BMJ Open

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population. Findings from the German health interview and examination survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034610
Article Type:	Original research
Date Submitted by the Author:	27-Sep-2019
Complete List of Authors:	Zeiher, Johannes; Robert Koch Institut, Department of Epidemiology and Health Monitoring Duch, Maurice; Robert Koch Institut, Department of Epidemiology and Health Monitoring; University of Potsdam, Department of Sports and Health Sciences Kroll, Lars; Central Research Institute of Ambulatory Health Care in Germany Mensink, Gert; Robert Koch Institut Finger, Jonas D.; Robert Koch Institut, Department of Epidemiology and Health Monitoring Keil, Thomas; Bavarian Health and Food Safety Authority, State Institute of Health; Charité Universitätsmedizin Berlin, Institute for Social Medicine, Epidemiology and Health Economics
Keywords:	cardiorespiratory fitness, adults, physical activity, physical fitness, occupational physical activity

Research article

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population. Findings from the German health interview and examination survey

Johannes Zeiher[a]*, Maurice Duch[a,b], Lars E. Kroll[c], Gert B. M. Mensink[a] Jonas D. Finger[a] Thomas Keil[d,e,f]

[a] Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin, Germany
[b] University of Potsdam, Potsdam, Germany
[c] Central Research Institute of Ambulatory Health Care in Germany, Berlin, Germany
[d] Institute for Clinical Epidemiology and Biometry, University of Würzburg, Würzburg, Germany
[e] State Institute of Health, Bavarian Health and Food Safety Authority, Bad Kissingen, Germany
[f] Institute for Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin Berlin, Berlin, Germany

* Corresponding author:
Johannes Zeiher
Unit of Health Behaviour
Department of Epidemiology and Health Monitoring
Robert Koch Institute
General-Pape-Straße 62-66
12101 Berlin, Germany
Email: zeiherj@rki.de
Phone: 0049 30 18754 3775

Word count (main text): 3,469 words

ABSTRACT

Objectives:

This study aims to investigate the associations of patterns occupational physical activity (OPA) and leisure time PA (LTPA) with cardiorespiratory fitness (CRF) among men and women from the German working population.

Design:

Population-based cross-sectional study

Setting:

Two-stage cluster-randomized general population sample selected from population registries of 180 nationally distributed sample points. Information was collected from 2008 to 2011.

Participants:

1,296 women and 1,199 men aged 18-64 from the resident working population.

Outcome measure:

Estimated low maximal oxygen consumption ($\dot{V}O_2max$), defined as 1st and 2nd sex-specific quintile, assessed by a standardized, submaximal cycle ergometer test.

Results:

A strong association between low LTPA and low estimated $\dot{V}O_2max$, but not between OPA and low $\dot{V}O_2max$ was observed. The association of domain-specific PA patterns with low $\dot{V}O_2max$ varied by sex: women without LTPA engagement and with high OPA level showed the highest likelihood of having a low $\dot{V}O_2max$ (odds ratio (OR) 6.54; 95%-confidence interval (CI) 2.98 to 14.3) compared to women with ≥ 2 hours of LTPA and high OPA. Among men, those with no LTPA and low OPA level showed the highest risk of low $\dot{V}O_2max$ (OR 4.37; 95%-CI 2.02 to 9.47).

Conclusion:

Our results showed a strong association between LTPA and CRF and suggest an interaction between OPA and LTPA patterns on CRF within the adult working population in Germany. Women without LTPA are at high risk of having a low CRF, especially if they work in physically demanding jobs. Further investigation is needed to elucidate the pathways through which different domains of PA lead to divergent health effects and to develop suitable measures to enhance the PA level of identified populations groups at risk.

KEYWORDS

cardiorespiratory fitness; adults; physical activity; physical fitness; occupational physical activity

ARTICLE SUMMARY

Strengths and limitations of this study

1. This is among the first study to examine the association of leisure time and occupational physical activity patterns with cardiorespiratory fitness in Germany.
2. We used a large nationally representative population-based sample of the resident adult working population, which allows the generalizability of our findings.
3. Leisure-time physical activity was assessed by self-reports which may be prone to recall and social desirability bias.

BACKGROUND

Physical activity (PA) is crucial for health and the unfavorable effects of an increasing sedentary lifestyle are acknowledged as a major public health challenge (1, 2). PA, defined as all bodily movement produced by skeletal muscles that require energy expenditure (3), has a positive influence on physical and mental health and contributes to the prevention of non-communicable diseases and premature mortality (1). Throughout the individual daily routine and life course, PA can appear in different forms and can take place in different domains. For example, one may participate in sports during leisure time (leisure time physical activity, LTPA) or be active during work (occupational physical activity, OPA). To date, PA in any form and setting has been considered as beneficial and recent recommendations do not distinguish between PA domains. The current WHO guideline recommends at least 150 minutes of moderate intensity aerobic exercise per week, stating that "[…] Physical activity includes leisure time physical activity, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities." (3, p. 8)

Even if manual and physical demanding occupations are declining in the historical perspective, especially in high income economies, OPA still makes up a large part of the daily amount of PA (4). While the beneficial effects of LTPA are well established, the results regarding OPA are inconclusive. Studies in the past often argued that OPA should also be considered as health enhancing PA (5), but recent studies suggest that OPA has no health-enhancing or even contrary effects (6, 7). As a possible explanation for this 'health paradox', the domain-specific effects of PA on cardiorespiratory fitness (CRF) has come to attention (8, 9). Defined as the ability of circulatory, respiratory and muscular systems to supply oxygen during prolonged physical exercise (3), CRF can be enhanced by regular endurance exercise (10) and is a strong predictor of adverse health outcomes (11). It has been argued, that OPA rarely has the adequate intensity, duration, and volume to induce positive changes in CRF (8, 9, 12).

However, data on the association of different domains of PA and CRF for Germany is limited. Notably, the interplay between these different domains has yet not been analyzed. Following an explorative approach rather than hypothesis testing, this study aims to investigate the associations between patterns of OPA and LTPA and CRF among men and women from the German working population.

METHODS

Study design

Data was derived from the nationwide cross-sectional German Health Interview and Examination Survey for Adults (DEGS1). DEGS1 is part of the Federal Health Monitoring System administered by the Robert Koch Institute (13). In detail, the study design is described elsewhere (14). Briefly, the study is based on a two-stage cluster randomized sampling procedure. First, 180 sample points were sampled from a list of German communities stratified to represent regional distribution. Second, within these units, adult individuals were randomly drawn from local population registries stratified by 10-year age groups. The response rate was 42%. A total of 5,262 participants aged 18–64 years took part in the physical measurements component of the DEGS1 from November 2008 to December 2011. Out of the gross sample 3,110 individuals were categorized as test-qualified for the exercise test (Figure S1, Online Supplemental Material). Overall, 3,030 participants completed the exercise test (participation rate 97.4 %). $\dot{V}O_2max$ was estimated for all participants reaching at least 75% of the age-predicted maximum heart rate. Two hundred and four participants terminated the test before reaching this heart rate. As a result, $\dot{V}O_2max$ was calculated for 2.826 participants. Overall, 1,296 working women and 1,199 working men had valid information on $\dot{V}O_2max$, OPA and LTPA.

Patient and public involvement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Outcome variable

CRF was measured using a standardized, submaximal cycle ergometer test (Ergosana Sana Bike 350/450, Ergosana, Bitz, Germany). Test methodology, protocol, and exclusion criteria were in detail already described elsewhere (15-17). The participants initially complete a modified version of the Physical Activity Readiness Questionnaire (PAR-Q) (18, 19). Participants saw a physician if PAR-Q contraindications were reported and the physician decided whether or not the participant should be enrolled into the exercise test. CRF was assessed using the test protocol recommended by the World Health Organization (WHO) (20): Beginning at 25 watts, the workload was incrementally increased by 25 watts every two minutes until 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 watts was achieved or the study staff terminated the test. Heart rate was monitored continuously throughout the test. The formula $208 - 0.7 \cdot Age$ was used to calculate the age-predicted maximum heart rate (HR_{max}) (21). To derive physical work capacity at HR_{max} ($PWC_{100\%}$), the measured heart rate (beats per minute) during the incremental phase was regressed against corresponding workload in watts for each participant. Assuming a linear relationship between heart rate and workload, $PWC_{100\%}$ was obtained by extrapolation using the individual regression equation $PWC_{100\%} = intercept + HR_{max} \cdot slope$ (22). $PWC_{100\%}$ was further converted to $\dot{V}O_2max$ using a metabolic equation provided by the American College of Sports Medicine (23): $3.5\ ml \cdot min^{-1} \cdot kg^{-1} + 12.24 \cdot (PWC_{100\%}) \cdot (body\ weight^{-1})$. According to sex-specific quintiles, estimated $\dot{V}O_2max$ was categorized into low $\dot{V}O_2max$ (quintile 1-2) and intermediate to high $\dot{V}O_2max$ (quintile 3-5) quintile), as meta-analyses show, that individuals in the low fitness group compared to the high fitness group have a 70 % higher risk of all-cause mortality (11).

Exposure variable

Occupational physical activity: a physical work demands index

To assess PA at work we used an indirect method and developed job exposure matrices (JEMs) that can distinguish the participant's occupation by the criterion of physical demands. JEMs are an established methodological tool allowing for inclusion of specific occupational exposures in analyses based on studies that assess information about the participant's occupational titles, even if the individual exposure is not assessed. JEMs are constructed using available secondary data to determine exposure profiles for each occupation and matching these profiles to the primary data using standardised job-classifications. In our case, JEMs were constructed using data of a large-scale representative study on working conditions of n = 20,000 employees in Germany (24, 25). It was part of the European Working Conditions Survey, which is regularly conducted in the member states of the European Union. The Overall Job Index and specific indexes were already described and applied elsewhere (26-28). In this study, we used a specific sub-index of perceived physical work demands. Based on hierarchic multilevel analyses adjusted for sex, age, job experience and part time employment, the physical demand index was assigned to the occupations and these JEMs were then classified into deciles. . Occupations with the lowest level of physical work demands have a value of 1 (First decile), and those with the highest level have a value of 10 (tenth decile). Using the International Classification of Occupations of 1988 (ISCO-88), the JEMs were matched to DEGS1. This index was then dichotomized in a 'low OPA' (index values 1-7) and a 'high OPA' category (index values 8-10). A list of the most frequent occupations in DEGS1 according to OPA level for men and women is presented in Table S1 (Online Supplemental Material).

Leisure time physical activity: physical exercise

LTPA was assessed by asking participants "How often do you engage in physical exercise?" [38]. Even though LTPA is usually referring to all PA in their freely disposable time, sport and exercise constitute the core area of LTPA (29) and are therefore used as a proxy for LTPA in this study. Responses were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week. For the analyses, the categories of the five-point scale "less than 1 h a week" and "regularly 1-2 h a week", "regularly up to 4 h" and "regularly more than 4 h" were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.

Combined variable of occupational and leisure time physical activity

To analyse the interactional effect of OPA and LTPA on CRF, we generated a combined variable containing the categories no LTPA/low OPA, no LTPA/high OPA, <2h LTPA/low OPA, <2h LTPA/high OPA, ≥2h LTPA/low OPA, and ≥2h LTPA/high OPA.

Covariates

Relevant covariates were selected based on evidence in the literature (17, 30). Age was categorised into five groups: 18-24 years, 25-34 years, 35-44 years, 45-54 years and 55-64 years. Smoking was grouped into daily, occasionally, former and never smoking. Alcohol intake was estimated by multiplying the calculated quantity of each alcoholic beverage, assessed by a food frequency questionnaire, with standard ethanol content (beer: 4.8%; wine: 11%, spirits: 33%) and classified into low alcohol consumption (quintile 1), medium alcohol consumption (quintile 2-4), and high alcohol consumption (quintile 5) using sex-specific quintiles. Body height and weight was measured by standardized procedures. Body mass index (kg/m^2) was categorized according to WHO guidelines (31). Waist circumference was measured at the smallest site between the lowest rib and the superior border of the iliac crest and categorized as 'normal', 'increased' and 'strongly increased' according to international guidelines (32). Socioeconomic status (SES) was determined using a composite additive index, based on information about participants' education, occupational position and net equivalent income (33).

Statistical Analyses

Prevalence and 95% confidence intervals (CI) of low $\dot{V}O_2max$ were calculated for OPA, LTPA and covariates. Multivariable logistic regression models were computed to estimate the associations between domains of PA and low $\dot{V}O_2max$. In a first step, separate models for OPA and LTPA were fitted, in a second step the combined variable of OPA*LTPA was used. In both steps an age-adjusted model and a model adjusting for body mass index, waist circumference, smoking, alcohol intake and SES were fitted. Finally, we computed predicted margins (34) from the final logistic regression model to plot adjusted prevalences of low $\dot{V}O_2max$ according to domain specific PA. All analyses were conducted separately for men and women to identify sex-specific physical activity patterns associated with CRF and to reduce potential sex bias. Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA) and conducted with a weighting factor to adjust for distribution of the sample by sex, age, education, and region to match the German population. Stata's survey procedures were applied to account for the clustered sampling design.

RESULTS

Participants

Table 1 illustrates demographic, anthropometric and health behavior variables from this representative sample of the adult working population of Germany. Women comprised 48.0 % of the sample, the mean age of the participants was 39.6 years (range 18-64years). Generally, unweighted and weighted percentage did not differ substantially.

<<< Table 1 about here >>>

OPA and LTPA

Prevalence of high OPA was 40.3% among men and 33.0% among women (Table 1). Among men, 24.9% did not engage in LTPA, whereas 39.8% engaged in LTPA less than two hours per week, and 35.3% two hours or more per week. Among women, the corresponding LTPA prevalences were 24.7%, 49.9%, and 25.3%, respectively. While LTPA did not vary according to OPA level among men, women with high OPA were less likely to engage in LTPA for two hours or more per week than women with low OPA (Table 2).

<<< Table 2 about here >>>

low $\dot{V}O_2max$

Overall, the prevalence of estimated low $\dot{V}O_2max$ was 41.2% (95% CI 37.6 to 44.8) among men and 40.5% among women (95% CI 37.1 to 44.0). Table 3 presents the prevalence of low $\dot{V}O_2max$ by domain specific PA and sociodemographic, health behavior and anthropometric variables. Binary analyses showed that men and women with higher LTPA levels had a substantial lower prevalence of low $\dot{V}O_2max$. While there were no relevant differences in low $\dot{V}O_2max$ regarding OPA among men, women with high OPA showed a higher prevalence of low $\dot{V}O_2max$ compared to women with low OPA.

<<< Table 3 about here >>>

Multivariable analyses (Table 4) showed that women in jobs with high levels of OPA were more likely to have a low estimated $\dot{V}O_2max$ when adjusting only for age (OR 1.71; 95% CI 1.23 to 2.36). This association disappeared when controlling for LTPA and other covariates (OR 1.06; 95% CI 0.75 to 1.49). Among men, both models showed no association between low $\dot{V}O_2max$ and OPA (OR 1.05; 95% CI 0.75 to 1.46 and OR 0.95; 95% CI 0.64 to 1.42, respectively).

<<< Table 4 about here >>>

Men and women with no or a low level of engagement in LTPA (i.e. less than 2 hours per week) showed a considerable higher chance of having a low $\dot{V}O_2max$ than participants with 2 hours or more of LTPA. The effect size did not change considerably when adjusting for OPA and other controls.

Multivariable analyses of the combined OPA/LTPA variable (fully-adjusted model) showed, that less-active men were more likely to have a low $\dot{V}O_2max$ with ORs of 4.37 (95% CI 2.02 to 9.47) for no LTPA/ low OPA, 11.1 (95% CI 5.15 to 24.1) for no LTPA/ high OPA, 2.84 (95% CI 1.39 to 5.78) for <2h LTPA/low OPA, 4.01 (95% CI 1.90 to 8.49) for <2h LTPA/high OPA, 1.37 (95% CI 0.64 to 2.92) for ≥2h LTPA /low OPA compared to men with ≥2h LTPA /high OPA. The corresponding ORs for women were 6.54 (95% CI 2.98 to 14.3), 10.5 (95% CI 4.39 to 24.9), 3.52 (95% CI 1.75 to 7.09), 3.69 (95% CI 1.80 to 7.60), 1.93 (95% CI 0.90 to 4.13), indicating the highest likelihood of low fitness for women working in physically demanding jobs and not engaging in LTPA.

Based on the final model with the combined OPA/LTPA variable, we plotted predicted probabilities of having a low $\dot{V}O_2max$ to illustrate these different patterns between men and women (Figure 1).

<<< Figure 1 about here >>>

DISCUSSION

Summary of results

This cross-sectional study showed a strong association between low LTPA and low estimated $\dot{V}O_2max$, but not between OPA and $\dot{V}O_2max$. Furthermore, the association of domain-specific PA patterns with low $\dot{V}O_2max$ varied according to sex: After adjustment for potential confounding, women not participating in LTPA and working in highly physically demanding occupations showed the highest likelihood of having a low $\dot{V}O_2max$. In contrary, men that did not engage in LTPA and not working in physically demanding occupations showed the highest risk of low $\dot{V}O_2max$.

Comparison with findings from other studies

The strong association between LTPA and CRF has been shown in numerous studies (30). In contrast, evidence of the association of OPA with CRF is inconclusive. In a historical perspective, OPA has often been considered as health enhancing in behavioral medicine, but is traditionally seen as a potential health hazard in occupational medicine (6). Recent studies support the thesis that OPA does not lead to increased CRF (35-38). A Swiss study among adults reported no association between amount of steps during work-time and $\dot{V}O_2max$, and a lower $\dot{V}O_2max$ among participants having conducting manual work compared to those with sedentary work, while controlling for LTPA and various covariates (35). A study among regional samples from Germany also found higher levels of $\dot{V}O_2max$ among participants with high levels of LTPA, but lower levels of $\dot{V}O_2max$ among participants with high OPA compared to low OPA (37). Another study among the Danish working population observed that work and leisure sitting time were differently associated with $\dot{V}O_2max$: while there was a strong negative association between sitting leisure time and $\dot{V}O_2max$, a similar association was not observed with sitting time at work (39). In contrast, a study among male workers from Japan found higher levels of $\dot{V}O_2max$ among those with high OPA compared to low OPA (40) and a study from Finland found a positive association of CRF and OPA even after adjustment for LTPA among men (41).

Irrespective of the association of OPA with individual fitness, OPA and LTPA has been linked to negative health outcomes: in a meta-analysis Li and colleagues (6) found evidence that OPA might increase the risk of cardio vascular disease, while LTPA considerably reduced the risk. Another current meta-analysis found that men with high OPA had an increased risk of preliminary mortality, but women did not (7). In particular, the combination of high OPA with low CRF seems to be associated with a higher risk of adverse cardiovascular outcomes (42, 43).

Potential working mechanisms

It has been shown that regular aerobic exercise induces biological changes like increased stroke volume and decrease in venous oxygen content that lead to increased individual CRF (10). This exercise should ideally be performed with sufficient intensity at ≥ 50% of the maximal aerobic capacity (10). LTPA, as far as it referring to sport activity, is usually activity of relatively short duration but high intensity and contains sufficient recovery time between the occasions. OPA, on the other hand, can be of too long duration, of too low intensity and with limited control about work speed and duration (9, 44). Therefore, no sufficient recovery is possible, as individuals can't decide how to perform and when to interrupt their work themselves.

The observed results suggest, that the association of domain-specific PA and CRF vary between men and women. Among women with low levels of LTPA, high OPA is associated with lower fitness. As Table S1 shows, men with physically demanding occupation mainly work in manual and technical professions (e.g., electricians, plumbers, mechanics) while women in physically demanding jobs work mainly in the service sector (e.g. nursing/care, catering, and cleaning). The latter jobs, mainly performed by females, are particularly affected by limited work control and higher job-strain, which may be a possible explanation for these gender-specific patterns. For example, health care workers in Germany report very high level of job demands compared with the average level of all occupations while having a low decision-making autonomy (45) (46, p. 76-84). This would be of special concern as studies have shown, that high strain-jobs can lead to lower LTPA (47) and high occupational stress in combination with low CRF has been shown to considerably increase the cardiovascular risk (48).

When recommending higher levels of LTPA, one should consider the embedded and dependent relationship of the different domains of PA: First, OPA and LTPA are not the exclusive domains of PA; transportation and domestic activities are also relevant. This is of importance, because like OPA both of these domains can also be described non-discretionary time (49) with limited autonomy by the individual. Second, performing PA in all of these domains does depend on structures at the societal, environmental and individual level (50). As individuals face varying obstacles to engage in more LTPA like cultural temporal structures (e.g., public-transport timetables) or individual responsibilities (e.g. parenthood), measures and policies aiming to create a activity friendly environment are needed rather than blaming the individual (1).

Strengths and Limitations

A major strength of this study is the use of a large population-based nationally representative sample of the non-institutionalized, resident adult working population, which allows the generalizability of our findings.

However, even though in DEGS1 great efforts have been taken to reduce potential sources of bias (51, 52), the results of our study need to be interpreted in the context of some limitations. First, the cross-sectional design of the study does not permit a causal inference of the observed relationship between PA pattern and CRF. Even if it is well established that regular PA can enhance CRF, reversed causality for instance that individuals who have inherited a higher CRF tend to be more active, cannot be ruled out (53). Second, as in most large-scale epidemiological studies (10, 30), $\dot{V}O_2max$ was estimated based on a submaximal ergometer test in a highly standardized and quality assured procedure (15) and not directly assessed by breath gas analysis. Third, self-reports on PA levels are prone to recall and social desirability bias (54, 55). Thus, we cannot exclude the possibility that the level of LTPA was over- or underreported. Furthermore, LTPA was assessed based on information about the duration per week but not about intensity. The latter may have an additional impact on CRF (10). Fourth, OPA was assessed indirectly via JEMs. Even though these JEMs were based on a very large sample and the use of hierarchical linear regression models, controlling for age, sex, working hours and job experience, reducing the likelihood of confounding, JEMs are generally not able to account for variability of exposures within jobs (56).

CONCLUSIONS

Our results showed a strong association between LTPA and CRF and suggest an interaction between OPA and LTPA patterns on CRF within the adult working population in Germany. Women without LTPA are likely to have a low CRF, especially if they work in physically demanding jobs. Further investigations are needed to elucidate the pathways through which different domains of PA lead to divergent health effects and to develop suitable measures to enhance the PA level of identified populations groups at risk. As the ability to engage a more active lifestyle significantly depends on societal conditions and restrictions, measures should not only focus on the individual, but in accordance with the Global Action Plan on Physical Activity of the WHO include actions at the political and environmental level.

STATEMENTS

Author Contributions

GBMM and JDF were involved in the design and conduct of DEGS1, JDF in particular for the ergometer testing. JZ, LEK, and JFD conceptualized the current study. JZ, MD and LEK conducted the analysis. JZ drafted the manuscript. GBMM, JDF and TK contributed to the analysis plan and interpretation of the results. MD, GBMM, JDF and TK critically revised it. All authors contributed to the interpretation of findings, reviewed, edited and approved the final manuscript.

Funding

No external funding was received. The study was financed by the Robert Koch Institute which is a federal institute within the portfolio of the German Federal Ministry of Health.

Competing interests

None declared.

Patient consent

Participants signed an informed written consent prior to participation.

Ethics approval

DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité – Universitätsmedizin Berlin ethic committee (no EA2/047/08).

Data sharing statement

A dataset of DEGS1 is available via Public Use File (https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html [accessed 23 Sep 2019]).

REFERENCES

1. World Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: WHO; 2018.

2. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. Geneva: WHO; 2013.

3. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO; 2010. Available from: http://www.who.int/dietphysicalactivity/global-PA-recs-2010.pdf.

4. Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. Obes Rev. 2012;13(8):659-80.

5. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. Int J Epidemiol. 2011;40(5):1382-400.

6. Li J, Loerbroks A, Angerer P. Physical activity and risk of cardiovascular disease: what does the new epidemiological evidence show? Current Opinion in Cardiology. 2013;28(5):575-83.

7. Coenen P, Huysmans MA, Holtermann A, Krause N, van Mechelen W, Straker LM, et al. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. Br J Sports Med. 2018;52(20):1320-6.

8. Holtermann A, Hansen JV, Burr H, Søgaard K, Sjøgaard G. The health paradox of occupational and leisure-time physical activity. Br J Sports Med. 2012;46(4):291-5.

9. Holtermann A, Krause N, van der Beek AJ, Straker L. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med. 2018;52(3):149-50.

10. Ross R, Blair SN, Arena R, Church TS, Despres JP, Franklin BA, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. Circulation. 2016;134(24):e653-e99.

11. Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. JAMA. 2009;301(19):2024-35.

12. Coenen P. Preventing disease by integrating physical activity in clinical practice: What works for whom? Heart. 2018;104(14):1-2.

13. Kurth B-M. The RKI health monitoring - What it contains and how it can be used [Das RKI-Gesundheitsmonitoring - Was es enthält und wie es genutzt werden kann]. Public Health Forum. 2012;20(3):4. e1-4. e3.

14. Scheidt-Nave C, Kamtsiuris P, Gößwald A, Holling H, Lange M, Busch M, et al. German health interview and examination survey for adults (DEGS) - design, objectives and implementation of the first data collection wave. BMC Public Health. 2012;12(1):730.

15. Finger JD, Gosswald A, Hartel S, Muters S, Krug S, Holling H, et al. Measurement of cardiorespiratory fitness in the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5-6):885-93.

16. Finger JD, Krug S, Gößwald A, Härtel S, Bös K. Cardiorespiratory fitness among adults in Germany. Results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):772-8.

17. Zeiher J, Manz K, Kuntz B, Perumal N, Keil T, Mensink GBM, et al. Individual and interpersonal correlates of cardiorespiratory fitness in adults – Findings from the German Health Interview and Examination Survey. Sci Rep. Subm.

18. Deutsche Gesellschaft für Sportmedizin und Prävention (DGSP). PAR-Q-Fragebogen (German version). 2007.

19. Canadian Society for Exercise Physiology. Physical Activity Readiness Questionnaire - PAR-Q (revised 2002). Ottawa: Health Canada; 2002.

20. Andersen KL, Shephard R, Denolin H, Varnauskas E, Masironi R. Fundamentals of exercise testing 1971. Available from: https://apps.who.int/iris/handle/10665/40145.

21. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol. 2001;37(1):153-6.

22. Gore CJ, Booth ML, Bauman A, Owen N. Utility of pwc75% as an estimate of aerobic power in epidemiological and population-based studies. Med Sci Sports Exerc. 1999;31(2):348-51.

23. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 5th Edition ed. Baltimore:: Williams & Wilkins; 1995, p.280.

24. Kroll LE. Construction and validation of a general index for job demands in occupations based on ISCO-88 and KldB-92 [Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten anhand von ISCO-88 und KldB-92]. Methoden — Daten — Analysen. 2011;5(1):63-90.

25. Zopf S, Tiemann M. BIBB/BAuA-employment survey 2005/06. Schmollers Jahrbuch. 2010;130(3):409- 20.

26. Kroh M, Neiss H, Kroll L, Lampert T. High-income people live longer [Menschen mit hohem Einkommen leben länger]. DIW-Wochenbericht. 2012;79(38):3-15.

27. Santi I, Kroll LE, Dietz A, Becher H, Ramroth H. To what degree is the association between educational inequality and laryngeal cancer explained by smoking, alcohol consumption, and occupational exposure? Scand J Work Environ Health. 2014;40(3):315-22.

28. Santi I, Kroll LE, Dietz A, Becher H, Ramroth H. Occupation and educational inequalities in laryngeal cancer: the use of a job index. BMC Public Health. 2013;13(1):1080.

29. Steinbach D, Graf C. Leisure Time Physical Activity and SedentarinessLeisure time physical activity and sedentariness. In: Kirch W, editor. Encyclopedia of Public Health. Dordrecht: Springer; 2008. p. 849-51.

30. Zeiher J, Ombrellaro KJ, Perumal N, Keil T, Mensink GBM, Finger JD. Correlates and determinants of cardiorespiratory fitness in adults: a systematic review. Sports Med Open. 2019;5(39).

31. World Health Organization. BMI classification 2019. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.

32. World Health Organization. Obesity: preventing and managing the global epidemic. Genf: WHO; 2000.

33. Lampert T, Kroll L, Müters S, Stolzenberg H. Measurement of socioeconomic status in the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56:1-5.

34. Graubard BI, Korn EL. Predictive margins with survey data. Biometrics. 1999;55(2):652-9.

35. Mundwiler J, Schüpbach U, Dieterle T, Leuppi JD, Schmidt-Trucksäss A, Wolfer DP, et al. Association of occupational and leisure-time physical activity with aerobic capacity in a working population. PLoS ONE. 2017;12(1).

36. Ruzic L, Heimer S, Misigoj-Durakovic M, Matkovic BR. Increased occupational physical activity does not improve physical fitness. Occupational and environmental medicine. 2003;60(12):983-5.

37. Bahls M, Groß S, Baumeister SE, Völzke H, Gläser S, Ewert R, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. Sci Rep. 2018;8(1):16066.

38. Lakka TA, Laaksonen DE, Lakka HM, Mannikko N, Niskanen LK, Rauramaa R, et al. Sedentary lifestyle, poor cardiorespiratory fitness, and the metabolic syndrome. Med Sci Sports Exerc. 2003;35(8):1279-86.

39. Saidj M, Jørgensen T, Jacobsen RK, Linneberg A, Aadahl M. Differential cross-sectional associations of work- and leisure-time sitting, with cardiorespiratory and muscular fitness among working adults. Scand J Work Environ Health. 2014(5):531-8.

40. Nagaya T, Kondo Y, Shibata T. Effects of sedentary work on physical fitness and serum cholesterol profile in middle-aged male workers. International archives of occupational and environmental health. 2001;74(5):366-70.

41. Tammelin T, Nayha S, Rintamaki H, Zitting P. Occupational physical activity is related to physical fitness in young workers. Med Sci Sports Exerc. 2002;34(1):158-65.

42. Holtermann A, Mortensen OS, Burr H, Sogaard K, Gyntelberg F, Suadicani P. Physical work demands and physical fitness in low social classes--30-year ischemic heart disease and all-cause mortality in the Copenhagen Male Study. J Occup Environ Med. 2011;53(11):1221-7.

43. Holtermann A, Mortensen OS, Burr H, Sogaard K, Gyntelberg F, Suadicani P. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. Scand J Work Environ Health. 2010;36(5):357-65.

44. Krause N. Physical activity and cardiovascular mortality – disentangling the roles of work, fitness, and leisure. Scand J Work Environ Health. 2010(5):349-55.

45. Schmucker R. Working conditions in nursing care [Arbeitsbedingungen in Pflegeberufen]. In: Jacobs K, Kuhlmey A, Greß S, Klauber J, Schwinger A, editors. Pflege-Report 2019: Mehr Personal in der Langzeitpflege - aber woher? Berlin, Heidelberg: Springer; 2019. p. 49-60.

46. Theobald H, Szebehely M, Preuß M. Working conditions in geriatric care [Arbeitsbedingungen in der Altenpflege]. Berlin: Ed. Sigma 2013.

47. Fransson EI, Heikkila K, Nyberg ST, Zins M, Westerlund H, Westerholm P, et al. Job strain as a risk factor for leisure-time physical inactivity: an individual-participant meta-analysis of up to 170,000 men and women: the IPD-Work Consortium. Am J Epidemiol. 2012;176(12):1078-89.

48. Schilling R, Colledge F, Ludyga S, Pühse U, Brand S, Gerber M. Does cardiorespiratory fitness moderate the association between occupational stress, cardiovascular risk, and mental health in police officers? Int J Environ Res Public Health. 2019;16(13).

49. van Tienoven TP, Deyaert J, Harms T, Weenas D, Minnen J, Glorieux I. Active work, passive leisure? Associations between occupational and non-occupational physical activity on weekdays. Soc Sci Res. 2018;76:1-11.

50. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258-71.

51. Gößwald A, Lange M, Dölle R, Hölling H. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Recruitment of participants, fieldwork, and quality assurance. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):1-8.

52. Kamtsiuris P, Lange M, Hoffmann R, Schaffrath Rosario A, Dahm S, Kuhnert R, et al. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Sampling design, response, weighting, and representativeness. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):1-10.

53. Després JP. Physical Activity, Sedentary Behaviours, and Cardiovascular Health: When Will Cardiorespiratory Fitness Become a Vital Sign? Can J Cardiol. 2016;32(4):505-13.

54. Prince SA, Adamo KB, Hamel ME, Hardt J, Gorber SC, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. International Journal of Behavioral Nutrition and Physical Activity. 2008;5(1):56.

55. Brenner PS, DeLamater J. Lies, Damned Lies, and Survey Self-Reports? Identity as a Cause of Measurement Bias. Social Psychology Quarterly. 2016;79(4):333-54.

56. Tielemans E, Heederik D, Burdorf A, Vermeulen R, Veulemans H, Kromhout H, et al. Assessment of occupational exposures in a general population: Comparison of different methods. Occupational and environmental medicine. 1999;56(3):145-51.

FIGURES & TABLES

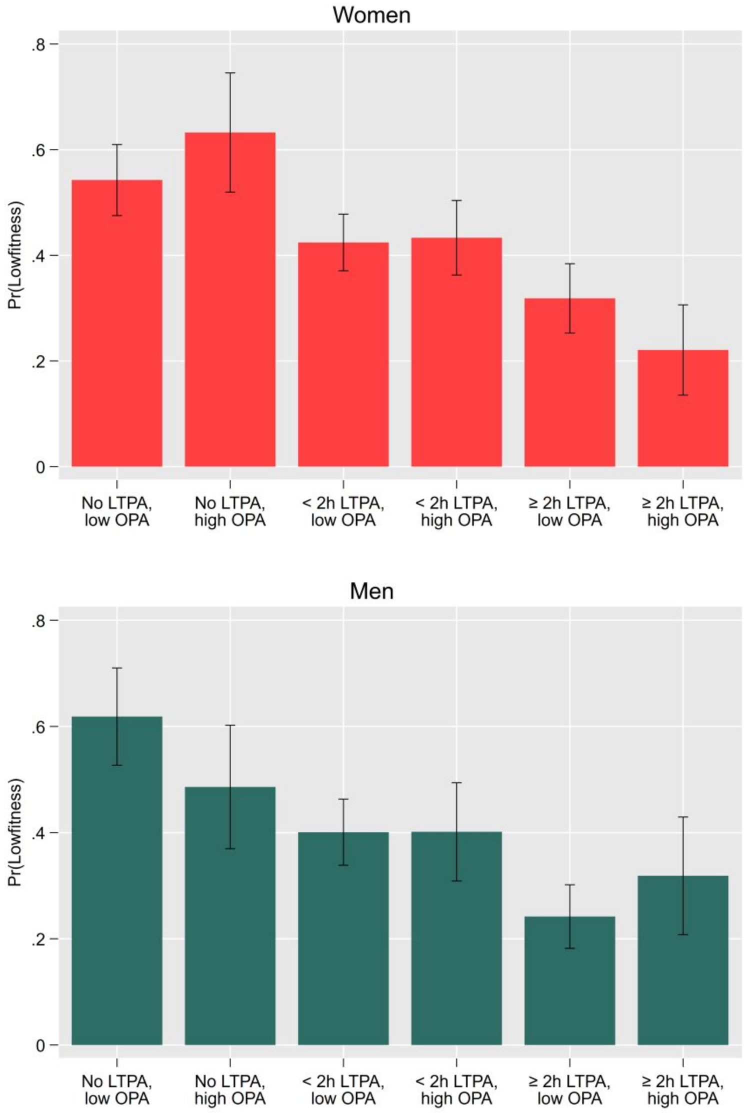

Figure 1: Predicted probabilities (with 95 % confidence intervalls) of low $\dot{V}O_2max$ according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

Table 1: Characteristics of study participants in DEGS1

	Men			Women			Total		
	n	%[1]	%[2]	n	%[1]	%[2]	n	%[1]	%[2]
$\dot{V}O_2max$									
Low	705	58.8	58.8	750	57.9	59.5	1455	58.3	59.1
Intermediate/high	494	41.2	41.2	546	42.1	40.5	1040	41.7	40.9
Missing	0	0.0	-	0	0.0	-	0	0.0	-
LTPA									
no	297	24.8	24.9	309	23.8	24.7	606	24.3	24.8
<2h	492	41.0	39.8	647	49.9	49.9	1139	45.7	44.7
≥2h	410	34.2	35.3	340	26.2	25.3	750	30.1	30.5
Missing	0	0.0	-	0	0.0	-	0	0.0	-
OPA									
low	750	62.6	59.7	895	69.1	67.0	1645	65.9	63.2
high	449	37.4	40.3	401	30.9	33.0	850	34.1	36.8
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Age									
18-24 Years	137	11.4	11.3	138	10.6	11.8	275	11.0	11.5
25-34 Years	277	23.1	26.4	250	19.3	22.5	527	21.1	24.5
35-44 Years	287	23.9	26.8	338	26.1	27.7	625	25.1	27.2
45-54 Years	308	25.7	23.2	369	28.5	25.8	677	27.1	24.5
55-64 Years	190	15.8	12.3	201	15.5	12.3	391	15.7	12.3
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Waist circumference									
Normal	719	60.0	61.7	702	54.2	57.0	1421	57.0	59.4
Increased	256	21.4	20.1	289	22.3	22.5	545	21.8	21.3
Strongly increased	224	18.7	18.2	303	23.4	20.5	527	21.1	19.3
Missing	0	0.0	-	2	0.2	-	2	0.1	-
Body mass index									
Underweight	9	0.8	0.8	32	2.5	2.8	41	1.6	1.8
Normal Weight	467	38.9	37.7	748	57.7	58.1	1215	48.7	47.5
Overweight	548	45.7	46.1	348	26.9	27.1	896	35.9	37.0
Obese	171	14.3	15.4	164	12.7	11.9	335	13.4	13.7
Missing	4	0.3	-	4	0.3	-	8	0.3	-
Smoking status									
Daily	349	29.1	31.3	268	20.7	23.2	617	24.7	27.4
Occasionally	106	8.8	8.2	96	7.4	7.6	202	8.1	7.9
Former	323	26.9	26.9	354	27.3	25.8	677	27.1	26.3
Never	420	35.0	33.7	576	44.4	43.4	996	39.9	38.3
Missing	1	0.1	-	2	0.2	-	3	0.1	-
Alcohol consumption									
Low	180	15.0	16.7	151	11.7	12.3	331	13.3	14.6
Moderate	760	63.4	64.3	821	63.3	64.8	1581	63.4	64.6
High	245	20.4	19.0	314	24.2	22.9	559	22.4	20.9
Missing	14	1.2	-	10	0.8	-	24	1.0	-
Socio economic status									
Low	151	12.6	14.7	113	8.7	9.6	264	10.6	12.3
Medium	702	58.5	61.4	800	61.7	63.5	1502	60.2	62.4
High	346	28.9	23.9	382	29.5	26.8	728	29.2	25.3
Missing	0	0	-	1	0.1	-	1	0.0	-

[1]Unweighted percentage [2]Weighted percentage (Weighting factors were used to adjust the distribution of the sample to match the German population according to sex, age, education and region. DEGS1 German Health Interview and

Examination Survey for Adults, $\dot{V}O_2max$ Maximal oxygen consumption LTPA Leisure time physical activity, OPA Occupational physical activity

Table 2: Association of LTPA and OPA among male and female DEGS1 participants

	Low OPA		High OPA	
	%	(95%-CI)	%	(95%-CI)
Men				
No LTPA	24,0	(20,1-28,3)	26,2	(21,4-31,5)
<2h LTPA	39,4	(35,2-43,7)	40,4	(34,9-46,2)
≥2h LTPA	36,6	(32,7-40,7)	33,4	(27,7-39,7)
Women				
No LTPA	21,6	(17,9-25,9)	31,1	(25,6-37,3)
<2h LTPA	49,6	(44,8-54,3)	50,6	(44,9-56,4)
≥2h LTPA	28,8	(25,1-32,8)	18,2	(14,4-22,9)

DEGS1 German Health Interview and Examination Survey for Adults, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

Table 3: Prevalence of low $\dot{V}O_2max$ according to domain specific physical activity, health behavioral, anthropometric, and sociodemographic characteristics among male and female DEGS1 participants

	Men		Women	
	%	(95%-CI)	%	(95%-CI)
Total	41.2	(37.6-44.8)	40.5	(37.1-44.0)
Physical exercise				
No	63.2	(56.4-69.4)	56.1	(49.1-62.9)
<2h	42.2	(36.5-48.0)	41.2	(36.6-45.9)
≥2h	24.7	(19.8-30.5)	24.1	(19.0-30.1)
Physical job demands				
Low to moderate	41.5	(36.8-46.4)	37.2	(33.0-41.6)
high	40.8	(35.0-46.8)	47.4	(41.5-53.4)
OPA/LTPA				
No LTPA, low OPA	68.5	(59.2-76.4)	48.0	(39.7-56.3)
No LTPA, high OPA	56.0	(44.9-66.5)	67.7	(56.7-77.0)
<2h LTPA, low OPA	42.6	(35.8-49.7)	39.3	(33.5-45.5)
<2h LTPA, high OPA	41.6	(32.3-51.5)	44.9	(37.5-52.5)
≥2h LTPA, low OPA	22.8	(17.1-29.6)	25.4	(19.0-33.0)
≥2h LTPA, high OPA	28.0	(19.1-39.0)	19.9	(11.6-32.1)
Age				
18-24 Years	28.0	(19.9-37.7)	25.8	(17.9-35.7)
25-34 Years	36.0	(28.9-43.8)	29.2	(23.3-35.9)
35-44 Years	41.9	(34.9-49.2)	36.1	(30.3-42.3)
45-54 Years	47.2	(40.9-53.7)	48.5	(42.1-55.1)
55-64 Years	51.9	(42.3-61.4)	68.7	(60.2-76.1)
Waist circumference				
Normal	27.1	(23.2-31.4)	26.9	(23.0-31.1)
Increased	54.6	(46.2-62.8)	46.4	(38.5-54.6)
Strongly increased	74.2	(66.7-80.4)	72.5	(66.3-77.9)
Body mass index				
Underweight	19.8	(3.3-64.1)	18.9	(7.7-39.4)
Normal Weight	21.7	(16.9-27.4)	27.1	(23.4-31.2)
Overweight	47.5	(42.3-52.8)	53.7	(46.4-60.8)
Obese	71.1	(62.4-78.4)	83.1	(75.3-88.8)
Smoking status				
Daily	40.7	(34.9-46.8)	38.8	(31.6-46.7)
Occasionally	31.7	(22.3-42.9)	33.5	(22.9-46.0)
Former	49.6	(42.3-56.9)	46.7	(40.0-53.6)
Never	37.5	(31.4-44.0)	39.0	(34.0-44.3)

Alcohol consumption				
Low	45.7	(38.0-53.7)	50.2	(40.8-59.5)
Moderate	39.1	(34.9-43.6)	41.1	(36.6-45.8)
High	43.4	(35.1-52.2)	33.2	(26.7-40.5)
Socio economic status				
Low	39.9	(30.7-49.8)	56.3	(45.8-66.3)
Medium	43.3	(38.7-48.1)	43.4	(39.3-47.5)
High	36.8	(30,8-43,2)	28.2	(22,4-34,9)

$\dot{V}O_2max$ Maximal oxygen consumption, DEGS1 German Health Interview and Examination Survey for Adults, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

Table 4: Domain-specific physical activity and low estimated $\dot{V}O_2max$ among male and female DEGS1 participants

	Men				Women			
	OR[1]	(95 % CI)	OR[2]	(95 % CI)	OR[1]	(95 % CI)	OR[2]	(95 % CI)
OPA Model								
low OPA	(ref.)		(ref.)		(ref.)		(ref.)	
high OPA	1.05	(0.75 - 1.46)	0.95	(0.64 - 1.42)	1.71	(1.23 - 2.36)	1.06	(0.75 - 1.49)
LTPA Model								
no LTPA	4.97	(3.47 - 7.13)	4.46	(2.89 - 6.89)	4.96	(3.26 - 7.54)	4.65	(2.90 - 7.45)
<2h LTPA	2.17	(1.48 - 3.19)	2.04	(1.32 - 3.15)	2.49	(1.72 - 3.62)	2.13	(1.44 - 3.14)
≥2h LTPA	(ref.)		(ref.)		(ref.)		(ref.)	
OPA/LTPA Model								
No LTPA, low OPA	4.92	(2.56 - 9.46)	4.37	(2.02 - 9.47)	4.45	(2.14 - 9.23)	6.54	(2.98 - 14.3)
No LTPA, high OPA	2.86	(1.47 - 5.58)	11.1	(5.15 - 24.1)	2.34	(1.08 - 5.07)	10.5	(4.39 - 24.9)
<2h LTPA, low OPA	1.69	(0.94 - 3.06)	2.84	(1.39 - 5.78)	1.54	(0.77 - 3.06)	3.52	(1.75 - 7.09)
<2h LTPA, high OPA	1.70	(0.91 - 3.17)	4.01	(1.90 - 8.49)	1.54	(0.75 - 3.16)	3.69	(1.80 - 7.60)
≥2h LTPA, low OPA	0.67	(0.35 - 1.27)	1.37	(0.64 - 2.92)	0.64	(0.32 - 1.27)	1.93	(0.90 - 4.13)
≥2h LTPA, high OPA	(ref.)		(ref.)		(ref.)		(ref.)	
n	1,199		1,181		1,296		1,277	

[1]adjusted for age; [2]adjusted for LTPA [OPA-Model], OPA [LTPA-Model], age, waist circumference, body mass index, smoking status, alcohol consumption, SES index
$\dot{V}O_2max$ Maximal oxygen consumption, DEGS1 German Health Interview and Examination Survey for Adults, OR Odds ratios, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

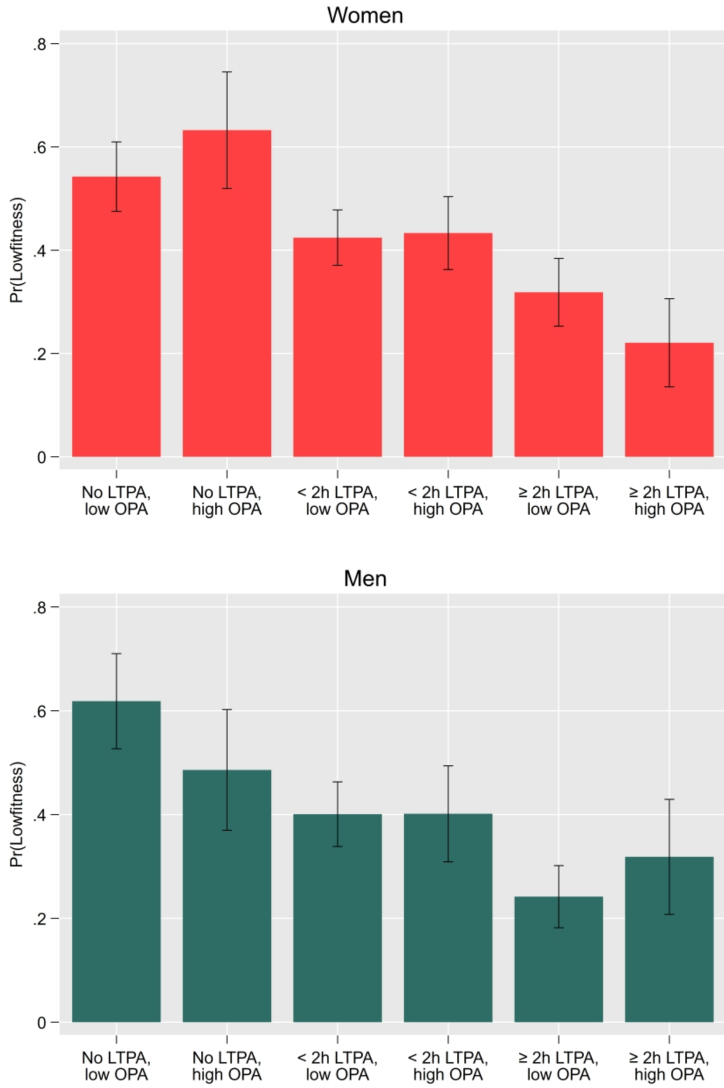

Figure 1: Predicted probabilities (with 95 % confidence intervalls) of low V O_2 max according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

1411x2116mm (72 x 72 DPI)

Online Supplemental Material 1: Supplementary figures and tables

Additional file to: Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity patterns and cardiorespiratory fitness among the working population. Findings from the German health interview and examination survey

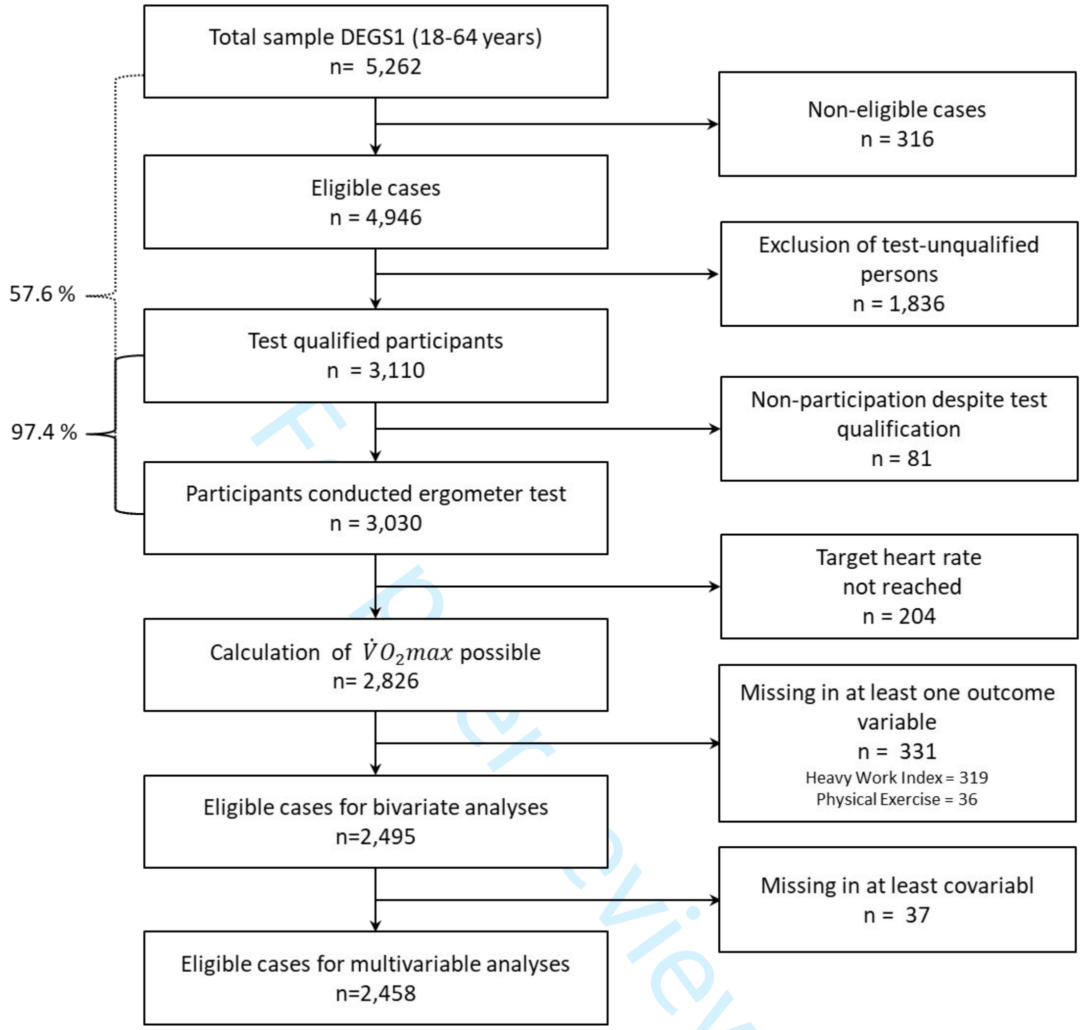

Figure S1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; $\dot{V}O_2max$: Maximal oxygen consumption

Table S1 Top ten occupations (ISCO-88; 4-digit) among men and women according to OPA

Men				Women			
Rank	**Occupations [ISCO-88]**	**%**	**95% CI**	**Rank**	**Occupations [ISCO-88]**	**%**	**95% CI**
	High OPA				**High OPA**		
1.	Electronics mechanics and servicers	7,6	(5,1-11,3)	1.	Institution-based personal care workers	16,6	(12,4-22,0)
2.	Plumbers and pipe fitters	5,7	(3,6-9,0)	2.	Nursing associate professionals	13,6	(10,1-18,0)
3.	Skilled agricultural and fishery workers	4,7	(2,6-8,3)	3.	Social work associate professionals	5,5	(3,6-8,2)
4.	Agricultural- or industrial-machinery mechanics and fitters	4,6	(2,7-7,6)	4.	Childcare workers	5,3	(2,8-9,8)
5.	Machine-tool setters and setter-operators	4,1	(2,4-6,7)	5.	Pre-primary education teaching associate professionals	4,8	(2,9-7,8)
6.	Cooks	3,7	(1,5-8,5)	6.	Shop salespersons and demonstrators	4,4	(2,5-7,7)
7.	Structural-metal preparers and erectors	3,6	(2,0-6,5)	7.	Waiters, waitresses and bartenders	4,3	(2,2-8,1)
8.	Building and related electricians	3,3	(1,6-6,5)	8.	Cooks	3,6	(1,8-7,1)
9.	Painters, upholsterers and related workers	3,0	(1,8-5,1)	9.	Hairdressers, barbers, beauticians and related workers	3,0	(1,5-5,8)
10.	Cabinet makers and related workers	2,7	(1,5-4,7)	10.	Helpers and cleaners in offices, hotels and other establishments	3,0	(1,5-5,8)
	Low OPA				**Low OPA**		
1.	Other office clerks	4,4	(2,8-6,9)	1.	Shop salespersons and demonstrators	10,6	(8,3-13,6)
2.	Shop salespersons and demonstrators	3,4	(2,0-5,7)	2.	Other office clerks	7,5	(5,3-10,5)
3.	Business professionals not elsewhere classified	3,2	(1,9-5,3)	3.	Bookkeepers	5,7	(4,1-8,0)
4.	Heavy-truck and lorry drivers	2,7	(1,4-5,0)	4.	Secondary education teaching professionals	4,8	(3,4-6,8)
5.	Computer assistants	2,6	(1,6-4,4)	5.	Secretaries	3,9	(2,4-6,2)
6.	Computing professionals not elsewhere classified	2,5	(1,3-4,7)	6.	Statistical and finance clerks	3,8	(2,5-5,6)
7.	Technical and commercial sales representatives	2,4	(1,4-4,1)	7.	Administrative secretaries and related associate professionals	3,6	(2,4-5,3)
8.	Finance and sales associate professionals not elsewhere classified	2,4	(1,3-4,5)	8.	Legal and related business associate professionals	2,7	(1,5-4,9)
9.	Stock clerks	2,4	(1,3-4,6)	9.	Finance and sales associate professionals not elsewhere classif.	2,4	(1,5-3,6)
10.	Civil engineers	2,0	(1,1-3,7)	10.	Cashiers and ticket clerks	2,3	(1,2-4,3)

CI Confidence intervals, ISCO-88 International Standard Classification of Occupations, OPA Occupational physical activity

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	FigS1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	9
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5/ Supl.
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	Supl.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Supl.
		(b) Indicate number of participants with missing data for each variable of interest	Tab1
Outcome data	15*	Report numbers of outcome events or summary measures	Tab1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tab2/ Tab3

		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	14/ 11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population – Findings from the cross-sectional German health interview and examination survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034610.R1
Article Type:	Original research
Date Submitted by the Author:	20-Jan-2020
Complete List of Authors:	Zeiher, Johannes; Robert Koch Institut, Department of Epidemiology and Health Monitoring Duch, Maurice; Robert Koch Institut, Department of Epidemiology and Health Monitoring; University of Potsdam, Department of Sports and Health Sciences Kroll, Lars; Central Research Institute of Ambulatory Health Care in Germany Mensink, Gert; Robert Koch Institut Finger, Jonas D.; Robert Koch Institut, Department of Epidemiology and Health Monitoring Keil, Thomas; Bavarian Health and Food Safety Authority, State Institute of Health; Charité Universitätsmedizin Berlin, Institute for Social Medicine, Epidemiology and Health Economics
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Occupational and environmental medicine
Keywords:	cardiorespiratory fitness, adults, physical activity, physical fitness, occupational physical activity

Research article

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population – Findings from the cross-sectional German health interview and examination survey

Johannes Zeiher[a]*, Maurice Duch[a,b], Lars E. Kroll[c], Gert B. M. Mensink[a] Jonas D. Finger[a] Thomas Keil[d,e,f]

[a] Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin, Germany

[b] University of Potsdam, Potsdam, Germany

[c] Central Research Institute of Ambulatory Health Care in Germany, Berlin, Germany

[d] Institute for Clinical Epidemiology and Biometry, University of Würzburg, Würzburg, Germany

[e] State Institute of Health, Bavarian Health and Food Safety Authority, Bad Kissingen, Germany

[f] Institute for Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin Berlin, Berlin, Germany

* Corresponding author:
Johannes Zeiher
Unit of Health Behaviour
Department of Epidemiology and Health Monitoring
Robert Koch Institute
General-Pape-Straße 62-66
12101 Berlin, Germany
Email: zeiherj@rki.de
Phone: 0049 30 18754 3775

Word count (main text): 4,367 words

ABSTRACT

Objectives:

This study aims to investigate the associations of patterns occupational physical activity (OPA, assessed based on physical work demands linked to job title) and leisure time PA (LTPA, assessed by questionnaire) with cardiorespiratory fitness (CRF, assessed by exercise test) among men and women from the German working population.

Design:

Population-based cross-sectional study

Setting:

Two-stage cluster-randomized general population sample selected from population registries of 180 nationally distributed sample points. Information was collected from 2008 to 2011.

Participants:

1,296 women and 1,199 men aged 18-64 from the resident working population.

Outcome measure:

Estimated low maximal oxygen consumption ($\dot{V}O_2max$), defined as 1st and 2nd gender-specific quintile, assessed by a standardized, submaximal cycle ergometer test.

Results:

A strong association between low LTPA and low estimated $\dot{V}O_2max$, but not between OPA and low $\dot{V}O_2max$ was observed. The association of domain-specific PA patterns with low $\dot{V}O_2max$ varied by gender: women without LTPA engagement and with high OPA level showed the highest likelihood of having a low $\dot{V}O_2max$ (odds ratio (OR) 6.54; 95%-confidence interval (CI) 2.98 to 14.3) compared to women with ≥ 2 hours of LTPA and high OPA. Among men, those with no LTPA and low OPA level showed the highest risk of low $\dot{V}O_2max$ (OR 4.37; 95%-CI 2.02 to 9.47).

Conclusion:

Our results showed a strong association between patterns of PA during leisure time and work and CRF within the adult working population in Germany. Women without LTPA are at high risk of having a low CRF, especially if they work in physically demanding jobs. Further investigation is needed to explain the pathways through which different domains of PA lead to divergent health effect. Moreover, as current guidelines do not distinguish between PA during work and leisure time, specifying LTPA recommendations according to the OPA level should be considered.

KEYWORDS

cardiorespiratory fitness; adults; physical activity; physical fitness; occupational physical activity

ARTICLE SUMMARY

Strengths and limitations of this study

1. This is among the first study to examine the association of leisure time and occupational physical activity patterns with cardiorespiratory fitness in Germany.
2. We used a large nationally representative population-based sample of the resident adult working population, which allows the generalizability of our findings.
3. Leisure-time physical activity was assessed by self-reports which may be prone to recall and social desirability bias.

BACKGROUND

Physical activity (PA) is crucial for health and the unfavorable effects of an increasing sedentary lifestyle are acknowledged as a major public health challenge (1, 2). PA, defined as all bodily movement produced by skeletal muscles that require energy expenditure (3), has a positive influence on physical and mental health and contributes to the prevention of non-communicable diseases and premature mortality (1). Throughout the individual daily routine and life course, PA can appear in different forms and can take place in different domains. For example, one may participate in sports during leisure time (leisure time physical activity, LTPA) or be active during work (occupational physical activity, OPA). To date, PA in any form and setting has been considered as beneficial and recent recommendations do not distinguish between PA domains. The current WHO guideline recommends at least 150 minutes of moderate intensity aerobic exercise per week, stating that "[…] Physical activity includes leisure time physical activity, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities." (3, p. 8)

Even if manual and physical demanding occupations have been declining for decades, OPA is still accounting for a large part of the daily amount of overall PA (4). While the beneficial effects of LTPA are well established, the results regarding OPA are inconclusive. Studies in the past often argued that OPA should also be considered as health enhancing PA (5), but recent studies suggest that OPA has no health-enhancing or even contrary effects (6, 7). As a possible explanation for this 'health paradox', the domain-specific effects of PA on cardiorespiratory fitness (CRF) has come to attention (8, 9). Defined as the ability of circulatory, respiratory and muscular systems to supply oxygen during prolonged physical exercise (3), CRF can be enhanced by regular endurance exercise (10) and is a strong predictor of adverse health outcomes (11). It has been argued, that OPA rarely has the adequate intensity, duration, and volume to induce positive changes in CRF (8, 9, 12, 13).

However, data on the association of different domains of PA and CRF for Germany is limited. In particular, the interplay between these different domains has not yet been analyzed in relation to

CRF. Thus, this study aims to investigate the associations between patterns of OPA and LTPA with CRF among the German working population. As men and women are differently exposed to physical demands at work (14), work in different occupations (15), and may respond differently to PA (16), our analyses were performed stratified by gender.

METHODS

Study design

We used data from the nationwide cross-sectional German Health Interview and Examination Survey for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1). DEGS1 is part of the Federal Health Monitoring System administered by the Robert Koch Institute (17). In detail, the study design is described elsewhere (18). Briefly, the study is based on a two-stage cluster randomized sampling procedure. First, 180 sample points were sampled from a list of German communities stratified to represent regional distribution. Second, within these units, adult individuals were randomly drawn from local population registries stratified by 10-year age groups. The response rate was 42%. A total of 5,262 participants aged 18–64 years took part in the physical measurements component of the DEGS1 from November 2008 to December 2011. Out of the gross sample 3,110 individuals were categorized as test-qualified for the exercise test (Figure 1).

<<< Figure 1 about here >>>

Overall, 3,030 participants completed the exercise test (participation rate 97.4 %). $\dot{V}O_2max$ was estimated for all participants reaching at least 75% of the age-predicted maximum heart rate (HR_{max}). Two hundred and four participants terminated the test before reaching this heart rate. As a result, $\dot{V}O_2max$ could be calculated for 2.826 participants. Further cases were excluded based on missing data on the PA variables. Overall, valid information on $VO2max$, OPA and LTPA was available for 1,296 women and 1,199 men. Table 1 illustrates demographic, anthropometric and health behavior variables from this representative sample of the adult working population of Germany. Women comprised 48.0 % of the sample, the mean age of the participants was 39.6 years (range 18-64years).

Generally, unweighted and weighted percentage did not differ substantially. In detail, weighting lead to slightly smaller share of participants in the older age groups and a smaller share of participants in the high socioeconomic status group.

<<< Table 1 about here >>>

Patient and public involvement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Outcome variable

CRF was measured using a standardized, submaximal cycle ergometer test (Ergosana Sana Bike 350/450 [Ergosana, Germany], heart rate monitor [Polar, Finland], blood pressure cuffs [Ergosana, Germany], a heart rate transmitter [Oregon Scientific, USA] and a notebook with ergometer software [Dr Schmidt GmbH, Germany]). Test methodology, protocol, and exclusion criteria were in detail already described elsewhere (19, 20). DEGS1 participants were included in the ergometer test if they were aged 18-64 years, signed an informed consent, and were categorized as test-qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q) (21, 22). Participants were consulted by a physician if any PAR-Q contraindications were reported and the physician decided whether or not the participant should be enrolled into the exercise test. CRF was assessed using the test protocol recommended by the World Health Organization (WHO) (23): Beginning at 25 watts, the workload was incrementally increased by 25 watts every two minutes until 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 watts was achieved or the study staff terminated the test. Heart rate was monitored continuously throughout the test. The formula $208 - 0.7 \cdot Age$ was used to calculate the age-predicted maximum heart rate (24). To derive physical work capacity at HR_{max} ($PWC_{100\%}$), the measured heart rate (beats per minute) during the incremental phase was regressed against corresponding workload in watts for each participant. Assuming a linear relationship between heart rate and workload, $PWC_{100\%}$ was obtained by extrapolation using the individual regression equation $PWC_{100\%} = intercept + HR_{max} \cdot slope$ (25). $PWC_{100\%}$ was further converted to $\dot{V}O_2max$ using a metabolic equation provided by the American College of Sports Medicine (26): $3.5\ ml \cdot min^{-1} \cdot kg^{-1} + 12.24 \cdot (PWC_{100\%}) \cdot (body\ weight^{-1})$. According to gender-specific quintiles, estimated $\dot{V}O_2max$ was categorized into low $\dot{V}O_2max$ (quintile 1-2) and intermediate to high $\dot{V}O_2max$ (quintile 3-5).

Exposure variable

Occupational physical activity: a physical work demands index

To assess PA at work we used an indirect method and computed specific job exposure matrices (JEMs) that can distinguish the participant's occupation by the criterion of physical demands. JEMs are an established methodological tool allowing for inclusion of specific occupational exposures in analyses based on studies that assess information about the participant's occupational titles, even if the individual exposure is not assessed. JEMs are constructed using available secondary data to determine exposure profiles for each occupation and matching these profiles to the primary data using standardised job-classifications. In our case, JEMs were constructed using data of a large-scale representative study on working conditions of n = 20,000 employees in Germany (27, 28). It was part of the European Working Conditions Survey, which is regularly conducted in the member states of the European Union. The Overall Job Index and specific indexes were already described and applied elsewhere (29-31). In this study, we used a specific sub-index of perceived physical work demands. To construct the index we used data regarding the frequency of lifting and carrying heavy loads (men >=20 kg, women >=10 kg). The item was assessed with a frequency scale with four answer categories: "often", "sometimes", "rarely" and "never" (27, 28). Based on hierarchic multilevel analyses adjusted for gender, age, job experience and part time employment, the physical demand index was assigned to the occupations. In contrast to the use of occupations-specific means, this procedure allows to adjust for further variables that could influence the level of demands besides the specific occupation (e.g., the gender ratio or the level of part time employment). The levels for the multi-level estimation were defined by the 2-, 3- and 4-digit codes of the ISCO-88 classification. These JEMs were then classified into deciles. Occupations with the lowest level of physical work demands have a value of 1 (first decile), and those with the highest level have a value of 10 (tenth decile). Using the International Classification of Occupations of 1988 (ISCO-88), the JEMs were matched to DEGS1. To create a combined OPA/LTPA variable, this index was then dichotomized in a 'low OPA' (index values 1-6) and a 'high OPA' category (index values 7-10). A list of the most frequent occupations in DEGS1 according to OPA level for men and women is presented in Table S1 (Online Supplemental Material).

Leisure time physical activity: physical exercise

LTPA was assessed by asking participants "How often do you engage in physical exercise?" (32). Even though LTPA is usually referring to all PA in their freely disposable time, sport and exercise constitute the core area of LTPA (33) and are therefore used in this study. For the analyses, the categories of the five-point scale "no physical exercise", "less than 1 h a week" and "regularly 1-2 h a week", "regularly up to 4 h" and "regularly more than 4 h" were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.

Combined variable of occupational and leisure time physical activity

To analyse the combined relationship of OPA and LTPA on CRF, we generated a combined variable containing the categories no LTPA/low OPA, no LTPA/high OPA, <2h LTPA/low OPA, <2h LTPA/high OPA, ≥2h LTPA/low OPA, and ≥2h LTPA/high OPA.

Covariates

Relevant covariates were selected based on evidence in the literature (34, 35). Age was categorised into five groups: 18-24 years, 25-34 years, 35-44 years, 45-54 years and 55-64 years. Smoking was grouped into daily, occasionally, former and never smoking. Alcohol intake was estimated by multiplying the calculated quantity of each alcoholic beverage, assessed by a food frequency questionnaire, with standard ethanol content (beer: 4.8%; wine: 11%, spirits: 33%) and classified into low alcohol consumption (quintile 1), medium alcohol consumption (quintile 2-4), and high alcohol consumption (quintile 5) using gender-specific quintiles. As body mass index and waist circumference have been shown to be independently related with CRF in previous studies (34, 35) we included both parameters as covariates. Body height and weight were measured by standardized procedures using portable electronic scales (SECA, Germany) and stadiometer (Holtain, UK). Body mass index (kg/m^2) was categorized according to WHO guidelines (36). Waist circumference was measured at the smallest site between the lowest rib and the superior border of the iliac crest with flexible, non-stretchable measurement tape (Sibner Hegner, Switzerland) and categorized as 'normal', 'increased' and 'strongly increased' according to international guidelines (37). Socioeconomic status (SES) was determined using a composite additive index, based on information about participants' education, occupational position and net equivalent income (38).

Statistical Analyses

To show the association of the domain-specific activity levels LTPA was cross-tabulated with OPA. Prevalence and 95% confidence intervals (CI) of low $\dot{V}O_2max$ were calculated for OPA, LTPA and covariates. Multivariable logistic regression models were computed to estimate the associations between domains of PA and low $\dot{V}O_2max$ (reference category: intermediate to high $\dot{V}O_2max$). In a first step, separate models for OPA and LTPA were fitted, in a second step the combined variable of OPA and LTPA was used. In both steps an age-adjusted model and a model adjusting for body mass index, waist circumference, smoking, alcohol intake and SES were fitted. The separate models for OPA and LTPA were additionally adjusted for LTPA and OPA, respectively. Finally, we computed predicted margins (39) from the final logistic regression model to plot adjusted prevalences of low $\dot{V}O_2max$ according to domain specific PA. All analyses were conducted separately for men and women to identify gender-specific physical activity patterns associated with CRF and to detect a potential effect modification by gender. Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA). To enhance the external validity of the results weighting factors were used to adjust for distribution of the sample by gender, age, education, and region to match the German population. Stata's survey procedures were applied to account for the clustered sampling design.

RESULTS

OPA and LTPA

Prevalence of high OPA was 40.3% among men and 33.0% among women (Table 1). Among men, 24.9% did not engage in LTPA, whereas 39.8% engaged in LTPA less than two hours per week, and 35.3% two hours or more per week. Among women, the corresponding LTPA prevalences were 24.7%, 49.9%, and 25.3%, respectively. While LTPA did not vary according to OPA level among men, women with high OPA were less likely to engage in LTPA for two hours or more per week than women with low OPA (Table 2).

<<< Table 2 about here >>>

low $\dot{V}O_2max$

Overall, the prevalence of estimated low $\dot{V}O_2max$ was 41.2% (95% CI 37.6 to 44.8) among men and 40.5% among women (95% CI 37.1 to 44.0). Table 3 presents the prevalence of low $\dot{V}O_2max$ by domain specific PA and sociodemographic, health behavior and anthropometric variables. Binary analyses showed that men and women with higher LTPA levels had a substantial lower prevalence of low $\dot{V}O_2max$. While there were no relevant differences in low $\dot{V}O_2max$ regarding OPA among men, women with high OPA showed a higher prevalence of low $\dot{V}O_2max$ compared to women with low OPA.

<<< Table 3 about here >>>

Multivariable analyses (Table 4) showed that women in jobs with high levels of OPA were more likely to have a low estimated $\dot{V}O_2max$ when adjusting only for age (OR 1.71; 95% CI 1.23 to 2.36). This association disappeared when controlling for LTPA and other covariates (OR 1.06; 95% CI 0.75 to 1.49). Among men, both models showed no association between low $\dot{V}O_2max$ and OPA (OR 1.05; 95% CI 0.75 to 1.46 and OR 0.95; 95% CI 0.64 to 1.42, respectively).

<<< Table 4 about here >>>

Men and women with no or less than 2 hours LTPA per week were more likely to have a low $\dot{V}O_2max$ than participants with 2 hours or more LTPA per week. The effect size did not change considerably when adjusting for OPA and other controls.

Multivariable analyses of the combined OPA/LTPA variable (fully-adjusted model) showed, that less-active men were more likely to have a low $\dot{V}O_2max$ with ORs of 4.45 (95% CI 2.14 to 9.23) for no LTPA/low OPA, 2.34 (95% CI 1.08 to 5.07) for no LTPA/high OPA, 1.54 (95% CI 0.77 to 3.06) for <2h LTPA/low OPA, 1.54 (95% CI 0.75 to 3.16) for <2h LTPA/high OPA, 0.64 (95% CI 0.32 to 1.27) for ≥2h LTPA /low OPA compared to men with ≥2h LTPA /high OPA. The corresponding ORs for women were 6.54 (95% CI 2.98 to 14.3), 10.5 (95% CI 4.39 to 24.9), 3.52 (95% CI 1.75 to 7.09), 3.69 (95% CI 1.80 to 7.60), 1.93 (95% CI 0.90 to 4.13), indicating the highest likelihood of low fitness for women working in physically demanding jobs and not engaging in LTPA.

Based on the final model with the combined OPA/LTPA variable, we plotted predicted probabilities of having a low $\dot{V}O_2max$ to illustrate these different patterns between men and women (Figure 2).

<<< Figure 2 about here >>>

DISCUSSION

Summary of results

This cross-sectional study showed a strong association between low LTPA and low estimated $\dot{V}O_2 max$, but not between OPA and $\dot{V}O_2max$. Furthermore, the association of domain-specific PA patterns with low $\dot{V}O_2max$ varied according to gender: After adjustment for potential confounding, women not participating in LTPA and working in highly physically demanding occupations showed the highest likelihood of having a low $\dot{V}O_2max$. In contrary, men that did not engage in LTPA and not working in physically demanding occupations showed the highest risk of low $\dot{V}O_2max$.

Comparison with findings from other studies

The strong association between LTPA and CRF has been shown in numerous studies (34). In contrast, evidence of the association of OPA with CRF is inconclusive. In a historical perspective, OPA has often been considered as health enhancing in behavioral medicine, but is traditionally seen as a potential health hazard in occupational medicine (6, 40). Recent studies support the thesis that OPA does not lead to increased CRF (41-44). A Swiss study among adults reported no association between the amount of objectively assessed steps during work-time and $\dot{V}O_2max$, and a lower $\dot{V}O_2max$ among participants having conducting manual work compared to those with sedentary work (according to reported job title), while controlling for LTPA and various covariates (41). A study among regional samples from Germany also found higher levels of $\dot{V}O_2max$ among participants with high levels of LTPA, but lower levels of $\dot{V}O_2max$ among participants with high OPA compared to low OPA (assessed by questionnaire) (43). Another study among the Danish working population observed that self-reported work and leisure sitting time were differently associated with $\dot{V}O_2max$: while there was a strong negative association between sitting leisure time and $\dot{V}O_2max$, a similar association was not observed with sitting time at work (45). In contrast, a study among male workers from Japan found higher levels of $\dot{V}O_2max$ among those with self-reported high OPA compared to low OPA (46) and a study from Finland found a positive association of CRF and self-reported OPA even after adjustment for LTPA among young men (47).

Irrespective of the association of OPA with individual fitness, OPA has been linked to negative health outcomes: in a meta-analysis Li and colleagues (6) found evidence that OPA might increase the risk of cardiovascular disease, while LTPA considerably reduced the risk. Another current meta-analysis found that men with high OPA had an increased risk of preliminary mortality, but women did not (7). In particular, the combination of high OPA with low CRF seems to be associated with a higher risk of adverse cardiovascular outcomes (48, 49).

Potential working mechanisms

It has been shown that regular aerobic exercise induces biological changes like increased stroke volume and decrease in venous oxygen content that lead to increased individual CRF (10). To increase $\dot{V}O_2max$, this exercise should ideally be performed with sufficient intensity at ≥ 50% of the maximal aerobic capacity for rather untrained individuals (10). As CRF is determined by the cardiac output and the arteriovenous oxygen difference, it can be enhanced by an increase in stroke volume, in the oxygen difference, or in both (10). LTPA, as far as it refers to sport activity, is usually activity of relatively short duration but high intensity and contains sufficient recovery time between the occasions. This is important, because it is this type of activity that can achieve a training effect of the myocardium. As a result of this effect the heart rate is reduced, the heart muscle remains longer in diastole and the stroke volume increases (50). In contrast, physical activity without recovery leads to prolonged elevations of heart rate and blood pressure (51) which can result in an erosion of the endothelium that can provoke atherosclerosis (52). This prolonged activity behavior is typically observed in OPA, which in addition is often performed with limited control about work speed and duration (9, 50). Therefore, no sufficient recovery is possible, as individuals can't decide how to perform and when to interrupt their work themselves. Also, it has been proposed that OPA might be of too low intensity to increase the individual fitness level (9). However, this might not hold true for all occupations in the same way. Studies among blue-collar workers found that directly assessed intensity of PA was higher during work than in leisure time (53), especially among those with low fitness (54).

The observed results suggest, that the association of domain-specific PA and CRF vary between men and women. Among women with low levels of LTPA, high OPA is associated with lower fitness. As Table S1 shows, men with physically demanding occupation mainly work in manual and technical professions (e.g., electricians, plumbers, mechanics) while women in physically demanding jobs work mainly in the service sector (e.g. nursing/care, catering, and cleaning). The latter jobs, mainly performed by females, are particularly affected by limited work control and higher job-strain, which may be a possible explanation for these gender-specific patterns. For example, health care workers in Germany report very high level of job demands compared with the average level of all occupations while having a low decision-making autonomy (55) (56, p. 76-84). This can be of special concern as studies have shown, that high strain-jobs can lead to lower LTPA (57) whereas high occupational stress in combination with low CRF has been shown to considerably increase the cardiovascular risk (58). Furthermore, the potential physiological mechanisms described above hold especially true for the prevalent high work demand professions among women: studies have shown, that e.g. among cleaners OPA is often of long duration, but with insufficient intensity and goes along with an high relative workload (13).

When recommending higher levels of LTPA, one should consider the embedded and dependent relationship of the different domains of PA: First, OPA and LTPA are not the exclusive domains of PA; transportation and domestic activities are also relevant. This is of importance because, like OPA, both of these domains can also be described as non-discretionary time (59) with limited autonomy by the individual. Second, performing PA in all of these domains does depend on structures at the societal, environmental and individual level (60). As individuals face varying obstacles to engage in more LTPA like cultural temporal structures (e.g., public-transport timetables) or individual responsibilities (e.g. parenthood), measures and policies aiming to create an activity friendly environment are needed rather than blaming the individual (1). In addition, it has to be noted that some studies found that a moderate to high level of LTPA was associated with adverse health outcomes among those exposed to high OPA (61, 62). Thus, the interrelationships between OPA and LTPA remains not fully understood and there is a need for further research to explain these partly contradictory results in the literature. To take into account the observed gender differences, it is highly recommended that future studies should investigate both men and women separately. Furthermore, a high share of the research on this topic is based on self-reported PA with a high heterogeneity among the instruments used. Thus, future research investigating the domains-specific effects of PA using objective measures is necessary (63). Finally, it is recommended that policy makers and public health experts involved in the development of PA recommendations consider specifying these recommendations according to the level of OPA, as recent guidelines do not make a distinction between activity levels during work.

Strengths and Limitations

A major strength of this study is the use of a large population-based nationally representative sample of the non-institutionalized, resident adult working population, which allows the generalizability of our findings.

However, even though in DEGS1 great efforts have been taken to reduce potential sources of bias (64, 65), the results of our study need to be interpreted in the context of some limitations. First, the cross-sectional design of the study does not permit a causal inference of the observed relationship between PA pattern and CRF. Even if it is well established that regular PA can enhance CRF, reversed causality for instance that individuals who have inherited a lower CRF tend to be less active, cannot be ruled out (66). Thus, it cannot be drawn from our study, that a higher CRF can be traced to high LTPA levels. Second, due to the use of the PAR-Q screening questionnaire, our sample consists of a relatively healthy study-population. This implies the exclusion of most study participants using cardiorespiratory related medications. However, it cannot be ruled out that the use of other medications (e.g. psychotropic or antidiabetic drugs) act as a source of bias in our investigations. Furthermore, the use of relatively healthy study-population may have hampered the generalizability of our results. In addition, it cannot be ruled out that our results are affected by the so called healthy worker effect describing a specific form of selection bias were more healthy individuals are more likely to work in physically demanding occupations. Third, as in most large-scale epidemiological studies (10, 34), $\dot{V}O_2max$ was estimated based on a submaximal ergometer test in a highly standardized and quality assured procedure (19) and not directly assessed by breath gas analysis. Fourth, self-reports on PA levels are prone to recall and social desirability bias (67, 68). Thus, we cannot exclude the possibility that the level of PA was over- or underreported. This holds true not only for this study, but also for most of the studies cited in the discussion. Furthermore, LTPA was assessed based on information about the duration per week but not about intensity. The latter may have an additional impact on CRF (10). In the case of OPA, in contrast to objectively measured activity levels, which usually includes general activities during work, self-reports are often restricted to specific task, such as lifting of heavy loads. This is particularly important, because such physically demanding task influence CRF in a different way than general activities. Fifth, OPA was assessed indirectly via JEMs. Even though these JEMs were based on a very large sample and the use of hierarchical linear regression models, controlling for age, gender, working hours and job experience, reducing the likelihood of confounding, JEMs are generally not able to account for variability of exposures within jobs (69). If the prevalence of high physical demands within occupations varies widely, this could have led to biased results regarding the observed OPA levels, which would tend to reduce the magnitude of the observed associations.

CONCLUSIONS

This study showed a strong association between patterns of PA during leisure time and work and CRF among men and women in the working population in Germany. For example, women without LTPA are likely to have a low CRF, especially if they work in physically demanding jobs. Hence, these findings contribute to the increasing body of evidence of different domain-specific effects of PA on health outcomes and emphasize the importance of considering different domains of PA in future studies. Moreover, as current guidelines do not distinguish between PA during work and leisure time, specifying LTPA recommendations according to the OPA level should be considered. Further research is needed to elucidate the pathways through which different domains of PA lead to divergent health effects and to confirm these findings with objective measures of PA.

STATEMENTS

Author Contributions

GBMM and JDF were involved in the design and conduct of DEGS1, JDF in particular for the ergometer testing. JZ, LEK, and JDF conceptualized the current study. JZ, MD and LEK conducted the analysis. JZ drafted the manuscript. GBMM, JDF and TK contributed to the analysis plan and interpretation of the results. MD, GBMM, JDF and TK critically revised it. All authors contributed to the interpretation of findings, reviewed, edited and approved the final manuscript.

Funding

No external funding was received. The study was financed by the Robert Koch Institute which is a federal institute within the portfolio of the German Federal Ministry of Health.

Competing interests

None declared.

Patient consent

Participants signed an informed written consent prior to participation.

Ethics approval

DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité – Universitätsmedizin Berlin ethic committee (no EA2/047/08).

Data sharing statement

A dataset of DEGS1 is available via Public Use File (https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html [accessed 23 Sep 2019]).

REFERENCES

1. World Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: WHO; 2018.
2. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. Geneva: WHO; 2013.
3. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO; 2010 http://www.who.int/dietphysicalactivity/global-PA-recs-2010.pdf. (date accessed 05 Sept 2018).
4. Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. Obes Rev. 2012;13(8):659-80.
5. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. Int J Epidemiol. 2011;40(5):1382-400.
6. Li J, Loerbroks A, Angerer P. Physical activity and risk of cardiovascular disease: what does the new epidemiological evidence show? Current Opinion in Cardiology. 2013;28(5):575-83.
7. Coenen P, Huysmans MA, Holtermann A, et al. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. Br J Sports Med. 2018;52(20):1320-6.
8. Holtermann A, Hansen JV, Burr H, et al. The health paradox of occupational and leisure-time physical activity. Br J Sports Med. 2012;46(4):291-5.
9. Holtermann A, Krause N, van der Beek AJ, et al. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med. 2018;52(3):149-50.
10. Ross R, Blair SN, Arena R, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. Circulation. 2016;134(24):e653-e99.
11. Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. JAMA. 2009;301(19):2024-35.
12. Coenen P. Preventing disease by integrating physical activity in clinical practice: What works for whom? Heart. 2018;104(14):1-2.
13. Korshøj M, Krustrup P, Jespersen T, et al. A 24-h assessment of physical activity and cardio-respiratory fitness among female hospital cleaners: a pilot study. Ergonomics. 2013;56(6):935-43.
14. Finger JD, Tylleskär T, Lampert T, et al. Physical activity patterns and socioeconomic position: the German National Health Interview and Examination Survey 1998 (GNHIES98). BMC Public Health. 2012;12(1):1079.
15. Hobler D, Pfahl S, Spitznagel J. Horizontale Segregation des Arbeitsmarktes 2017. WSI GenderDatenPortal [horizontal segregation of the labor market] 2020 (date accessed 10 Jan 2020). Available from: https://www.boeckler.de/121336.htm#.
16. Hands B, Parker H, Larkin D, et al. Male and Female Differences in Health Benefits Derived from Physical Activity: Implications for Exercise Prescription. Journal of Womens Health, Issues and Care. 2016;5.
17. Kurth B-M. The RKI health monitoring - What it contains and how it can be used [Das RKI-Gesundheitsmonitoring - Was es enthält und wie es genutzt werden kann]. Public Health Forum. 2012;20(3):4. e1-4. e3.
18. Scheidt-Nave C, Kamtsiuris P, Gößwald A, et al. German health interview and examination survey for adults (DEGS) - design, objectives and implementation of the first data collection wave. BMC Public Health. 2012;12(1):730.

19. Finger JD, Gosswald A, Hartel S, et al. Measurement of cardiorespiratory fitness in the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5-6):885-93.
20. Finger JD, Krug S, Gößwald A, et al. Cardiorespiratory fitness among adults in Germany. Results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):772-8.
21. Deutsche Gesellschaft für Sportmedizin und Prävention (DGSP). PAR-Q-Fragebogen (German version). 2007.
22. Canadian Society for Exercise Physiology. Physical Activity Readiness Questionnaire - PAR-Q (revised 2002). Ottawa: Health Canada; 2002.
23. Andersen KL, Shephard R, Denolin H, et al. Fundamentals of exercise testing 1971 https://apps.who.int/iris/handle/10665/40145. (date accessed 15 Feb 2019).
24. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. Journal of the American College of Cardiology. 2001;37(1):153-6.
25. Gore CJ, Booth ML, Bauman A, et al. Utility of pwc75% as an estimate of aerobic power in epidemiological and population-based studies. Med Sci Sports Exerc. 1999;31(2):348-51.
26. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 5th Edition ed. Baltimore:: Williams & Wilkins; 1995, p.280.
27. Kroll LE. Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten anhand von ISCO-88 und KldB-92 [Construction and validation of a general index for job demands in occupations based on ISCO-88 and KldB-92]. Methoden — Daten — Analysen. 2011;5(1):63-90.
28. Rohrbach-Schmidt D, Hall A. BIBB/BAuA employment survey 2012. BIBB-FDZ Data and Methodological Reports Federal Institute for Vocational Education and Training Bonn, Germany. 2013.
29. Kroh M, Neiss H, Kroll L, et al. High-income people live longer [Menschen mit hohem Einkommen leben länger]. DIW-Wochenbericht. 2012;79(38):3-15.
30. Santi I, Kroll LE, Dietz A, et al. To what degree is the association between educational inequality and laryngeal cancer explained by smoking, alcohol consumption, and occupational exposure? Scand J Work Environ Health. 2014;40(3):315-22.
31. Santi I, Kroll LE, Dietz A, et al. Occupation and educational inequalities in laryngeal cancer: the use of a job index. BMC Public Health. 2013;13(1):1080.
32. Krug S, Jordan S, Mensink GBM, et al. Physical activity. Results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):765-71.
33. Steinbach D, Graf C. Leisure Time Physical Activity and SedentarinessLeisure time physical activity and sedentariness. In: Kirch W, editor. Encyclopedia of Public Health. Dordrecht: Springer; 2008. p. 849-51.
34. Zeiher J, Ombrellaro KJ, Perumal N, et al. Correlates and determinants of cardiorespiratory fitness in adults: a systematic review. Sports Med Open. 2019;5(39).
35. Zeiher J, Manz K, Kuntz B, et al. Individual and Interpersonal Correlates of Cardiorespiratory Fitness in Adults – Findings from the German health interview and examination survey Sci Rep. 2020;10(445).
36. World Health Organization. BMI classification 2019 http://apps.who.int/bmi/index.jsp?introPage=intro_3.html. (date accessed 20.02.2019).
37. World Health Organization. Obesity: preventing and managing the global epidemic. Genf: World Health Organization; 2000.
38. Lampert T, Kroll L, Müters S, et al. Measurement of socioeconomic status in the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56:1-5.
39. Graubard BI, Korn EL. Predictive margins with survey data. Biometrics. 1999;55(2):652-9.

40. Morris JN, Heady JA, Raffle PAB, et al. Coronary Heart Disease and Physical Activity of Work. The Lancet. 1953;262(6796):1111-20.
41. Mundwiler J, Schüpbach U, Dieterle T, et al. Association of occupational and leisure-time physical activity with aerobic capacity in a working population. PLoS ONE. 2017;12(1).
42. Ruzic L, Heimer S, Misigoj-Durakovic M, et al. Increased occupational physical activity does not improve physical fitness. Occupational and environmental medicine. 2003;60(12):983-5.
43. Bahls M, Groß S, Baumeister SE, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. Sci Rep. 2018;8(1):16066.
44. Lakka TA, Laaksonen DE, Lakka HM, et al. Sedentary lifestyle, poor cardiorespiratory fitness, and the metabolic syndrome. Med Sci Sports Exerc. 2003;35(8):1279-86.
45. Saidj M, Jørgensen T, Jacobsen RK, et al. Differential cross-sectional associations of work- and leisure-time sitting, with cardiorespiratory and muscular fitness among working adults. Scand J Work Environ Health. 2014(5):531-8.
46. Nagaya T, Kondo Y, Shibata T. Effects of sedentary work on physical fitness and serum cholesterol profile in middle-aged male workers. International archives of occupational and environmental health. 2001;74(5):366-70.
47. Tammelin T, Nayha S, Rintamaki H, et al. Occupational physical activity is related to physical fitness in young workers. Med Sci Sports Exerc. 2002;34(1):158-65.
48. Holtermann A, Mortensen OS, Burr H, et al. Physical work demands and physical fitness in low social classes--30-year ischemic heart disease and all-cause mortality in the Copenhagen Male Study. J Occup Environ Med. 2011;53(11):1221-7.
49. Holtermann A, Mortensen OS, Burr H, et al. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. Scand J Work Environ Health. 2010;36(5):357-65.
50. Krause N. Physical activity and cardiovascular mortality – disentangling the roles of work, fitness, and leisure. Scand J Work Environ Health. 2010(5):349-55.
51. Hall C, Heck JE, Sandler DP, et al. Occupational and leisure-time physical activity differentially predict 6-year incidence of stroke and transient ischemic attack in women. Scand J Work Environ Health. 2019;45(3):267-79.
52. Khera A, Mitchell JH, Levine BD. Preventive cardiology: The effects of exercise. In: Willerson JT, Cohn JN, Wellens HJJ, Holmes DR, editors. Cardiovascular Medicine: Springer; 2007. p. 2631-48.
53. Gram B, Westgate K, Karstad K, et al. Occupational and leisure-time physical activity and workload among construction workers – a randomized control study. International Journal of Occupational and Environmental Health. 2016;22(1):36-44.
54. Coenen P, Korshøj M, Hallman DM, et al. Differences in heart rate reserve of similar physical activities during work and in leisure time – A study among Danish blue-collar workers. Physiology and Behavior. 2018;186:45-51.
55. Schmucker R. Working conditions in nursing care [Arbeitsbedingungen in Pflegeberufen]. In: Jacobs K, Kuhlmey A, Greß S, Klauber J, Schwinger A, editors. Pflege-Report 2019: Mehr Personal in der Langzeitpflege - aber woher? Berlin, Heidelberg: Springer; 2019. p. 49-60.
56. Theobald H, Szebehely M, Preuß M. Working conditions in geriatric care [Arbeitsbedingungen in der Altenpflege]. Berlin: Ed. Sigma 2013.
57. Fransson EI, Heikkila K, Nyberg ST, et al. Job strain as a risk factor for leisure-time physical inactivity: an individual-participant meta-analysis of up to 170,000 men and women: the IPD-Work Consortium. Am J Epidemiol. 2012;176(12):1078-89.
58. Schilling R, Colledge F, Ludyga S, et al. Does cardiorespiratory fitness moderate the association between occupational stress, cardiovascular risk, and mental health in police officers? Int J Environ Res Public Health. 2019;16(13).
59. van Tienoven TP, Deyaert J, Harms T, et al. Active work, passive leisure? Associations between occupational and non-occupational physical activity on weekdays. Soc Sci Res. 2018;76:1-11.

60. Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258-71.

61. Clays E, De Bacquer D, Janssens H, et al. The association between leisure time physical activity and coronary heart disease among men with different physical work demands: a prospective cohort study. European journal of epidemiology. 2013;28(3):241-7.

62. Korshøj M, Lidegaard M, Skotte JH, et al. Does aerobic exercise improve or impair cardiorespiratory fitness and health among cleaners? A cluster randomized controlled trial. Scand J Work Environ Health. 2015(2):140-52.

63. Ketels M, De Bacquer D, Geens T, et al. Assessing physiological response mechanisms and the role of psychosocial job resources in the physical activity health paradox: study protocol for the Flemish Employees' Physical Activity (FEPA) study. BMC Public Health. 2019;19(1):765.

64. Gößwald A, Lange M, Dölle R, et al. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Recruitment of participants, fieldwork, and quality assurance. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):1-8.

65. Kamtsiuris P, Lange M, Hoffmann R, et al. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Sampling design, response, weighting, and representativeness. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2013;56(5):1-10.

66. Després JP. Physical Activity, Sedentary Behaviours, and Cardiovascular Health: When Will Cardiorespiratory Fitness Become a Vital Sign? Can J Cardiol. 2016;32(4):505-13.

67. Prince SA, Adamo KB, Hamel ME, et al. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. International Journal of Behavioral Nutrition and Physical Activity. 2008;5(1):56.

68. Brenner PS, DeLamater J. Lies, Damned Lies, and Survey Self-Reports? Identity as a Cause of Measurement Bias. Social Psychology Quarterly. 2016;79(4):333-54.

69. Tielemans E, Heederik D, Burdorf A, et al. Assessment of occupational exposures in a general population: Comparison of different methods. Occupational and environmental medicine. 1999;56(3):145-51.

FIGURES & TABLES

Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; $\dot{V}O_2max$: Maximal oxygen consumption

Figure 2: Predicted probabilities (with 95 % confidence intervalls) of low $\dot{V}O_2max$ according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

Table 1: Characteristics of study participants in DEGS1

	Men			Women			Total		
	n	%[1]	%[2]	n	%[1]	%[2]	n	%[1]	%[2]
$\dot{V}O_2max$									
Low	705	58.8	58.8	750	57.9	59.5	1455	58.3	59.1
Intermediate/high	494	41.2	41.2	546	42.1	40.5	1040	41.7	40.9
Missing	0	0.0	-	0	0.0	-	0	0.0	-
LTPA									
no	297	24.8	24.9	309	23.8	24.7	606	24.3	24.8
<2h	492	41.0	39.8	647	49.9	49.9	1139	45.7	44.7
≥2h	410	34.2	35.3	340	26.2	25.3	750	30.1	30.5
Missing	0	0.0	-	0	0.0	-	0	0.0	-
OPA									
low	750	62.6	59.7	895	69.1	67.0	1645	65.9	63.2
high	449	37.4	40.3	401	30.9	33.0	850	34.1	36.8
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Age									
18-24 Years	137	11.4	11.3	138	10.6	11.8	275	11.0	11.5
25-34 Years	277	23.1	26.4	250	19.3	22.5	527	21.1	24.5
35-44 Years	287	23.9	26.8	338	26.1	27.7	625	25.1	27.2
45-54 Years	308	25.7	23.2	369	28.5	25.8	677	27.1	24.5
55-64 Years	190	15.8	12.3	201	15.5	12.3	391	15.7	12.3
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Waist circumference									
Normal	719	60.0	61.7	702	54.2	57.0	1421	57.0	59.4
Increased	256	21.4	20.1	289	22.3	22.5	545	21.8	21.3
Strongly increased	224	18.7	18.2	303	23.4	20.5	527	21.1	19.3
Missing	0	0.0	-	2	0.2	-	2	0.1	-
Body mass index									
Underweight	9	0.8	0.8	32	2.5	2.8	41	1.6	1.8
Normal Weight	467	38.9	37.7	748	57.7	58.1	1215	48.7	47.5
Overweight	548	45.7	46.1	348	26.9	27.1	896	35.9	37.0
Obese	171	14.3	15.4	164	12.7	11.9	335	13.4	13.7
Missing	4	0.3	-	4	0.3	-	8	0.3	-
Smoking status									
Daily	349	29.1	31.3	268	20.7	23.2	617	24.7	27.4
Occasionally	106	8.8	8.2	96	7.4	7.6	202	8.1	7.9
Former	323	26.9	26.9	354	27.3	25.8	677	27.1	26.3
Never	420	35.0	33.7	576	44.4	43.4	996	39.9	38.3
Missing	1	0.1	-	2	0.2	-	3	0.1	-
Alcohol consumption									
Low	180	15.0	16.7	151	11.7	12.3	331	13.3	14.6
Moderate	760	63.4	64.3	821	63.3	64.8	1581	63.4	64.6
High	245	20.4	19.0	314	24.2	22.9	559	22.4	20.9
Missing	14	1.2	-	10	0.8	-	24	1.0	-
Socio economic status									
Low	151	12.6	14.7	113	8.7	9.6	264	10.6	12.3
Medium	702	58.5	61.4	800	61.7	63.5	1502	60.2	62.4
High	346	28.9	23.9	382	29.5	26.8	728	29.2	25.3
Missing	0	0	-	1	0.1	-	1	0.0	-

[1]Percentage of the sample (unweighted) [2]Weighted percentage (Weighting factors were used to adjust the distribution of the sample to match the German population according to gender, age, education and region)DEGS1 German Health

Interview and Examination Survey for Adults, $\dot{V}O_2max$ Maximal oxygen consumption LTPA Leisure time physical activity, OPA Occupational physical activity

Table 2: Association of LTPA and OPA among male and female DEGS1 participants

	Low OPA		High OPA	
	%	(95%-CI)	%	(95%-CI)
Men				
No LTPA	24,0	(20,1-28,3)	26,2	(21,4-31,5)
<2h LTPA	39,4	(35,2-43,7)	40,4	(34,9-46,2)
≥2h LTPA	36,6	(32,7-40,7)	33,4	(27,7-39,7)
Women				
No LTPA	21,6	(17,9-25,9)	31,1	(25,6-37,3)
<2h LTPA	49,6	(44,8-54,3)	50,6	(44,9-56,4)
≥2h LTPA	28,8	(25,1-32,8)	18,2	(14,4-22,9)

DEGS1 German Health Interview and Examination Survey for Adults, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

Table 3: Prevalence of low $\dot{V}O_2max$ according to domain specific physical activity, health behavioral, anthropometric, and sociodemographic characteristics among male and female DEGS1 participants

	Men		Women	
	%	(95%-CI)	%	(95%-CI)
Total	41.2	(37.6-44.8)	40.5	(37.1-44.0)
LTPA				
No	63.2	(56.4-69.4)	56.1	(49.1-62.9)
<2h	42.2	(36.5-48.0)	41.2	(36.6-45.9)
≥2h	24.7	(19.8-30.5)	24.1	(19.0-30.1)
OPA				
Low	41.5	(36.8-46.4)	37.2	(33.0-41.6)
high	40.8	(35.0-46.8)	47.4	(41.5-53.4)
OPA/LTPA				
No LTPA, low OPA	68.5	(59.2-76.4)	48.0	(39.7-56.3)
No LTPA, high OPA	56.0	(44.9-66.5)	67.7	(56.7-77.0)
<2h LTPA, low OPA	42.6	(35.8-49.7)	39.3	(33.5-45.5)
<2h LTPA, high OPA	41.6	(32.3-51.5)	44.9	(37.5-52.5)
≥2h LTPA, low OPA	22.8	(17.1-29.6)	25.4	(19.0-33.0)
≥2h LTPA, high OPA	28.0	(19.1-39.0)	19.9	(11.6-32.1)
Age				
18-24 Years	28.0	(19.9-37.7)	25.8	(17.9-35.7)
25-34 Years	36.0	(28.9-43.8)	29.2	(23.3-35.9)
35-44 Years	41.9	(34.9-49.2)	36.1	(30.3-42.3)
45-54 Years	47.2	(40.9-53.7)	48.5	(42.1-55.1)
55-64 Years	51.9	(42.3-61.4)	68.7	(60.2-76.1)
Waist circumference				
Normal	27.1	(23.2-31.4)	26.9	(23.0-31.1)
Increased	54.6	(46.2-62.8)	46.4	(38.5-54.6)
Strongly increased	74.2	(66.7-80.4)	72.5	(66.3-77.9)
Body mass index				
Underweight	19.8	(3.3-64.1)	18.9	(7.7-39.4)
Normal Weight	21.7	(16.9-27.4)	27.1	(23.4-31.2)
Overweight	47.5	(42.3-52.8)	53.7	(46.4-60.8)
Obese	71.1	(62.4-78.4)	83.1	(75.3-88.8)
Smoking status				
Daily	40.7	(34.9-46.8)	38.8	(31.6-46.7)
Occasionally	31.7	(22.3-42.9)	33.5	(22.9-46.0)
Former	49.6	(42.3-56.9)	46.7	(40.0-53.6)
Never	37.5	(31.4-44.0)	39.0	(34.0-44.3)

Alcohol consumption				
Low	45.7	(38.0-53.7)	50.2	(40.8-59.5)
Moderate	39.1	(34.9-43.6)	41.1	(36.6-45.8)
High	43.4	(35.1-52.2)	33.2	(26.7-40.5)
Socio economic status				
Low	39.9	(30.7-49.8)	56.3	(45.8-66.3)
Medium	43.3	(38.7-48.1)	43.4	(39.3-47.5)
High	36.8	(30,8-43,2)	28.2	(22,4-34,9)

$\dot{V}O_2max$ Maximal oxygen consumption, DEGS1 German Health Interview and Examination Survey for Adults, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

Table 4: Domain-specific physical activity and low estimated $\dot{V}O_2max$ among male and female DEGS1 participants

	Men				Women			
	OR[1]	(95 % CI)	OR[2]	(95 % CI)	OR[1]	(95 % CI)	OR[2]	(95 % CI)
OPA Model								
low OPA	(ref.)		(ref.)		(ref.)		(ref.)	
high OPA	1.05	(0.75 - 1.46)	0.95	(0.64 - 1.42)	1.71	(1.23 - 2.36)	1.06	(0.75 - 1.49)
LTPA Model								
no LTPA	4.97	(3.47 - 7.13)	4.46	(2.89 - 6.89)	4.96	(3.26 - 7.54)	4.65	(2.90 - 7.45)
<2h LTPA	2.17	(1.48 - 3.19)	2.04	(1.32 - 3.15)	2.49	(1.72 - 3.62)	2.13	(1.44 - 3.14)
≥2h LTPA	(ref.)		(ref.)		(ref.)		(ref.)	
OPA/LTPA Model								
No LTPA, low OPA	4.92	(2.56 - 9.46)	4.45	(2.14 - 9.23)	4.37	(2.02 - 9.47)	6.54	(2.98 - 14.3)
No LTPA, high OPA	2.86	(1.47 - 5.58)	2.34	(1.08 - 5.07)	11.1	(5.15 - 24.1)	10.5	(4.39 - 24.9)
<2h LTPA, low OPA	1.69	(0.94 - 3.06)	1.54	(0.77 - 3.06)	2.84	(1.39 - 5.78)	3.52	(1.75 - 7.09)
<2h LTPA, high OPA	1.70	(0.91 - 3.17)	1.54	(0.75 - 3.16)	4.01	(1.90 - 8.49)	3.69	(1.80 - 7.60)
≥2h LTPA, low OPA	0.67	(0.35 - 1.27)	0.64	(0.32 - 1.27)	1.37	(0.64 - 2.92)	1.93	(0.90 - 4.13)
≥2h LTPA, high OPA	(ref.)		(ref.)		(ref.)		(ref.)	
n	1,199		1,181		1,296		1,277	

[1]adjusted for age; [2]adjusted for LTPA [OPA-Model], OPA [LTPA-Model], age, waist circumference, body mass index, smoking status, alcohol consumption, SES index

$\dot{V}O_2max$ Maximal oxygen consumption, DEGS1 German Health Interview and Examination Survey for Adults, OR Odds ratios, CI Confidence intervals, LTPA Leisure time physical activity, OPA Occupational physical activity

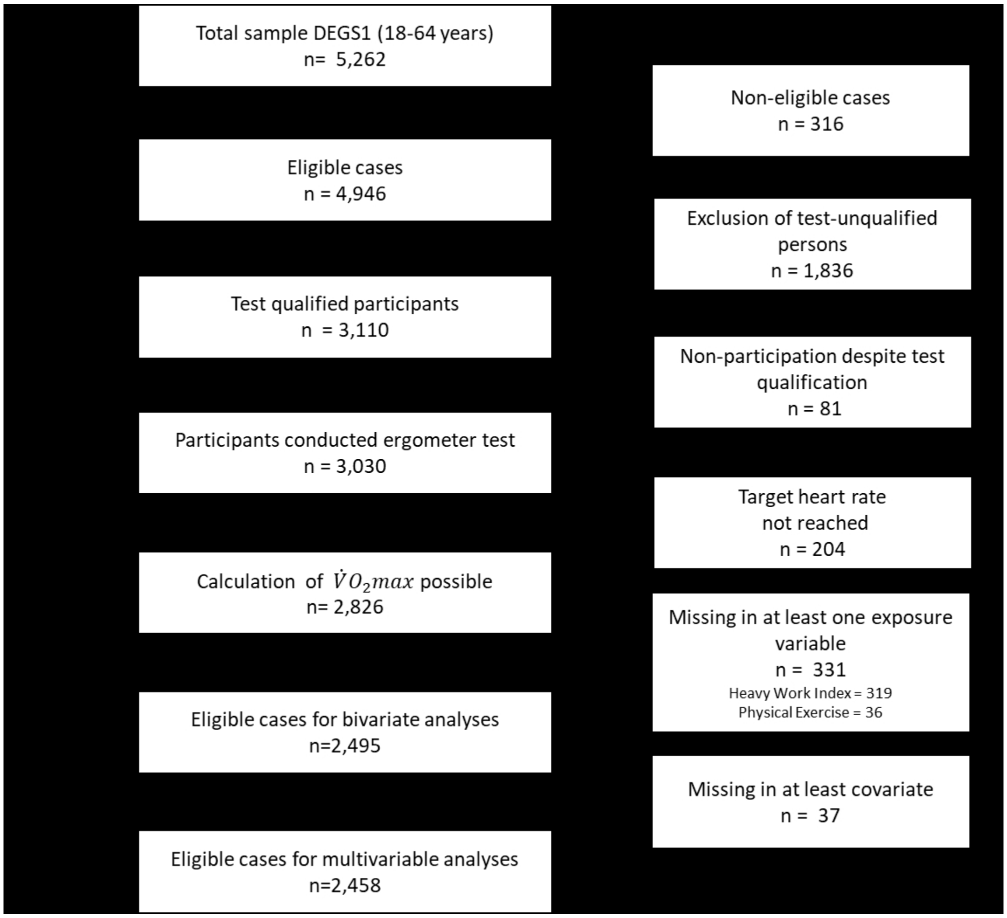

Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; VO2max: Maximal oxygen consumption

193x176mm (150 x 150 DPI)

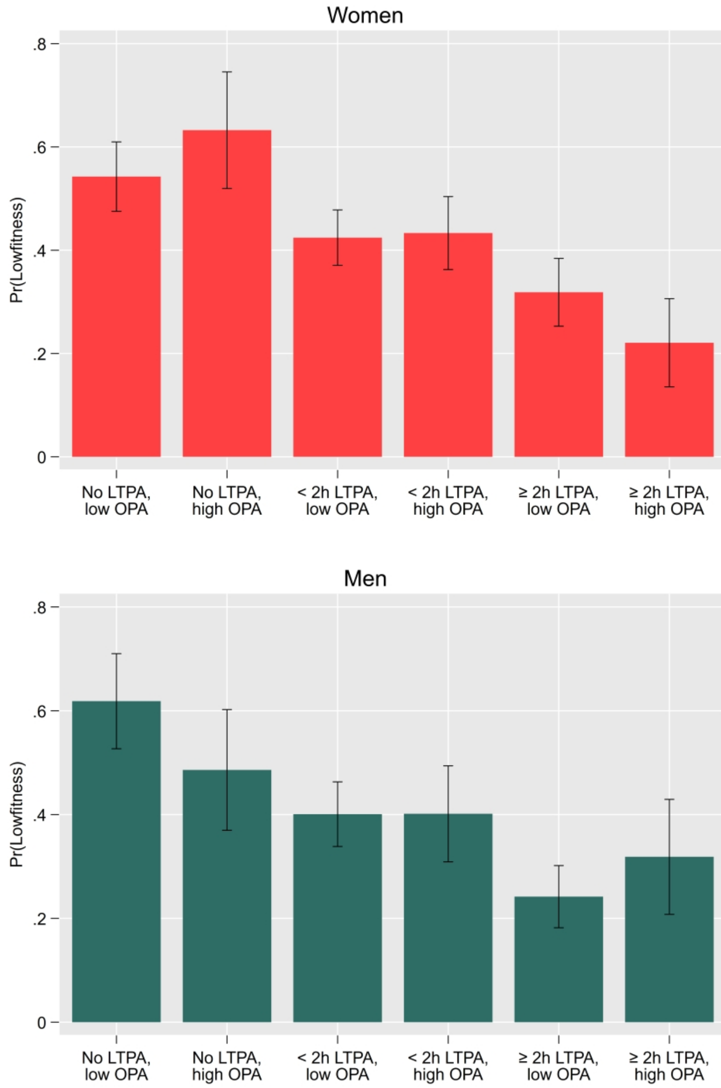

Figure 2: Predicted probabilities (with 95 % confidence intervalls) of low VO2max according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

1411x2116mm (72 x 72 DPI)

Online Supplemental Material 1: Supplementary tables

Additional file to: Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity patterns and cardiorespiratory fitness among the working population. Findings from the German cross-sectional health interview and examination survey

Table S1 Top ten occupations (ISCO-88; 4-digit) among men and women according to OPA

Men				Women			
Rank	**Occupations [ISCO-88]**	**%**	**95% CI**	**Rank**	**Occupations [ISCO-88]**	**%**	**95% CI**
	High OPA				**High OPA**		
1.	Electronics mechanics and servicers	7,6	(5,1-11,3)	1.	Institution-based personal care workers	16,6	(12,4-22,0)
2.	Plumbers and pipe fitters	5,7	(3,6-9,0)	2.	Nursing associate professionals	13,6	(10,1-18,0)
3.	Skilled agricultural and fishery workers	4,7	(2,6-8,3)	3.	Social work associate professionals	5,5	(3,6-8,2)
4.	Agricultural- or industrial-machinery mechanics and fitters	4,6	(2,7-7,6)	4.	Childcare workers	5,3	(2,8-9,8)
5.	Machine-tool setters and setter-operators	4,1	(2,4-6,7)	5.	Pre-primary education teaching associate professionals	4,8	(2,9-7,8)
6.	Cooks	3,7	(1,5-8,5)	6.	Shop salespersons and demonstrators	4,4	(2,5-7,7)
7.	Structural-metal preparers and erectors	3,6	(2,0-6,5)	7.	Waiters, waitresses and bartenders	4,3	(2,2-8,1)
8.	Building and related electricians	3,3	(1,6-6,5)	8.	Cooks	3,6	(1,8-7,1)
9.	Painters, upholsterers and related workers	3,0	(1,8-5,1)	9.	Hairdressers, barbers, beauticians and related workers	3,0	(1,5-5,8)
10.	Cabinet makers and related workers	2,7	(1,5-4,7)	10.	Helpers and cleaners in offices, hotels and other establishments	3,0	(1,5-5,8)
	Low OPA				**Low OPA**		
1.	Other office clerks	4,4	(2,8-6,9)	1.	Shop salespersons and demonstrators	10,6	(8,3-13,6)
2.	Shop salespersons and demonstrators	3,4	(2,0-5,7)	2.	Other office clerks	7,5	(5,3-10,5)
3.	Business professionals not elsewhere classified	3,2	(1,9-5,3)	3.	Bookkeepers	5,7	(4,1-8,0)
4.	Heavy-truck and lorry drivers	2,7	(1,4-5,0)	4.	Secondary education teaching professionals	4,8	(3,4-6,8)
5.	Computer assistants	2,6	(1,6-4,4)	5.	Secretaries	3,9	(2,4-6,2)
6.	Computing professionals not elsewhere classified	2,5	(1,3-4,7)	6.	Statistical and finance clerks	3,8	(2,5-5,6)
7.	Technical and commercial sales representatives	2,4	(1,4-4,1)	7.	Administrative secretaries and related associate professionals	3,6	(2,4-5,3)
8.	Finance and sales associate professionals not elsewhere classified	2,4	(1,3-4,5)	8.	Legal and related business associate professionals	2,7	(1,5-4,9)
9.	Stock clerks	2,4	(1,3-4,6)	9.	Finance and sales associate professionals not elsewhere classif.	2,4	(1,5-3,6)
10.	Civil engineers	2,0	(1,1-3,7)	10.	Cashiers and ticket clerks	2,3	(1,2-4,3)

CI Confidence intervals, ISCO-88 International Standard Classification of Occupations, OPA Occupational physical activity

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	FigS1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	9
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5/ Supl.
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	Supl.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Supl.
		(b) Indicate number of participants with missing data for each variable of interest	Tab1
Outcome data	15*	Report numbers of outcome events or summary measures	Tab1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tab2/ Tab3

		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	14/ 11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population – Findings from the cross-sectional German health interview and examination survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034610.R2
Article Type:	Original research
Date Submitted by the Author:	06-Mar-2020

Complete List of Authors:	Zeiher, Johannes; Robert Koch Institut, Department of Epidemiology and Health Monitoring Duch, Maurice; Robert Koch Institut, Department of Epidemiology and Health Monitoring; University of Potsdam, Department of Sports and Health Sciences Kroll, Lars; Central Research Institute of Ambulatory Health Care in Germany Mensink, Gert; Robert Koch Institut Finger, Jonas D.; Robert Koch Institut, Department of Epidemiology and Health Monitoring Keil, Thomas; Bavarian Health and Food Safety Authority, State Institute of Health; Charité Universitätsmedizin Berlin, Institute for Social Medicine, Epidemiology and Health Economics

Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Occupational and environmental medicine
Keywords:	cardiorespiratory fitness, adults, physical activity, physical fitness, occupational physical activity

Research article

Domain-specific physical activity patterns and cardiorespiratory fitness among the working population – Findings from the cross-sectional German health interview and examination survey

Johannes Zeiher[a]*, Maurice Duch[a,b], Lars E. Kroll[c], Gert B. M. Mensink[a] Jonas D. Finger[a] Thomas Keil[d,e,f]

[a] Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin, Germany
[b] University of Potsdam, Potsdam, Germany
[c] Central Research Institute of Ambulatory Health Care in Germany, Berlin, Germany
[d] Institute for Clinical Epidemiology and Biometry, University of Würzburg, Würzburg, Germany
[e] State Institute of Health, Bavarian Health and Food Safety Authority, Bad Kissingen, Germany
[f] Institute for Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin Berlin, Berlin, Germany

* Corresponding author:
Johannes Zeiher
Unit of Health Behaviour
Department of Epidemiology and Health Monitoring
Robert Koch Institute
General-Pape-Straße 62-66
12101 Berlin, Germany
Email: zeiherj@rki.de
Phone: 0049 30 18754 3775

Word count (main text): 4,375 words

ABSTRACT

Objectives:

This study aimed to investigate associations between occupational physical activity patterns (physical work demands linked to job title) and leisure time physical activity (assessed by questionnaire) with cardiorespiratory fitness (assessed by exercise test) among men and women in the German working population.

Design:

Population-based cross-sectional study

Setting:

Two-stage cluster-randomized general population sample selected from population registries of 180 nationally-distributed sample points. Information was collected from 2008 to 2011.

Participants:

1,296 women and 1,199 men aged 18–64 from the resident working population.

Outcome measure:

Estimated low maximal oxygen consumption ($\dot{V}O_2max$), defined as first and second sex-specific quintile, assessed by a standardized, submaximal cycle ergometer test.

Results:

Low estimated $\dot{V}O_2max$ was strongly linked to low leisure time physical activity, but not occupational physical activity. The association of domain-specific physical activity patterns with low $\dot{V}O_2max$ varied by sex: women doing no leisure time physical activity with high occupational physical activity levels were more likely to have low $\dot{V}O_2max$ (odds ratio (OR) 6.54; 95% confidence interval (CI) 2.98–14.3) compared with women with ≥ 2 hours of leisure time physical activity and high occupational physical activity. Men with no leisure time physical activity and low occupational physical activity had the highest odds of low $\dot{V}O_2max$ (OR 4.37; 95% CI 2.02–9.47).

Conclusion:

There was a strong association between patterns of leisure time and occupational physical activity and cardiorespiratory fitness within the adult working population in Germany. Women doing no leisure time physical activity were likely to have poor cardiorespiratory fitness, especially if they worked in physically-demanding jobs. However, further investigation is needed to understand the relationships between activity and fitness in different domains. Current guidelines do not distinguish between activity during work and leisure time, so specifying leisure time recommendations by occupational activity level should be considered.

KEYWORDS
cardiorespiratory fitness; adults; physical activity; physical fitness; occupational physical activity

ARTICLE SUMMARY

Strengths and limitations of this study

1. This is among the first studies to examine the association between leisure time and occupational physical activity patterns and cardiorespiratory fitness in Germany.
2. We used a large nationally-representative population-based sample of the resident adult working population, to allow our findings to be generalized.
3. Leisure time physical activity was assessed by self-reports, which may be prone to recall and social desirability bias.

BACKGROUND

Physical activity is crucial for health and the unfavourable effects of an increasingly sedentary lifestyle are acknowledged as a major public health challenge.[1, 2] Physical activity is defined as all bodily movement produced by skeletal muscles that require energy expenditure.[3] It has a positive influence on physical and mental health and contributes to the prevention of non-communicable diseases and premature mortality.[1] It can also take different forms and happen in different domains of individual daily routines and life courses. For example, people may participate in sports during their leisure time (leisure time physical activity) or be active at work (occupational physical activity). To date, physical activity in any form and setting has been considered beneficial and recent recommendations do not distinguish between domains. The current World Health Organization (WHO) guideline recommends at least 150 minutes of moderate intensity aerobic physical activity per week, stating that "[…] Physical activity includes leisure time physical activity, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities."[3, p. 8]

Manual and physically-demanding occupations have been declining for decades, but occupational physical activity still accounts for a large part of many people's daily activity.[4] The beneficial effects of leisure time physical activity are well established, but the effect of occupational activity is inconclusive. Studies in the past often argued that occupational activity should also be considered to improve health,[5] but recent studies suggest that it is not health-enhancing and may even have the opposite effect.[6, 7] As a possible explanation for this 'health paradox', the domain-specific effects of physical activity on cardiorespiratory fitness have come to attention.[8, 9] Defined as the ability of circulatory, respiratory and muscular systems to supply oxygen during prolonged physical exercise,[3] cardio respiratory fitness can be enhanced by regular endurance exercise[10] and is a strong predictor of adverse health outcomes.[11] It has been argued, that occupational physical activity rarely has the adequate intensity, duration, and volume to increase cardiorespiratory fitness.[8, 9, 12, 13]

However, research on the association between different activity domains and cardiorespiratory fitness in Germany is limited. In particular, the interplay between different domains has not yet been analysed for cardiorespiratory fitness. This study therefore aimed to investigate the associations between leisure time and occupational physical activity with cardiorespiratory fitness among the German working population. Furthermore, in addition to the direct effects of the domain-specific physical activity, their interactional effects on cardiorespiratory fitness are investigated. The analyses were stratified by sex because men and women may vary in their exposure to physical demands at work,[14] type of occupations,[15] and response to physical activity.[16]

METHODS

Study design

We used data from the nationwide cross-sectional German Health Interview and Examination Survey for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1). DEGS1 is part of the Federal Health Monitoring System administered by the Robert Koch Institute.[17] In detail, the study design is described elsewhere.[18] Briefly, the study is based on a two-stage cluster randomized sampling procedure. First, 180 sample points were sampled from a list of German communities stratified to represent the regional distribution. Second, within these units, adult individuals were randomly drawn from local population registries stratified by 10-year age groups. The response rate was 42%. A total of 5,262 participants aged 18–64 years took part in the physical measurements component from November 2008 to December 2011. Of these, 3,110 individuals were test-qualified for the exercise test (Figure 1).

<<< Figure 1 about here >>>

Overall, 3,030 participants completed the exercise test (participation rate 97.4%). $\dot{V}O_2max$ was estimated for all participants reaching at least 75% of the age-predicted maximum heart rate (HR_{max}). In total, 204 participants terminated the test before reaching this heart rate, so $\dot{V}O_2max$ could be calculated for 2,826 participants. Further cases were excluded from this analysis because of missing physical activity data. Overall, valid information on $VO2max$ and occupational and leisure time physical activity was available for 1,296 women and 1,199 men. Table 1 shows demographic, anthropometric and health behaviour variables from this representative sample of the adult working population of Germany. Women made up 48.0% of the sample, and the mean age of the participants was 39.6 years (range 18–64 years). The unweighted and weighted percentages did not differ substantially, although weighting led to a slightly smaller proportion of participants in the older age groups and a smaller proportion in the high socioeconomic status group.

<<< Table 1 about here >>>

Patient and public involvement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient-relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Outcome variable

Cardiorespiratory fitness was measured using a standardized, submaximal cycle ergometer test (Ergosana Sana Bike 350/450 [Ergosana, Germany], heart rate monitor [Polar, Finland], blood pressure cuffs [Ergosana, Germany], a heart rate transmitter [Oregon Scientific, USA] and a notebook with ergometer software [Dr Schmidt GmbH, Germany]). Test methodology, protocol, and exclusion criteria have been described elsewhere.[19, 20] DEGS1 participants were included in the ergometer test if they were aged 18–64 years, gave informed consent, and were test-qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q).[21, 22] If any PAR-Q contraindications were reported, the participant was seen by a physician, who decided whether they should be enrolled into the exercise test. Cardiorespiratory fitness was assessed using the test protocol recommended by the WHO.[23] Beginning at 25 watts, the workload was increased by 25 watts every two minutes until 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 watts was achieved or the study staff terminated the test. Heart rate was monitored continuously throughout the test. The formula *208 − 0.7 × Age* was used to calculate the age-predicted maximum heart rate.[24] To derive physical work capacity at HR_{max} ($PWC_{100\%}$), the measured heart rate (beats per minute) during the incremental phase was regressed against corresponding workload in watts for each participant. Assuming a linear relationship between heart rate and workload, $PWC_{100\%}$ was obtained by extrapolation using the individual regression equation $PWC_{100\%} = intercept + HR_{max} \times slope$.[25] $PWC_{100\%}$ was converted to $\dot{V}O_2max$ using a metabolic equation provided by the American College of Sports Medicine: $3.5\ ml/min/kg + 12.24 \times (PWC_{100\%}) / (body\ weight)$.[26] Estimated $\dot{V}O_2max$ was categorized into low (sex-specific quintiles 1–2) and intermediate to high (quintiles 3–5).

Exposure variable

Occupational physical activity: a physical work demands index

To assess occupational physical activity, we used an indirect method and computed specific job exposure matrices to distinguish participants' occupation by level of physical demand. These matrices are an established methodological tool to allow inclusion of specific occupational exposure in analyses, drawing on studies that assess information about job titles. They are constructed using available secondary data to determine exposure profiles for each occupation. These profiles are matched to primary data using standardised job classifications. In our case, such matrices were constructed using data from a large-scale representative study on working conditions of 20,000 employees in Germany,[27, 28] which was part of the European Working Conditions Survey regularly conducted in member states of the European Union. The overall job index and specific indexes have been described and applied elsewhere.[29–31] In this study, we used a specific sub-index of perceived physical work demands. To construct the index, we used data on the frequency of lifting and carrying heavy loads (men ≥ 20 kg, women ≥ 10 kg). The item was assessed with a frequency scale with four answer categories: "often", "sometimes", "rarely" and "never".[27, 28] The physical demand index was assigned to the occupations based on hierarchic multilevel analyses adjusted for sex, age, job experience and part time employment. In contrast to the use of occupation-specific means, this procedure allows adjustment for other variables besides the specific occupation that could also influence the level of demand (e.g., the sex ratio or the level of part time employment). The levels for the multi-level estimation were defined by the 2-, 3- and 4-digit codes of the International Classification of Occupations of 1988 (ISCO-88) classification. These matrices were then classified into deciles. Occupations with the lowest level of physical work demands had a value of 1 (first decile), and those with the highest level had a value of 10 (tenth decile). Using the ISCO-88, the matrices were matched to DEGS1. To create a combined physical activity variable, this index was then dichotomized into low (index values 1–6) and high occupational physical activity (index values 7–10). A list of the most frequent occupations in DEGS1 by occupational activity level for men and women is shown in Table S1 (Online Supplemental Material).

Leisure time physical activity: physical exercise

Leisure time physical activity was assessed by asking participants "How often do you engage in physical exercise?".[32] Leisure time physical activity usually refers to all physical activity in freely disposable time, but sport and exercise are the main elements[33] so were used in this study. Responses were on a five-point scale of "no physical exercise", "less than 1 h a week" and "regularly 1–2 h a week", "regularly up to 4 h" and "regularly more than 4 h", and were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.

Combined occupational and leisure time physical activity

To analyse the combined relationship of occupational and leisure time physical activity on cardiorespiratory fitness, we generated a combined variable by grouping no, < 2 hours, and ≥ 2 hours leisure time physical activity with each of low and high occupational physical activity, giving six possible categories.

Covariates

Relevant covariates were selected from the literature.[34, 35] Age was categorised into five groups: 18–24 years, 25–34 years, 35–44 years, 45–54 years and 55–64 years. Smoking was grouped into daily, occasionally, former and never. Alcohol intake was estimated by multiplying the calculated quantity of each alcoholic beverage, assessed by a food frequency questionnaire, with standard ethanol content (beer: 4.8%; wine: 11%, spirits: 33%) and classified into low (quintile 1), medium (quintile 2–4), and high (quintile 5) alcohol consumption using sex-specific quintiles. Body mass index and waist circumference have been shown to be independently related to cardiorespiratory fitness,[34, 35] so we included both parameters as covariates. Body height and weight were measured by standardized procedures using portable electronic scales (SECA, Germany) and stadiometer (Holtain, UK). Body mass index (kg/m^2) was categorized using WHO guidelines.[36] Waist circumference was measured at the smallest site between the lowest rib and the superior border of the iliac crest with flexible, non-stretchable measurement tape (Sibner Hegner, Switzerland) and categorized as 'normal', 'increased' and 'strongly increased' using international guidelines.[37] Socioeconomic status was determined using a composite additive index, based on information about participants' education, occupational position and net equivalent income.[38]

Statistical Analyses

Leisure time and occupational physical activity were cross-tabulated to show the association of the domain-specific activity levels. Prevalence and 95% confidence intervals (CI) of low $\dot{V}O_2max$ were calculated by occupational and leisure time physical activity and covariates. Multivariable logistic regression models were computed to estimate the associations between domain-specific physical activity (exposure) and low $\dot{V}O_2max$ (outcome). In a first step, the main effects of occupational and leisure time physical activity were investigated, in a second step the combined activity variable was used. In both steps, we fitted an age-adjusted model and one adjusting for age, body mass index, waist circumference, smoking, alcohol intake and socioeconomic status. Finally, we computed predicted margins[39] from the fully adjusted logistic regression model investigating the combined physical activity variable to plot adjusted prevalence of low $\dot{V}O_2max$ by domain-specific physical activity. All analyses were performed separately for men and women to identify sex-specific physical activity patterns associated with cardiorespiratory fitness and to detect potential effect modification by sex. Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA). To enhance the external validity of the results, weighting factors were used to adjust for distribution of the sample by sex, age, education, and region, to match the German population. Stata's survey procedures were applied to account for the clustered sampling design.

RESULTS

Occupational and leisure time physical activity levels

Prevalence of high occupational physical activity was 40.3% among men and 33.0% among women (Table 1). In total, 24.9% of men and 24.7% of women engaged in no leisure time physical activity, 39.8% and 49.9% in less than two hours per week, and 35.3% and 25.3% in two hours or more per week. Leisure time physical activity did not vary with occupational activity level among men, but women with high occupational physical activity were less likely to engage in two hours or more leisure time physical activity per week than women with low occupational activity (Table 2).

<<< Table 2 about here >>>

low $\dot{V}O_2max$

Overall, the prevalence of estimated low $\dot{V}O_2max$ was 41.2% (95% CI 37.6–44.8) for men and 40.5% for women (95% CI 37.1–44.0). Table 3 shows the prevalence of low $\dot{V}O_2max$ by domain-specific physical activity and sociodemographic, health behaviour and anthropometric variables. Binary analyses showed that men and women with higher leisure time activity levels had substantially lower prevalence of low $\dot{V}O_2max$. There were no relevant differences in low $\dot{V}O_2max$ by occupational physical activity among men, but women with high occupational physical activity had a higher prevalence of low $\dot{V}O_2max$ than women with low occupational physical activity.

<<< Table 3 about here >>>

Multivariable analyses (Table 4) showed that women in jobs with high levels of occupational physical activity were more likely to have a low estimated $\dot{V}O_2max$ when adjusting only for age (odds ratio [OR] 1.71; 95% CI 1.23–to 2.36). This association disappeared when controlling for leisure time physical activity and other covariates (OR 1.06; 95% CI 0.75–1.49). Neither model showed any association between low $\dot{V}O_2max$ and occupational physical activity for men (OR 1.05; 95% CI 0.75–1.46 and OR 0.95; 95% CI 0.64–1.42).

<<< Table 4 about here >>>

Men and women who did no or less than 2 hours leisure time physical activity per week were more likely to have a low $\dot{V}O_2max$ than participants who did 2 hours or more. The effect size did not change considerably when adjusting for occupational physical activity and other controls.

Multivariable analyses of the combined physical activity variable (fully-adjusted model) showed that less-active men were more likely to have a low $\dot{V}O_2max$ with ORs of 4.45 (95% CI 2.14–9.23) for no leisure time/low occupational physical activity, 2.34 (95% CI 1.08–5.07) for no leisure time/high occupational physical activity, 1.54 (95% CI 0.77–3.06) for < 2 h leisure time/low occupational physical activity, 1.54 (95% CI 0.75–3.16) for < 2 h leisure time/high occupational physical activity, and 0.64 (95% CI 0.32–1.27) for ≥ 2 h leisure time/low occupational physical activity compared with men with ≥ 2 h leisure time/high occupational physical activity. The corresponding ORs for women were 6.54 (95% CI 2.98–14.3), 10.5 (95% CI 4.39–24.9), 3.52 (95% CI 1.75–7.09), 3.69 (95% CI 1.80–7.60), and 1.93 (95% CI 0.90–4.13), indicating women were most likely to have a low fitness if they worked in physically-demanding jobs and did not engage in leisure time physical activity.

Based on the final model with the combined variable, we plotted predicted probabilities of having a low $\dot{V}O_2max$ to show these different patterns for men and women (Figure 2).

<<< Figure 2 about here >>>

DISCUSSION

Summary of results

This cross-sectional study showed a strong association between low leisure time physical activity and low estimated $\dot{V}O_2max$, but not between occupational physical activity and $\dot{V}O_2max$. The association between domain-specific physical activity and low $\dot{V}O_2max$ also varied by sex. After adjustment for potential confounding, women working in physically-demanding occupations who did not participate in leisure time physical activity had the highest likelihood of having a low $\dot{V}O_2max$. However, the men with the highest risk of low $\dot{V}O_2max$ were those who did not engage in leisure time physical activity and were not working in physically-demanding occupations.

Comparison with other studies

The strong association between leisure time physical activity and cardiorespiratory fitness has been shown in numerous studies.[34] However, evidence of the association between occupational physical activity and cardiorespiratory fitness is inconclusive. Historically, occupational physical activity has been seen as a way to improve health in behavioural medicine, but as a potential health hazard in occupational medicine.[6, 40] Recent studies agree that occupational physical activity does not lead to increased cardiorespiratory fitness.[41-44] A Swiss study among adults reported no association between the amount of objectively-assessed steps during work-time and $\dot{V}O_2max$, and a lower $\dot{V}O_2 max$ among participants doing manual work than those doing sedentary work (according to reported job title), while controlling for leisure time physical activity and various other covariates.[41] A cross-regional study in Germany also found higher levels of $\dot{V}O_2max$ among participants with high levels of leisure time physical activity, but $\dot{V}O_2max$ was lower among participants with higher levels of occupational physical activity (assessed by questionnaire).[43] A study among the Danish working population observed that self-reported work and leisure sitting time had different associations with $\dot{V}O_2max$: there was a strong negative association between sitting leisure time and $\dot{V}O_2max$, but no similar association with sitting time at work.[45] However, a study among male workers in Japan found higher levels of $\dot{V}O_2max$ among those with self-reported high occupational physical activity than low[46] and a study from Finland found a positive association between cardiorespiratory fitness and self-reported occupational physical activity even after adjustment for leisure time physical activity among young men.[47]

Occupational physical activity has been linked to negative health outcomes: in a meta-analysis, Li and colleagues[6] found evidence that it might increase the risk of cardiovascular disease, although leisure time physical activity considerably reduced the risk. Another meta-analysis found that men with high occupational physical activity had an increased risk of preliminary mortality, but women did not.[7] In particular, the combination of high occupational physical activity with low cardiorespiratory fitness seems to be associated with a higher risk of adverse cardiovascular outcomes.[48, 49]

Potential mechanisms

Regular aerobic exercise induces biological changes, such as increased stroke volume and decreased venous oxygen content, both of which lead to increased individual cardiorespiratory fitness.[10] To increase $\dot{V}O_2max$, exercise should ideally be performed with sufficient intensity at ≥ 50% of the maximal aerobic capacity for untrained individuals.[10] Cardiorespiratory fitness is determined by the cardiac output and arteriovenous oxygen difference, so it can be enhanced by an increase in stroke volume, oxygen difference, or both.[10] Leisure time physical activity, especially sport, is usually relatively short duration but high intensity, and provides sufficient recovery time between occasions. This is important, because this type of activity can achieve a training effect of the myocardium. This reduces the heart rate, the heart muscle remains longer in diastole and the stroke volume increases.[50] In contrast, physical activity without recovery leads to prolonged elevation of heart rate and blood pressure.[51] This can result in erosion of the endothelium, which can provoke atherosclerosis.[52] This prolonged activity is typically observed in occupational physical activity, where workers also have limited control of work speed and duration.[9, 50] Sufficient recovery is therefore not possible, because individuals are unable to decide for themselves how to perform their work, and when to pause. Assuming average occupational physical activity as a constant, monotonous but low intensity activity, it has also been proposed that its intensity might be too low to increase individual fitness.[9] However, this might not hold true for all occupations. Studies among blue-collar workers found that directly-assessed intensity of physical activity was higher during work than leisure time,[53] especially among those with low fitness levels.[54]

Differences between men and women

The results suggest that the association between domain-specific physical activity and cardiorespiratory fitness is different for men and women. High occupational physical activity was associated with lower fitness among women doing low levels of leisure time physical activity. Table S1 shows that men in physically-demanding occupations mainly worked in manual and technical professions (e.g., electricians, plumbers, mechanics), and women in physically-demanding jobs worked mainly in the service sector (e.g. nursing/care, catering, and cleaning). These service jobs are particularly affected by limited work control and higher job-strain, which may be a possible explanation for these sex-specific patterns. For example, healthcare workers in Germany reported very high levels of job demands compared with the average level for all occupations, and also had low decision-making autonomy.[55, 56] This is particularly concerning because high-strain jobs can lead to lower leisure time physical activity[57] and high occupational stress in combination with low cardiorespiratory fitness considerably increases the cardiovascular risk.[58] These potential physiological mechanisms hold especially true for the most common high activity demand professions for women. For example, cleaners often work continuously for long periods, but at insufficient intensity to increase fitness, and this is coupled with a high relative workload.[13]

Recommendations for further research and practical implications

To take into account the observed sex differences, it is recommended that future studies should investigate men and women separately. It is generally assumed that high levels of leisure time physical activity increase individual cardiorespiratory fitness and are also beneficial for general health. However, some studies have found that a moderate to high level of leisure time physical activity was associated with adverse health outcomes among those exposed to high occupational physical activity levels.[59, 60] Thus, the interrelationships between occupational and leisure time physical activity remain unclear and further research is needed to explain these potentially contradictory results. Furthermore, much of the research on this topic is based on self-reported physical activity with high heterogeneity among the instruments used. Future studies should investigate the domain-specific effects of physical activities using objective measures.[61]

When recommending higher levels of leisure time physical activities, it is important to consider the embedded and dependent relationship of the different domains of physical activity. Occupational and leisure time activity are not the only areas of physical activity. Transportation and domestic activities are also relevant. This is important because both these domains can also be described as non-discretionary time[62] with limited individual autonomy. Second, physical activity in all these domains depends on structures at the societal, environmental and individual level.[63] Individuals face obstacles in engaging in more leisure time physical activity, such as cultural temporal structures (e.g., public transport timetables) or individual responsibilities (e.g. parenthood). Thus, measures and policies to create an activity-friendly environment are needed, rather than blaming individuals for lack of exercise.[1] Finally, we recommend that policy-makers and public health experts involved in the development of physical activity recommendations consider specifying these recommendations by level of occupational physical activity, because recent guidelines do not make this distinction.

Strengths and Limitations

A major strength of this study is its use of a large population-based nationally-representative sample of the non-institutionalized, resident adult working population. This allows the findings to be generalized. Significant efforts were made to reduce potential sources of bias in DEGS1,[64, 65] but our study still needs to be interpreted in the context of some limitations. First, the study's cross-sectional design does not permit any causal inferences to be drawn about the observed relationship between physical activity patterns and cardiorespiratory fitness. It is well-known that regular physical activity can increase cardiorespiratory fitness, but reversed causality cannot be ruled out: for example, individuals who have inherited a lower cardiorespiratory fitness may tend to be less active.[66] We therefore cannot conclude that a higher cardiorespiratory fitness can be traced to higher leisure time physical activity levels. Second, due to the use of the PAR-Q screening questionnaire, our sample consists of a relatively healthy study-population. This implies the exclusion of most study participants using cardiorespiratory-related medication. However, it is possible that the use of other medications (e.g. psychotropic or antidiabetic drugs) may act as a source of bias. The use of a relatively healthy study population may also have hampered the generalizability of our results. The results might also be affected by the so-called healthy worker effect, a specific form of selection bias where more healthy individuals are more likely to work in physically-demanding occupations. Third, as in most large-scale epidemiological studies,[10, 34] $\dot{V}O_2max$ was estimated using a submaximal ergometer test in a highly standardized and quality-assured procedure[19] and not directly assessed by breath gas analysis. Fourth, self-reports on physical activity levels are prone to recall and social desirability bias.[67, 68] We cannot exclude the possibility that the level of physical activity was over- or underreported. This is also true for most of the studies cited. Leisure time physical activity was assessed based on information about the duration per week, but not intensity, although intensity may have an additional impact on cardiorespiratory fitness.[10] In the case of occupational physical activity, self-reports are restricted to specific task, such as lifting of heavy loads. In contrast, objectively-measured activity levels usually include general activities at work. This is particularly important, because this type of task influences cardiorespiratory fitness in a different way from general activities. Fifth, occupational physical activity was assessed indirectly via job exposure matrices. These were based on a very large sample and the use of hierarchical linear regression models, controlling for age, sex, working hours and job experience, reduced the likelihood of confounding. However, they are generally not able to account for variability of exposure within jobs.[69] If the prevalence of high physical demands within occupations varied widely, this could have led to biased results on observed occupational physical activity levels, which would reduce the magnitude of the observed associations.

CONCLUSIONS

This study showed a strong association between patterns of physical activity during leisure time and work and cardiorespiratory fitness among men and women in the working population in Germany.

For example, women doing little or no leisure time physical activity were likely to have low cardiorespiratory fitness, especially if they worked in physically-demanding jobs. These findings therefore contribute to the increasing body of evidence about different domain-specific effects of physical activity on health outcomes. They also emphasize the importance of considering different domains of physical activity in future studies. Current guidelines do not distinguish between work and leisure time physical activity, and it may be helpful to specify leisure time physical activity recommendations by occupational physical activity levels. Further research is needed to understand the pathways through which different domains of physical activity lead to divergent health effects and to confirm these findings with objective measures of physical activity.

STATEMENTS

Author Contributions

GBMM and JDF were involved in the design and conduct of DEGS1, JDF in particular for the ergometer testing. JZ, LEK, and JDF conceptualized the current study. JZ, MD and LEK conducted the analysis. JZ drafted the manuscript. GBMM, JDF and TK contributed to the analysis plan and interpretation of the results. MD, GBMM, JDF and TK critically revised it. All authors contributed to the interpretation of findings, reviewed, edited and approved the final manuscript.

Acknowledgements

We thank Melissa Leffler for editing a draft of this manuscript.

Funding

No external funding was received. The study was financed by the Robert Koch Institute which is a federal institute within the portfolio of the German Federal Ministry of Health.

Competing interests

None declared.

Patient consent

Participants signed an informed written consent prior to participation.

Ethics approval

DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité – Universitätsmedizin Berlin ethic committee (no EA2/047/08).

Data sharing statement

A dataset of DEGS1 is available via Public Use File (https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html [accessed 23 Sep 2019]).

REFERENCES

1. World Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: WHO 2018.

2. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. Geneva: WHO 2013.

3. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO 2010. http://www.who.int/dietphysicalactivity/global-PA-recs-2010.pdf (accessed 5 September 2018).

4. Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. *Obes Rev* 2012;13(8):659–80.

5. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol* 2011;40(5):1382–400.

6. Li J, Loerbroks A, Angerer P. Physical activity and risk of cardiovascular disease: what does the new epidemiological evidence show? *Curr Opin Cardiol* 2013;28(5):575–83.

7. Coenen P, Huysmans MA, Holtermann A, et al. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. *Br J Sports Med* 2018;52(20):1320–6.

8. Holtermann A, Hansen JV, Burr H, et al. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med* 2012;46(4):291–5.

9. Holtermann A, Krause N, van der Beek AJ, et al. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. *Br J Sports Med* 2018;52(3):149–50.

10. Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. *Circulation* 2016;134(24):e653–e99.

11. Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. *JAMA* 2009;301(19):2024–35.

12. Coenen P. Preventing disease by integrating physical activity in clinical practice: What works for whom? *Heart* 2018;104(14):1–2.

13. Korshøj M, Krustrup P, Jespersen T, et al. A 24-h assessment of physical activity and cardio-respiratory fitness among female hospital cleaners: a pilot study. *Ergonomics* 2013;56(6):935–43.

14. Finger JD, Tylleskär T, Lampert T, et al. Physical activity patterns and socioeconomic position: the German National Health Interview and Examination Survey 1998 (GNHIES98). *BMC Public Health* 2012;12(1):1079.

15. Hobler D, Pfahl S, Spitznagel J. Horizontale Segregation des Arbeitsmarktes 2017. WSI GenderDatenPortal [horizontal segregation of the labor market] 2020. https://www.boeckler.de/121336.htm# (accessed 10 Jan 2020).

16. Hands B, Parker H, Larkin D, et al. Male and female differences in health benefits derived from physical activity: implications for exercise prescription. *J Womens Health Issues Care* 2016;5.

17. Kurth B-M. The RKI health monitoring - What it contains and how it can be used [Das RKI-Gesundheitsmonitoring - Was es enthält und wie es genutzt werden kann]. *Public Health Forum* 2012;20(3):4.e1–4.e3.

18. Scheidt-Nave C, Kamtsiuris P, Gößwald A, et al. German health interview and examination survey for adults (DEGS) - design, objectives and implementation of the first data collection wave. *BMC Public Health* 2012;12(1):730.

19. Finger JD, Gosswald A, Hartel S, et al. Measurement of cardiorespiratory fitness in the German Health Interview and Examination Survey for Adults (DEGS1). *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013;56(5-6):885–93.

20. Finger JD, Krug S, Gößwald A, et al. Cardiorespiratory fitness among adults in Germany. Results of the German Health Interview and Examination Survey for Adults (DEGS1). *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013;56(5):772–8.
21. Deutsche Gesellschaft für Sportmedizin und Prävention (DGSP). PAR-Q-Fragebogen (German version). 2007.
22. Canadian Society for Exercise Physiology. Physical Activity Readiness Questionnaire - PAR-Q (revised 2002). Ottawa: Health Canada 2002.
23. Andersen KL, Shephard R, Denolin H, et al. Fundamentals of exercise testing. 1971. https://apps.who.int/iris/handle/10665/40145 (accessed 15 Feb 2019).
24. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol* 2001;37(1):153-6.
25. Gore CJ, Booth ML, Bauman A, et al. Utility of $PWC_{75\%}$ as an estimate of aerobic power in epidemiological and population-based studies. *Med Sci Sports Exerc* 1999;31(2):348–51.
26. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 5th Edition. Baltimore: Williams & Wilkins 1995:280.
27. Kroll LE. Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten anhand von ISCO-88 und KldB-92 [Construction and validation of a general index for job demands in occupations based on ISCO-88 and KldB-92]. *Methoden — Daten — Analysen* 2011;5(1):63–90.
28. Rohrbach-Schmidt D, Hall A. BIBB/BAuA employment survey 2012. BIBB-FDZ Data and Methodological Reports Federal Institute for Vocational Education and Training. Bonn, Germany 2013.
29. Kroh M, Neiss H, Kroll L, et al. High-income people live longer [Menschen mit hohem Einkommen leben länger]. *DIW-Wochenbericht* 2012;79(38):3–15.
30. Santi I, Kroll LE, Dietz A, et al. To what degree is the association between educational inequality and laryngeal cancer explained by smoking, alcohol consumption, and occupational exposure? *Scand J Work Environ Health* 2014;40(3):315–22.
31. Santi I, Kroll LE, Dietz A, et al. Occupation and educational inequalities in laryngeal cancer: the use of a job index. *BMC Public Health* 2013;13(1):1080.
32. Krug S, Jordan S, Mensink GBM, et al. Physical activity. Results of the German Health Interview and Examination Survey for Adults (DEGS1). *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013;56(5):765-–1.
33. Steinbach D, Graf C. Leisure time physical activity and sedentariness. In: Kirch W, ed. Encyclopedia of Public Health. Dordrecht: Springer 2008:849–51.
34. Zeiher J, Ombrellaro KJ, Perumal N, et al. Correlates and determinants of cardiorespiratory fitness in adults: a systematic review. *Sports Med Open* 2019;5(39).
35. Zeiher J, Manz K, Kuntz B, et al. Individual and Interpersonal Correlates of Cardiorespiratory Fitness in Adults – Findings from the German health interview and examination survey. *Sci Rep* 2020;10(445).
36. World Health Organization. BMI classification 2019 http://apps.who.int/bmi/index.jsp?introPage=intro_3.html (accessed 20 February 2019).
37. World Health Organization. Obesity: preventing and managing the global epidemic. Geneva: World Health Organization 2000.
38. Lampert T, Kroll L, Müters S, et al. Measurement of socioeconomic status in the German Health Interview and Examination Survey for Adults (DEGS1). *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013;56:1–5.
39. Graubard BI, Korn EL. Predictive margins with survey data. *Biometrics*. 1999;55(2):652–9.
40. Morris JN, Heady JA, Raffle PAB, et al. Coronary heart disease and physical activity of work. *Lancet* 1953;262(6796):1111–20.
41. Mundwiler J, Schüpbach U, Dieterle T, et al. Association of occupational and leisure-time physical activity with aerobic capacity in a working population. *PLoS ONE* 2017;12(1).

42. Ruzic L, Heimer S, Misigoj-Durakovic M, et al. Increased occupational physical activity does not improve physical fitness. *Occup Environ Med* 2003;60(12):983–5.

43. Bahls M, Groß S, Baumeister SE, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. *Sci Rep* 2018;8(1):16066.

44. Lakka TA, Laaksonen DE, Lakka HM, et al. Sedentary lifestyle, poor cardiorespiratory fitness, and the metabolic syndrome. *Med Sci Sports Exerc* 2003;35(8):1279–86.

45. Saidj M, Jørgensen T, Jacobsen RK, et al. Differential cross-sectional associations of work- and leisure-time sitting, with cardiorespiratory and muscular fitness among working adults. *Scand J Work Environ Health* 2014;5:531–8.

46. Nagaya T, Kondo Y, Shibata T. Effects of sedentary work on physical fitness and serum cholesterol profile in middle-aged male workers. *Int Arch Occup Environ Health* 2001;74(5):366–70.

47. Tammelin T, Nayha S, Rintamaki H, et al. Occupational physical activity is related to physical fitness in young workers. *Med Sci Sports Exerc* 2002;34(1):158–65.

48. Holtermann A, Mortensen OS, Burr H, et al. Physical work demands and physical fitness in low social classes--30-year ischemic heart disease and all-cause mortality in the Copenhagen Male Study. *J Occup Environ Med* 2011;53(11):1221–7.

49. Holtermann A, Mortensen OS, Burr H, et al. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. *Scand J Work Environ Health* 2010;36(5):357–65.

50. Krause N. Physical activity and cardiovascular mortality – disentangling the roles of work, fitness, and leisure. *Scand J Work Environ Health* 2010(5):349–55.

51. Hall C, Heck JE, Sandler DP, et al. Occupational and leisure-time physical activity differentially predict 6-year incidence of stroke and transient ischemic attack in women. *Scand J Work Environ Health* 2019;45(3):267–79.

52. Khera A, Mitchell JH, Levine BD. Preventive cardiology: The effects of exercise. In: Willerson JT, Cohn JN, Wellens HJJ, Holmes DR, eds. Cardiovascular Medicine: Springer 2007:2631–48.

53. Gram B, Westgate K, Karstad K, et al. Occupational and leisure-time physical activity and workload among construction workers – a randomized control study. *Int J Occup Environ Health* 2016;22(1):36–44.

54. Coenen P, Korshøj M, Hallman DM, et al. Differences in heart rate reserve of similar physical activities during work and in leisure time – A study among Danish blue-collar workers. *Physiol Behav* 2018;186:45–51.

55. Schmucker R. Working conditions in nursing care [Arbeitsbedingungen in Pflegeberufen]. In: Jacobs K, Kuhlmey A, Greß S, Klauber J, Schwinger A, editors. Pflege-Report 2019: Mehr Personal in der Langzeitpflege - aber woher? Berlin, Heidelberg: Springer 2019:49–60.

56. Theobald H, Szebehely M, Preuß M. Working conditions in geriatric care [Arbeitsbedingungen in der Altenpflege]. Berlin: Sigma 2013.

57. Fransson EI, Heikkila K, Nyberg ST, et al. Job strain as a risk factor for leisure-time physical inactivity: an individual-participant meta-analysis of up to 170,000 men and women: the IPD-Work Consortium. *Am J Epidemiol* 2012;176(12):1078–89.

58. Schilling R, Colledge F, Ludyga S, et al. Does cardiorespiratory fitness moderate the association between occupational stress, cardiovascular risk, and mental health in police officers? *Int J Environ Res Public Health* 2019;16(13).

59. Clays E, De Bacquer D, Janssens H, et al. The association between leisure time physical activity and coronary heart disease among men with different physical work demands: a prospective cohort study. *Eur J Epidemiol* 2013;28(3):241–7.

60. Korshøj M, Lidegaard M, Skotte JH, et al. Does aerobic exercise improve or impair cardiorespiratory fitness and health among cleaners? A cluster randomized controlled trial. *Scand J Work Environ Health* 2015(2):140–52.

61. Ketels M, De Bacquer D, Geens T, et al. Assessing physiological response mechanisms and the role of psychosocial job resources in the physical activity health paradox: study protocol for the Flemish Employees' Physical Activity (FEPA) study. *BMC Public Health* 2019;19(1):765.

62. van Tienoven TP, Deyaert J, Harms T, et al. Active work, passive leisure? Associations between occupational and non-occupational physical activity on weekdays. *Soc Sci Res* 2018;76:1–11.

63. Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012;380(9838):258–71.

64. Gößwald A, Lange M, Dölle R, et al. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Recruitment of participants, fieldwork, and quality assurance. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013;56(5):1–8.

65. Kamtsiuris P, Lange M, Hoffmann R, et al. The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Sampling design, response, weighting, and representativeness. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*. 2013;56(5):1–10.

66. Després JP. Physical activity, sedentary behaviours, and cardiovascular health: when will cardiorespiratory fitness become a vital sign? *Can J Cardiol* 2016;32(4):505–13.

67. Prince SA, Adamo KB, Hamel ME, et al. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act* 2008;5(1):56.

68. Brenner PS, DeLamater J. Lies, damned lies, and survey self-reports? Identity as a cause of measurement bias. *Soc Psychol Q* 2016;79(4):333–54.

69. Tielemans E, Heederik D, Burdorf A, et al. Assessment of occupational exposures in a general population: Comparison of different methods. *Occup Environ Med* 1999;56(3):145–51.

FIGURES & TABLES

Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; $\dot{V}O_2max$: Maximal oxygen consumption

Figure 2: Predicted probabilities (with 95% confidence intervals) of low $\dot{V}O_2max$ by domain-specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, and socioeconomic status index. LTPA: leisure time physical activity, OPA: occupational physical activity.

Table 1: Characteristics of study participants in DEGS1. Values shown are frequencies in percentages.

	Men			Women			Total		
	n	%[1]	%[2]	n	%[1]	%[2]	n	%[1]	%[2]
$\dot{V}O_2max$									
Low	705	58.8	58.8	750	57.9	59.5	1455	58.3	59.1
Intermediate/high	494	41.2	41.2	546	42.1	40.5	1040	41.7	40.9
Missing	0	0.0	-	0	0.0	-	0	0.0	-
LTPA									
no	297	24.8	24.9	309	23.8	24.7	606	24.3	24.8
<2h	492	41.0	39.8	647	49.9	49.9	1139	45.7	44.7
≥2h	410	34.2	35.3	340	26.2	25.3	750	30.1	30.5
Missing	0	0.0	-	0	0.0	-	0	0.0	-
OPA									
low	750	62.6	59.7	895	69.1	67.0	1645	65.9	63.2
high	449	37.4	40.3	401	30.9	33.0	850	34.1	36.8
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Age									
18-24 Years	137	11.4	11.3	138	10.6	11.8	275	11.0	11.5
25-34 Years	277	23.1	26.4	250	19.3	22.5	527	21.1	24.5
35-44 Years	287	23.9	26.8	338	26.1	27.7	625	25.1	27.2
45-54 Years	308	25.7	23.2	369	28.5	25.8	677	27.1	24.5
55-64 Years	190	15.8	12.3	201	15.5	12.3	391	15.7	12.3
Missing	0	0.0	-	0	0.0	-	0	0.0	-
Waist circumference									
Normal	719	60.0	61.7	702	54.2	57.0	1421	57.0	59.4
Increased	256	21.4	20.1	289	22.3	22.5	545	21.8	21.3
Strongly increased	224	18.7	18.2	303	23.4	20.5	527	21.1	19.3
Missing	0	0.0	-	2	0.2	-	2	0.1	-
Body mass index									
Underweight	9	0.8	0.8	32	2.5	2.8	41	1.6	1.8
Normal Weight	467	38.9	37.7	748	57.7	58.1	1215	48.7	47.5
Overweight	548	45.7	46.1	348	26.9	27.1	896	35.9	37.0
Obese	171	14.3	15.4	164	12.7	11.9	335	13.4	13.7
Missing	4	0.3	-	4	0.3	-	8	0.3	-
Smoking status									
Daily	349	29.1	31.3	268	20.7	23.2	617	24.7	27.4
Occasionally	106	8.8	8.2	96	7.4	7.6	202	8.1	7.9
Former	323	26.9	26.9	354	27.3	25.8	677	27.1	26.3
Never	420	35.0	33.7	576	44.4	43.4	996	39.9	38.3
Missing	1	0.1	-	2	0.2	-	3	0.1	-
Alcohol consumption									
Low	180	15.0	16.7	151	11.7	12.3	331	13.3	14.6
Moderate	760	63.4	64.3	821	63.3	64.8	1581	63.4	64.6
High	245	20.4	19.0	314	24.2	22.9	559	22.4	20.9
Missing	14	1.2	-	10	0.8	-	24	1.0	-
Socio economic status									
Low	151	12.6	14.7	113	8.7	9.6	264	10.6	12.3
Medium	702	58.5	61.4	800	61.7	63.5	1502	60.2	62.4
High	346	28.9	23.9	382	29.5	26.8	728	29.2	25.3
Missing	0	0	-	1	0.1	-	1	0.0	-

[1]Percentage of the sample (unweighted) [2]Weighted percentage (weighting factors were used to adjust the distribution of the sample to match the German population for sex, age, education and region). DEGS1: German Health Interview and

Examination Survey for Adults, $\dot{V}O_2max$: maximal oxygen consumption, LTPA: leisure time physical activity, OPA: occupational physical activity

Table 2: Association of leisure time and occupational physical activity among male and female DEGS1 participants. Values shown are frequencies in percentages with 95% confidence intervals (CI).

	Low OPA		High OPA	
	%	(95% CI)	%	(95% CI)
Men				
No LTPA	24.0	(20.1-28.3)	26.2	(21.4-31.5)
<2h LTPA	39.4	(35.2-43.7)	40.4	(34.9-46.2)
≥2h LTPA	36.6	(32.7-40.7)	33.4	(27.7-39.7)
Women				
No LTPA	21.6	(17.9-25.9)	31.1	(25.6-37.3)
<2h LTPA	49.6	(44.8-54.3)	50.6	(44.9-56.4)
≥2h LTPA	28.8	(25.1-32.8)	18.2	(14.4-22.9)

DEGS1: German Health Interview and Examination Survey for Adults, CI: confidence intervals, LTPA: leisure time physical activity, OPA: occupational physical activity

Table 3: Prevalence and 95% confidence intervals of low $\dot{V}O_2max$ by domain-specific physical activity, health behavioural, anthropometric, and sociodemographic characteristics among male and female DEGS1 participants

	Men		Women	
	%	(95% CI)	%	(95% CI)
Total	41.2	(37.6-44.8)	40.5	(37.1-44.0)
LTPA				
No	63.2	(56.4-69.4)	56.1	(49.1-62.9)
<2h	42.2	(36.5-48.0)	41.2	(36.6-45.9)
≥2h	24.7	(19.8-30.5)	24.1	(19.0-30.1)
OPA				
Low	41.5	(36.8-46.4)	37.2	(33.0-41.6)
high	40.8	(35.0-46.8)	47.4	(41.5-53.4)
OPA/LTPA				
No LTPA, low OPA	68.5	(59.2-76.4)	48.0	(39.7-56.3)
No LTPA, high OPA	56.0	(44.9-66.5)	67.7	(56.7-77.0)
<2h LTPA, low OPA	42.6	(35.8-49.7)	39.3	(33.5-45.5)
<2h LTPA, high OPA	41.6	(32.3-51.5)	44.9	(37.5-52.5)
≥2h LTPA, low OPA	22.8	(17.1-29.6)	25.4	(19.0-33.0)
≥2h LTPA, high OPA	28.0	(19.1-39.0)	19.9	(11.6-32.1)
Age				
18-24 Years	28.0	(19.9-37.7)	25.8	(17.9-35.7)
25-34 Years	36.0	(28.9-43.8)	29.2	(23.3-35.9)
35-44 Years	41.9	(34.9-49.2)	36.1	(30.3-42.3)
45-54 Years	47.2	(40.9-53.7)	48.5	(42.1-55.1)
55-64 Years	51.9	(42.3-61.4)	68.7	(60.2-76.1)
Waist circumference				
Normal	27.1	(23.2-31.4)	26.9	(23.0-31.1)
Increased	54.6	(46.2-62.8)	46.4	(38.5-54.6)
Strongly increased	74.2	(66.7-80.4)	72.5	(66.3-77.9)
Body mass index				
Underweight	19.8	(3.3-64.1)	18.9	(7.7-39.4)
Normal Weight	21.7	(16.9-27.4)	27.1	(23.4-31.2)
Overweight	47.5	(42.3-52.8)	53.7	(46.4-60.8)
Obese	71.1	(62.4-78.4)	83.1	(75.3-88.8)
Smoking status				
Daily	40.7	(34.9-46.8)	38.8	(31.6-46.7)
Occasionally	31.7	(22.3-42.9)	33.5	(22.9-46.0)
Former	49.6	(42.3-56.9)	46.7	(40.0-53.6)

Never	37.5	(31.4-44.0)	39.0	(34.0-44.3)
Alcohol consumption				
Low	45.7	(38.0-53.7)	50.2	(40.8-59.5)
Moderate	39.1	(34.9-43.6)	41.1	(36.6-45.8)
High	43.4	(35.1-52.2)	33.2	(26.7-40.5)
Socio economic status				
Low	39.9	(30.7-49.8)	56.3	(45.8-66.3)
Medium	43.3	(38.7-48.1)	43.4	(39.3-47.5)
High	36.8	(30,8-43,2)	28.2	(22,4-34,9)

$\dot{V}O_2max$: maximal oxygen consumption, DEGS1: German Health Interview and Examination Survey for Adults, CI: confidence intervals, LTPA: leisure time physical activity, OPA: occupational physical activity

Table 4: Domain-specific physical activity and low estimated $\dot{V}O_2max$ among male and female DEGS1 participants. Different adjustment criteria were used in multivariable logistic regression analyses.

	Men				Women			
	OR[1]	(95 % CI)	OR[2]	(95 % CI)	OR[1]	(95 % CI)	OR[2]	(95 % CI)
Main effects model								
OPA								
low OPA	(ref.)		(ref.)		(ref.)		(ref.)	
high OPA	1.05	(0.75 - 1.46)	0.95	(0.64 - 1.42)	1.71	(1.23 - 2.36)	1.06	(0.75 - 1.49)
LTPA								
no LTPA	4.97	(3.47 - 7.13)	4.46	(2.89 - 6.89)	4.96	(3.26 - 7.54)	4.65	(2.90 - 7.45)
<2h LTPA	2.17	(1.48 - 3.19)	2.04	(1.32 - 3.15)	2.49	(1.72 - 3.62)	2.13	(1.44 - 3.14)
≥2h LTPA	(ref.)		(ref.)		(ref.)		(ref.)	
OPA/LTPA model								
No LTPA, low OPA	4.92	(2.56 - 9.46)	4.45	(2.14 - 9.23)	4.37	(2.02 - 9.47)	6.54	(2.98 - 14.3)
No LTPA, high OPA	2.86	(1.47 - 5.58)	2.34	(1.08 - 5.07)	11.1	(5.15 - 24.1)	10.5	(4.39 - 24.9)
<2h LTPA, low OPA	1.69	(0.94 - 3.06)	1.54	(0.77 - 3.06)	2.84	(1.39 - 5.78)	3.52	(1.75 - 7.09)
<2h LTPA, high OPA	1.70	(0.91 - 3.17)	1.54	(0.75 - 3.16)	4.01	(1.90 - 8.49)	3.69	(1.80 - 7.60)
≥2h LTPA, low OPA	0.67	(0.35 - 1.27)	0.64	(0.32 - 1.27)	1.37	(0.64 - 2.92)	1.93	(0.90 - 4.13)
≥2h LTPA, high OPA	(ref.)		(ref.)		(ref.)		(ref.)	
n	1,199		1,181		1,296		1,277	

[1]Adjusted for age; [2]adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, socioeconomic status index
$\dot{V}O_2max$: maximal oxygen consumption, DEGS1: German Health Interview and Examination Survey for Adults, OR: odds ratios, CI: confidence intervals, LTPA: leisure time physical activity, OPA: occupational physical activity

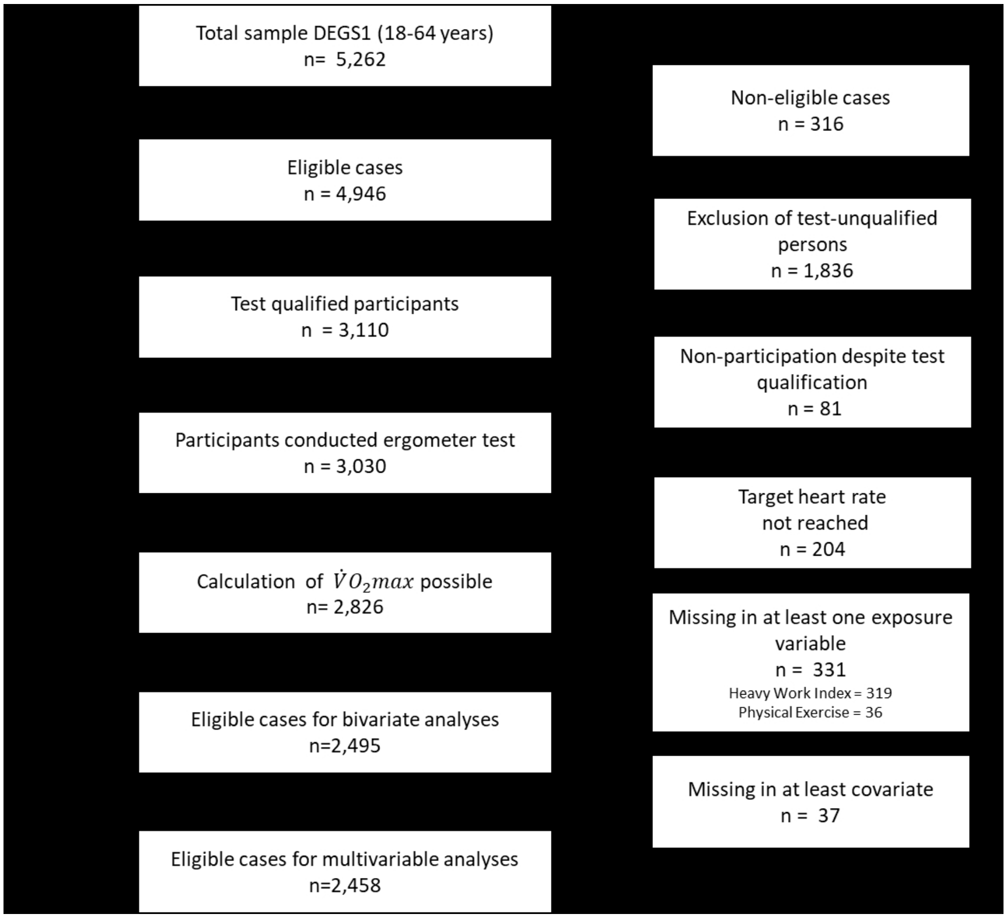

Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; VO2max: Maximal oxygen consumption

193x176mm (150 x 150 DPI)

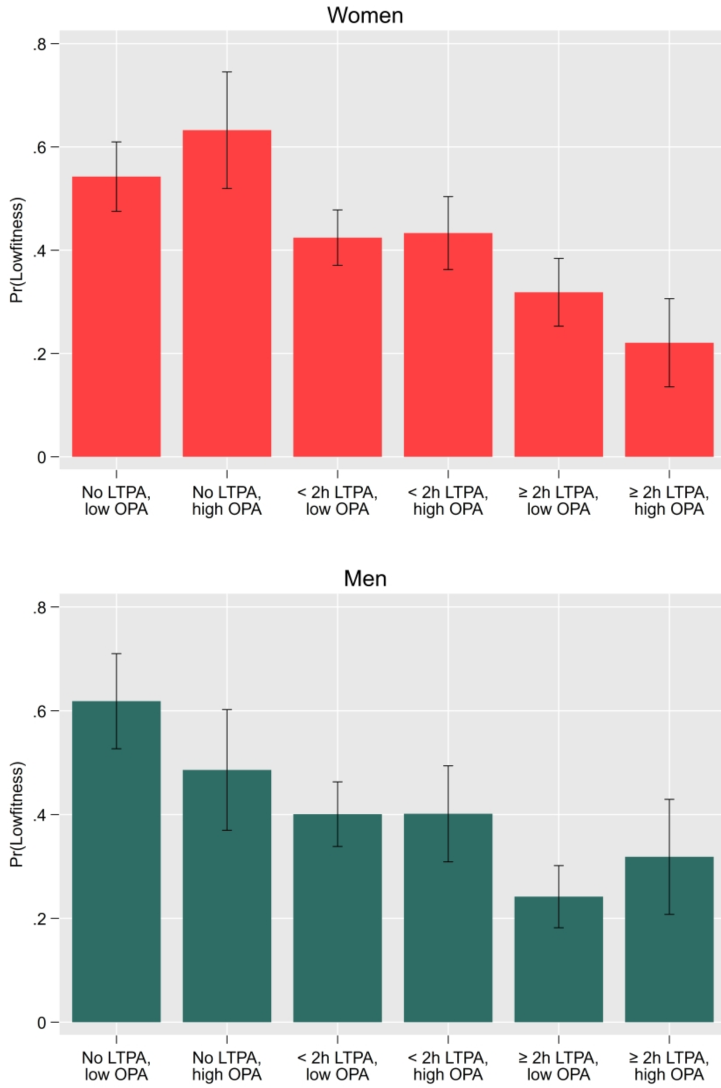

Figure 2: Predicted probabilities (with 95 % confidence intervalls) of low VO2max according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

1411x2116mm (72 x 72 DPI)

Online Supplemental Material 1: Supplementary tables

Additional file to: Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity patterns and cardiorespiratory fitness among the working population. Findings from the German cross-sectional health interview and examination survey

Table S1 Top ten occupations (ISCO-88; 4-digit) among men and women according to OPA

Men				Women			
Rank	**Occupations [ISCO-88]**	**%**	**95% CI**	**Rank**	**Occupations [ISCO-88]**	**%**	**95% CI**
	High OPA				**High OPA**		
1.	Electronics mechanics and servicers	7,6	(5,1-11,3)	1.	Institution-based personal care workers	16,6	(12,4-22,0)
2.	Plumbers and pipe fitters	5,7	(3,6-9,0)	2.	Nursing associate professionals	13,6	(10,1-18,0)
3.	Skilled agricultural and fishery workers	4,7	(2,6-8,3)	3.	Social work associate professionals	5,5	(3,6-8,2)
4.	Agricultural- or industrial-machinery mechanics and fitters	4,6	(2,7-7,6)	4.	Childcare workers	5,3	(2,8-9,8)
5.	Machine-tool setters and setter-operators	4,1	(2,4-6,7)	5.	Pre-primary education teaching associate professionals	4,8	(2,9-7,8)
6.	Cooks	3,7	(1,5-8,5)	6.	Shop salespersons and demonstrators	4,4	(2,5-7,7)
7.	Structural-metal preparers and erectors	3,6	(2,0-6,5)	7.	Waiters, waitresses and bartenders	4,3	(2,2-8,1)
8.	Building and related electricians	3,3	(1,6-6,5)	8.	Cooks	3,6	(1,8-7,1)
9.	Painters, upholsterers and related workers	3,0	(1,8-5,1)	9.	Hairdressers, barbers, beauticians and related workers	3,0	(1,5-5,8)
10.	Cabinet makers and related workers	2,7	(1,5-4,7)	10.	Helpers and cleaners in offices, hotels and other establishments	3,0	(1,5-5,8)
	Low OPA				**Low OPA**		
1.	Other office clerks	4,4	(2,8-6,9)	1.	Shop salespersons and demonstrators	10,6	(8,3-13,6)
2.	Shop salespersons and demonstrators	3,4	(2,0-5,7)	2.	Other office clerks	7,5	(5,3-10,5)
3.	Business professionals not elsewhere classified	3,2	(1,9-5,3)	3.	Bookkeepers	5,7	(4,1-8,0)
4.	Heavy-truck and lorry drivers	2,7	(1,4-5,0)	4.	Secondary education teaching professionals	4,8	(3,4-6,8)
5.	Computer assistants	2,6	(1,6-4,4)	5.	Secretaries	3,9	(2,4-6,2)
6.	Computing professionals not elsewhere classified	2,5	(1,3-4,7)	6.	Statistical and finance clerks	3,8	(2,5-5,6)
7.	Technical and commercial sales representatives	2,4	(1,4-4,1)	7.	Administrative secretaries and related associate professionals	3,6	(2,4-5,3)
8.	Finance and sales associate professionals not elsewhere classified	2,4	(1,3-4,5)	8.	Legal and related business associate professionals	2,7	(1,5-4,9)
9.	Stock clerks	2,4	(1,3-4,6)	9.	Finance and sales associate professionals not elsewhere classif.	2,4	(1,5-3,6)
10.	Civil engineers	2,0	(1,1-3,7)	10.	Cashiers and ticket clerks	2,3	(1,2-4,3)

CI Confidence intervals, ISCO-88 International Standard Classification of Occupations, OPA Occupational physical activity

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	FigS1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	9
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5/ Supl.
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	Supl.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Supl.
		(b) Indicate number of participants with missing data for each variable of interest	Tab1
Outcome data	15*	Report numbers of outcome events or summary measures	Tab1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tab2/ Tab3

		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	14/ 11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.