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Association of meeting both muscle strengthening and aerobic exercise guidelines with prevalent overweight and obesity classes - results from a nationally representative sample of German adults

Susanne A Tittlbach[1], Sascha W Hoffmann[2] and Jason A Bennie[3]

[1]Department of Social and Health Sciences in Sport, Institute of Sport Science, University of Bayreuth, Universitätsstraße 30, 95440 Bayreuth, Germany

[2]Department of Theory and Practice of Sports and Movement Fields, Institute of Sport Science, University of Bayreuth, Universitätsstraße 30, 95440 Bayreuth, Germany

[3] Physically Active Lifestyles Research Group (USQ PALs), Institute for Resilient Regions, Centre for Health Sciences Research, University of Southern Queensland, 37 Sinnathamby Boulevard, Springfield Central, QLD 4300, Australia.

*Corresponding author: Susanne A. Tittlbach, susanne.tittlbach@uni-bayreuth.de; Telephone: +49 921 55-3487, Sascha W. Hoffmann, sascha.hoffmann@uni-bayreuth.de, Jason A. Bennie, Jason.Bennie@usq.edu.au

Abstract

Objectives: German national physical activity guidelines specify adults (≥18 years) should engage in at least: (i) 150 minutes of aerobic moderate-to-vigorous-intensity physical activity/week (MVPA); and (ii) muscle-strengthening exercise (MSE) 2 days/week. However, the relationship between MVPA and MSE and overweight/obesity has not been examined among German adults. Aim of this study was to examine whether meeting the

guidelines for both MVPA and MSE is associated with a lower prevalence of overweight/obesity compared to meeting MVPA or MSE alone or none of them, among a nationally representative sample of German adults. **Methods**: The cross-sectional study drew data from the 2014 German Health Update (GEDA) (n=22,822; ≥18 years). Physical activity (MVPA-MSE), height/weight, socio-demographic, health and lifestyle factors were assessed by self-report via validated questionnaires. Generalized linear models with Poisson regression were used to assess prevalence ratios of Body Mass Index-derived (BMI) overweight/obesity across categories of physical activity guideline adherence (met neither; MSE only; MVPA only; met both). **Results**: Compared to other physical activity groups, meeting both the MVPA-MSE guidelines was associated with the lowest prevalence rate of overweight/obesity (Adjusted Prevalence Ratios [APR] range: 0.25-0.73). Associations between BMI and physical activity were strongest among Class II obesity (APR range: 0.25-0.45). The associations remained consistent after adjusting sociodemographic and lifestyle factors. **Conclusions**: Meeting the combined MVPA-MSE guideline, as suggested in the German national physical activity recommendations, showed the lowest overweight/obesity prevalence. Promoting uptake and adherence of both MVPA and MSE at the population level could help to reduce the public health burden of obesity.

Keywords: Exercise, Health, Obesity, Quantitative Study, Strength

INTRODUCTION

Obesity prevention is a major global public health challenge. Being obese increases the risk of multiple common noncommunicable diseases (NCDs) such as cardiovascular diseases, hypertension, diabetes, depression, musculoskeletal disorders, some cancers, and leads to poor quality of life (1, 2). For the OECD (Organisation for Economic Cooperation and

Development) countries, average rates of adult obesity have increased from 21.3% in 2010 to 24.0% in 2016, which corresponds to about an additional 50 million people with obesity (3). In Germany, it is estimated that ~18.0 % of adults are obese (4). Besides an increased risk of further health problems (i.e. depression, cardiometabolic biomarkers), the high prevalence of obesity results in a significantly increased economic burden (i.e. costs for medical services, increased sick leave, early retirement) of up to 104% compared to the normal-weight group (5-7).

Research suggests that regular physical activity is beneficial for preventing multiple NCDs (8, 9), and is a modifiable key behaviour for the prevention/management of overweight and obesity (1, 2, 10, 11). Both the WHO Global Recommendations on Physical Activity for Health (12), as well as the German National Recommendations for Physical Activity (13) recommend: (i) at least 150 minutes/week of aerobic moderate-to-vigorous-physical-activity (MVPA); and (ii) muscle-strengthening exercise (MSE) on at least two days per week (12, 13).

At present, most of the evidence that physical activity for a healthy weight is based on research examining aerobic MVPA (14-16). A recent review of 33 prospective cohort studies identified robust evidence, that greater volumes of aerobic MVPA help to prevent excessive weight gain/obesity and to maintain a healthy weight (17). In large population studies, the associations between MSE and obesity have only been considered for some selected countries (18, 19). Recent US epidemiological studies suggest that MSE alone or combined MVPA-MSE may have a role in the prevention/management of overweight and obesity (18, 20). The research on the role of different physical activity/exercise modalities with obesity among

German populations is key to inform future national public health approaches to prevent and manage this detrimental health condition.

However, at present, little is known about the extent to which meeting both the muscle-strengthening and aerobic exercise guidelines (11) is associated with the prevalence of overweight and obesity classes within the German population, particularly considering the role of sex, age and self-reported health status.

The aim of this study was to examine whether meeting the guidelines for both MVPA and MSE is associated with a lower prevalence of overweight and obesity classes compared to meeting MVPA or MSE alone or none of them, among a nationally representative sample of German adults.

METHODS

German Health Update 2014

Data were drawn from the 2014 German Health Update (hereafter: GEDA 2014). GEDA 2014 is a population-based cross-sectional health interview survey that was 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, health behaviour and health care utilization (21).

An overview of the GEDA 2014 methodology has been described elsewhere (7, 21). In brief, GEDA 2014 was conducted between November 2014 and July 2015, and for recruitment of a nationally representative sample of German adults, a two-stage stratified cluster sampling

approach was implemented. According to the EHIS specifications, the sample are German adults aged 15 years and older with permanent residence in Germany. For the national GEDA analyses, adults aged 18 years and older are included only (i.e. n=808 aged 15-17 years were excluded; 3.3% of total sample) (22). This procedure is also in line with the MSE recommendations, which are different for those aged 15-17 years and those aged 18 years and older (≥3 vs. ≥2 days/week) (13). Originally, 90,102 invitations to participate were sent with a response rate of 27.6% (24,016 initially responding). To ensure representativeness to account for nonresponse, weighting factors were applied to normalized to the size of the sample (22). In the present study, we excluded those who did not complete the physical activity items (n=1,194; 5% of the total sample). We included adults aged ≥18 years since the German physical activity guidelines for MVPA and MSE apply to adults (aged 18–64 years) as well as older adults (aged ≥65 years) (13). Consistent with similar studies (19, 23, 24), to increase generalisability, we did not apply any further inclusion/exclusion criteria.

Physical activity (aerobic MVPA and MSE) assessments

Self-reported physical activity levels were assessed using the European Health Interview Survey Physical Activity Questionnaire (EHIS-PAQ) (25). The EHIS-PAQ is a reliable and valid physical activity assessment tool for use in public health surveillance and is used throughout Europe (25).

Aerobic MVPA

Based on previous studies, we included physical activity during a 'typical week', with the bout of activity having to last for at least 10 minutes within the domains of [i] moderate-to-vigorous aerobic recreational physical activity (e.g. Nordic or brisk walking, ball games, jogging, bicycling, swimming, aerobics, badminton); and [ii] transport-related physical

activity (e.g. walking/cycling) to count towards the compliance with the aerobic MVPA guideline (25). Respondents reported both the number of days per week and total time spent (hours/minutes) in each domain. MVPA was then summed up to provide a weekly aerobic MVPA estimate. A previous validation study showed good to acceptable reliability and validity concerning the EHIS-PAQ items assessing moderate-to-vigorous aerobic recreational and transport-related physical activity (test-retest reliability: Intraclass correlation coefficient [ICC] =0.72-0.73 and concurrent validity: Spearman's rank-order correlation =0.36-0.43, using accelerometry as the standard) (25).

Muscle-strengthening exercise (MSE)

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?*". Respondents were asked to consider a variety of MSE-related activities, such as resistance/weight training using weights or muscle-strengthening exercises with own body weight (i.e. knee bends (squats), push-ups, sit-ups, etc.). This item has shown evidence of concurrent validity (using the ≥ 2 times/week threshold against metabolic syndrome) (26), and 'fair' test-retest reliability (ICC = 0.55) (25).

Physical activity categories

According to the German national physical activity guidelines (13), four activity categories were created: (i) "Meet neither" (MVPA = 0-149 min/wk and MSE < 2 sessions/wk), (ii) "MSE only" (MSE ≥ 2 sessions/wk and MVPA = 0-149 min/wk), (iii) "MVPA only" (MVPA ≥ 150 min/wk and MSE < 2 sessions/wk), or (iv) "Meet both" (MVPA ≥ 150 min/wk and MSE ≥ 2 sessions/wk). To examine the potential for dose-dependent associations between MVPA-MSE and overweight/obesity beyond the current guidelines, similar to a previous

study (15), we created further categories on meeting or not meeting double the national physical activity guidelines (MVPA ≥ 300 min/wk and MSE ≥ 4 sessions/wk).

Overweight and obesity classification

Classification into overweight or obesity was based on standardized Body Mass Index (BMI) classes. BMI was calculated using the following formula BMI = kg/m^2, based on self-reported height (meters) and weight (kilograms). A previous study has shown a strong correlation (r = 0.95) between self-reported height/weight calculated BMI and objectively measured height/weight-calculated BMI (27). Since health risks of overweight and obesity increase with the severity of obesity (28), we classified increasing levels of overweight and obesity by using the following BMI classes: (i) 25.0-29.9 kg/m^2 (overweight), (ii) 30.0-34.9 kg/m^2 (Class I), (iii) ≥35.0 kg/m^2 (Class II). Due to a small sample size among those classified with Class III obesity (≥ 40 kg/m^2), in the current study we used two obesity classifications.

Covariates

Sociodemographic (age, sex, nationality, socioeconomic status [SES], employment status, household type), health status (self-rated health, being restricted by chronic disease in the last 6 months) and lifestyle (smoking status, fruit/vegetable intake) characteristics were assessed using standardized survey items. All covariates were included in the models as potential confounding factors because of their relationship with MVPA-MSE as well as overweight/obesity (14, 28). Each subcategory was chosen to be consistent with previous studies from GEDA (7). Socioeconomic position (low, medium or high) was assessed using the previously validated, German-specific, SES index (29), which is based on information

from three constructs: [i] formal education/vocational training; [ii] occupational status; and [iii] equivalenced to net household income.

Statistical analysis

Analyses were conducted using the Complex Samples module of SPSS version 26. In the analyses, to enhance population representativeness, individual weighting factors to correct for nonresponse and stratification were implemented (30). Descriptive statistics were used to describe the weighted percentages (%) across all potential covariates, physical activity guideline categories and overweight group/obesity classes.

Generalized linear models with Poisson regression with robust error variance were used to calculate prevalence ratios (PR) assessing the associations between overweight group /obesity categories (Dependant variable; Dichotomous outcome 'healthy weight' BMI 18.5-24.9 kg/m^2 vs overweight group/obesity category of interest) and physical activity groups (explanatory variable; reference = meet neither physical activity guidelines'). In our analytical approach, we conducted two generalized linear models: (i) unadjusted; and (ii) adjusted for the covariates described above. We tested for collinearity between confounders, and no collinearity problems exist (VIF between 1.01 and 1.48).

We performed sensitivity analyses to allow for a more robust understanding of the results. First, we conducted sex (males vs females) and age-stratified analyses (18-64 vs ≥ 65 years). Second, to minimise the risk of reverse causation, we compared adjusted prevalence ratios (APRs) among those with "very good-to-good" with those with "moderate-to-very poor" self-rated health, and among those being restricted by chronic diseases during the last 6 months (yes vs no).

RESULTS

Sample description

The final sample was 22,822 (≥18 years); the sample characteristics are shown in Table 1 (see Appendix 1 for a full overview). Over just half were female and employed, most were German and 20% had a high SES. 37% were aged 45-64 years, and almost 40% were living as a couple without children younger than 25 years old. 15% reported 'very good' self-rated health, almost 94% reported not being limited by chronic diseases in the last 6 months, more than 75% were never smokers. For BMI, 44.6% were of healthy weight (BMI: 18.5- 24.9 kg/m^2), 35.7% overweight (BMI: 25.0-29.99 kg/m^2) and 17.9% obese (BMI: ≥ 30 kg/m^2). For physical activity, only 22.6% met both guidelines, 6.7% met MSE only, 22.8% met MVPA only and 48% met neither guideline.

The unadjusted PRs and APRs for overweight and obesity by current physical activity guideline adherence (reference = 'meet neither') are shown in Table 2. Overall, PRs remained consistent after adjusting covariates. In the fully adjusted model, those meeting both guidelines had the lowest adjusted prevalence ratios (APRs) across all classes of overweight/obesity (APR range: 0.25-0.73), compared with other categories. For the overweight category, similar APRs were observed for MSE only and MVPA only. However, for Class I and Class II obesity, the APRs were lower among those meeting the MVPA guideline only, compared to MSE only. Across each physical activity category, the APRs were lowest for all physical activity categories for Class II obesity. Meeting double guidelines resulted in similar APRs across different physical activity categories for respondents in the overweight/obesity classes.

The results from the sensitivity analyses are shown in Table 3. Overall, in each stratified analysis, the APRs followed similar gradients for obesity to the total sample, with a lower likelihood of obesity among those with meeting both guidelines. In brief, similar associations between MVPA/MSE guideline adherence and overweight/obesity were observed for both sexes. For the age-stratified analyses, the APRs were consistently lower among the younger (APR range 0.25-0.82) compared to the older adults (APR range 0.22-0.90). Table 3 also shows that the APRs were lower among those reporting "excellent and good" self-rated health (APR range 0.24-.0.85) compared with those reporting "moderate to very poor" self-rated health (range 0.45-0.90), and for those reporting "no restrictions due to chronic diseases" (range 0.24-0.84) compared with those reporting restrictions (range 0.26-0.98).

DISCUSSION

Among a nationally representative sample of German adults, meeting both MVPA-MSE guidelines showed the lowest prevalence of overweight/obesity, compared to those within other guideline adherence categories. Moreover, the strength of association between MVPA-MSE and overweight/obesity was more pronounced among increasing levels of obesity.

While much is known about the benefits of aerobic MVPA on overweight/obesity (10, 11), less is known about the associations between MSE and combined MVPA-MSE. The present study is important because it suggests that a combination of MVPA-MSE is likely to be beneficial for maintaining a healthy weight. To our knowledge, this is the first study to report German data on associations between overweight/obesity and different activity categories according to national guidelines. The findings of the current study are consistent with the results based on US data (15). Also consistent with that US study, meeting double the MVPA-MSE guidelines was not associated with a significant reduction in obesity prevalence.

These findings seem to contradict the results of studies, which showed that weight loss and prevention of weight gain is most prominent when MVPA is above 150 min/week, especially above 300 MVPA min/week (31). However, it should be noted, that these recommendations are based on prospective studies. Our cross-sectional study, however, refers to a single time point without any insight into temporal associations. Therefore, our lack of dose-dependent associations between MVPA and BMI should be carefully interpreted.

While the epidemiological nature of the current study precludes any concise insights into the biological underpinnings of the key outcomes, there is some data from clinical exercise studies to support these findings. For example, systematic reviews have shown that the combination of MVPA and MSE significantly reduced body weight and fat mass while increasing lean body mass (32), and may improve cardiovascular endurance in individuals with class II and III obesity (33). Further clinical trials reported about beneficial impacts of the combined effects of MVPA and MSE of the individual cardiometabolic profile, including lower levels of fasting glucose, insulin sensitivity, and health-enhancing lipid status (34, 35).

The results show that joint MVPA-MSE should be an important component of lifestyle interventions for weight loss and the prevention of obesity. The prevalence of overweight, including obesity, in Germany, has remained high in recent years and has increased compared to GEDA 2010 (4). Therefore, physical activity should be given high priority both in terms of obesity prevention and weight loss measures. Since compliance with the full guidelines which include both MVPA-MSE was most effective in terms of obesity prevalence, the current study suggests that interventions should focus those with higher obesity levels. However, currently, most exercise programmes for overweight and obese individuals in Germany are aimed at the promotion of aerobic MVPA. Sports such as swimming, cycling

and walking are mostly recommended (e.g. programmes of health insurances and sports associations) (36). For a reduction in obesity prevalence, our analysis suggests that the additional inclusion of MSE twice a week in exercise programmes for overweight and obese individuals should also be pursued by exercise providers and physiotherapists.

Historically physical activity promotion has focused on aerobic MVPA, with MSE garnering limited attention (37). The findings presented here suggest that MSE is likely to have a key role in optimal health and wellbeing. This is all the more important against the background of the current COVID-19 pandemic. For example, MSE provides a suitable alternative to aerobic MVPA, as it can be performed within the home setting with the need for minimal equipment (e.g. bodyweight exercise, resistance bands) and reduces the need to leave this setting. Conversley, MSE is a particularly complex behaviour, as it requires a basic understanding of exercise prescription, as well as access to specialised equipment and professional instruction (38). Future studies are needed to examine how MSE can be effectively integrated into an individual's physical activity routines (e.g. using app-based technology, 'virtual' fitness trainers and the provision of equipment).

Strengths of the study are the nationwide survey, including a large and representative sample of German adults. The use of the EHIS-PAQ, a standardized physical activity assessment, allowing European comparisons in the future, is a further strength of the used data. The inclusion of MVPA and MSE as physical activity categories in their relationship to overweight/obesity in Germany is unique until now and therefore a further strength.

Limitations of the current study are the use of self-reported MVPA-MSE assessments instead of direct measurements (39). Known problems associated with self-reported physical activity

(e.g. over-/underreporting, social desirability) could be the case (40). However, self-reported physical activity assessments are still the most common method for large population samples. A further limitation is the lack of detailed energy intake data in addition to vegetable and fruit consumption since this is a key determinant of overweight and obesity. The low GEDA response rate of 27.2% could have biased the MVPA-MSE estimates and overweight/obesity prevalences despite using the accurate survey weighting to correct for non-response . It is most likely that non-responders are among the least active and most obese population. A further limitation is the cross-sectional analysis, which limits the ability for causal inferences between combined MVPA and MSE and overweight/obesity. However, our stratified analyses carried out to minimize the risk of reverse causation, suggested some potential for a causal association. For example, the APRs for overweight/obesity across all physical activity categories were consistently lower among the 'more healthy' compared with 'less healthy' population subgroups.

CONCLUSION

The aim of the current study was to examine whether meeting the guidelines for both MVPA and MSE is associated with a lower prevalence of overweight and obesity classes compared to meeting MVPA or MSE alone or none of them, among a nationally representative sample of German adults.

The results show, that adherence to the combined MVPA and MSE guideline, as proposed in the German national physical activity recommendations, was associated with a reduced prevalence of overweight and obesity. Thus, the results suggest that the public health burden of obesity may be reduced with the promotion of uptake and adherence of both MVPA and MSE at the population level. Future longitudinal studies are needed to confirm the preliminary cross-sectional data presented in the current study.

Declaration of conflict of interests

The authors declare that they have no conflict of interests.

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Table 1: Weighted[a] sample characteristics and 95% confidence intervals (95% CI), physical activity levels[b,c], BMI[d] classifications, and sociodemographic, health and lifestyle factors.

	N[e]	**Weighted % (95% CI)**
Total sample	22,822	
Characteristics		
Female	12,432	50.5 (49.7-51.3)
45-64 years	8,658	37.1 (36.3-37.8)
German	21,956	96.4 (96.0-96.7)
High SES	6,475	20.6 (20.0-21.1)
Employed	14,462	63.5 (62.7-64.3)
Household type: Couple without child(ren)<25	8,640	39.6 (38.8-40.4)
Very good self-rated health	3,714	15.2 (14.6-15.8)
Not being restricted by chronic disease in the last 6 months	22,598	93.8 (93.3-94.2)
Never smoked	17,597	75.8 (75.1-76.5)
Daily fruit and vegetable servings, mean (95% CI)	22,493	2.27 (2.2-2.3)
BMI (kg/m^2)[d]		
Underweight (<18.5)	428	1.9 (1.7-2.1)
Normal (≥18.5-<25)	10,570	44.6 (43.8-45.4)

	N[e]	Weighted % (95% CI)
Overweight (25– <30)	7,839	35.7 (34.9-36.4)
Obese I (≥30)	2,657	12.5 (12.0-13.1)
Obese II (≥35)	776	3.6 (3.3-3.9)
Obese III (≥40)	360	1.8 (1.5-2.0)
Physical activity guidelines[b]		
Meet neither	10,467	48.0 (47.2-48.8)
MSE only	1,555	6.7 (6.3-7.1.)
MVPA only	5,447	22.8 (22.1-23.4)
Meet both	5,353	22.6 (21.9-23.2)

[a] Sample weights provided by GEDA 2014 (29)
Physical activity levels:
[b] Guidelines: Meet neither: MVPA = 0-149 min/wk and MSE < 2 sessions/wk; MSE only: MSE ≥ 2 sessions/wk and MVPA = 0-149 min/wk; MVPA only: MVPA ≥ 150 min/wk and MSE < 2 sessions/wk; and Meet both: MVPA ≥ 150 min/wk and MSE ≥ 2 sessions/wk.
[c] BMI calculated from self-reported height and weight.
[e] unweighted numbers; numbers different because of missing responses; missing cases as follows: nationality n=151 (0.6%), SES n=41 (0.2%), Employment status n=214 (0.9%), household type n=1098 (4.8%), self-rated health n=99 (0.4%), being restricted by chronic conditions n=224 (1%), smoking status n=40 (1.8%), fruit and vegetable servings per day n=329 (1,4 %), BMI n=192 (0.8%)

Table 2: Prevalence ratios[a] (PR) describing the association between physical activity (PA) guideline adherence[b] and class-specific body mass index[c]-derived obesity (n=22,822).

Body mass index[c] kg/m^2		**PA guideline adherence[b]**	**Unadjusted PR[a] (95% CI)**	**n included**	**Adjusted[d] PR (95% CI)**	**n included**
≥25.0 'overweight and above'[e]		Meet neither	1 (reference)	22,202	1 (reference)	20,338
		MSE only	0.85 (0.79-0.92)		0.84 (0.77-0.91)	
		MVPA only	0.84 (0.80-0.88)		0.84 (0.80-0.88)	
		Meet both	0.73 (0.70-0.77)		0.73 (0.69-0.77)	
≥30.0 'Class I obesity and above'[e]		Meet neither	1 (reference)	14.363	1 (reference)	13,182
		MSE only	0.72 (0.63-0.81)		0.69 (0.60-0.79)	
		MVPA only	0.59 (0.54-0.64)		0.58 (0.53-0.64)	
		Meet both	0.42 (0.38-0.46)		0.41 (0.37-0.45)	
≥35.0 'Class II obesity and above'[e]		Meet neither	1 (reference)	11,706	1 (reference)	10,748
		MSE only	0.63 (0.50-0.79)		0.57 (0.44-0.73)	
		MVPA only	0.38 (0.32-0.45)		0.38 (0.32-0.45)	
		Meet both	0.25 (0.21-0.31)		0.25 (0.20-0.30)	
≥25.0 'overweight and above'[e]		**Double PA guidelines[f]**				
		Meet neither	1 (reference)	22,202	1 (reference)	20,338
		MSE only	0.84 (0.77-0.93)		0.84 (0.76-0.93)	
		MVPA only	0.84 (0.80-0.89)		0.84 (0.80-0.88)	
		Meet both	0.77 (0.70-		0.77	

			0.84)		(0.70-0.85)	
≥30.0 'Class I obesity and above'[e]		Meet neither	1 (reference)	14,363	1 (reference)	13,182
		MSE only	0.62 (0.51-0.74)		0.60 (0.49-0.73)	
		MVPA only	0.58 (0.53-0.64)		0.58 (0.52-0.64)	
		Meet both	0.31 (0.29-0.32)		0.39 (0.31-0.48)	
≥35.0 'Class II obesity and above'[e]		Meet neither	1 (reference)	11,706	1 (reference)	10,748
		MSE only	0.54 (0.38-0.74)		0.45 (0.30-0.65)	
		MVPA only	0.37 (0.31-0.45)		0.38 (0.31-0.47)	
		Meet both	0.21 (0.13-0.32)		0.21 (0.12-0.33)	

[a] PR calculated using Poisson regression with a robust error variance.

[b] Physical activity levels: 'Meet neither': MVPA=0-149 mins/week & MSE <2 sessions/week; 'MSE only': MSE ≥2 sessions/week & MVPA=0-149 mins/week); 'MVPA only': MVPA≥150 mins/week & MSE<2 sessions/week; and 'Meet both': MVPA≥150 mins/week & MSE ≥2 sessions/week.

[c] Body mass index calculated from self-report height and weight.

[d] Prevalence ratio adjusted for sex, age, race/ethnicity, employment status, SES, type of household, smoking, self-rated health, fruit/vegetable intake and being restricted by chronic conditions in the past 6 months

[e] Dichotomous outcome: 'healthy weight' (BMI 18.5-24.9 kg/m^2) vs indicated overweight group/obesity category of interest

[f] Physical activity levels: 'Meet neither': MVPA=0-299 mins/week & MSE <4 sessions/week; 'MSE only': MSE ≥4 sessions/week & MVPA=0-299 mins/week); 'MVPA only': MVPA≥300 mins/week & MSE<4 sessions/week; and 'Meet both': MVPA≥300 mins/week & MSE ≥4 sessions/week

Table 3: Adjusted prevalence ratios[a] (PR) of class-specific body mass index[c]-derived obesity according to PA guideline adherence: stratified by sex, age and self-rated health (n=22,822).

		Sex-stratified			
Body mass index[c] kg/m^2	**PA guideline adherence[b]**	**Males**		**Females**	
		APR[d] (95% CI)	**n included**	**APR (95% CI)**	**n included**
≥25.0 'overweight and above'[e]	Meet neither	1 (reference)	9,383	1 (reference)	10,955
	MSE only	0.88 (0.79-0.98)		0.79 (0.70-0.89)	
	MVPA only	0.90 (0.84-0.96)		0.75 (0.69-0.80)	
	Meet both	0.78 (0.73-0.84)		0.64 (0.59-0.69)	
≥30.0 'Class I obesity and above'[e]	Meet neither	1 (reference)	5,205	1 (reference)	7,977
	MSE only	0.70 (0.57-0.85)		0.69 (0.57-0.83)	
	MVPA only	0.63 (0.55-0.71)		0.54 (0.48-0.61)	
	Meet both	0.40 (0.34-0.46)		0.40 (0.35-0.46)	
≥35.0 'Class II obesity and above'[e]	Meet neither	1 (reference)	3,951	1 (reference)	6,797
	MSE only	0.55 (0.36-0.81)		0.59 (0.43-0.81)	
	MVPA only	0.36 (0.27-0.47)		0.40 (0.32-0.49)	
	Meet both	0.20 (0.14-0.27)		0.28 (0.21-0.36)	
		Age-stratified			
		18-64 years		**65+ years**	
		APR[d] (95% CI)		**APR (95% CI)**	
≥25.0 'overweight and above'[e]	Meet neither	1 (reference)	15,947	1 (reference)	4,391
	MSE only	0.80 (0.72-0.88)		0.89 (0.77-1.02)	
	MVPA only	0.82 (0.77-0.87)		0.90 (0.82-0.99)	
	Meet both	0.71		0.81	

		(0.66-0.75)		(0.73-0.89)	
≥30.0 'Class I obesity and above'[e]	Meet neither	1 (reference)	10,742	1 (reference)	2,440
	MSE only	0.64 (0.54-0.75)		0.78 (0.61-0.98)	
	MVPA only	0.56 (0.51-0.62)		0.68 (0.57-0.80)	
	Meet both	0.39 (0.34-0.43)		0.49 (0.40-0.59)	
≥35.0 'Class II obesity and above'[e]	Meet neither	1 (reference)	8,962	1 (reference)	1,786
	MSE only	0.54 (0.40-0.72)		0.63 (0.38-0.99)	
	MVPA only	0.38 (0.31-0.45)		0.42 (0.29-0.61)	
	Meet both	0.25 (0.20-0.32)		0.22 (0.13-0.35)	
		Self-rated health-stratified			
		"Excellent to good"		**"Medium to very poor"**	
		APR[d] (95% CI)		**APR (95% CI)**	
≥25.0 'overweight and above'[e]	Meet neither	1 (reference)	14,572	1 (reference)	5,766
	MSE only	0.80 (0.72-0.89)		0.89 (0.79-1.01)	
	MVPA only	0.85 (0.81-0.91)		0.90 (0.83-0.98)	
	Meet both	0.73 (0.69-0.78)		0.86 (0.79-0.95)	
≥30.0 'Class I obesity and above'[e]	Meet neither	1 (reference)	9,565	1 (reference)	3,617
	MSE only	0.59 (0.47-0.72)		0.82 (0.68-0.98)	
	MVPA only	0.59 (0.53-0.66)		0.76 (0.66-0.86)	
	Meet both	0.39 (0.34-0.44)		0.65 (0.55-0.76)	

≥35.0 'Class II obesity and above'[e]	Meet neither	1 (reference)	8,194	1 (reference)	2,554
	MSE only	0.46 (0.29-0.69)		0.69 (0.49-0.93)	
	MVPA only	0.41 (0.32-0.52)		0.54 (0.42-0.68)	
	Meet both	0.24 (0.18-0.32)		0.45 (0.33-0.59)	
		Restricted by chronic disease in the last 6 months			
		No		**Yes**	
		APR[a] (95% CI)		**APR[a] (95% CI)**	
≥25.0 'overweight and above'[e]	Meet neither	1 (reference)	19,261	1 (reference)	1,077
	MSE only	0.81 (0.75-0.89)		0.98 (0.78-1.22)	
	MVPA only	0.84 (0.80-0.89)		0.85 (0.66-1.08)	
	Meet both	0.73 (0.69-0.77)		0.89 (0.71-1.10)	
≥30.0 'Class I obesity and above'[e]	Meet neither	1 (reference)	12,509	1 (reference)	673
	MSE only	0.65 (0.56-0.75)		0.94 (0.66-1.29)	
	MVPA only	0.59 (0.54-0.65)		0.70 (0.46-1.01)	
	Meet both	0.40 (0.36-0.45)		0.68 (0.46-0.97)	
≥35.0 'Class II obesity and above'[e]	Meet neither	1 (reference)	10,261	1 (reference)	487
	MSE only	0.54 (0.40-0.71)		0.70 (0.37-1.20)	
	MVPA only	0.41 (0.35-0.49)		0.26 (0.09-0.58)	
	Meet both	0.24 (0.19-0.30)		0.56 (0.30-0.95)	

[a] PR calculated using Poisson regression with a robust error variance.

[b]Physical activity levels: 'Meet neither': MVPA=0-149 mins/week & MSE <2 sessions/week; 'MSE only': MSE ≥2 sessions/week & MVPA=0-149 mins/week); 'MVPA only': MVPA≥150 mins/week & MSE<2 sessions/week; and 'Meet both': MVPA≥150 mins/week & MSE ≥2 sessions/week.

[c] Body mass index calculated from self-report height and weight.

[d]Prevalence ratio adjusted for sex, age, race/ethnicity, employment status, education, SES, smoking, self-rated health, fruit/vegetable intake and being restricted by chronic conditions in the past 6 months

[e]Dichotomous outcome: 'healthy weight' (BMI 18.5-24.9 kg/m^2) vs indicated overweight group/obesity category of interest

Appendix Table 1: Weighted[a] sample characteristics, physical activity levels[b,c], BMI[d] classifications, and sociodemographic, health and lifestyle factors. sociodemographic, health and lifestyle factors.

	N[f]	**Weighted % (95% CI)**
Total	22,822	
Sex		
Male	10,390	49.5 (48.7-50.3)
Female	12,432	50.5 (49.7-51.3)
Age (years)		
18-29	3,825	17.5 (16.9-18.1)
30-44	5,224	23.0 (22.3-23.6)
45-64	8,658	37.1 (36.3-37.8)
≥65	5,115	22.5 (21.8-23.2)
Nationality		
German	21,956	96.4 (96.0-96.7)
Non-German, but EU	398	1.8 (1.6-2.0)
Non-German, non EU	317	1.8 (1.6-2.1)
SES		

	N[f]	Weighted % (95% CI)
Low	3,507	19.4 (18.7-20.1)
Medium	12,799	60.1 (59.3-60.8)
High	6,475	20.6 (20.0-21.1)
Employment status		
Student	871	3.3 (3.0-3.6)
Employed	14,462	63.5 (62.7-64.3)
Unemployed	540	2.7 (2.4-2.9)
Military of community service	45	0.2 (0.1-0.3)
Homemaker	496	2.5 (2.2-2.7)
Retired	5,110	22.9 (22.2-23.6)
Unable to work	387	1.9 (1.7-2.1)
Other reasons	697	3.1 (2.8-3.4)
Household type		
Single person household	4,169	19.6 (19.0-20-3)
Single parent with child(ren) < 25	540	2.3 (2.1-2.5)
Couple without child(ren)<25	8,640	39.6 (38.8-40.4)
Couple with child(ren) <25	5,057	22.6 (21.9-23.3)
Couple with child(ren)<25 and other persons in the household	413	2.0 (1.8-2.3)
Other	2,905	13.9
Self-rated health		
Very good	3,714	15.2 (14.6-15.8)
Good	12,431	53.9 (53.1-54.7)
Moderate	5,516	25.6 (24.9-26.4)
Poor	930	4.5 (4.2-4.9)
Very poor	132	0.7 (0.6-0.9)
Being restricted by chronic disease in the last 6 months		
No	21,341	93.8 (93.3-94.2)
Yes	1,257	6.2 (5.8-6.7)

	N[f]	Weighted % (95% CI)
BMI (kg/m^2)[f]		
Underweight (<18.5)	428	1.9 (1.7-2.1)
Normal (≥18.5-<25)	10,570	44.6 (43.8-45.4)
Overweight (25– <30)	7,839	35.7 (34.9-36.4)
Obese I (≥30)	2,657	12.5 (12.0-13.1)
Obese II (≥35)	776	3.6 (3.3-3.9)
Obese III ((≥40)	360	1.8 (1.5-2.0)
Smoking status		
daily	3,869	18.7 (18.1-19.4)
occasionally	1,316	5.5 (5.2-5.9)
never	17,597	75.8 (75.1-76.5)
Daily fruit and vegetable servings, mean (95% CI)	22,493	2.27 (2.2-2.3)
Physical activity guidelines[b]		
Meet neither	10,467	48.0 (47.2-48.8)
MSE only	1,555	6.7 (6.3-7.1)
MVPA only	5,447	22.8 (22.1-23.4)
Meet both	5,353	22.6 (21.9-23.2)

[a] Sample weights provided by GEDA 2014 (29)

Physical activity levels:

[b] Guidelines: Meet neither: MVPA = 0-149 min/wk and MSE < 2 sessions/wk; MSE only: MSE ≥ 2 sessions/wk and MVPA = 0-149 min/wk; MVPA only: MVPA ≥ 150 min/wk and MSE < 2 sessions/wk; and Meet both: MVPA ≥ 150 min/wk and MSE ≥ 2 sessions/wk.

[d] BMI calculated from self-reported height and weight.

[f] Unweighted numbers; numbers different because of missing responses; missing cases as follows: nationality n=151 (0.6%), SES n=41 (0.2%), Employment status n=214 (0.9%), household type n=1098 (4.8%), self-rated health n=99 (0.4%), being restricted by chronic conditions n=224 (1%), smoking status n=40 (1.8%), fruit and vegetable servings per day n=329 (1,4 %), BMI n=192 (0.8%)