**Leisure-time physical activity and sarcopenia among older adults from low- and middle-income countries**

**Running title:** Leisure-time physical activity and sarcopenia

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**Abstract**

*Background:* There is no data on the association between leisure-time physical activity (LTPA) and sarcopenia in older adults from low- and middle-income countries (LMICs). This study aimed to investigate the association between LTPA and sarcopenia in individuals aged ≥65 years living in six LMICs.

*Methods:* Cross-sectional data from the Study on Global AGEing and Adult Health (SAGE; China, Ghana, India, Mexico, Russia, South Africa) were analyzed. Sarcopenia referred to the presence of both low skeletal muscle mass and weak handgrip strength. LTPA was assessed using the Global Physical Activity Questionnaire (GPAQ) and was analyzed as a dichotomized variable [high LPTA (>150 minutes/week of moderate-to-vigorous LTPA) or low LPTA (≤150 minutes/week)]. Multivariable logistic regression analysis was conducted to assess associations.

*Results:* There were 14585 individuals included in this study [mean (SD) age 72.6 (11.5) years; 55.0% women]. The prevalence of high LTPA and sarcopenia were 8.9% and 12.0%, respectively. After adjusting for potential confounders, low LTPA was significantly associated with higher odds for sarcopenia **[POR (prevalence odds ratio)**=1.85, 95%CI=1.29-2.65] compared with high LTPA. Significant associations were found in women (**P**OR=3.22, 95%CI=1.82-5.68) but not men (**P**OR=1.52, 95%CI=0.99-2.35).

*Conclusions:* A positive and significant association between low LTPA and sarcopenia was found among older adults from LMICs. The promotion of LTPA among older adults in LMICs may aid in the prevention of sarcopenia, especially among females, pending future longitudinal research.

**Keywords:** leisure-time physical activity; sarcopenia; older adults; low- and middle-income countries; epidemiology

**Introduction**

Sarcopenia is an age-related condition characterized by the progressive loss of skeletal muscle mass and function, and this loss is one of the most critical changes related to aging.1 Sarcopenia is now recognized as a muscle disease, and is included in the International Classification of Diseases. The prevalence of sarcopenia is high in older adults and can reach 25% in those living in low- and middle-income countries (LMICs).2 Given that the worldwide population is aging rapidly, where the number of people ≥60 years is projected to increase from current figures of around 1 billion to 1.4 billion by 2030 and 2.1 billion by 2050,3 the prevalence of sarcopenia is expected to increase substantially in the coming decades. This is a major problem as sarcopenia is associated with higher risks of physical disability,4 impaired mental health,5 and premature mortality.6 In this context, it is of utmost importance to identify the risk factors for sarcopenia, particularly in LMICs where the treatment and management of sarcopenia may be limited.

In recent decades, literature has shown that physical activity may protect against sarcopenia. Physical activity can be defined as body movements produced by skeletal muscles with the expenditure of energy.7 Physical activity may prevent sarcopenia via **an** increase in muscle mass and strength, prevention of several chronic physical conditions (e.g., cardiovascular diseases, dementia, diabetes)8 and polypharmacy,9,10 as well as decreased risk of hospitalization.11,12 Indeed, a 2017 systematic review and meta-analysis of 25 studies revealed that physical activity was associated with a significant decrease in the odds for sarcopenia [odds ratio (OR)=0.45, 95% confidence interval (95%CI)=0.37-0.55].13 However, currently, there is very limited information on the effects of specific domains of physical activity on sarcopenia. There are several domains of physical activity, such as leisure-time, occupational, and travel-related physical activity. It is possible for leisure-time physical activity (LPTA) to be particularly important for the prevention of sarcopenia. Indeed, LTPA may be the most effective way to increase overall physical activity, especially in older age, as many older people are less likely to engage in occupational physical activity or active travel (e.g., walking and cycling). **Moreover, levels of LTPA in older adults living in LMICs may be particularly low, as there frequently is a lack of sports facilities and insufficient information delivered to the general population on the benefits of regular LTPA in these countries, highlighting the importance of focusing on this type of physical activity in older people from these settings.14** To the best of the authors’ knowledge, only two studies have focused on the effects of LTPA on sarcopenia, and in both studies, data were collected in high-income countries (i.e., Italy15 and Spain16). These bodies of research identified an inverse and significant association between LTPA and sarcopenia. Given that **low levels of** LTPA **are** common in LMICs,17 and that there is a significant relationship between LTPA and sarcopenia reported from high-income countries, interventions to increase LTPA among people in LMICs may have a large potential for the prevention of sarcopenia. However, data are lacking from LMICs, and thus, more data on this topic from this setting are needed.

Therefore, this study aimed to investigate the association between LTPA and sarcopenia in older adults living in six LMICs. Given that most older people reside in LMICs,3 identifying risk factors for sarcopenia in these regions of the world is a public health priority.

**Methods**

*The survey*

This study used data from the Study on Global AGEing and Adult Health (SAGE), a survey undertaken in China, Ghana, India, Mexico, Russia, and South Africa between 2007 and 2010. These countries were all classified as LMICs based on the World Bank classification at the time of the survey. The methodology of the survey has been described extensively in the literature.18 Briefly, nationally representative samples were obtained using a multistage clustered sampling design method. Samples included individuals aged ≥18 years, and adults aged ≥50 years were oversampled. Face-to-face interviews were conducted by trained staff with the use of a standard questionnaire. Questionnaires were translated based on a standard procedure to allow comparability between the participating countries. The survey response rates ranged from 53% for Mexico to 93% for China. Population structure, as reported by the United Nations Statistical Division, was further used to construct sampling weights. Finally, the WHO Ethical Review Committee and local ethics research review boards provided ethical approval, and each participant gave written informed consent.

*Sarcopenia*

Based on the criteria of the revised European consensus on the definition and diagnosis of sarcopenia,19 sarcopenia corresponded to the presence of both low skeletal muscle mass (SMM) and weak handgrip strength. SMM was calculated using the equation developed by Lee and colleagues: SMM = 0.244\*weight + 7.8\*height + 6.6\*sex – 0.098\*age + race – 3.3 [where sex=0 (female) and sex=1 (male); race=0 (White and Hispanic), race=1.4 (Black) and race=-1.2 (Asian)].20 Skeletal mass index (SMI) was further obtained by dividing SMM by body mass index (BMI) based on measured weight and height.21 Low SMM corresponded to the lowest quintile of sex-stratified SMI values.22 Given that there may be racial differences in body composition,23 low SMI was determined using country-specific cut-offs. Finally, the average of two handgrip measurements of the dominant hand was used to define handgrip strength, and weak handgrip strength corresponded to <27 kg in males and <16 kg in females.19 **As this cut-off for handgrip strength was based on European studies, we also conducted a sensitivity analysis where weak handgrip strength was defined as the lowest tertile of handgrip strength based on sex- and country-stratified values.**

*Leisure-time physical activity (LTPA)*

The assessment of LTPA relied on questions from the Global Physical Activity Questionnaire (GPAQ) on sports, fitness, and leisure and recreational activities.24 Participants were asked how many days they do vigorous**-**intensity sports, fitness, or recreational (leisure) activities in a typical week and how much time they spend doing such activities on a typical day **(e.g., running or playing football)**. Similar questions were asked for moderate**-**intensity sports, fitness, or recreational (leisure) activities **(e.g., brisk walking, cycling, or swimming)**. Time spent in moderate-to-vigorous LTPA per week was calculated based on these questions, and this time was dichotomized as high LTPA (i.e., >150 minutes/week) or low LTPA (i.e., ≤150 minutes/week) as in a previous SAGE publication.25 In some analyses, moderate-to-vigorous LTPA was used as a continuous variable (hours/week).

*Control variables*

Control variables were selected based on past literature13 and included age (in years), sex (female or male), country-wise wealth quintiles based on income, highest level of education achieved (≤primary, secondary, or tertiary), BMI, number of chronic conditions, activities of daily living (ADL) difficulty, smoking (never, past, or current), alcohol consumption in the past 30 days (yes or no), occupational physical activity, and active travel. BMI corresponded to measured weight in kg divided by measured height in meters squared and was used as a four-category variable [<18.5 (i.e., underweight), 18.5-24.9 (i.e., normal weight), 25.0-29.9 (i.e., overweight), and ≥30 kg/m2 (i.e., obesity)]. Eleven chronic physical diseases were documented: angina, arthritis, asthma, chronic back pain, chronic lung disease, diabetes, edentulism, hearing problem, hypertension, stroke, and visual impairment. **Table S1** (Appendix) provides details on the diagnosis of these 11 conditions. The number of chronic conditions was included in the analyses as a three-category variable (0, 1, or ≥2 chronic conditions). The assessment of ADL difficulty relied on questions about six standard basic ADL.26–28 All questions began with the introductory phrase “overall in the last 30 days, how much difficulty did you have” and continued with the following: “in washing your whole body?**”**; “in getting dressed?**”**; “with moving around inside your home?**”**; “with eating (including cutting up your food)?**”**; “with getting up from lying down?**”**; and “with getting to and using the toilet?”. The answers were “none”, “mild”, “moderate”, “severe”, and “extreme/cannot do”. ADL difficulty was used as a dichotomous variable, and people answering “severe” or “extreme/cannot do” to at least one of the six questions were considered to have ADL difficulty.29 Finally, the GPAQ was used to calculate the amount of domain-specific physical activity,24 and occupational physical activity and active travel were included as dichotomous variables (>150 or ≤150 minutes/week) as in previous SAGE studies.25,30

*Statistical analysis*

The statistical analysis was undertaken using Stata 14.2 (Stata Corp LP, College station, Texas). Given that sarcopenia is an age-related condition, the analysis only included adults aged ≥65 years. Differences in the characteristics of the sample by minutes/week of LTPA (>150 versus ≤150 minutes/week) were tested by Chi-squared tests for categorical variables and Student’s *t*-tests for continuous variables. The association between LTPA (exposure) and sarcopenia (outcome) was studied using a multivariable logistic regression model. LTPA was included in the model as a dichotomous variable (i.e., >150 or ≤150 minutes/week) or as a continuous variable (hours/week). **We also conducted analysis using the two components of sarcopenia as separate outcomes (i.e., low skeletal muscle mass and weak handgrip strength).** The analysis was done using the overall sample and sex-stratified samples. All regression analyses were adjusted for age, sex, wealth, education, BMI, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, except for 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**.**31,32 **Predicted probability of sarcopenia by hours/week of LTPA was also calculated based on a model adjusted for age, sex, wealth, education, body mass index, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, using mean values.** The sample weighting and the complex study design were considered in all analyses. Results from the regression analyses are displayed as **POR (prevalence odds ratio)** and 95%CI. The level of statistical significance was set at **p**<0.050.

**Results**

The analytical sample consisted of 14585 individuals aged ≥65 years. The sample size in each country was: China, n=5360; Ghana, n=1975; India, n=2441; Mexico, n=1375; Russia, n=1950; and South Africa, n=1484. Overall, the prevalence of >150 minutes/week of LTPA and sarcopenia were 8.9% and 12.0%, respectively. **The prevalence of >150 minutes/week of LTPA by country was: China 14.4%; Ghana 9.0%; India 6.3%; Mexico 2.8%; Russia 3.9%; and South Africa 5.2%.** The characteristics of the sample are displayed in **Table 1**. The mean (SD) age was 72.6 (11.5) years, while 55.0% were females. Engagement in ≤150 minutes/week of LTPA (versus >150 minutes/week) was significantly associated with older age, female sex, lower levels of wealth and education, underweight, obesity, ADL difficulty, less alcohol consumption, less occupational physical activity, and less active travel. The prevalence of sarcopenia was much higher among those with low levels of LTPA (**Figure 1**). For example, in the overall sample, the prevalence of sarcopenia among those with >150 and ≤150 minutes/week of LTPA were 5.9% and 12.6%, respectively. **Unadjusted analysis showed that ≤150 minutes/week of LTPA (versus >150 minutes/week) was associated with 2.29 (95%CI=1.67-3.14), 1.80 (95%CI=1.23-2.63), and 3.93 (95%CI=2.33-6.63) times higher odds for sarcopenia in the overall sample, males, and females, respectively.** After adjustment for potential confounders, ≤150 minutes/week of LTPA (versus >150 minutes/week) was associated with 1.85 (95%CI=1.29-2.65) times higher odds for sarcopenia, and this was particularly pronounced among women (**POR**=3.22; 95%CI=1.82-5.68) (**Table 2**). Other types of physical activity (i.e., occupational physical activity and active travel) were not significantly associated with sarcopenia. A one-hour increase in LTPA per week was associated with 5% **lower** odds for sarcopenia (**POR**=0.95; 95%CI=0.92-0.98)**,** with relatively similar figures for males (**POR**=0.96; 95%CI=0.93-0.99) and females (**POR**=0.92; 95%CI=0.86-0.98) (data only shown in **the** text). A visual display of the adjusted predicted probability of sarcopenia by hours/week of LTPA based on the overall sample can be found in **Figure 2**. **The sensitivity analysis using a different criterion for weak handgrip strength (i.e., lowest tertile based on country- and sex-stratified values) to define sarcopenia showed that the results were almost the same as the main analysis (Table S2 of the Appendix). The associations between LTPA and the two components of sarcopenia are shown in Table S3 (low SMM) and Table S4 (weak handgrip strength) of the Appendix. Significant associations were observed for both measures, but this was sometimes sex-specific or exposure specific (i.e., dichotomous or continuous LTPA variable).**

**Discussion**

*Main findings*

In this cross-sectional study including more than 14500 older adults from six LMICs, after adjustment for potential confounders, compared with >150 minutes/week of LTPA, ≤150 minutes/week of LTPA was associated with 1.85-fold (95%CI=1.29-2.65) **higher** odds for sarcopenia in the overall sample. Interestingly, the LTPA-sarcopenia relationship was much more pronounced among females, while there was no significant association between occupational physical activity or active travel and sarcopenia. To the best of the authors’ knowledge, this is the largest study on LTPA and sarcopenia to date, while it is the first study based on data collected in LMICs.

*Interpretation of findings*

The finding that LTPA was associated with lower odds for sarcopenia is in line with the only two studies on this topic, which were conducted in high-income countries**.**15,16 First, in a sample of 122 nursing home older residents in Italy, at least one hour of LTPA per day was cross-sectionally associated with lower odds of sarcopenia compared with less than one hour of LTPA per day (OR=0.40; 95%CI=0.12-0.98).15 A second cross-sectional study, including 1539 older adults living in Spain, found a significant relationship between moderate-to-vigorous LTPA and sarcopenia (per one-hour increase in physical activity per day: prevalence ratio=0.74; 95%CI=0.62-0.89).16 The present study corroborates these results and adds to the literature by showing that the negative association between LTPA and sarcopenia also exists in LMICs. Compared with the two prior studies, which had relatively small sample sizes and were single-country studies, our study had a large sample size, was nationally representative, and included data collected in six countries, increasing the generalizability of the findings.

There are several hypotheses to explain the relationship between physical activity and sarcopenia. First, physical activity has a direct and positive impact on muscle mass and strength.13 A systematic review and meta-analysis of four randomized controlled trials and three non-randomized interventional studies (n=235 patients) revealed that exercise had a large effect on physical performance and a medium effect on muscle strength in older adults with sarcopenia.33 Second, although the logistic regression analysis was adjusted for chronic conditions, only 11 conditions were considered, and it is possible that other diseases (e.g., cancer) play a mediating role in the association between physical activity and sarcopenia. For example, physical activity is a protective factor against cancer**,** potentially via effects on hormones and the immune system.34 Meanwhile, sarcopenia is a frequent comorbidity in patients with cancer, and cancer can lead to sarcopenia through inflammation, insufficient food intake, and dysphagia for certain types of tumors (e.g., head and neck, esophageal, and gastric cancer).35 Third, some data suggest that physical activity may reduce risk for polypharmacy via its positive effect on health,10 while polypharmacy may lead to sarcopenia via drug-related muscle toxicity, hormonal disturbances, and poor nutritional status.9 Finally, physically active older individuals are less likely to be hospitalized than those who are not physically active, and this association likely involves fewer chronic conditions, decreased ADL disability, and better self-rated health.11 In turn, hospitalization within the past year has been identified as a risk factor for sarcopenia.12

It should also be noted that occupational physical activity and active travel were not significantly associated with sarcopenia. LTPA has been found to have stronger positive effects on cardiovascular risk factors (e.g., BMI, body fat, and waist circumference) compared with occupational physical activity,36 and these stronger effects may explain, at least partially, the different associations by type of physical activity observed in our study. In terms of active travel (e.g., walking **or** cycling), it is possible that the intensity is not high enough**,** or it may not be the most ideal form of physical activity to increase muscle mass and strength to prevent sarcopenia in older adults. For example, walking and cycling at a moderate pace may have little effect on upper body muscles compared with leisure activities such as total body resistance training and swimming. Finally, in terms of LTPA, it may be possible to tailor the content of physical activity based on individual needs and focus more on increasing muscle mass and strength than in other types of physical activity, and these specific exercises may be particularly effective in preventing sarcopenia. However, clearly, more research is necessary on the different types of physical activity and sarcopenia, and the underlying mechanisms.

Another important finding of the present study is that the association between low LTPA and sarcopenia was more pronounced among women. Although this sex-difference is difficult to explain, some literature indicates that sex differences exist in the epidemiology of sarcopenia,37 while there are differences in physical activity between women and men.38 Furthermore, it is possible for the type and intensity of LTPA to differ between females and males, and females in our study could have been engaging more in LTPA which is more beneficial in the prevention of sarcopenia. Next, women may be less likely to engage in occupational physical activity and active travel than men, and the effects of LTPA on sarcopenia may therefore be stronger, as their level of physical activity overall may largely be determined by levels of LTPA. Another hypothesis is that, for the same level of LTPA, women may be more health conscientious and consume healthier food than men, which may lead to reduced risk for sarcopenia (e.g., high protein diet). However, these explanations are largely speculative, and thus, future research mainly of a qualitative nature is needed to understand these **sex differences**.

*Public health interventions and directions for future research*

Based on the results of this study, LTPA was negatively and significantly associated with sarcopenia in older adults living in LMICs. Several interventions have been recently developed to increase physical activity in older adults.39 Some of these interventions can be implemented in LMICs, and these interventions include, for example, balance strength/resistance training, physical recreation, and health promotion. The prevalence of LTPA was low in the present study, and specific measures should also be taken to encourage regular LTPA in LMICs. These measures should consider sociocultural factors and may involve, for instance, the construction of exercise machines in parks or the promotion of home-based exercise routines. In terms of future research, more studies of longitudinal nature are warranted to investigate the association between physical activity (including type) and incident sarcopenia in LMICs, while additional data are warranted to better understand potential sex differences in the physical activity-sarcopenia relationship.

*Strengths and limitations of the study*

The major strengths of this study are the large sample size, the use of nationally representative data collected in six LMICs, and the analysis of different types of physical activity **(i.e.**, LTPA, occupational physical activity, **and** active travel). Nonetheless, the study findings should be interpreted in light of several limitations. First, data on physical activity were self-reported, potentially biasing some of the findings of the study. Second, SMM was estimated based on an equation. That being said, there is good concordance between the equation and direct methods, such as dual-energy X-ray absorptiometry and magnetic resonance imaging.22 Third, there was no information on nutritional status, despite the fact that this is an important determinant of sarcopenia. Thus, some level of residual confounding due to this factor may exist. **Fourth, we were unable to conduct country-wise analyses as meaningful estimates could not be obtained due to small sample size in each country and lack of statistical power. Future studies with larger sample size should consider conducting country-wise analyses to assess whether associations are context-specific. Fifth, there is no established cut-off to define low LTPA. Thus, the cut-off used in our main analysis (150 minutes/week) should not necessarily be interpreted as the optimal cut-off for sarcopenia prevention. Sixth, due to a lack of data, we were unable to conduct analyses on the association between sarcopenia and different categories of sports, fitness, and recreational activities.** Finally, since this was a cross-sectional study, it was not possible to investigate the temporal association between LTPA and sarcopenia.

*Conclusions*

LTPA was negatively and significantly associated with sarcopenia among older adults inLMICs, with this association potentially being more pronounced among women. Promotion of LTPA may be important in the prevention of sarcopenia among older adults in LMICs**,** but future longitudinal and interventional studies are necessary before concrete recommendations can be made.

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*Conflicts of interest*

Louis Jacob, Razak M. Gyasi, Hans Oh, Lee Smith, Karel Kostev, Guillermo F. López Sánchez, Masoud Rahmati, Josep Maria Haro, Mark A. Tully, Jae Il Shin, Dong Keon Yon, and Ai Koyanagi declare that they have no conflict of interest.

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*Author contributions*

Louis Jacob contributed to the design of the study, managed the literature searches, wrote the first draft of the manuscript, and corrected the manuscript. Razak M. Gyasi, Hans Oh, Lee Smith, Karel Kostev, Guillermo F. López Sánchez, Masoud Rahmati, Josep Maria Haro, Mark A. Tully, Jae Il Shin, and Dong Keon Yon contributed to the design of the study and corrected the manuscript. Ai Koyanagi contributed to the design of the study, performed the statistical analyses, managed the literature searches, and corrected the manuscript. All authors contributed to and have approved the final manuscript.

*Ethics committee approval*

The WHO Ethical Review Committee and local ethics research review boards provided ethical approval, and the study has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

*Informed consent*

All participants gave written informed consent.

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**Table 1.** Sample characteristic**s** (overall and by minutes/week of leisure-time physical activity)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Characteristic |  |  | Leisure-time physical activity | |  |
|  | Overall | >150 minutes/week | ≤150 minutes/week | P-valuea |
| Age (years) | Mean (SD) | 72.6 (11.5) | 71.0 (9.1) | 72.6 (11.5) | <0.001 |
| Sex | Female | 55.0 | 44.6 | 56.0 | <0.001 |
| Male | 45.0 | 55.4 | 44.0 |
| Wealth | Poorest | 21.7 | 14.6 | 22.3 | <0.001 |
| Poorer | 21.0 | 13.3 | 21.7 |
| Middle | 20.4 | 22.0 | 20.2 |
| Richer | 17.5 | 21.3 | 17.2 |
| Richest | 19.4 | 28.7 | 18.6 |
| Education | ≤Primary | 63.7 | 49.7 | 64.8 | <0.001 |
| Secondary | 29.9 | 36.9 | 29.4 |
| Tertiary | 6.4 | 13.4 | 5.8 |
| Body mass index (kg/m2) | <18.5 | 19.3 | 11.4 | 20.1 | <0.001 |
| 18.5-24.9 | 46.4 | 52.6 | 45.7 |
| 25.0-29.9 | 23.9 | 29.5 | 23.4 |
| ≥30.0 | 10.4 | 6.5 | 10.8 |
| Number of chronic conditions | 0 | 16.0 | 17.8 | 15.8 | 0.103 |
| 1 | 28.7 | 31.9 | 28.4 |
| ≥2 | 55.3 | 50.3 | 55.8 |
| ADL difficulty | No | 88.1 | 94.5 | 87.5 | 0.001 |
| Yes | 11.9 | 5.5 | 12.5 |
| Smoking | Never | 62.2 | 63.3 | 62.1 | 0.596 |
| Past | 8.5 | 9.3 | 8.4 |
| Current | 29.3 | 27.3 | 29.5 |
| Alcohol consumption | No | 86.1 | 81.5 | 86.6 | 0.003 |
| Yes | 13.9 | 18.5 | 13.4 |
| Occupational physical activity | >150 minutes/week | 45.8 | 52.1 | 45.2 | 0.025 |
| ≤150 minutes/week | 54.2 | 47.9 | 54.8 |
| Active travel | >150 minutes/week | 37.6 | 57.0 | 35.7 | <0.001 |
| ≤150 minutes/week | 62.4 | 43.0 | 64.3 |

Abbreviations: SD standard deviation; ADL activities of daily living.

Data are % unless otherwise stated.

a P-value was based on Chi-squared tests except for age (Student’s *t*-test).

**Table 2.** Association between leisure-time physical activity (and covariates) and sarcopenia (outcome) estimated by multivariable logistic regression (overall and by sex)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristic |  | Overall | | Male | | Female | |
|  | **POR** | 95%CI | **POR** | 95%CI | **POR** | 95%CI |
| Leisure-time physical activity | >150 minutes/week | 1.00 |  | 1.00 |  | 1.00 |  |
| ≤150 minutes/week | 1.85\*\*\* | [1.29,2.65] | 1.52 | [0.99,2.35] | 3.22\*\*\* | [1.82,5.68] |
| Age (years) | Per one-year increase | 1.13\*\*\* | [1.11,1.15] | 1.11\*\*\* | [1.09,1.14] | 1.15\*\*\* | [1.12,1.19] |
| Sex | Female | 1.00 |  |  |  |  |  |
| Male | 1.53\*\*\* | [1.20,1.95] |  |  |  |  |
| Wealth | Poorest | 1.00 |  | 1.00 |  | 1.00 |  |
| Poorer | 0.74 | [0.54,1.02] | 0.74 | [0.47,1.17] | 0.80 | [0.49,1.31] |
| Middle | 0.62\* | [0.43,0.89] | 0.55\* | [0.34,0.89] | 0.78 | [0.49,1.24] |
| Richer | 0.50\*\*\* | [0.37,0.67] | 0.50\*\* | [0.30,0.83] | 0.49\*\*\* | [0.34,0.72] |
| Richest | 0.36\*\*\* | [0.26,0.51] | 0.32\*\*\* | [0.19,0.52] | 0.39\*\*\* | [0.23,0.67] |
| Education | ≤Primary | 1.00 |  | 1.00 |  | 1.00 |  |
| Secondary | 0.75 | [0.55,1.01] | 0.62\*\* | [0.44,0.88] | 0.68 | [0.33,1.39] |
| Tertiary | 0.63 | [0.36,1.09] | 0.57 | [0.33,1.01] | 0.35 | [0.08,1.60] |
| Body mass index (kg/m2) | <18.5 | 0.59\*\* | [0.40,0.87] | 0.31\*\*\* | [0.18,0.54] | 1.17 | [0.71,1.91] |
| 18.5-24.9 | 1.00 |  | 1.00 |  | 1.00 |  |
| 25.0-29.9 | 1.46\*\* | [1.11,1.93] | 2.53\*\*\* | [1.80,3.55] | 0.92 | [0.59,1.41] |
| ≥30.0 | 2.04\*\* | [1.33,3.15] | 6.21\*\*\* | [3.12,12.38] | 1.00 | [0.58,1.72] |
| Number of chronic conditions | 0 | 1.00 |  | 1.00 |  | 1.00 |  |
| 1 | 1.23 | [0.88,1.72] | 1.22 | [0.78,1.91] | 1.20 | [0.67,2.15] |
| ≥2 | 1.63\*\* | [1.15,2.33] | 1.54 | [0.93,2.55] | 1.71 | [0.95,3.05] |
| ADL difficulty | No | 1.00 |  | 1.00 |  | 1.00 |  |
| Yes | 1.71\* | [1.09,2.67] | 1.37 | [0.82,2.27] | 2.08\* | [1.07,4.07] |
| Smoking | Never | 1.00 |  | 1.00 |  | 1.00 |  |
| Past | 1.02 | [0.70,1.50] | 1.02 | [0.66,1.58] | 0.83 | [0.37,1.86] |
| Current | 0.90 | [0.65,1.24] | 0.74 | [0.52,1.04] | 1.39 | [0.84,2.28] |
| Alcohol consumption | No | 1.00 |  | 1.00 |  | 1.00 |  |
| Yes | 0.72 | [0.48,1.07] | 0.69 | [0.42,1.12] | 0.89 | [0.52,1.53] |
| Occupational physical activity | >150 minutes/week | 1.00 |  | 1.00 |  | 1.00 |  |
| ≤150 minutes/week | 0.84 | [0.64,1.10] | 0.87 | [0.60,1.26] | 0.78 | [0.55,1.10] |
| Active travel | >150 minutes/week | 1.00 |  | 1.00 |  | 1.00 |  |
| ≤150 minutes/week | 1.02 | [0.79,1.33] | 0.97 | [0.69,1.36] | 1.11 | [0.72,1.72] |

Abbreviations: **POR prevalence** odds ratio; CI confidence interval; ADL activities of daily living.

Models are adjusted for all variables in the respective column and country.

**The n for leisure-time physical activity >150 and ≤150 minutes/week were 1204 and 12994, respectively.**

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Figure 1.** Prevalence of sarcopenia by minutes/week of leisure-time physical activity (overall and by sex)

Bars denote 95% confidence interval.



**Figure 2.** Predicted probability of sarcopenia by hours/week of leisure-time physical activity

Abbreviation: ADL activities of daily living.

Predictions are based on a model adjusted for age, sex, wealth, education, body mass index, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, using mean values.

Bars denote 95% confidence interval.

**Appendix**

**Table S1.** Details on the diagnosis of the 11 chronic conditions

|  |  |  |
| --- | --- | --- |
| Condition | (a) Self-reported diagnosis or symptoms | (b) Symptom-based algorithm or other method of diagnosis |
| Angina | Have you ever been diagnosed with angina or angina pectoris (a heart disease)? | Rose questionnaire |
| Arthritis | Have you ever been diagnosed with/told you have arthritis (a disease of the joints, or by other names rheumatism or osteoarthritis)? | Not applicable |
| Asthma | Have you ever been diagnosed with asthma (an allergic respiratory disease)? | Not applicable |
| Chronic back pain | Back pain everyday during the last 30 days. | Not applicable |
| Chronic lung disease | Have you ever been diagnosed with chronic lung disease (emphysema, bronchitis, COPD)? | Not applicable |
| Diabetes | Have you ever been diagnosed with diabetes (high blood sugar)? (not including diabetes associated with a pregnancy) | Not applicable |
| Edentulism | Have you lost all of your natural teeth? | Not applicable |
| Hearing problem | Not applicable | Interviewer observation |
| Hypertension | Have you ever been diagnosed with high blood pressure (hypertension)? | Blood pressure was measured three times with a one-minute interval with the use of a wrist blood pressure monitor (Medistar Wrist Blood Pressure Model S), and the mean value of the three measurements was calculated. Hypertension was defined as having at least one of the following: systolic blood pressure ≥140 mmHg; diastolic blood pressure ≥90 mmHg. |
| Stroke | Have you ever been told by a health professional that you have had a stroke? | Not applicable |
| Visual impairment | Extreme difficulty in seeing and recognizing a person that the participant knows across the road | Not applicable |

Abbreviation: COPD chronic obstructive pulmonary disease.

**Table S2.** Sensitivity analysis on the association between leisure-time physical activity and sarcopenia (outcome) estimated by multivariable logistic regression using a different criterion of weak handgrip strength (overall and by sex)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Overall | | Male | | Female | |
|  |  | POR | 95%CI | POR | 95%CI | POR | 95%CI |
| ≤150 minutes/week of LTPA | No | 1.00 |  | 1.00 |  | 1.00 |  |
|  | Yes | 1.99\*\*\* | [1.32,2.99] | 1.47 | [0.91,2.35] | 3.65\*\*\* | [1.87,7.12] |
| LTPA (per hour/week) | Per one-hour increase | 0.95\*\* | [0.92,0.98] | 0.96\* | [0.93,1.00] | 0.92\* | [0.86,0.98] |

Abbreviations: POR prevalence odds ratio; CI confidence interval; LTPA leisure-time physical activity.

Models are adjusted for age, sex, wealth, education, body mass index, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, with the exception of the sex-stratified analysis which was not adjusted for sex.

Low handgrip strength was defined as the lowest tertile of handgrip strength based on sex- and country-stratified values.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table S3.** Association between leisure-time physical activity and low skeletal muscle mass (outcome) estimated by multivariable logistic regression (overall and by sex)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Overall | | Male | | Female | |
|  |  | POR | 95%CI | POR | 95%CI | POR | 95%CI |
| ≤150 minutes/week of LTPA | No | 1.00 |  | 1.00 |  | 1.00 |  |
|  | Yes | 1.33 | [0.94,1.88] | 1.29 | [0.84,1.96] | 1.62\* | [1.00,2.63] |
| LTPA (per hour/week) | Per one-hour increase | 0.96\*\* | [0.93,0.99] | 0.96\* | [0.93,0.99] | 0.95\* | [0.91,1.00] |

Abbreviations: POR prevalence odds ratio; CI confidence interval; LTPA leisure-time physical activity.

Models are adjusted for age, sex, wealth, education, body mass index, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, with the exception of the sex-stratified analysis which was not adjusted for sex.

\* p<0.05, \*\* p<0.01.

**Table S4.** Association between leisure-time physical activity and weak handgrip strength (outcome) estimated by multivariable logistic regression (overall and by sex)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Overall | | Male | | Female | |
|  |  | POR | 95%CI | POR | 95%CI | POR | 95%CI |
| ≤150 minutes/week of LTPA | No | 1.00 |  | 1.00 |  | 1.00 |  |
|  | Yes | 1.59\*\* | [1.20,2.10] | 1.37 | [0.97,1.94] | 1.91\*\* | [1.19,3.07] |
| LTPA (per hour/week) | Per one-hour increase | 0.98 | [0.94,1.03] | 0.97\* | [0.95,1.00] | 1.00 | [0.92,1.07] |

Abbreviations: POR prevalence odds ratio; CI confidence interval; LTPA leisure-time physical activity.

Models are adjusted for age, sex, wealth, education, body mass index, number of chronic conditions, ADL difficulty, smoking, alcohol consumption, occupational physical activity, active travel, and country, with the exception of the sex-stratified analysis which was not adjusted for sex.

\* p<0.05, \*\* p<0.01.