleep duration among females can lead to lower risk for sarcopenia onset in LMICs.

Key Words: Sleep problems, Sarcopenia, Low- and- middle income countries, Older adults

INTRODUCTION

Sarcopenia may be defined as "age-related muscle loss, affecting a combination of appendicular muscle mass, muscle strength, and/or physical performance measures" [1]. The syndrome is most common in older adults. Indeed, a systematic review and meta-analyses of studies including adults aged 55 years and over found that the prevalence of sarcopenia was approximately 10% [2]. However, it should be noted that the prevalence of sarcopenia varies depending on the definition of sarcopenia employed, with 10% being the most conservative estimate [2]. In September 2016, sarcopenia was introduced in the ICD-10-CM [3], which represents a major step forward in the recognition of sarcopenia as a disease. Importantly, sarcopenia is associated with multiple negative health outcomes. In an umbrella review including six meta-analyses with 14 associations, highly suggestive evidence pointed to an association between sarcopenia and premature mortality, disability, and falls [4]. Considering the high prevalence of sarcopenia in older adults and its association with multiple adverse outcomes, risk factors of sarcopenia need to be identified to inform targeted interventions.

To date, studies have identified some risk factors for sarcopenia. Low levels of physical activity has consistently been shown to increase risk of developing sarcopenia [5–7], and so has malnutrition [8–10]. Other identified risk factors include, for example, smoking [11, 12], and excessive alcohol consumption [13, 14]. However, one potentially important but understudied risk factor of sarcopenia is sleep duration. Importantly, greater than 50% of the older adult population complain of sleep problems [15]. Sleep duration may be associated with sarcopenia via, for example, the impact of impaired sleep on the function of endocrine factors and consequent reduction in muscle health [16, 17]. In a systematic review and meta-analyses including just four cross-sectional studies carried out in China, Korea, Netherlands, and Taiwan, it was found that long and short sleep duration were associated with higher risk for sarcopenia, with females being affected by both short and long sleep, while males were only affected by long sleep duration [18]. Furthermore, a recent longitudinal study (not included in the review) found that long sleep duration was associated with an increased risk of progression to sarcopenia over 4-years among 3918 older community-dwelling adults from Japan [19]. However, the existing literature has some important limitations. First, existing studies consist of relatively small sample sizes that are not nationally representative. Second, almost all studies have been carried out in Asian settings with only one study from Europe, while there is only one study from low- and-middle income countries (LMICs; i.e., China). It is important to investigate the present association in other settings, and in particular LMICs, since in such settings, there is a high prevalence of sarcopenia [20, 21], as well as sleep problems [22].

Given this background, the aim of the present study was to investigate the association between sleep duration and sarcopenia in a representative sample of 13,210 adults aged ≥ 65 years from China,

Ghana, India, Russia, and South Africa. Moreover, since previous literature has identified sex differences in this association, we aimed to investigate whether this association differs by sex.

METHODS

The survey

Data from the Study on Global Ageing and Adult Health (SAGE) were analyzed. These data are publicly available through http:// www. who. int/ healt hinfo/ sage/ en/. This survey was undertaken in China, Ghana, India, Mexico, Russia, and South Africa between 2007 and 2010. Based on the World Bank classification at the time of the survey, all countries were LMICs. Details of the survey methodology have been published elsewhere [23]. Briefly, to obtain nationally representative samples, a multistage clustered sampling design method was used. The sample consisted of adults aged ≥ 18 years with oversampling of those aged ≥ 50 years. Trained interviewers conducted face-to-face interviews using a standard questionnaire. Standard translation procedures were undertaken to ensure comparability between countries. If a respondent was unable to undertake the interview because of limited cognitive function, then a separate questionnaire was administered to a proxy respondent. These individuals were not included in the current study. The survey response rates were China 93%; Ghana 81%; India 68%; Mexico 53%; Russia 83%; and South Africa 75%. Sampling weights were constructed to adjust for the population structure as reported by the United Nations Statistical Division. Ethical approval was obtained from the WHO Ethical Review Committee and local ethics research review boards. Written informed consent was obtained from all participants.

Sarcopenia

Following the criteria of the revised European consensus on the definition and diagnosis of sarcopenia [24], sarcopenia was defined as having low skeletal muscle mass (SMM) as reflected by lower skeletal mass index (SMI) and weak handgrip strength, while severe sarcopenia was defined as having low SMM, weak handgrip strength, and slow gait speed. SMM was calculated based on the equation proposed by Lee and colleagues: SMM = 0.244*weight + 7.8*heigh t + 6.6*sex − 0.098*age + race − 3.3 (where female = 0 and male = 1; race = 0 [White and Hispanic], race = 1.4 [Black] and race = − 1.2 [Asian]) [25]. SMM was further divided by body mass index (BMI) based on measured weight and height to create a SMI [26]. Low SMM was defined as the lowest quintile of the SMI based on sex-stratified values [27]. Country-specific cut-offs were used to determine low SMI, as this indicator is likely to be affected by racial differences in body composition [28]. Weak handgrip strength was defined as < 27 kg for men and < 16 kg for women using the average value of the two handgrip measurements of the dominant hand [24]. Gait speed was based on a 4 m timed walk and was measured by asking the participant to walk at a normal pace. The interviewer recorded the time to completion of the 4 m walk. Slow gait speed referred to ≤ 0.8 m/s [24].

Sleep duration

Information on sleep duration in the preceding two nights were available. Specifically, the questions were "How many hours did you sleep the night before last?" and "How many hours did you sleep last night?" The respondent provided their answers in hours and minutes. These values were averaged and categorized as 0–6 h/day, > 6 to 9 h/day, and > 9 h/ day [29].

Control variables

The selection of the control variables was based on past literature [19], and included age, sex, highest education achieved (≤ primary, secondary, tertiary), wealth quintiles based on income, physical activity, smoking (never, current, past), alcohol consumption in the past 30 days, BMI, angina, chronic lung disease (i.e., emphysema, bronchitis, COPD), diabetes, hypertension, stroke, and depression. Levels of physical activity were assessed with the Global Physical Activity Questionnaire and were classified as low, moderate, and high based on conventional cut-offs [30]. BMI was calculated as weight in kilograms divided by height in meters squared. BMI was categorized as < 18.5 kg/m2 (underweight), 18.5–24.9 kg/m2 (normal weight), 25.0–29.9 kg/ m2 (overweight), and ≥ 30.0 kg/m2 (obesity) [31]. Chronic lung disease, diabetes, and stroke were based solely on lifetime self-reported diagnosis. For angina, the validated Rose questionnaire [32] was used in addition to a lifetime self-reported diagnosis. Hypertension was defined as having at least one of: systolic blood pressure ≥ 140 mmHg; diastolic blood pressure ≥ 90 mmHg; or self-reported diagnosis. Questions based on the World Mental Health Survey version of the Composite International Diagnostic Interview [33] were used for the endorsement of past 12-month DSM-IV depression [34].

Statistical analysis

The statistical analysis was performed with Stata 14.2 (Stata Corp LP, College station, Texas). The analysis was restricted to those aged ≥ 65 years as sarcopenia is an age-related condition. Furthermore, Mexico was omitted from the analysis as data on sleep duration was not collected. Differences in sample characteristics by sarcopenia or sleep duration were tested by Chi-squared tests for categorical variables and by one-way ANOVA or Student's t-tests for continuous variables. Multivariable logistic regression was conducted to assess the association between sleep duration (exposure) and sarcopenia or severe sarcopenia (outcomes). Analyses using the overall sample and sex-stratified samples were conducted as previous studies have shown that the association between sleep duration and sarcopenia may differ by sex [18].

The regression analyses were adjusted for age, sex, education, wealth, physical activity, smoking, alcohol consumption, diabetes, chronic lung disease, angina, hypertension, stroke, BMI, depression, and country, with the exception of the sex-stratified analysis which was not adjusted for sex. Adjustment for country was done by including dummy variables for each country in the model as in

previous SAGE publications [35, 36]. The sample weighting and the complex study design were taken into account in the analyses. Results from the regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The level of statistical significance was set at $P < 0.05$.

RESULTS

The analytical sample consisted of 13,210 adults aged ≥ 65 years (China *n* = 5360; Ghana *n* = 1975; India *n* = 2441; Russia *n* = 1950; South Africa *n* = 1484). The mean (SD) age of the sample was 72.6 (11.3) years and 55.0% were females. The sample characteristics are provided in Table 1. The prevalence of sarcopenia and severe sarcopenia were 12.0% and 7.8%, respectively. Overall, 20.9%, 66.0%, and 13.1% of the sample had sleep durations of ≤ 6 h/day, > 6 to ≤ 9 h/day, and > 9 h/day, respectively. Compared to males, women had higher prevalence of a sleep duration of > 9 h/day (10.5% vs. 15.3%). The difference in sample characteristics by sarcopenia or sleep duration is shown in Table S1 of the Online Appendix. Significant differences were found for factors such as age, wealth, physical activity, and BMI etc. The prevalence of sarcopenia by sleep duration is shown in Fig. 1. Distinct patterns were observed between males and females where the prevalence of sarcopenia was particularly high among females with a sleep duration of >9 h/day. Similar patterns were observed for severe sarcopenia (Fig. 2). The association between sleep duration and sarcopenia estimated by multivariable logistic regression is shown in Table 2. Compared to > 6 to ≤ 9 h/day of sleep duration, > 9 h/day was associated with 1.70 (95% CI 1.15–2.51) times higher odds for sarcopenia in the overall sample. This association was particularly pronounced among females (OR = 2.19; 95% CI 1.26–3.81) but sleep duration was not significantly associated with sarcopenia among males. Similar associations were found for severe sarcopenia with the OR for > 9 h/day (vs. > 6 to ≤ 9 h/day) being 1.75 (95% CI 1.08–2.84) in the overall sample and 2.26 (95% CI 1.20–4.23) among females (Table 3).

DISCUSSION

Main findings

In this large representative sample of older adults from five LMICs, it was found that compared to >6 to ≤9 hours/day of sleep duration, >9 hours/day was associated with 1.70 times higher odds for sarcopenia in the overall sample. This association was particularly pronounced among females (OR=2.19) but sleep duration was not significantly associated with sarcopenia among males. Similar findings were observed for severe sarcopenia.

Interpretation of the findings

Findings from the present study support, contradict and add to previous literature. They support previous literature through confirming that an association exists between long sleep duration and sarcopenia [18, 19, 37], and add to this through showing such an association holds in a large

representative sample across five LMICs. However, the present findings contradict previous literature by showing that long sleep duration was only associated with females whereas previous work has found such an association in males [18].

There are several plausible mechanisms that may explain why long sleep duration is associated with a higher risk of sarcopenia. It is important to highlight that the onset of sleep problems has been found to be the transition point for short or long sleep duration [38]. First, sleep problems impact on testosterone and anabolic hormones such as insulin-like growth factor-1 that regulate protein synthesis and thus maintain skeletal muscle mass [39]. Second, insulin resistance associated with sleep problems can cause loss of muscle mass and function in older adults [40]. Third, chronic sleep problems may dysregulate the hypothalamopituitaryadrenal axis resulting in endocrine changes [41]. Fourth, sleep problems may result in excessive daytime sleepiness that will likely increase sedentary time, which is a risk factor for sarcopenia [37, 42]. Finally, sarcopenia may cause sleep problems owing to muscle strength/function decline and thus, it is possible that the relationship is bidirectional [43].

It is important to note that when stratified by sex, the present study found a significant association between long sleep duration and sarcopenia only in females and not males. Although the reason for this is unclear, the differences may be owing to different daily sleep duration and/or requirements between the sexes due to their different hormone levels. Indeed, sex hormones regulate muscle mass and function and differ between sexes [18]. Interestingly, the only meta-analysis on this topic including four studies found a significant association among males only [18]. The reason why previous studies found the opposite to the present is not known and future research is required. However, these differences may be partly explained by the social and cultural settings of the countries studied, and the fact that previous studies used non-representative samples.

Public health implications and areas for future research

Findings from the present study suggest that targeting long sleep duration may aid in the prevention of sarcopenia, at least in females. It may be shrewd to utilize physical activity interventions to achieve this aim as physical activity per se reduces risk of sarcopenia and improves sleep quality [44]. Moreover, clinicians should be aware of the sleep-sarcopenia relationship and consider prescribing lifestyle changes to those who present with long sleep duration to aid in the prevention of sarcopenia. Future studies should assess the mechanisms that link long sleep duration and sarcopenia, and also examine whether modifications in sleep duration or addressing sleep problems can lead to lower risk for sarcopenia onset.

Strengths and limitations

The use of large representative samples of older adults from five LMICs is a clear strength of the present paper. However, findings should be interpreted in light of the study limitations. First, the study is cross-sectional in nature and thus, it is not known whether sleep duration causes sarcopenia or vice versa; the relationship is likely bidirectional. Second, the survey did not include a robust dietary assessment, and thus, the role of diet could not be considered in the investigated associations. Third, sleep duration was based on self report and previous studies have shown that some people tend to overestimate sleep duration. Next, we were unable to adjust for factors such as skipping breakfast, morning stiffness) to further elucidate on the association between long sleep duration and risk of sarcopenia; however, such data was not collected in the present study. Future studies with more detailed data on the reasons for long sleep duration are likely to shed light on the underlying mechanisms of the investigated associations.

Conclusion

In conclusion, long sleep duration was associated with an increased odds for sarcopenia among older adults in LMICs, particularly in females. Contextualized and tailored interventions to address long sleep duration in females may aid in the prevention of sarcopenia, pending more longitudinal research.

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REFERENCES

1. Woo J (2017) Sarcopenia. Clin Geriatr Med 33:305–314
2. Mayhew AJ, Amog K, Phillips S et al (2019) The prevalence of sarcopenia in community-dwelling older adults, an exploration of differences between studies and within definitions: a systematic review and meta-analyses. Age Ageing 48:48–56
3. Anker SD, Morley JE, von Haehling S (2016) Welcome to the ICD-10 code for sarcopenia. J Cachexia Sarcopenia Muscle 7:512–514
4. Veronese N, Demurtas J, Soysal P et al (2019) Sarcopenia and health-related outcomes: an umbrella review of observational studies. Eur Geriatr Med 10:853–862
5. Mijnarends DM, Koster A, Schols JM et al (2016) Physical activity and incidence of sarcopenia: the population-based AGES—
Reykjavik Study. Age Ageing 45:614–620

6. Meier NF, Lee D (2019) Physical activity and sarcopenia in older adults. Aging Clin Exp Res 32:1675–1687
7. Ryu M, Jo J, Lee Y et al (2013) Association of physical activity with sarcopenia and sarcopenic obesity in community-dwelling older adults: the Fourth Korea National Health and Nutrition Examination Survey. Age Ageing 42:734–740
8. Beaudart C, Sanchez-Rodriguez D, Locquet M et al (2019) Malnutrition as a strong predictor of the onset of sarcopenia. Nutrients
11:2883
9. Verstraeten L, van Wijngaarden JP, Pacifico J et al (2021) Association between malnutrition and stages of sarcopenia in geriatric rehabilitation inpatients: RESORT. Clin Nutr 40:4090–4096
10. Alexandre TdS, Duarte YAdO, Santos JLF, Lebrão ML (2019) Prevalence and associated factors of sarcopenia, dynapenia, and sarcodynapenia in community-dwelling elderly in São PauloSABE Study. Rev Bras Epidemiol 21(Suppl 02):e180009. https:// doi. org/ 10. 1590/ 1980-54972 01800 09. supl.2
11. Jo Y, Linton JA, Choi J et al (2019) Association between cigarette smoking and sarcopenia according to obesity in the middle-aged and elderly Korean population: the Korea National Health and Nutrition Examination Survey (2008–2011). Korean J Fam Med 40:87
12. Lee EJ, Yang SK, Lee DC (2018) Smoking and its relationship with sarcopenia: result from the 2008–2011 Korean national health and nutrition examination survey. Korean J Fam Pract 8:752–758
13. Yoo J, Ha Y, Lee Y et al (2017) High prevalence of sarcopenia among binge drinking elderly women: a nationwide populationbased study. BMC Geriatr 17:1–8
14. Buchmann N, Spira D, König M et al (2019) Problematic drinking in the old and its association with muscle mass and muscle function in type II diabetes. Sci Rep 9:1–8
15. Neikrug AB, Ancoli-Israel S (2010) Sleep disorders in the older adult–a mini-review. Gerontology 56:181–189
16. Dockray S, Steptoe A (2011) Chronotype and diurnal cortisol profile in working women: differences between work and leisure days. Psychoneuroendocrinology 36:649–655
17. Lucassen EA, Rother KI, Cizza G (2012) Interacting epidemics? Sleep curtailment, insulin resistance, and obesity. Ann N Y Acad Sci 1264:110
18. Pourmotabbed A, Ghaedi E, Babaei A et al (2019) Sleep duration and sarcopenia risk: a systematic review and dose-response meta-analysis. Sleep Breath 24:1267–1278. https:// doi. org/ 10. 1007/ s11325- 019- 01965-6
19. Nakakubo S, Doi T, Tsutsumimoto K et al (2021) Sleep duration and progression to sarcopenia in Japanese community-dwelling older adults: a 4 year longitudinal study. J Cachexia Sarcopenia Muscle 12:1034–1041

20. Morley JE, Anker SD, Von Haehling S (2014) Prevalence, incidence, and clinical impact of sarcopenia: facts, numbers, and epidemiology—update 2014. J Cachexia Sarcopenia Muscle 5:253–259
21. von Haehling S, Morley JE, Anker SD (2012) From muscle wasting to sarcopenia and myopenia: update 2012. J Cachexia Sarcopenia Muscle 3:213–217
22. Simonelli G, Marshall NS, Grillakis A et al (2018) Sleep health epidemiology in low and middle-income countries: a systematic review and meta-analysis of the prevalence of poor sleep quality and sleep duration. Sleep Health 4:239–250
23. Kowal P, Chatterji S, Naidoo N et al (2012) Data resource profile: the World Health Organization Study on global AGEing and adult health (SAGE). Int J Epidemiol 41:1639–1649
24. Cruz-Jentoft AJ, Bahat G, Bauer J et al (2019) Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing
48:16–31
25. Lee RC, Wang Z, Heo M et al (2000) Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. Am J Clin Nutr 72:796–803
26. Studenski SA, Peters KW, Alley DE et al (2014) The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci 69:547–558
27. Tyrovolas S, Koyanagi A, Olaya B et al (2016) Factors associated with skeletal muscle mass, sarcopenia, and sarcopenic obesity in older adults: a multi-continent study. J Cachexia Sarcopenia Muscle 7:312–321
28. Ortiz O, Russell M, Daley TL et al (1992) Differences in skeletal muscle and bone mineral mass between black and white females and their relevance to estimates of body composition. Am J Clin Nutr 55:8–13
29. Gildner TE, Liebert MA, Kowal P et al (2014) Associations between sleep duration, sleep quality, and cognitive test performance among older adults from six middle income countries: results from the Study on Global Ageing and Adult Health (SAGE). J Clin Sleep Med 10:613–621
30. Bull FC, Maslin TS, Armstrong T (2009) Global physical activity questionnaire (GPAQ): nine country reliability and validity study. J Phys Act Health 6:790–804
31. World Health Organization (2000) Obesity: preventing and managing the global epidemic. https://a pps.who.i nt /iris/h andle /10665 /
42330
32. Rose GA (1962) The diagnosis of ischaemic heart pain and intermittent claudication in field surveys. Bull World Health Organ 27:645
33 . Kessler RC, Üstün TB (2004) The world mental health (WMH) survey initiative version of the world health organization (WHO) composite international diagnostic interview (CIDI). Int J Methods Psychiatr Res 13:93–121

34. American Psychiatric Association (2013) Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric
Pub
35 . Koyanagi A, Lara E, Stubbs B et al (2018) Chronic physical conditions, multimorbidity, and mild cognitive impairment in low-and middle-income countries. J Am Geriatr Soc 66:721–727
36. Koyanagi A, Garin N, Olaya B et al (2014) Chronic conditions and sleep problems among adults aged 50 years or over in nine countries: a multi-country study. PLoS One 9:e114742
37. Soysal P, Smith L, Tan SG et al (2021) Excessive daytime sleepiness is associated with an increased frequency of falls and sarcopenia. Exp Gerontol 150:111364
38. Bin YS (2016) Is sleep quality more important than sleep duration for public health? Sleep 39:1629–1630
39. Dattilo M, Antunes HKM, Medeiros A et al (2011) Sleep and muscle recovery: endocrinological and molecular basis for a new and promising hypothesis. Med Hypotheses 77:220–222
40. Kalyani RR, Corriere M, Ferrucci L (2014) Age-related and disease-related muscle loss: the effect of diabetes, obesity, and other diseases. Lancet Diabetes Endocrinol 2:819–829
41. Seelig E, Keller U, Klarhöfer M et al (2013) Neuroendocrine regulation and metabolism of glucose and lipids in primary chronic insomnia: a prospective case-control study. PLoS One 8:e61780
42. Smith L, Tully M, Jacob L et al (2020) The association between sedentary behavior and sarcopenia among adults aged≥ 65 years in low-and middle-income countries. Int J Environ Res Public Health 17:1708
43. Nishikawa H, Enomoto H, Yoh K et al (2019) Effect of sarcopenia on sleep disturbance in patients with chronic liver diseases. J Clin Med 8:16
44. Dolezal BA, Neufeld EV, Boland DM, Martin JL, Cooper CB (2017) Interrelationship between sleep and exercise: a systematic review. Adv Prev Med 2017:1364387. https:// doi. org/ 10. 1155/ 2017/ 13643 87

Table 1 Sample characteristics (overall and by sex)

Characteristic		Overall	Male	Female
Sarcopenia	No	88.0	87.1	88.7
	Yes	12.0	12.9	11.3
Severe sarcopenia	No	92.2	92.5	91.9
	Yes	7.8	7.5	8.1
Sleep duration	≤6 hours/day	20.9	21.6	20.3
	>6 to ≤9 hous/day	66.0	67.9	64.4
	>9 hours/day	13.1	10.5	15.3
Age (years)	Mean (SD)	72.6 (11.3)	72.1 (10.9)	72.9 (11.5)
Sex	Female	55.0		
	Male	45.0		
Education	≤Primary	63.7	58.7	67.7
	Secondary	29.9	32.5	27.7
	Tertiary	6.4	8.7	4.6
Wealth	Poorest	21.7	19.1	23.8
	Poorer	21.0	20.5	21.5
	Middle	20.4	19.6	21.0
	Richer	17.5	19.4	15.9
	Richest	19.4	21.5	17.7
Physical activity	High	35.2	37.7	33.2
	Moderate	25.2	24.3	25.9
	Low	39.6	38.0	40.9
Smoking	Never	62.2	35.6	84.0
	Smoker	29.3	48.4	13.6
	Quit	8.5	16.0	2.3
Alcohol consumption	No	86.1	76.4	94.1
	Yes	13.9	23.6	5.9
Diabetes	No	91.4	92.0	90.9
	Yes	8.6	8.0	9.1
Chronic lung disease	No	89.9	88.3	91.2
	Yes	10.1	11.7	8.8
Angina	No	75.8	80.5	71.9
	Yes	24.2	19.5	28.1

Hypertension	No	36.6	41.8	32.4
	Yes	63.4	58.2	67.6
Stroke	No	95.4	94.7	95.9
	Yes	4.6	5.3	4.1
Body mass index	Underweight	19.3	21.9	17.1
	Normal	46.4	51.3	42.3
	Overweight	23.9	21.1	26.2
	Obese	10.4	5.7	14.4
Depression	No	93.5	94.2	92.9
	Yes	6.5	5.8	7.1

Abbreviation: SD Standard deviation
Data are % unless otherwise stated.

Table 2 Association between sleep duration or covariates and sarcopenia (outcome) estimated by multivariable logistic regression

		Overall		Male		Female	
Characteristic		OR	95%CI	OR	95%CI	OR	95%CI
Sleep duration	≤6 hours/day	1.19	[0.86,1.65]	1.17	[0.76,1.79]	1.20	[0.81,1.79]
	>6 to ≤9 hours/day	1.00		1.00		1.00	
	>9 hours/day	1.70**	[1.15,2.51]	1.00	[0.69,1.43]	2.19**	[1.26,3.81]
Age (years)		1.13***	[1.11,1.15]	1.11***	[1.09,1.14]	1.16***	[1.12,1.19]
Sex	Male vs. Female	1.48**	[1.15,1.91]				
Education	≤Primary	1.00		1.00		1.00	
	Secondary	0.70*	[0.51,0.95]	0.54***	[0.38,0.77]	0.68	[0.34,1.34]
	Tertiary	0.52*	[0.29,0.93]	0.46**	[0.25,0.82]	0.22	[0.03,1.66]
Wealth	Poorest	1.00		1.00		1.00	
	Poorer	0.72*	[0.52,1.00]	0.66	[0.42,1.03]	0.82	[0.48,1.42]
	Middle	0.67*	[0.47,0.94]	0.58*	[0.37,0.93]	0.82	[0.50,1.33]
	Richer	0.53***	[0.40,0.71]	0.48**	[0.30,0.77]	0.56**	[0.38,0.82]
	Richest	0.36***	[0.26,0.51]	0.29***	[0.18,0.48]	0.43**	[0.25,0.75]
Physical activity	High	1.00		1.00		1.00	
	Moderate	1.17	[0.91,1.52]	1.40	[0.93,2.13]	0.87	[0.59,1.27]
	Low	1.14	[0.89,1.47]	1.25	[0.85,1.83]	0.96	[0.62,1.49]
Smoking	Never	1.00		1.00		1.00	
	Smoker	0.93	[0.68,1.27]	0.75	[0.53,1.06]	1.38	[0.85,2.26]
	Quit	1.12	[0.75,1.68]	1.06	[0.67,1.66]	1.04	[0.45,2.38]
Alcohol consumption	Yes vs. No	0.76	[0.51,1.14]	0.73	[0.47,1.14]	0.92	[0.53,1.61]
Diabetes	Yes vs. No	0.66*	[0.47,0.94]	0.71	[0.44,1.15]	0.63	[0.35,1.12]
Chronic lung disease	Yes vs. No	1.17	[0.82,1.66]	1.05	[0.65,1.70]	1.37	[0.90,2.09]
Angina	Yes vs. No	0.97	[0.72,1.32]	1.14	[0.76,1.73]	0.87	[0.54,1.38]
Hypertension	Yes vs. No	0.96	[0.78,1.17]	1.06	[0.77,1.46]	0.83	[0.58,1.18]
Stroke	Yes vs. No	1.26	[0.79,2.01]	1.22	[0.66,2.28]	1.18	[0.61,2.29]
Body mass index	Underweight	0.59**	[0.41,0.85]	0.30***	[0.18,0.50]	1.19	[0.72,1.94]
	Normal	1.00		1.00		1.00	

	Overweight	1.53**	[1.14,2.04]	2.23***	[1.62,3.08]	1.01	[0.66,1.56]
	Obese	2.09***	[1.39,3.14]	6.88***	[3.56,13.29]	1.01	[0.63,1.64]
Depression	Yes vs. No	0.82	[0.48,1.38]	0.49*	[0.24,1.00]	1.02	[0.49,2.14]

Abbreviation: OR Odds ratio; CI Confidence interval
Models are adjusted for all variables in the respective columns and country.
* p<0.05, ** p<0.01, *** p<0.001

Table 3 Association between sleep duration or covariates and severe sarcopenia (outcome) estimated by multivariable logistic regression

		Overall		Male		Female	
Characteristic		OR	95%CI	OR	95%CI	OR	95%CI
Sleep duration	≤6 hours/day	1.14	[0.78,1.68]	1.07	[0.61,1.90]	1.23	[0.79,1.93]
	>6 to ≤9 hous/day	1.00		1.00		1.00	
	>9 hours/day	1.75*	[1.08,2.84]	1.07	[0.58,1.95]	2.26*	[1.20,4.23]
Age (years)		1.14***	[1.11,1.16]	1.12***	[1.08,1.15]	1.16***	[1.12,1.20]
Sex	Male vs. Female	1.06	[0.76,1.48]				
Education	≤Primary	1.00		1.00		1.00	
	Secondary	0.87	[0.59,1.29]	0.82	[0.54,1.24]	0.72	[0.33,1.59]
	Tertiary	0.56	[0.25,1.23]	0.48	[0.22,1.08]	0.32	[0.05,2.23]
Wealth	Poorest	1.00		1.00		1.00	
	Poorer	0.76	[0.47,1.21]	0.54	[0.29,1.03]	0.97	[0.49,1.91]
	Middle	0.71	[0.49,1.04]	0.45*	[0.25,0.83]	1.08	[0.58,1.98]
	Richer	0.53**	[0.36,0.78]	0.40**	[0.22,0.73]	0.58*	[0.36,0.94]
	Richest	0.39***	[0.25,0.61]	0.23***	[0.12,0.46]	0.57	[0.30,1.07]
Physical activity	High	1.00		1.00		1.00	
	Moderate	1.39*	[1.00,1.94]	2.58**	[1.46,4.57]	0.81	[0.52,1.25]
	Low	1.35	[0.94,1.92]	2.00**	[1.19,3.36]	0.94	[0.54,1.64]
Smoking	Never	1.00		1.00		1.00	

	Smoker	1.09	[0.76,1.57]	0.76	[0.48,1.21]	1.87*	[1.09,3.19]
	Quit	1.26	[0.78,2.03]	1.08	[0.65,1.79]	1.52	[0.60,3.85]
Alcohol consumption	Yes vs. No	0.72	[0.42,1.24]	0.74	[0.37,1.48]	0.87	[0.50,1.51]
Diabetes	Yes vs. No	0.73	[0.47,1.13]	0.62	[0.33,1.18]	0.86	[0.46,1.60]
Chronic lung disease	Yes vs. No	1.21	[0.82,1.79]	1.27	[0.70,2.30]	1.20	[0.72,1.99]
Angina	Yes vs. No	1.11	[0.75,1.64]	1.43	[0.80,2.55]	0.89	[0.50,1.59]
Hypertension	Yes vs. No	1.05	[0.80,1.38]	1.19	[0.79,1.80]	0.93	[0.59,1.47]
Stroke	Yes vs. No	1.11	[0.63,1.97]	1.50	[0.69,3.26]	0.76	[0.32,1.83]
Body mass index	Underweight	0.66	[0.43,1.01]	0.38***	[0.22,0.66]	1.19	[0.63,2.22]
	Normal	1.00		1.00		1.00	
	Overweight	1.52*	[1.05,2.20]	2.35***	[1.57,3.52]	0.99	[0.61,1.60]
	Obese	1.96**	[1.21,3.18]	6.50***	[3.37,12.53]	0.96	[0.49,1.85]
Depression	Yes vs. No	0.62	[0.35,1.11]	0.65	[0.29,1.46]	0.50	[0.22,1.15]

Abbreviation: OR Odds ratio; CI Confidence interval
Models are adjusted for all variables in the respective columns and country.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$