Adherence to aerobic and muscle-strengthening activities guidelines: a systematic review and meta-analysis of 3.3 million participants across 32 countries

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ABSTRACT

Objective To estimate the global prevalence of meeting the WHO guidelines for both aerobic and muscle-strengthening activities (MSA) in populations aged ≥5 years, and whenever possible to explore this prevalence according to sociodemographic and lifestyle factors.
Design A systematic review and meta-analysis.
Data sources Five databases were systematically searched for studies published from inception to September 2022.
Eligibility criteria for selecting studies Articles with representative samples aged ≥5 years reporting the prevalence of meeting both aerobic and MSA guidelines were included.
Results Twenty-one studies comprising 3 390 001 individuals from 32 countries were included. Overall adherence to the aerobic and MSA guidelines was 17.12% (95% CI 15.42% to 18.88%) in adults ≥18 years (n=3 346 723). Among adolescents aged 12–17 years, adherence to both guidelines was 19.74% (95% CI 14.72% to 25.31%) (n=43 278). No studies reported data for children aged 5–11 years. Women, older age, low/medium education levels, underweight or obesity, and poor and moderate self-rated health were associated with lower adherence to the physical activity guidelines (p<0.001) among adults, although the prevalence remained very low in all cases. Subgroup analyses were not conducted with children and adolescents due to a lack of studies.
Conclusions Only one out of five adolescents and adults met the recommended combined aerobic and MSA guidelines. Large-scale public health interventions promoting both types of exercise are needed to reduce the associated burden of non-communicable diseases.
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INTRODUCTION

Increasing physical activity levels is a worldwide health priority.[1] Indeed, the WHO recognises physical inactivity as a key risk factor in the prevention and control of chronic diseases.[1] Evidence-based physical activity guidelines for health have been issued since 1995 by the US Centers for Disease Control and Prevention and the American College of Sports Medicine.[2] Traditionally, these guidelines focused solely on moderate-to-vigorous aerobic physical activity (MVPA); however, from 2007 in adults[3] and 2008 in youth[4] global physical activity guidelines for public health have included two or more days of muscle-strengthening activities (MSA) (eg, weight/resistance training). Specifically, the 2020 WHO guidelines on physical activity call for children and adolescents to accumulate at least an average of 60 min of MVPA per day and also vigorous physical activities and MSA should each be incorporated at least 3 days per week.[1] Among adults and older adults, the recommendation calls to accumulate an average weekly volume of 150–300 min of moderate intensity or 75–150 min of vigorous intensity, or an equivalent combination of MVPA and 2 or more days a week of MSA at moderate or greater intensity.[1]

Considering the estimates for physical activity levels in 122 countries from the WHO Global Health Observatory data repository,[5] nearly one out of three adults (31.1%) do not meet public health guidelines for recommended levels of aerobic physical activity. A later study from 358 population-based surveys across 168 countries with 1.9 million adults confirmed these findings, showing a prevalence of insufficient aerobic physical activity of 27.5%.[6] Global prevalence of insufficient aerobic physical activity among adolescents is even more worrying, reaching prevalence rates of ~81%.[5 7] However, MSA were overlooked in these studies in which those meeting only aerobic guidelines were considered as 'physically active'. Of note, estimates of physical activity prevalence based on aerobic physical activity guidelines are likely to underestimate the true extent of physical inactivity at the population level. For example, based on data from the National Health Interview Survey (NHIS) 1997–2014,[8] the prevalence of meeting aerobic guidelines was 23.7%, whereas the prevalence of meeting both aerobic and MSA guidelines was 15.9%. Similarly, data from the Youth Risk Behavior Survey 2019 in US adolescents revealed differences between the prevalence of meeting aerobic (31% and 15.4% in boys and girls, respectively) and both guidelines (23.1% and 10.2% in boys and girls, respectively).[9]

The value of combining aerobic and MSA guidelines is based on the epidemiological evidence showing that each activity type has independent and cumulative health benefits among adults.[10–12] Moreover, meeting guidelines for both activities in comparison with meeting the guidelines for only one activity was prospectively related to a lower risk of all-cause mortality in adults.[8 13] A recent meta-analysis examining the health outcomes of aerobic and MSA found a greater benefit for all-cause, cardiovascular disease, and total cancer mortality when both guidelines were combined.[10]

Despite being recommended globally, studies exploring the prevalence of both aerobic and MSA and its correlates among general populations are limited compared with those reporting the compliance with aerobic physical activities. Exploring physical activity guidelines adherence across key sociodemographic/lifestyle factors (eg, education, self-rated health, body mass index) is essential to assist policy makers to implement non-communicable diseases prevention strategies.[14] Accordingly, the main aim of this study was to determine the global prevalence of meeting both aerobic and MSA guidelines in the general population. Whenever possible, we also explored prevalence according to sociodemographic and lifestyle-related correlates categories.

METHODS

We used the methods proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[15]

Eligibility criteria

To be eligible for inclusion in the present meta-analysis, studies had to meet the following criteria: (1) participants: individuals aged ≥5 years; (2) outcome: adherence to both aerobic and MSA guidelines assessed with questionnaires and/or device-based measures (ie, accelerometers, heart rate monitors) and (3) study design: cross-sectional, prospective and retrospective cohort studies with representative samples. Studies were excluded if they reported duplicate data from the same source and year and those that only included populations diagnosed with chronic diseases (eg, cancer, arthritis). When two studies included duplicate data from the same source and year, the study with the larger sample size was selected.

Information sources

Two authors (YE and AG-H) independently searched PubMed, Web of Science, SportDiscus, EMBASE and Scopus databases for studies listed from inception to September 2022. Searching was restricted to articles in English and Spanish language in peer-reviewed journals. A professional librarian was consulted to verify the quality of the search strategy.

Search strategy

The following string of terms was used: 'aerobic exercise' AND 'muscle-strengthening' AND 'representative' AND 'guidelines'. Reference lists of eligible studies were manually examined for further identification of relevant articles and included if appropriate. Any disagreement was resolved by consensus with a third author (JFL-G). Full search strategies for all databases are shown in online supplemental emethod 1.

Selection process

After removing duplicates and reviewing the title and abstract of potential studies, two authors (YE and AG-H) systematically assessed the full text of identified manuscripts for eligibility.

Data collection process and data items

The following data were extracted from each study by two authors (YE and AG-H), using a Microsoft Excel spreadsheet specifically designed for the present study: (1) study characteristics (ie, first author's name, publication year, country, sample size and population representativeness) and study design; (2) participants' information (eg, sex and age); (3) physical activity assessment details (ie, self-reported, device-based measures, definition) and (4) the proportion of participants meeting both aerobic and MSA guidelines.

Study risk of bias assessment

The risk of study bias assessment was evaluated using a specific tool for prevalence studies.[16] The tool consists of 10 items that address both the external and internal validity of prevalence studies. Each item can be classified as 'yes (low risk)' or 'no (high risk)', which equals to 0 and 1 points, respectively. The overall risk of study bias is deemed to be at 'low risk of bias', 'moderate risk of bias' or 'high risk of bias', if the points scored are 0–3, 4–6 or 7–9, respectively.

Effect measures

Prevalence estimations and its 95% CIs were calculated based on the total number of people in the sample and the total number of individuals who meet both aerobic and MSA guidelines in the sample.

Synthesis methods

We used Stata V.17.0 (StataCorp) and the *metaprop* procedure[17] to pool data from multiple studies by applying a random-effects model that displayed the results as forest plots using the DerSimonian and Laird method. The exact or Clopper-Pearson method was used to establish 95% CIs for prevalence from the selected individual studies[18] and a Freeman-Tukey transformation was used to normalise the results before calculating the pooled prevalence.[19] When a study includes data from several year, a pooled prevalence of all years was calculated.

Metaprop tests for intragroup heterogeneity of pooled proportions were calculated using the I^2 statistic and its p value.

The Luis Furuya-Kanamori (LFK) index and the Doi plot were used to assess potential small-study effects due to publication bias. When the values of the LFK index were –1, between –1 and –2, and >–2, were deemed to represent no, minor and major asymmetry, respectively.[20]

Whenever possible, subgroup analyses were conducted by age group (adolescents, adults and older adults), sex, body weight status (underweight, normal weight, overweight and obesity), education level (low, medium and high), smoking status (former/non-smoker and current smoker) and self-rated health status (poor, moderate and good/excellent).

Finally, a sensitivity analysis was conducted to assess the robustness of the summary estimates and to determine whether a particular study accounted for the inconsistency. To examine the effects of each result from each study on the overall prevalence, results were analysed with each study removed from the model once.

RESULTS

Study selection

The electronic search strategy retrieved 3777 studies. After removing duplicates and screening titles, 67 studies were assessed for eligibility based on full text. A total of 21 studies were finally included in the present meta-analysis.[8 9 21–39] The PRISMA flow diagram illustrating the number of studies excluded at each stage of the systematic review and meta-analysis is shown in figure 1. A reference list of excluded

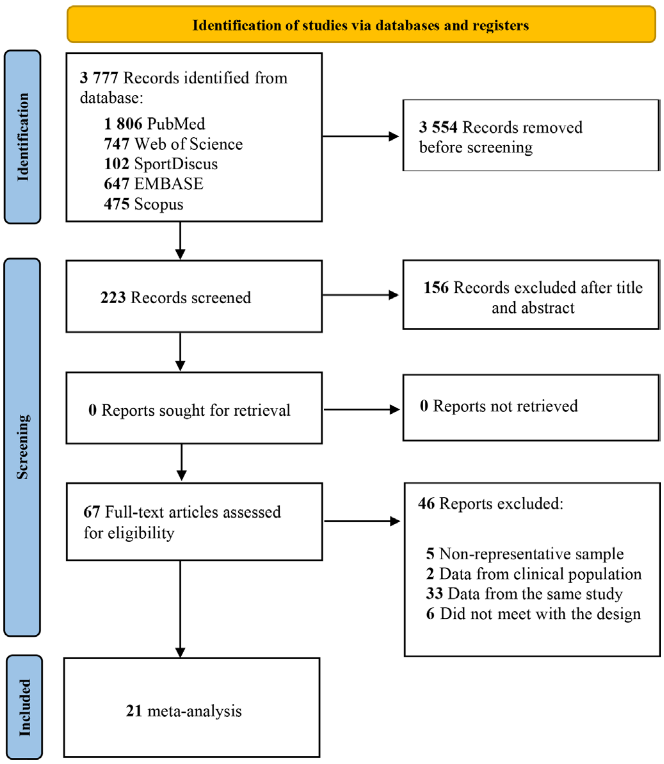

Figure 1 PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

articles and reasons for exclusion based on the full text is detailed in online supplemental emethod 2.

Study characteristics

The main characteristics of the included studies are described in online supplemental eTable 1. Twenty-one studies fulfilled eligibility criteria and were included in the systematic review, including 3 390 001 participants (51.1% women). Age of the participants ranged between 12 and 95 years, since no representative studies reported data for children aged 5–11 years.

Studies were conducted in Australia,[21] Austria,[30 32] Bulgaria,[26] Croatia,[26] Cyprus,[26] Czechia,[26] Denmark,[26] Estonia,[26] Finland,[22 26] France,[26] Germany,[25 26] Greece,[26] Hungary,[26] Iceland,[26] Ireland,[26] Italy,[26] Latvia,[26] Lithuania,[26] Luxemburg,[26] Malta,[26] The Netherlands,[26 31] Norway,[26] Poland,[26] Portugal,[26] Romania,[26] Slovakia,[26] Slovenia,[26] South Korea,[24 33 36] Spain,[26] Sweden,[26] the UK[26] and the USA.[8 9 23 27 29 35 38 39] Sources of information included the National Nutrition and Physical Activity Survey,[21] Regional Health and Well-being Study,[22] US Behavioural Risk Factor Surveillance System surveys,[23 27] Korea National Health and Nutritional Examination Survey,[24 36] German Health Update Survey,[25] European Health Interview Survey,[26] National Youth Physical Activity and Nutrition Study,[39] Youth Risk Behaviour Survey,[9] Health Survey for England study,[28] National Health and Nutrition Examination Survey,[29 35] Austrian Health Interview Surveys,[30 32] Dutch Health Survey/Lifestyle Monitor by Statistics Netherlands,[31] National Health Insurance Service of South Korea,[33] Active Lives Survey[34 37 37] and the NHIS.[8 38] Aerobic and MSA were self-reported in most studies, although one study[29] directly measured aerobic physical activity through accelerometers.

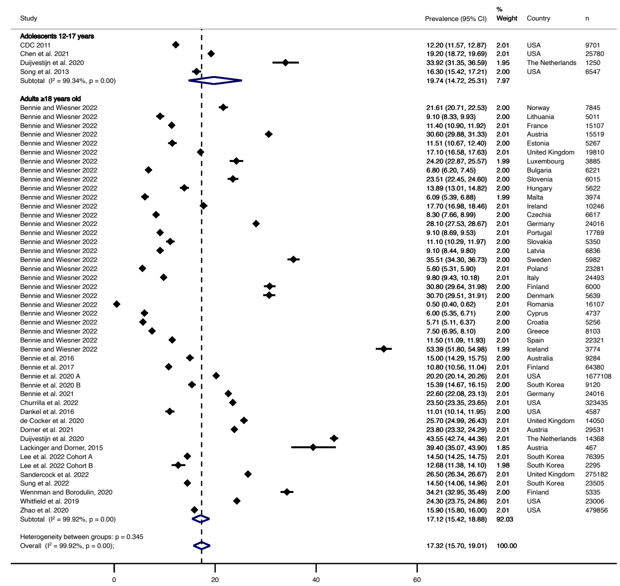

Figure 2 Forest plot of adherence to both aerobic and muscle-strengthening activities guidelines in adolescents aged 12–17 years and adults ≥18 years old.

Risk of bias in studies

All studies were deemed to be at low risk of bias, presenting scores ranging between 0 and 2 points. The main sources of bias were related to the reliability and validity of the study instrument that measured physical activity,[22 24–26 28 30 34 37 39] or to response rates lower than 75%.[22 23 28 33 35] A summary of the risk of bias scoring is shown in online supplemental eTable 2.

Results of individual studies and synthesis

Figure 2 shows the overall adherence to both aerobic and MSA guidelines in adults. A total of 670 505 participants met both physical activity guidelines. The overall adherence to both physical activity guidelines in participants ≥18 years was 17.12% (95% CI 15.42% to 18.88%, $p<0.001$, $I^2=99.92\%$) (n=3 346 723) and 19.74% (95% CI 14.72% to 25.31%, $p<0.001$, $I^2=99.34\%$) in individuals aged 12–17 years (n=43 278) (figure 2).

Subgroup analyses according to sex, age, body mass index, education level, smoking status and self-rated health status among adults are shown in figure 3. Unfortunately, sociodemographic and lifestyle factors among children and adolescents were not explored due to insufficient information in this population. Adherence to both physical activity guidelines was higher in men (23.50%, 95% CI 20.46% to 26.67%, $p<0.001$, $I^2=99.91\%$) than in women (17.42%, 95% CI 14.73% to 20.30%, $p<0.001$, $I^2=99.92\%$) (difference between groups $p<0.001$) (online supplemental eFigure 1). According to age group, adherence to physical activity guidelines was 21.21% (95% CI 17.45% to 25.22%, $p<0.001$, $I^2=99.90\%$) and 13.63% (95% CI 8.18% to 20.20%, $p<0.001$, $I^2=99.79\%$) in adults and older adults (difference between groups $p=0.049$), respectively (online supplemental eFigure 2). Regarding weight status, adherence to the physical activity guidelines was 12.62% (95% CI 9.92% to 15.60%, $p<0.001$, $I^2=82.72\%$), 19.87% (95% CI 17.93% to 21.87%, $p<0.001$, $I^2=99.31\%$), 14.98% (95% CI 12.76% to 17.35%, $p<0.001$, $I^2=99.62\%$), and 9.77% (95% CI 7.98%

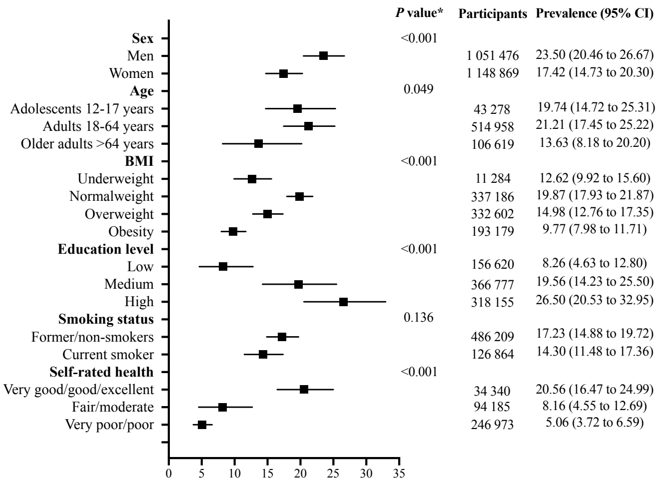

Figure 3 Forest plot of adherence to aerobic and muscle-strengthening activities guidelines by age group, sex, body weight status, education level, smoking status and self-rated health status. *Difference between groups. BMI, body mass index.

to 11.71%, $p<0.001$, $I^2=99.16\%$) in participants with underweight, normal weight, overweight and obesity (difference between groups $p<0.001$), respectively (online supplemental eFigure 3). In the case of education level, the adherence to both aerobic and MSA guidelines was 8.26% (95% CI 4.63% to 12.80%, $p<0.001$, $I^2=99.85\%$), 19.56% (95% CI 14.23% to 25.50%, $p<0.001$, $I^2=99.93\%$) and 26.50% (95% CI 20.53% to 32.95%, $p<0.001$, $I^2=99.85\%$), in participants with low, medium and high education (difference between groups $p<0.001$), respectively (online supplemental eFigure 4). In terms of smoking status, adherence to the physical activity guidelines was similar in former/non-smokers (17.23%, 95% CI 14.88% to 19.72%, $p<0.001$, $I^2=99.59\%$) and current smokers (14.30%, 95% CI 11.48% to 17.36%, $p<0.001$, $I^2=98.98\%$) (difference between groups $p=0.136$) (online supplemental eFigure 5). Finally, participants who self-reported very good/excellent/good health presented higher adherence to the physical activity guidelines (20.56%, 95% CI 16.47% to 24.99%, $p<0.001$, $I^2=99.75\%$) than peers reporting fair/moderate (8.16%, 95% CI 4.55% to 12.69%, $p<0.001$, $I^2=99.66\%$) and very poor/poor (5.06%, 95% CI 3.72% to 6.59%, $p<0.001$, $I^2=94.25\%$) health (difference between groups $p<0.001$) (online supplemental eFigure 6).

The LFK index for the Doi plots showed minor asymmetry in adults ≥18 years old (LFK=−1.20) (online supplemental eFigure 7) and adolescents aged 12–17 years old (LFK=1.02) (online supplemental eFigure 8).

Sensitivity analyses show that percentages remain similar even removing studies/countries with lower (17.71% 95% CI 16.11% to 19.37%, $p<0.001$, $I^2=99.91\%$)[26] and higher physical activity guidelines adherence (16.46, 95% CI 14.81% to 18.19%, $p<0.001$, $I^2=99.92\%$)[26] in adults. Among adolescents, range of prevalence was from 16.92% (95% CI 14.37% to 19.62%, $p<0.001$)[31] to 22.56% (95% CI 17.13% to 28.51%, $p<0.001$).[39]

DISCUSSION

The key finding of the present meta-analysis is that only one out of five adolescents and adults meet guidelines for aerobic and MSA in large representative population samples from 32 countries. Regarding sociodemographic and lifestyle factors, women, older age and individuals with low/medium education levels, underweight or obesity, and poorer or moderate self-rated health showed lower adherence to the physical activity guidelines, although the prevalence remained very low in all cases.

Two studies that pooled adult aerobic physical activity levels from large population surveys found that the global prevalence was 69%[5] and 73%.[6] The physical activity prevalence estimates presented in the present study suggest that physical inactivity among global population is underestimated. Our findings indicate that the prevalence of meeting both aerobic and MSA guidelines is threefold lower. Lower prevalence of meeting physical activity guidelines was found among adults from Southern and Central European countries (Romania, Poland, Croatia, Cyprus and Malta) and the USA when compared with those from Northern European countries (Iceland, Sweden, The Netherlands and Denmark). Within the context of the current meta-analysis, we are unable to identify the key causes of the geographical differences; however, a possible explanation for this might be the different instruments used to measure physical activity. Another possible explanation could be the adoption of different exercise promotion policies between countries. For example, The Netherlands, one of the countries with higher prevalence, adopted the physical activity guidelines in 2017, and aimed for 75% of the Dutch population to adhere to them. The government launched several national policies or action plans for the promotion of physical activity for health through the collaboration between central government, the sports sector, municipalities, businesses, care providers and civil society organisations.[40] In this country, Duijvestijn *et al*[31] reported a positive trend in adherence rates, with 39.9% adherence in 2001 to 46.0% in 2018. Furthermore, wealth inequalities across countries, which likely impact an individual's access to fitness facilities or the availability of free time to engage in aerobic and MSA, could also explain some of these differences. In addition, environmental and security factors, such as safe access to public transport, walkability (eg, access to parks, green space, street connectivity), and engagement in active commuting (ie, walking, cycling and other physical modes of travel to work, school, parks, cafes, shops, a friend's house or other destinations) could be other important aspects to consider.[5] By contrast, among adolescents the results are strikingly similar to previous estimates from large sample sizes and aerobic guidelines.[5 7] This could be attributable to the greater number of days and time needed to meet the aerobic guidelines compared with the MSA guidelines (ie, daily vs at least 3 days per week). Representative studies in populations aged 5–11 years are necessary.

The sociodemographic and lifestyle-related correlates of adherence to aerobic and MSA guidelines observed here are largely concordant with previous research using aerobic recommendations alone.[5 6] Specifically, our data show that the population subgroups at higher risk of not meeting the guidelines were women, older adults, individuals with low/medium education levels, those classified as underweight or obese, and those with poorer and moderate self-rated health. The lowest likelihood of meeting the combined guidelines was identified among those with poorer self-rated health, low education and in adults with obesity, all of them directly related.[41] Along this line, a study by Bennie *et al*[23] in ~1.7 million US adults found that meeting both aerobic and MSA guidelines was associated with a lower prevalence of obesity, and associations were stronger for higher obesity classes. Similar differences in adherence to physical activity guidelines have been reported in other countries, including Austria,[30] Australia,[21] Finland,[22] Germany,[25] The Netherlands[31] and South Korea,[33 36] indicating that these population subgroups should be the target for future large-scale aerobic and MSA interventions and health promotion strategies.

Our study provides an accurate estimate of prevalence of physical activity at the population level, which is an important modifiable chronic disease risk factor.[10 11] The importance of meeting both guidelines from a clinical perspective has previously been highlighted in some studies included in the present meta-analysis. For example, adults engaging in aerobic and MSA at recommended levels showed important reductions in the risk of all-cause and cause-specific mortality[8] in addition to a lower risk for multimorbidity (eg, cardiovascular risk and type 2 diabetes).[24 29 30]

The main strength of this study is the large representative sample sizes across 32 countries. Our study also has a number of limitations. The most important limitation is that the meta-analysis included only a small number of worldwide regions, mainly countries from Europe. Second, only two countries represented the adolescent populations (The Netherlands and USA) and no studies analysed children aged 5–11 years old. Third, the included studies evaluated aerobic and MSA guidelines compliance using different self-reported questionnaires or interview methods and used different instruments for measuring physical activity, which may have contributed to the heterogeneity in our findings. Actually, it has been shown that even in the same study population, responses may vary depending on the used survey and how a question is formulated,[42] which could affect comparability between studies. Fourth, the prevalence of physical activity was mostly determined by self-reported survey data, which is subject to recall bias, desirability bias and respondent knowledge. Nonetheless, self-report assessments remain the most common method used to assess physical activity in large population samples. Fifth, the assessment of MSA did not include non-exercise activities (eg, carrying shopping bags, gardening and walking upstairs). Sixth, it could be that individuals included MSA within overall training but, because these activities consume a small percentage of the session, they do not report it as MSA, partially explaining some differences across studies. Finally, most studies reported weighted prevalence rates, which may explain the slightly different confidence intervals shown in figure 2 compared with those reported by individual studies.

What is already known

- ⇒ Nearly one out of three adults and one out of five adolescents do not meet public health guidelines for recommended levels of aerobic physical activity.
- ⇒ Current physical activity guidelines recommend a combination of both aerobic and muscle-strengthening activities, however, the adherence to these guidelines across countries remains unknown.
- ⇒ Estimates of physical activity prevalence based on aerobic physical activity guidelines are likely to underestimate the true extent of physical inactivity at the population level.

What are the new findings

- ⇒ Only one out of five adolescents and adults meet international guidelines for combined aerobic and muscle-strengthening activities.
- ⇒ Physical activity remains very low independent of sex, age, body mass index, education level, smoking status and self-rated health status.

CONCLUSION

In large samples of individuals from 32 countries, only 19% of adolescents and 17% of adults met the guidelines for aerobic and MSA. These low prevalence levels are concerning from a public health perspective, and emphasise the need to provide large-scale physical activity interventions that must be supported by long-term political commitment and paired with coordinated and sustained dissemination and communication strategies across sectors.[43] Also, representative studies among children aged 5–11 years are needed.

Correction notice This article has been corrected since it published Online First. The title and results section have been updated as well as figures 2 and 3.

Contributors AG-H conceived the study, drafted the analysis plan and manuscript, and conducted statistical analyses; JFL-G reviewed the analysis plan and helped to draft the manuscript; YE assisted with data cleaning and preparation and helped to draft the manuscript; MI helped to draft the manuscript; RR-V and AMA-M helped to draft the manuscript and provided input on the analysis plan. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Competing interests YE is an associate editor of BJSM.

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