

Health-enhancing physical activity in Germany: findings from a national sample of 24,016 adults

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Abstract

Background

The German 'National Recommendations for Physical Activity and Physical Activity Promotion' state that adults (≥ 18 years) should engage in: [i] ≥ 150 minutes of aerobic moderate-to-vigorous-intensity physical activity/week (MVPA); and [ii] ≥ 2 days/week of muscle-strengthening exercise (MSE). However, there is limited research on the adherence to these guidelines among German adults. The present purpose was to describe the prevalence and correlates of physical activity guideline adherence among a nationally representative sample of German adults.

Methods

Data were drawn from the 2014 German Health Update survey, collected via a combination of web-based and mail surveys. Self-reported physical activity levels were assessed using the previously validated European Health Interview Survey Physical Activity Questionnaire. Weighted prevalence levels of the sample meeting the aerobic MVPA (≥ 150 minutes/week), MSE (≥ 2 times/week) and combined MVPA-MSE guidelines were calculated. Poisson regressions were used to assess prevalence ratios for physical activity guideline adherence categories across sociodemographic (age, sex, socioeconomic status) and lifestyle-related (self-rated health, BMI) variables.

Results

Out of 24,016 participants (response rate = 27.6%), aged ≥ 18 years, 45.3% (95% CI: 44.5-46.0%), 29.4% (95% CI: 28.7-30.1%) and 22.6% (95% CI: 21.9-23.2%) met the aerobic MVPA, MSE and combined guidelines, respectively. Population sub-groups independently less likely to meet the combined guidelines included those with poor self-rated health, low socioeconomic status and those being overweight or obese.

Conclusions

As almost 80% of German adults do not meet the nationally recommended aerobic combined MVPA-MSE physical activity guidelines, there is a necessity for large-scale public health interventions promoting both aerobic MVPA and MSE.

Background

Globally, approximately three quarters of deaths are attributable to chronic diseases [1]. In high-income countries, such as Germany, chronic diseases including ischemic heart disease, Alzheimer's disease, stroke and diabetes are the leading causes of mortality and morbidity [2]. Physical inactivity is an independent risk factor for the prevention/management of chronic diseases, with epidemiological evidence showing that physical activity decreases the risk of all-cause mortality, and the incidence of chronic health conditions [3].

Since the 1970's, most physical activity guidelines have focused on promoting moderate-to-vigorous aerobic physical activity (MVPA; e.g. walking, cycling, running) [4]. More recently, muscle-strengthening exercise (MSE; e.g. resistance exercise/weight training) has been added into global [5] and many national public health guidelines [6–8]. The 2016 German 'National Recommendations for Physical Activity and Physical Activity Promotion' based on an expert survey and an appraisal of researched studies [9], was the first German national guidelines to include both aerobic MVPA and MSE. These stated that adults (≥ 18 years) should participate in: [i] at least 150

minutes/week of moderate physical activity (e.g. walking) or 75 minutes/week of vigorous physical activity (e.g. jogging), or an equivalent combination of both; and [ii] 2 or more days per week of MSE involving major muscle groups [9].

The addition of combined MVPA-MSE into physical activity guidelines is due to the clinical and epidemiological evidence showing each activity mode has independent and cumulative health benefits [10]. In brief, aerobic MVPA is principally associated with a reduced risk of cardiovascular disease, diabetes, colon/breast cancer and depression [11]. MSE is largely linked to increased skeletal mass/strength, bone density, ability to perform activities of daily living and reduced risk of falls [12]. In addition, recent epidemiological studies have shown that compared to meeting one guideline alone, meeting both aerobic MVPA-MSE guidelines is prospectively associated with lower risk of all-cause mortality [13, 14].

Despite joint aerobic MVPA-MSE being nationally recommended, there is limited available data describing its prevalence and correlates among German adults. German public health surveillance studies have typically solely examined the population-levels of aerobic MVPA guideline adherence [9], with self-report estimates suggesting that ~ 50% of adults meet the aerobic MVPA guideline [15, 16]. A recent report showed that 29.4% of German adults reported meeting the MSE guideline, and 22.6% met the combined MVPA-MSE guidelines, with guideline adherence declining with age and education and males having a higher prevalence, compared to females [17]. However, limitations of that report, were first, physical activity guideline adherence across other key sociodemographic/lifestyle factors were not included (e.g. socioeconomic status, self-rated health, body mass index) [18], and second, a multivariable analysis was not conducted. Reporting of physical activity levels by population sub-groups is vital for determining the most 'at-risk' populations [19], and essential to inform/guide optimal public health policy.

The primary aim of this study is to determine the prevalence of MVPA, MSE and combined MVPA-MSE guideline adherence among a representative sample of German adults. A secondary aim is to examine how physical activity guideline adherence varies across sociodemographic/lifestyle factors.

Methods

Sample

Data were drawn from the 2014 German Health Update (hereafter: GEDA 2014). The GEDA 2014 is a population-based cross-sectional health interview survey conducted on behalf of the Robert-Koch-Institute as part of the German Federal Ministry of Health. Ethics approval for the GEDA 2014 was obtained by the Robert-Koch-Institute and all participants provided informed consent to participate. The purpose of the GEDA is to provide a health monitoring survey that produces reliable information on the actual German adult population's health status, health determinants and health care utilization [20].

An overview of the methods used in the GEDA 2014 is available elsewhere [20]. Conducted between November 2014 and July 2015, a two-stage stratified cluster sampling approach was used to recruit persons aged ≥ 18 years with permanent residence in Germany. Two modes of data collection were used: [i] self-administered web questionnaire (SAQ-Web); and [ii] self-administered paper questionnaire (SAQ-Paper). Initially, 90,102 invitations to participate were sent, with 24,016 fully completed (response rate = 26.9%), with 11,253 via SAQ-Web (45.3%) and 13,571 via SAQ-Paper (54.7%) [17, 20].

In the current study, we only included data from those who fully responded to the physical activity items. To increase generalisability, we did not apply any further inclusion/exclusion criteria [21–24]. Additionally, since the German physical activity guidelines for MVPA and MSE apply to both adults (aged 18–64 years) and older adults (aged ≥ 65 years) [9], we included adults aged ≥ 18 years.

Physical activity assessments

Self-reported physical activity levels were assessed using the European Health Interview Survey Physical Activity Questionnaire (EHIS-PAQ) [25]. The EHIS-PAQ has been shown to be a reliable and valid physical activity assessment tool for use in public health surveillance, and an overview of the development, design and psychometric testing this instrument has been described elsewhere [25]

Aerobic MVPA

Consistent with standardised protocols [25], to count towards meeting the aerobic MVPA guideline, we included physical activity accrued within the domains of: [i] moderate-to-vigorous aerobic recreational physical activity (e.g. Nordic walking, brisk walking, ball games, jogging, bicycling, swimming, aerobics, rowing, badminton); and [ii] transport-related physical activity (e.g. walking/cycling). For these two domains, respondents were asked to consider physical activity during a 'typical week', with the bout of activity having to last for ≥ 10 minutes. In each domain, respondents also were asked to report the number of days per week and total time spent (hours/minutes). MVPA was then summed the reported in the two domains to provide a weekly aerobic MVPA estimate. A validation study showed that when assessing moderate-to-vigorous aerobic recreational and transport-related physical activity, the EHIS-PAQ items have 'good' test-retest reliability (Intraclass correlation coefficient [ICC] = 0.72–0.73) and acceptable concurrent validity (Spearman's rank order correlation = 0.36–0.43), using accelerometry as the standard [25].

Concordant with the German physical activity guidelines (9), participants were dichotomised as either [i] 'meeting the aerobic MVPA guidelines' (≥ 150 minutes/week of moderate-intensity or ≥ 75 minutes/week of vigorous-intensity or an equivalent combination of both), or [ii] 'not meeting the aerobic MVPA guidelines' (not meeting the above classification).

Muscle-strengthening exercise

To assess participation in MSE, respondents were asked, "In a typical week, on how many days do you carry out physical activities specifically designed to strengthen your muscles such as doing resistance training or strength exercises? Include all such activities even if you have mentioned them before.". When considering this question, respondents were prompted to consider a range of MSE-related activities, such as resistance training, strength exercises (using weights, elastic band, own body weight, etc.), knee bends (squats) and push-ups (press-ups). This item has shown to have 'fair' test-retest reliability (ICC = 0.55) [25], and similar items have shown evidence of concurrent validity, using the two or more MSE days/week threshold against metabolic syndrome [26].

According to the German physical activity guidelines [9], participants were dichotomised as either; [i] 'meeting the MSE guideline' (≥ 2 days/week of MSE involving major muscle groups), or [ii] 'not meeting the MSE guideline' (not meeting the above classification).

Meeting the combined MVPA-MSE guidelines

Consistent with the German public health guidelines [9], the sample was dichotomised as either: [i] 'meeting the combined aerobic MVPA-MSE guidelines' (≥ 150 MVPA minutes/week AND ≥ 2 days/week of MSE); or [ii] 'not meeting the aerobic MVPA-MSE guidelines' (not meeting the above classification).

Sociodemographic, socioeconomic status and lifestyle variables

Sociodemographic (sex, age, nationality, socioeconomic status) and lifestyle variables (self-rated health, body mass index [BMI]) were assessed using standard survey items. Each sociodemographic/lifestyle variable was chosen due to its known association with combined MVPA-MSE [21–24], and sub-categories were created to be consistent with previous studies from the GEDA 2014 [27]. Socioeconomic status (low, medium or high) was assessed using the previously validated, German-specific, Socioeconomic SES index (SES Index) [27]. An overview of development of the SES Index can be found elsewhere [27]. The SES Index is based on information from three constructs: [i] formal education/vocational training; [ii] occupational status; and [iii] equivalenced to net household income. This index is calculated as a total points score on the basis of the point values assigned to each construct. A distribution-based distinction of three status groups is made for the analyses, with the low and high status groups each comprising 20% and the medium status group 60% of the population [27]. Self-rated health was assessed on a 5-point scale (1= 'very good' to 5= 'very poor'). BMI was calculated based on self-reported measured height and weight, and categorised into: < 18.5 kg/m² (underweight); from ≥ 18.5 kg/m² to < 25 kg/m² (acceptable weight range); from ≥ 25 kg/m² to < 30 kg/m² (overweight); and ≥ 30 kg/m² (obese).

Statistical analysis

All statistical analyses was conducted using Complex Sample Module, IBM SPSS 24.0 statistical software (SPSS Inc. an IBM Company, Chicago, IL). To enhance population representativeness, each GEDA 2014 responded was provided with a sample weight to correct for non-response. Detailed information on the methodological considerations for the sample weights in the GEDA 2014 is available elsewhere [28, 29].

To assess the primary study aim, weighted percentages and their 95% confidence intervals (95% CI) were calculated for: [i] meeting the aerobic MVPA guideline; [ii] meeting the MSE guideline; [iii] meeting both aerobic MVPA-MSE guidelines. Chi-squared tests were used to test the unadjusted differences between the prevalence rates by sociodemographic and lifestyle variables.

To assess the secondary aim, generalized linear models using Poisson regression with robust error variance were conducted to calculate prevalence ratios (PRs) between sociodemographic and lifestyle variables, and: [i] meeting/not meeting aerobic MVPA guideline; [ii] meeting/not meeting the MSE guideline; [iii] meeting/not meeting the combined MVPA-MSE guidelines. Each model included the following explanatory variables: sex (reference group [ref] = "male"); age (ref = "18–29 years"); socioeconomic status (ref = "high"); nationality (ref= "German"); self-rated health (ref = "very good"); and BMI (ref = "normal weight"). For these Poisson regression analyses, PRs and their 95% CIs were reported.

Results

Sample description

Data from 24,016 adults aged were included in the analysis. Socioeconomic and lifestyle characteristics of participants are shown in Table 1. Among the weighted sample, over half were female, over one third were aged

45–64 years, and the majority were of German nationality. Over half rated their health as ‘good’ and just under half had a ‘normal’ BMI (≥ 18.5 to < 25 kg/m²).

Prevalence of physical activity guideline adherence

A total of 45.3% (95% CI: 44.5%-46.0%) met the aerobic MVPA guideline, 29.4% (95% CI: 28.7%-30.1%) met the MSE guideline and 22.6% (95% CI: 21.9%-23.2%) met the combined aerobic MVPA-MSE guidelines. With the exception of nationality, significant differences between the proportions meeting all guidelines were observed across the remaining sociodemographic and lifestyle variables ($p < 0.001$ for all other comparisons) (Table 1).

Correlates of physical activity guideline adherence

In the multivariate adjusted analysis, across each sociodemographic and lifestyle factor, the adjusted PRs (APRs) were generally concordant for all physical activity guideline adherence categories (Table 2). Compared to men, females had lower likelihood (APR = 0.88; 95% CI: 0.83–0.92) of meeting both guidelines. By age, compared to the youngest respondents (aged 18–29 years), the APRs for meeting both guidelines were lowest among those aged 30–44 years (APR = 0.58; 95% CI: 0.53–0.63), and similarly lower for those aged 45–64 years and ≥ 65 years, respectively. Compared to those with German nationality, apart from those as Non-German and not in the European Union being 17% less likely to meet the MVPA guideline, there were no significant differences across the other guideline adherence categories.

The likelihood of meeting each physical activity guideline category decreased by decreasing socioeconomic status and self-rated health. The APRs for both aerobic MVPA-MSE guidelines were lowest among those with ‘very poor’, ‘poor’, and ‘moderate’ self-rated health (APR range = 0.20–0.46), and those with ‘low’ socioeconomic status (APR = 0.53; 95% CI: 0.48–0.59). Compared to those with ‘normal’ BMI, those classified as ‘overweight’ and ‘obese’ were 31% and 52% less likely to meet the combined guidelines, respectively.

Discussion

Approximately 80% of German adults did not meet the nationally recommended physical activity guidelines of ≥ 150 minutes per week of aerobic MVPA and MSE ≥ 2 days per week. Considering that evidence that combined aerobic MVPA-MSE is independently associated with a multiple beneficial health outcomes [13, 14, 22, 26, 30], our findings suggest the need for immediate public health action to address physical inactivity in Germany.

The physical activity prevalence estimates presented in the current paper suggest that inactivity among German adults is currently underestimated. A recent study based on pooled data from several national public health surveillance surveys worldwide from 2002–2016, stated that 42.2% of German adults (≥ 18 years) were classified as inactive [15]. However, the German data analysed in that study included physical activity estimates solely based on meeting/not meeting the aerobic MVPA guideline [15]. The present data suggest that when considering the prevalence of adults not meeting the combined MVPA-MSE guidelines (77.4%), physical inactivity among German adults is almost two-fold greater than estimates exclusively based on aerobic MVPA guideline adherence.

The aerobic MVPA guideline adherence estimated in the current study are consistent with previous studies on German adults [15, 16]. Cross-country comparisons show that a slightly higher prevalence of German adults meet the combined guidelines compared to U.S.[22] and U.K. [7] (22.6% vs. $\sim 20.0\%$). In contrast, lower MVPA-MSE

guideline adherence estimates have been observed among Australian [24], and Finnish adults [31] (10.8%-15.0%) For MSE guideline adherence, somewhat similar cross-country patterns to those for meeting the MVPA-MSE guidelines have been observed [22, 24, 31], with Germany levels comparable to U.S and U.K [7, 23], but higher than those from Australian [24] and Finnish studies [31].

With the inclusion of a larger number of sociodemographic/lifestyle factors and the use of a multivariate adjusted analysis, the current study expands on a previous report from the GEDA 2014 [17]. The lowest likelihood of meeting the combined MVPA-MSE guidelines were identified among those with poorer self-rated health, lower socioeconomic status, the overweight/obese and females. These sociodemographic/lifestyle correlates of combined MVPA-MSE guideline adherence are somewhat congruent with studies from other countries [21, 22, 24], and indicate that within the German context, these population sub-groups should be the target for future physical activity interventions.

Studies from Australia, Finland and U.S. have shown an inverse age gradient for the likelihood of meeting the combined MVPA-MSE guidelines [21, 22, 24]. Therefore, it was surprising to observe in our sample of German adults no such age gradient. For example, the second youngest group (30–44 years) had lower APR, when contrasted with their older counterparts (≥ 45 years). The increased physical activity among older populations is consistent with German research – especially for women [32]. While the causes of this are yet to be fully established, it might be that older German adults are better informed and more aware of health benefits of physical activity. This may positively influence being active especially among older populations who are perceiving health problems. Additionally, children leave the parental home (empty-nest-phase), so especially women have more time resources and sports clubs in Germany offer several activities, which are tailored to women [32]. Clearly, more research is needed to first, replicate this finding in prospective studies, and second, to determine its causes, especially for the decrease of physical activity in the younger age group. Nonetheless, the age-specific physical activity patterning shown in the current study might be reflective of increasing demands/life commitments encountered as German population's transition out of young adulthood into middle adulthood.

The finding that ~ 70% of German adults do not meet the MSE guideline indicates that this physical activity may warrant future national public health attention to increase population-level engagement. However, compared to aerobic MVPA, as with other countries [23, 24, 33], the promotion of MSE has been of limited focus in previous Germany public health promotion [9]. Importantly, our study showed that compared to those reporting insufficient aerobic MVPA, greater proportions report insufficient MSE (70.6% vs. 54.7%). Future large-scale public health MSE promotion approaches should include a combination of approaches [23]. Potential simultaneous and multi-level MSE strategies could include; providing physical environmental support (e.g. access to fitness centres/equipment in open spaces) [34], policy support (e.g. subsidizing equipment for home-based activity, gym memberships, access to qualified fitness professionals) and mass-media campaigns challenging the negative stereotypes often linked to MSE (e.g. high injury risk, excessive muscle gain) [35, 36].

This study examined only a limited number of the possible correlates of MVPA-MSE. Future studies are needed to examine other potential factors influencing physical activity among German adult populations. Some key influences for further research may include the examination of sociodemographic (marital/employment status etc.), lifestyle (smoking/alcohol/diet etc.), psychological (intentions/motivation etc.), social (peer/social support etc.) and environmental factors (location of/access to facilities etc.) [18]. In particular, research on modifiable factors related to MSE will be of interest when developing public health interventions.

A key limitation of this study is the use of self-report MVPA-MSE assessments. We are unable to exclude the possibility this method led to common problems associated with self-report physical activity assessment (e.g. recall bias [over/underreporting], social disability bias and issues around comprehension of survey items) [37]. Notwithstanding significant logistical constraints, such as substantial cost and high participant burden, forthcoming German physical activity surveillance studies could consider using accelerometers to assess aerobic MVPA and time-use diaries to assess MSE. Nonetheless, self-report assessments are still the most common method used to assess physical activity among large population samples [38]. The low GEDA 2014 response rate (27.2%) is likely to be impacted on our MVPA-MSE estimates. It is probable that non-responders are among the least active populations, and despite the steps to provide accurate survey weighting to correct for non-response, we urge that the physical activity estimates reported here be viewed as conservative.

Strengths of this study include the recruitment of a large national-representative sample of German adults. The GEDA 2014 sample (n = 24,016) is approximately 20-fold larger than previous German physical activity prevalence surveys [39]. A further strength was the use of the EHIS-PAQ, a standardised physical activity assessment tool.

Conclusions

Most German adults do not meet the nationally recommended aerobic MVPA-MSE guidelines. These low prevalence levels are concerning from a public health perspective, and highlight that there is a need to provide large-scale physical activity interventions to promote/support both MVPA-MSE uptake and adherence among German adults. Future public health interventions should target those with low socioeconomic status, poor self-rated health, and obese populations.

Abbreviations

Moderate-to-vigorous physical activity	MVPA
Muscle-strengthening exercise	MSE
German Health Update	GEDA
Web questionnaire	SAQ-Web
Self-administered paper questionnaire	SAQ-Paper
European Health Interview Physical Activity Questionnaire	EHIS-PAQ
Intraclass correlation coefficient	ICC
Body Mass Index	BMI
Socioeconomic SES index	SES Index
95% confidence intervals	95% CI
Adjusted prevalence ratios	APR

Declarations

Ethics approval and consent to participate

The study protocol was inspected and approved by the 'Federal Commissioner for Data Protection and Freedom of Information in Germany'. Written informed consent was obtained from all participants. Participants were informed about the goals and contents of the study, about privacy and data protection proceedings, and that their participation in the study was voluntary.

Consent for Publication

All authors provide consent for publication

Availability of data and materials

GEDA micro-data are accessible for scientific research (so-called Public Use Files) and can be obtained by completing an application form available at:

[http://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html]; e-mail: [geda@rki.de].

Competing interests

All authors declare that they have no competing interests.

Funding

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Authors' contributions

Bennie and Tittlbach conceptualised the study and developed the initial research plan. Bennie conducted the data analysis and drafted the initial manuscript. Tittlbach and De Cocker provided expertise on the analysis and interpretation of data and assisted in drafting the manuscript. All authors read and approved the final version of the manuscript for publication.

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References

1. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, Abbastabar H, Abd-Allah F, Abdela J, Abdelalim A: Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet* 2018, 392(10159):1789-1858.
2. Health Data: Germany [<http://www.healthdata.org/germany>]

3. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT: Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* (London, England) 2012, 380(9838):219-229.
4. Oja P, Titze S: Physical activity recommendations for public health: development and policy context. *Epma j* 2011, 2(3):253-259.
5. World Health Organization: Global Recommendations on Physical Activity for Health. In.; 2010.
6. Australian Government Department of Health: Australia's physical activity and sedentary behaviour guidelines (adults). In. Canberra, ACT: Australian Government 2014.
7. U.K Department of Health PA, Health Improvement and Protection: Start Active, Stay Active: A report on physical activity from the four home countries' Chief Medical Officers. In.; 2011.
8. UKK Institute: UKK Institute's Physical Activity Pie. In., vol. 2016; 2016.
9. National Recommendations for Physical Activity and Physical Activity Promotion [https://www.sport.fau.de/files/2015/05/National-Recommendations-for-Physical-Activity-and-Physical-Activity-Promotion.pdf]
10. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP: American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine and science in sports and exercise* 2011, 43(7):1334-1359.
11. Schoenborn C, Adams PF, Peregoy JA: Health behaviors of adults: United States, 2008–2010. In. Edited by Statistics NcfH, vol. 10: Vital Health Stat; 2013.
12. U.S. Department of Health and Human Services: Physical Activity Guidelines for Americans, 2nd edition. In. Washington, DC.; 2018.
13. Stamatakis E, Lee IM, Bennie J, Freeston J, Hamer M, O'Donovan G, Ding D, Bauman A, Mavros Y: Does Strength-Promoting Exercise Confer Unique Health Benefits? A Pooled Analysis of Data on 11 Population Cohorts With All-Cause, Cancer, and Cardiovascular Mortality Endpoints. *Am J Epidemiol* 2018, 187(5):1102-1112.
14. Tarasenko YN, Linder DF, Miller EA: Muscle-strengthening and aerobic activities and mortality among 3+ year cancer survivors in the U.S. *Cancer causes & control : CCC* 2018, 29(4-5):475-484.
15. Guthold R, Stevens GA, Riley LM, Bull FC: Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *The Lancet Global Health* 2018.
16. Physical Activity Country Card: Germany [http://www.globalphysicalactivityobservatory.com/Translation%20of%20country%20cards/Germany%20trad.pdf]
17. Finger JD, Mensink G, Lange C, Manz K: Health-enhancing physical activity during leisure time among adults in Germany. *Journal of Health Monitoring* 2017, 2(2).
18. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW: Correlates of physical activity: why are some people physically active and others not? *Lancet* (London, England) 2012, 380(9838):258-271.
19. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U: Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* (London, England) 2012, 380(9838):247-257.
20. Lange C, Finger JD, Allen J, Born S, Hoebel J, Kuhnert R, Müters S, Thelen J, Schmich P, Varga M: Implementation of the European health interview survey (EHIS) into the German health update (GEDA). *Archives of Public Health* 2017, 75(1):40.
21. Bennie JA: Health-enhancing physical activity in Finland: findings from a national sample of 64,380 adults. In: International Society for Behavioral Nutrition and Physical Activity (ISBNPA). Victoria, Canada; 2017.

22. Bennie JA, De Cocker K, Teychenne MJ, Brown WJ, Biddle SJH: The epidemiology of aerobic physical activity and muscle-strengthening activity guideline adherence among 383,928 U.S. adults. *International Journal of Behavioral Nutrition and Physical Activity* 2019, 16(1):34.
23. Bennie JA, Lee D-c, Khan A, Wiesner GH, Bauman AE, Stamatakis E, Biddle SJH: Muscle-Strengthening Exercise Among 397,423 U.S. Adults: Prevalence, Correlates, and Associations With Health Conditions. *American Journal of Preventive Medicine* 2018.
24. Bennie JA, Pedisic Z, Van Uffelen JG, Banting LK, Gale J, Vergeer I, Stamatakis E, Bauman A, Biddle SJH: The descriptive epidemiology of total physical activity, muscle-strengthening exercises and sedentary behaviour among Australian adults – results from the National Nutrition and Physical Activity Survey. *BMC Public Health* 2016, 16:73(DOI: 10.1186/s12889-016-2736-3).
25. Finger JD, Tafforeau J, Gisle L, Oja L, Ziese T, Thelen J, Mensink GB, Lange C: Development of the European Health Interview Survey - Physical Activity Questionnaire (EHIS-PAQ) to monitor physical activity in the European Union. *Archives of public health = Archives belges de sante publique* 2015, 73:59.
26. Dankel SJ, Loenneke JP, Loprinzi PD: The Individual, Joint, and Additive Interaction Associations of Aerobic-Based Physical Activity and Muscle Strengthening Activities on Metabolic Syndrome. *International journal of behavioral medicine* 2016, 23(6):707-713.
27. Lampert T, Kroll LE, Müters S, Stolzenberg H: Measurement of socioeconomic status in the German Health Interview and Examination Survey for Adults (DEGS1). 2013.
28. European Health Interview Survey (EHIS wave 2) Methodological manual [<https://ec.europa.eu/eurostat/documents/3859598/5926729/KS-RA-13-018-EN.PDF/26c7ea80-01d8-420e-bdc6-e9d5f6578e7c>]
29. Population projection [<https://www-genesis.destatis.de/genesis/online>]
30. Bird SR, Hawley JA: Update on the effects of physical activity on insulin sensitivity in humans. *BMJ Open Sport & Exercise Medicine* 2017, 2(1):e000143.
31. Bennie JA, Pedisic Z, Suni JH, Tokola K, Husu P, Biddle SJ, Vasankari T: Self-reported health-enhancing physical activity recommendation adherence among 64,380 Finnish adults. *Scandinavian journal of medicine & science in sports* 2017.
32. Tittlbach SA, Jekauc D, Schmidt SCE, Woll A, Bos K: The relationship between physical activity, fitness, physical complaints and BMI in German adults - results of a longitudinal study. *European journal of sport science* 2017, 17(8):1090-1099.
33. Strain T, Fitzsimons C, Kelly P, Mutrie N: The forgotten guidelines: cross-sectional analysis of participation in muscle strengthening and balance & co-ordination activities by adults and older adults in Scotland. *BMC public health* 2016, 16(1):1108.
34. Harada K, Oka K, Shibata A, Ishii K, Nakamura Y, Inoue S, Shimomitsu T: Strength-training behavior and perceived environment among Japanese older adults. *J Aging Phys Act* 2011, 19(3):262-272.
35. Phillips SM, Winett RA: Uncomplicated resistance training and health-related outcomes: evidence for a public health mandate. *Curr Sports Med Rep* 2010, 9(4):208-213.
36. Howe HS, Welsh TN, Sabiston CM: The association between gender role stereotypes, resistance training motivation, and participation. *Psychology of Sport and Exercise* 2017, 33(Supplement C):123-130.
37. Shephard RJ: Limits to the measurement of habitual physical activity by questionnaires. *Br J Sports Med* 2003, 37(3):197-206; discussion 206.
38. Pedišić Ž, Bauman A: Accelerometer-based measures in physical activity surveillance: current practices and issues. *British journal of sports medicine* 2014:bjsports-2013-093407.

39. Sjöström M, Oja P, Hagströmer M, Smith B, Bauman A: Health-enhancing physical activity across European Union countries: the Eurobarometer study. *Journal of Public Health* 2006, 14(5):291-300.

Tables

Table 1: Proportions (weighted^a) of the GEDA 2014 sample meeting the aerobic moderate to-vigorous aerobic physical activity (MVPA) guideline^b, muscle strengthening exercise guideline^c and combined aerobic MVPA and muscle strengthening exercise guidelines: overall and by sociodemographic and lifestyle factors.

		Met MVPA guideline ^b	Met muscle-strengthening exercise guideline ^c	Met both guidelines ^d
	n	% (95% CI)	% (95% CI)	% (95% CI)
Total	24,016	45.3 (44.5-46.0)	29.4 (28.7-30.1)	22.6 (21.9-23.2)
Sex	n^e (%^a)			
Male	10,873 (48.9)	48.0 (46.8-49.2)	31.2 (30.2-32.3)	24.7 (23.7-25.7)
Female	13,144 (51.1)	42.6 (41.5-43.6)	27.6 (26.7-28.6)	20.5 (19.6-21.3)
<i>p-value*</i>		<0.001	<0.001	<0.001
Age (years)				
18-29	3,888 (16.9)	51.2 (49.1-53.2)	39.4 (37.4-41.4)	30.1 (29.2-32.9)
30-44	5,325 (22.2)	41.8 (40.1-43.5)	24.8 (23.4-26.3)	19.4 (18.1-20.8)
45-64	8,977 (36.4)	46.7 (45.5-47.9)	27.8 (26.7-28.9)	21.9 (20.9-23.0)
≥65	5,826 (24.5)	41.8 (40.2-43.5)	29.0 (27.6-30.4)	20.2 (18.9-21.6)
<i>p-value*</i>		<0.001	<0.001	<0.001
Socioeconomic status				
Low	3,906 (20.3)	33.4 (31.5-35.2)	22.7 (21.2-24.4)	15.1 (13.7-16.5)
Medium	13,437 (59.8)	45.2 (44.1-46.2)	29.8 (28.9-30.8)	22.8 (22.0-23.7)
High	6,620 (19.9)	56.8 (55.3-58.2)	34.7 (33.4-36.1)	37.1 (35.7-38.5)
<i>p-value*</i>		<0.001	<0.001	<0.001
Nationality				
German	22,085 (96.4)	45.4 (44.6-46.2)	29.4 (28.7-30.2)	22.5 (21.9-23.2)
Non-German, but EU	400 (1.8)	47.4 (41.4-53.4)	30.9 (25.6-36.7)	25.5 (20.6-31.1)
Non-German, not EU	319 (1.8)	35.9 (29.6-42.7)	26.7 (21.0-33.2)	20.9 (15.8-27.2)
<i>p-value*</i>		0.06	0.157	0.04
Self-rated health^f				
Very good	3,729 (14.8)	62.0 (59.9-63.9)	40.7 (33.8-42.7)	35.5 (33.6-37.4)
Good	12,488 (53.4)	47.8 (46.7-48.9)	29.7 (28.8-30.7)	23.2 (22.3-24.1)
Moderate	5,570 (26.3)	35.1 (33.6-36.6)	23.7 (22.4-26.1)	16.1 (14.9-17.3)
Poor	938 (4.8)	23.3 (20.2-26.7)	23.4 (20.4-26.6)	11.8 (9.5-14.6)
Very poor	134 (0.7)	13.9 (8.3-22.2)	16.6 (10.5-25.2)	5.6 (2.6-11.6)
<i>p-value*</i>		<0.001	<0.001	<0.001
Body Mass Index (kg/m²)^f				
Underweight (<18.5)	430 (1.8)	38.6 (33.1-44.4)	27.8 (23.0-33.2)	18.5 (14.4-23.3)
Normal (≥18.5- <25)	10,671 (44.1)	51.3 (50.1-52.5)	34.3 (33.2-35.4)	27.2 (26.2-28.3)

Overweight (25- <30)	7,895 (35.9)	45.3 (44.0-46.6)	28.5 (27.3-29.7)	21.9 (20.8-23.0)
Obese (\geq 30)	3,824 (18.1)	31.7 (29.9-33.5)	19.6 (18.2-21.2)	13.0 (11.8-14.3)
<i>p-value*</i>		<i><0.001</i>	<i><0.001</i>	<i><0.001</i>

^a Sample weights provided by the GEDA 2014 (30, 31).

^b To meet the MVPA guideline respondents had to report engaging in at least 150 minutes per week of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity per week, or an equivalent combination both, and accumulated in bouts of at least 10 consecutive minutes during leisure time and for transport.

^c To meet muscle-strengthening exercise guideline the guideline respondents had to report engaging in muscle strengthening activity at least two days per week.

^d Meeting both guidelines.

^e Weighted percentage.

^f Numbers different to total sample due to missing responses.

*p-value for X^2 test.

Table 2: Adjusted^a prevalence ratio^b (APR), and 95% confidence intervals (95% CI) for meeting aerobic moderate to vigorous aerobic physical activity (MVPA) recommendation, muscle strengthening exercise (MSE) recommendation and both recommendations.

	Met MVPA guideline^c	Met muscle-strengthening exercise guideline^d	Met both guidelines^e
	APR (95% CI)	APR (95% CI)	APR (95% CI)
Sex (reference [ref]: Male)			
Female	0.91 (0.88-0.95)	0.92 (0.88-0.95)	0.88 (0.83-0.92)
Age (years) (ref: 18-29)			
30-44	0.78 (0.73-0.82)	0.62 (0.57-0.66)	0.58 (0.53-0.63)
45-64	0.87 (0.82-0.92)	0.69 (0.64-0.73)	0.66 (0.61-0.70)
≥65	0.80 (0.76-0.85)	0.77 (0.72-0.82)	0.66 (0.61-0.71)
Socioeconomic status (ref: High)			
Medium	0.82 (0.78-0.85)	0.87 (0.82-0.91)	0.81 (0.76-0.86)
Low	0.59 (0.55-0.63)	0.64 (0.59-0.70)	0.53 (0.48-0.59)
Nationality (ref: German)			
Non-German, but EU	1.07 (0.93-1.22)	1.03 (0.86-1.23)	1.14 (0.67-1.10)
Non-German, not EU	0.83 (0.69-0.99)	0.82 (0.66-1.02)	0.86 (0.67-1.37)
Self-rated health (ref: Very good)			
Good	0.77 (0.74-0.81)	0.74 (0.70-0.78)	0.66 (0.62-0.71)
Moderate	0.56 (0.53-0.66)	0.59 (0.55-0.64)	0.46 (0.42-0.50)
Poor	0.38 (0.33-0.43)	0.60 (0.53-0.69)	0.35 (0.28-0.42)
Very poor	0.21 (0.13-0.33)	0.46 (0.30-0.67)	0.20 (0.10-0.37)
Body Mass Index (kg/m²)^g (ref: Normal ≥18.5-<25)			
Underweight (<18.5)	0.79 (0.68-0.91)	0.82 (0.68-0.97)	0.69 (0.55-0.85)
Overweight (25- <30)	0.87 (0.84-0.91)	0.82 (0.78-0.86)	0.79 (0.74-0.84)
Obese (≥30)	0.61 (0.57-0.65)	0.58 (0.54-0.63)	0.48 (0.44-0.53)

^a Adjusted for all other explanatory variables in the table.

^b Prevalence ratio calculated using Poisson regression with a robust error variance.

^c To meet the MVPA guideline respondents had to report engaging in at least 150 minutes per week of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity per week, or an equivalent combination both, and accumulated in bouts of at least 10 consecutive minutes during leisure time and for transport.

^d To meet the muscle strengthening exercise guideline respondents had to report engaging in muscle strengthening activity at least two days per week.

^e Meeting both aerobic MVPA-MSE guidelines.