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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034610
Article Type:	Original research
Date Submitted by the Author:	27-Sep-2019
Complete List of Authors:	<p>Zeiger, 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</p>
Keywords:	cardiorespiratory fitness, adults, physical activity, physical fitness, occupational physical activity

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Research article

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

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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).

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3 However, data on the association of different domains of PA and CRF for Germany is limited.
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5 Notably, the interplay between these different domains has yet not been analyzed. Following an
6
7 explorative approach rather than hypothesis testing, this study aims to investigate the associations
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9 between patterns of OPA and LTPA and CRF among men and women from the German working
10
11 population.
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14 **METHODS**

15 **Study design**

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18 Data was derived from the nationwide cross-sectional German Health Interview and Examination
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20 Survey for Adults (DEGS1). DEGS1 is part of the Federal Health Monitoring System administered by
21
22 the Robert Koch Institute (13). In detail, the study design is described elsewhere (14). Briefly, the
23
24 study is based on a two-stage cluster randomized sampling procedure. First, 180 sample points were
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26 sampled from a list of German communities stratified to represent regional distribution. Second,
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28 within these units, adult individuals were randomly drawn from local population registries stratified
29
30 by 10-year age groups. The response rate was 42%. A total of 5,262 participants aged 18–64 years
31
32 took part in the physical measurements component of the DEGS1 from November 2008 to December
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34 2011. Out of the gross sample 3,110 individuals were categorized as test-qualified for the exercise
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36 test (Figure S1, Online Supplemental Material). Overall, 3,030 participants completed the exercise
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38 test (participation rate 97.4 %). $\dot{V}O_{2max}$ was estimated for all participants reaching at least 75% of
39
40 the age-predicted maximum heart rate. Two hundred and four participants terminated the test
41
42 before reaching this heart rate. As a result, $\dot{V}O_{2max}$ was calculated for 2,826 participants. Overall,
43
44 1,296 working women and 1,199 working men had valid information on $\dot{V}O_{2max}$, OPA and LTPA.
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51 *Patient and public involvement*

52
53 This research was done without patient involvement. Patients were not invited to comment on the
54
55 study design and were not consulted to develop patient relevant outcomes or interpret the results.
56
57 Patients were not invited to contribute to the writing or editing of this document for readability or
58
59 accuracy.
60

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): $3.5 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1} + 12.24 \cdot (PWC_{100\%}) \cdot (\text{body weight}^{-1})$. 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

1
2
3 based on studies that assess information about the participant's occupational titles, even if the
4 individual exposure is not assessed. JEMs are constructed using available secondary data to
5 determine exposure profiles for each occupation and matching these profiles to the primary data
6 using standardised job-classifications. In our case, JEMs were constructed using data of a large-scale
7 representative study on working conditions of n = 20,000 employees in Germany (24, 25). It was part
8 of the European Working Conditions Survey, which is regularly conducted in the member states of
9 the European Union. The Overall Job Index and specific indexes were already described and applied
10 elsewhere (26-28). In this study, we used a specific sub-index of perceived physical work demands.
11 Based on hierarchic multilevel analyses adjusted for sex, age, job experience and part time
12 employment, the physical demand index was assigned to the occupations and these JEMs were then
13 classified into deciles. . Occupations with the lowest level of physical work demands have a value of 1
14 (First decile), and those with the highest level have a value of 10 (tenth decile). Using the
15 International Classification of Occupations of 1988 (ISCO-88), the JEMs were matched to DEGS1. This
16 index was then dichotomized in a 'low OPA' (index values 1-7) and a 'high OPA' category (index
17 values 8-10). A list of the most frequent occupations in DEGS1 according to OPA level for men and
18 women is presented in Table S1 (Online Supplemental Material).

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Leisure time physical activity: physical exercise

41 LTPA was assessed by asking participants "How often do you engage in physical exercise?" [38]. Even
42 though LTPA is usually referring to all PA in their freely disposable time, sport and exercise constitute
43 the core area of LTPA (29) and are therefore used as a proxy for LTPA in this study. Responses were
44 categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week. For the
45 analyses, the categories of the five-point scale "less than 1 h a week" and "regularly 1-2 h a week",
46 "regularly up to 4 h" and "regularly more than 4 h" were categorized into three groups: no physical
47 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 $\dot{V}O_2\text{max}$ were calculated for OPA, LTPA and covariates. Multivariable logistic regression models were computed to estimate the associations between domains of PA and low $\dot{V}O_2\text{max}$. 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 $\dot{V}O_2\text{max}$ according to domain specific PA. All analyses were

1
2
3 conducted separately for men and women to identify sex-specific physical activity patterns
4 associated with CRF and to reduce potential sex bias. Analyses were performed with Stata 15.1 (Stata
5 Corp., College Station, TX, USA) and conducted with a weighting factor to adjust for distribution of
6 the sample by sex, age, education, and region to match the German population. Stata's survey
7 procedures were applied to account for the clustered sampling design.
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14 RESULTS

15 Participants

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

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33 Prevalence of high OPA was 40.3% among men and 33.0% among women (Table 1). Among men,
34 24.9% did not engage in LTPA, whereas 39.8% engaged in LTPA less than two hours per week, and
35 35.3% two hours or more per week. Among women, the corresponding LTPA prevalences were
36 24.7%, 49.9%, and 25.3%, respectively. While LTPA did not vary according to OPA level among men,
37 women with high OPA were less likely to engage in LTPA for two hours or more per week than
38 women with low OPA (Table 2).
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50 low $\dot{V}O_2max$

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52 Overall, the prevalence of estimated low $\dot{V}O_2max$ was 41.2% (95% CI 37.6 to 44.8) among men and
53 40.5% among women (95% CI 37.1 to 44.0). Table 3 presents the prevalence of low $\dot{V}O_2max$ by
54 domain specific PA and sociodemographic, health behavior and anthropometric variables. Binary
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3 analyses showed that men and women with higher LTPA levels had a substantial lower prevalence of
4 low $\dot{V}O_2max$. While there were no relevant differences in low $\dot{V}O_2max$ regarding OPA among men,
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6 women with high OPA showed a higher prevalence of low $\dot{V}O_2max$ compared to women with low
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10 OPA.

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15 Multivariable analyses (Table 4) showed that women in jobs with high levels of OPA were more likely
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17 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
18
19 association disappeared when controlling for LTPA and other covariates (OR 1.06; 95% CI 0.75 to
20
21 1.49). Among men, both models showed no association between low $\dot{V}O_2max$ and OPA (OR 1.05;
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23 95% CI 0.75 to 1.46 and OR 0.95; 95% CI 0.64 to 1.42, respectively).
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27 <<< Table 4 about here >>>

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30 Men and women with no or a low level of engagement in LTPA (i.e. less than 2 hours per week)
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32 showed a considerable higher chance of having a low $\dot{V}O_2max$ than participants with 2 hours or
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34 more of LTPA. The effect size did not change considerably when adjusting for OPA and other
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36 controls.
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39 Multivariable analyses of the combined OPA/LTPA variable (fully-adjusted model) showed, that less-
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41 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
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43 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
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45 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
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47 LTPA /low OPA compared to men with ≥2h LTPA /high OPA. The corresponding ORs for women were
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49 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
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51 7.60), 1.93 (95% CI 0.90 to 4.13), indicating the highest likelihood of low fitness for women working
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53 in physically demanding jobs and not engaging in LTPA.
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57 Based on the final model with the combined OPA/LTPA variable, we plotted predicted probabilities of
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59 having a low $\dot{V}O_2max$ to illustrate these different patterns between men and women (Figure 1).
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<<< 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).

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3 Irrespective of the association of OPA with individual fitness, OPA and LTPA has been linked to
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5 negative health outcomes: in a meta-analysis Li and colleagues (6) found evidence that OPA might
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7 increase the risk of cardio vascular disease, while LTPA considerably reduced the risk. Another
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9 current meta-analysis found that men with high OPA had an increased risk of preliminary mortality,
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11 but women did not (7). In particular, the combination of high OPA with low CRF seems to be
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13 associated with a higher risk of adverse cardiovascular outcomes (42, 43).
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16 17 **Potential working mechanisms**

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19 It has been shown that regular aerobic exercise induces biological changes like increased stroke
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21 volume and decrease in venous oxygen content that lead to increased individual CRF (10). This
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23 exercise should ideally be performed with sufficient intensity at $\geq 50\%$ of the maximal aerobic
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25 capacity (10). LTPA, as far as it referring to sport activity, is usually activity of relatively short duration
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27 but high intensity and contains sufficient recovery time between the occasions. OPA, on the other
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29 hand, can be of too long duration, of too low intensity and with limited control about work speed
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31 and duration (9, 44). Therefore, no sufficient recovery is possible, as individuals can't decide how to
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33 perform and when to interrupt their work themselves.
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38 The observed results suggest, that the association of domain-specific PA and CRF vary between men
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40 and women. Among women with low levels of LTPA, high OPA is associated with lower fitness. As
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42 Table S1 shows, men with physically demanding occupation mainly work in manual and technical
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44 professions (e.g., electricians, plumbers, mechanics) while women in physically demanding jobs work
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46 mainly in the service sector (e.g. nursing/care, catering, and cleaning). The latter jobs, mainly
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48 performed by females, are particularly affected by limited work control and higher job-strain, which
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50 may be a possible explanation for these gender-specific patterns. For example, health care workers
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52 in Germany report very high level of job demands compared with the average level of all occupations
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54 while having a low decision-making autonomy (45) (46, p. 76-84). This would be of special concern as
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3 studies have shown, that high strain-jobs can lead to lower LTPA (47) and high occupational stress in
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5 combination with low CRF has been shown to considerably increase the cardiovascular risk (48).
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8 When recommending higher levels of LTPA, one should consider the embedded and dependent
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10 relationship of the different domains of PA: First, OPA and LTPA are not the exclusive domains of PA;
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12 transportation and domestic activities are also relevant. This is of importance, because like OPA both
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14 of these domains can also be described non-discretionary time (49) with limited autonomy by the
15
16 individual. Second, performing PA in all of these domains does depend on structures at the societal,
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18 environmental and individual level (50). As individuals face varying obstacles to engage in more LTPA
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20 like cultural temporal structures (e.g., public-transport timetables) or individual responsibilities (e.g.
21
22 parenthood), measures and policies aiming to create a activity friendly environment are needed
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24 rather than blaming the individual (1).
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29 **Strengths and Limitations**

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31 A major strength of this study is the use of a large population-based nationally representative sample
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33 of the non-institutionalized, resident adult working population, which allows the generalizability of
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35 our findings.
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38 However, even though in DEGS1 great efforts have been taken to reduce potential sources of bias
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40 (51, 52), the results of our study need to be interpreted in the context of some limitations. First, the
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42 cross-sectional design of the study does not permit a causal inference of the observed relationship
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44 between PA pattern and CRF. Even if it is well established that regular PA can enhance CRF, reversed
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46 causality for instance that individuals who have inherited a higher CRF tend to be more active, cannot
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48 be ruled out (53). Second, as in most large-scale epidemiological studies (10, 30), $\dot{V}O_{2max}$ was
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50 estimated based on a submaximal ergometer test in a highly standardized and quality assured
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52 procedure (15) and not directly assessed by breath gas analysis. Third, self-reports on PA levels are
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54 prone to recall and social desirability bias (54, 55). Thus, we cannot exclude the possibility that the
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56 level of LTPA was over- or underreported. Furthermore, LTPA was assessed based on information
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3 about the duration per week but not about intensity. The latter may have an additional impact on
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5 CRF (10). Fourth, OPA was assessed indirectly via JEMs. Even though these JEMs were based on a
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7 very large sample and the use of hierarchical linear regression models, controlling for age, sex,
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9 working hours and job experience, reducing the likelihood of confounding, JEMs are generally not
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11 able to account for variability of exposures within jobs (56).
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14 **CONCLUSIONS**

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

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FIGURES & TABLES

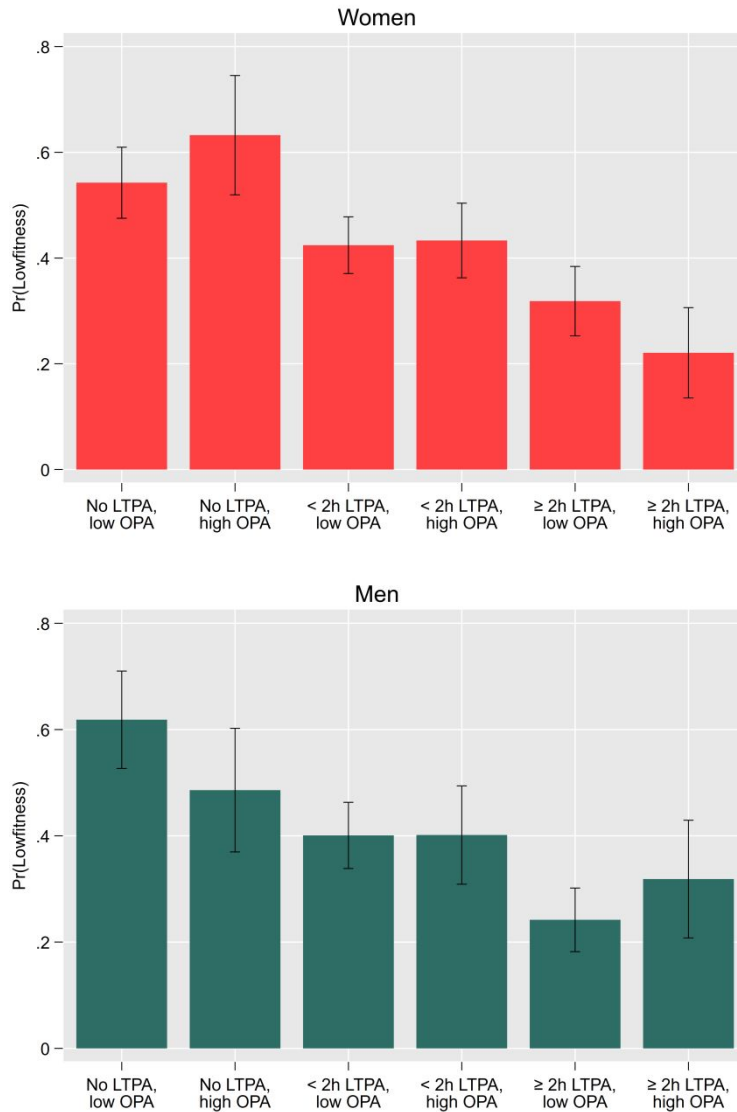


Figure 1: Predicted probabilities (with 95 % confidence intervals) of low $\dot{V}O_2max$ according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body 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	-

¹Unweighted percentage ²Weighted 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

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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	

¹adjusted for age; ²adjusted 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

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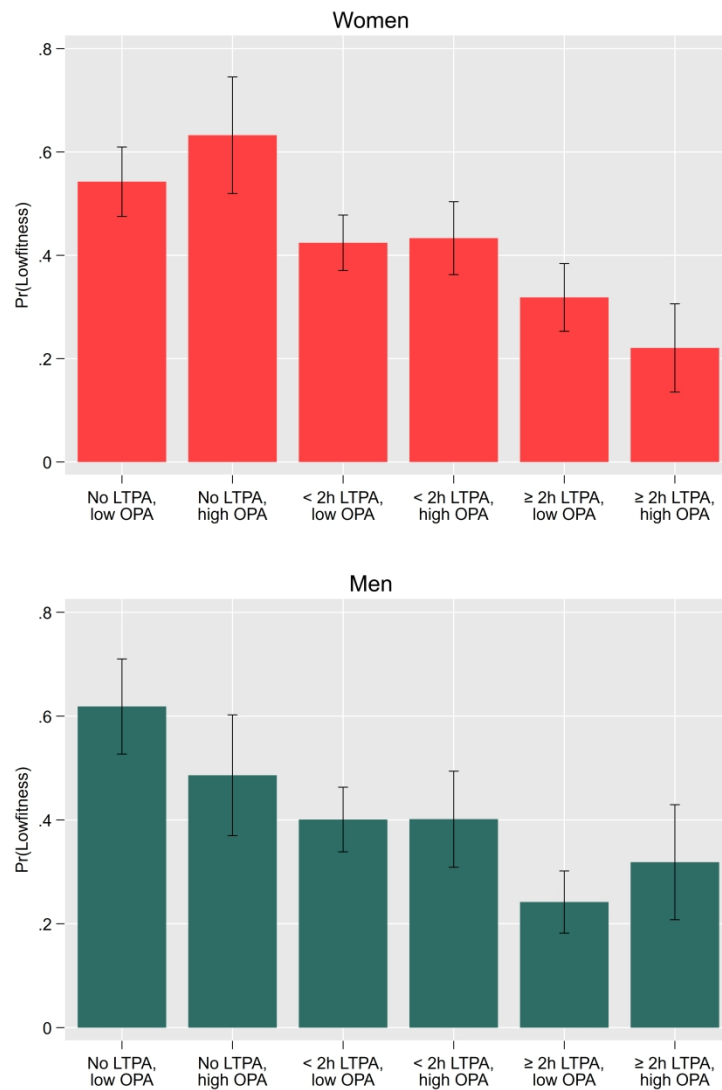


Figure 1: Predicted probabilities (with 95 % confidence intervals) of low V O₂ max according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity, OPA Occupational physical activity.

1411x2116mm (72 x 72 DPI)

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5 **Online Supplemental Material 1: Supplementary figures and tables**
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9 **Additional file to:** Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity
10 patterns and cardiorespiratory fitness among the working population. Findings from the German
11 health interview and examination survey
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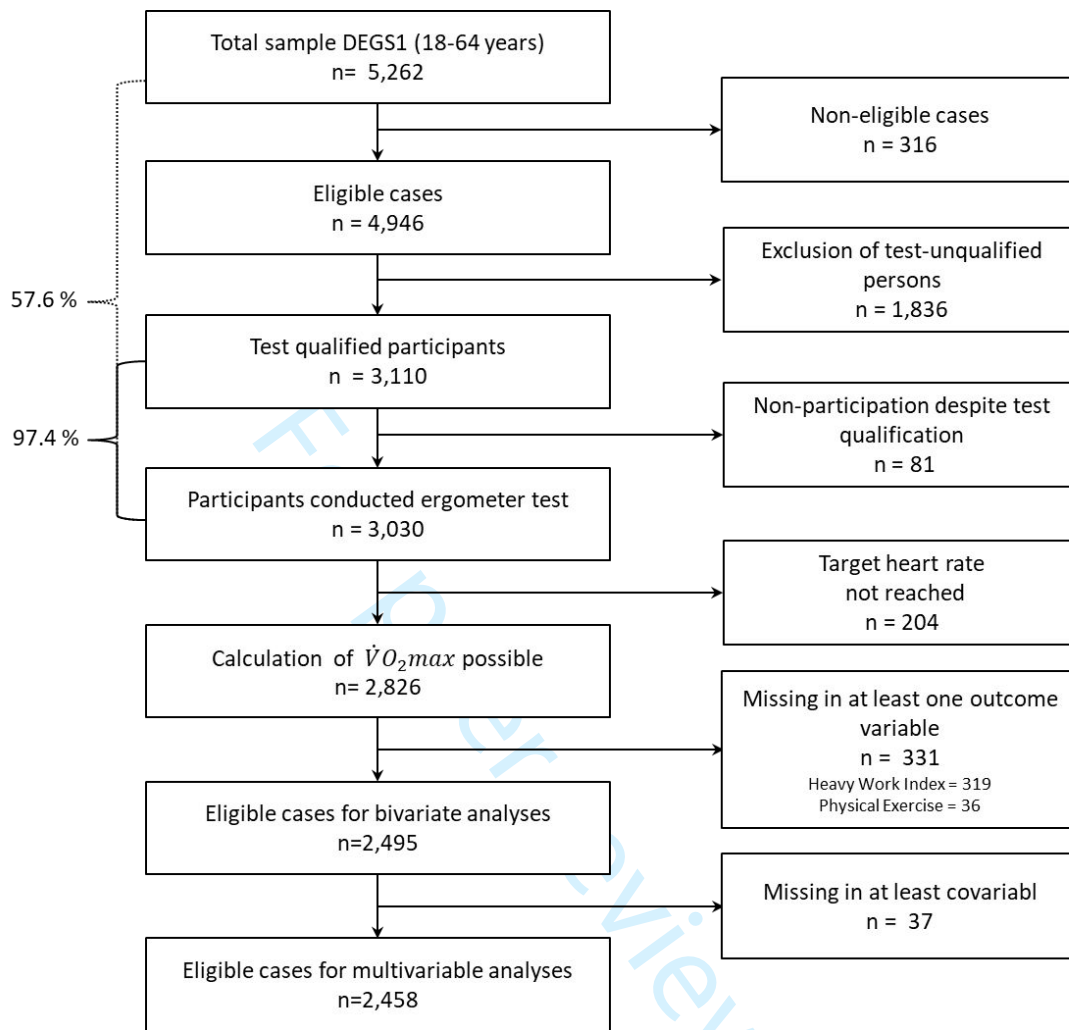


Figure S1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults; $\dot{V}O_2max$: Maximal oxygen consumption

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:	<i>BMJ Open</i>
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

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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

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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

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3 CRF. Thus, this study aims to investigate the associations between patterns of OPA and LTPA with
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5 CRF among the German working population. As men and women are differently exposed to physical
6
7 demands at work (14), work in different occupations (15), and may respond differently to PA (16),
8
9 our analyses were performed stratified by gender.
10

11 12 **METHODS**

13 14 **Study design**

15
16 We used data from the nationwide cross-sectional German Health Interview and Examination Survey
17
18 for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1). DEGS1 is part of the Federal
19
20 Health Monitoring System administered by the Robert Koch Institute (17). In detail, the study design
21
22 is described elsewhere (18). Briefly, the study is based on a two-stage cluster randomized sampling
23
24 procedure. First, 180 sample points were sampled from a list of German communities stratified to
25
26 represent regional distribution. Second, within these units, adult individuals were randomly drawn
27
28 from local population registries stratified by 10-year age groups. The response rate was 42%. A total
29
30 of 5,262 participants aged 18–64 years took part in the physical measurements component of the
31
32 DEGS1 from November 2008 to December 2011. Out of the gross sample 3,110 individuals were
33
34 categorized as test-qualified for the exercise test (Figure 1).
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41 <<< Figure 1 about here >>>

42
43 Overall, 3,030 participants completed the exercise test (participation rate 97.4 %). $\dot{V}O_{2max}$ was
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45 estimated for all participants reaching at least 75% of the age-predicted maximum heart rate (HR_{max}).
46
47 Two hundred and four participants terminated the test before reaching this heart rate. As a result, \dot{V}
48
49 O_{2max} could be calculated for 2,826 participants. Further cases were excluded based on missing
50
51 data on the PA variables. Overall, valid information on $\dot{V}O_{2max}$, OPA and LTPA was available for
52
53 1,296 women and 1,199 men. Table 1 illustrates demographic, anthropometric and health behavior
54
55 variables from this representative sample of the adult working population of Germany. Women
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57 comprised 48.0 % of the sample, the mean age of the participants was 39.6 years (range 18-64years).
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3 Generally, unweighted and weighted percentage did not differ substantially. In detail, weighting lead
4
5 to slightly smaller share of participants in the older age groups and a smaller share of participants in
6
7 the high socioeconomic status group.
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9

10 <<< Table 1 about here >>>
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12

13 *Patient and public involvement*

14 This research was done without patient involvement. Patients were not invited to comment on the
15
16 study design and were not consulted to develop patient relevant outcomes or interpret the results.
17
18 Patients were not invited to contribute to the writing or editing of this document for readability or
19
20 accuracy.
21
22

23 **Outcome variable**

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25
26 CRF was measured using a standardized, submaximal cycle ergometer test (Ergosana Sana Bike
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28 350/450 [Ergosana, Germany], heart rate monitor [Polar, Finland], blood pressure cuffs [Ergosana,
29
30 Germany], a heart rate transmitter [Oregon Scientific, USA] and a notebook with ergometer software
31
32 [Dr Schmidt GmbH, Germany]). Test methodology, protocol, and exclusion criteria were in detail
33
34 already described elsewhere (19, 20). DEGS1 participants were included in the ergometer test if they
35
36 were aged 18-64 years, signed an informed consent, and were categorized as test-qualified based on
37
38 a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q) (21, 22).
39
40 Participants were consulted by a physician if any PAR-Q contraindications were reported and the
41
42 physician decided whether or not the participant should be enrolled into the exercise test. CRF was
43
44 assessed using the test protocol recommended by the World Health Organization (WHO) (23):
45
46 Beginning at 25 watts, the workload was incrementally increased by 25 watts every two minutes until
47
48 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 watts
49
50 was achieved or the study staff terminated the test. Heart rate was monitored continuously
51
52 throughout the test. The formula $208 - 0.7 \cdot \text{Age}$ was used to calculate the age-predicted maximum
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54 heart rate (24). To derive physical work capacity at HR_{max} (PWC_{100%}), the measured heart rate (beats
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56 per minute) during the incremental phase was regressed against corresponding workload in watts for
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3 each participant. Assuming a linear relationship between heart rate and workload, $PWC_{100\%}$ was
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5 obtained by extrapolation using the individual regression equation $PWC_{100\%} = intercept + HR_{max} \cdot slope$
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7 (25). $PWC_{100\%}$ was further converted to $\dot{V}O_{2max}$ using a metabolic equation provided by the
8
9 American College of Sports Medicine (26): $3.5 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1} + 12.24 \cdot (PWC_{100\%}) \cdot (\text{body weight}^{-1})$.
10
11 According to gender-specific quintiles, estimated $\dot{V}O_{2max}$ was categorized into low $\dot{V}O_{2max}$
12
13 (quintile 1-2) and intermediate to high $\dot{V}O_{2max}$ (quintile 3-5).
14
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16 17 **Exposure variable**

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20 *Occupational physical activity: a physical work demands index*

21 To assess PA at work we used an indirect method and computed specific job exposure matrices
22
23 (JEMs) that can distinguish the participant's occupation by the criterion of physical demands. JEMs
24
25 are an established methodological tool allowing for inclusion of specific occupational exposures in
26
27 analyses based on studies that assess information about the participant's occupational titles, even if
28
29 the individual exposure is not assessed. JEMs are constructed using available secondary data to
30
31 determine exposure profiles for each occupation and matching these profiles to the primary data
32
33 using standardised job-classifications. In our case, JEMs were constructed using data of a large-scale
34
35 representative study on working conditions of $n = 20,000$ employees in Germany (27, 28). It was part
36
37 of the European Working Conditions Survey, which is regularly conducted in the member states of
38
39 the European Union. The Overall Job Index and specific indexes were already described and applied
40
41 elsewhere (29-31). In this study, we used a specific sub-index of perceived physical work demands.
42
43 To construct the index we used data regarding the frequency of lifting and carrying heavy loads (men
44
45 ≥ 20 kg, women ≥ 10 kg). The item was assessed with a frequency scale with four answer categories:
46
47 "often", "sometimes", "rarely" and "never" (27, 28). Based on hierarchic multilevel analyses adjusted
48
49 for gender, age, job experience and part time employment, the physical demand index was assigned
50
51 to the occupations. In contrast to the use of occupations-specific means, this procedure allows to
52
53 adjust for further variables that could influence the level of demands besides the specific occupation
54
55 (e.g., the gender ratio or the level of part time employment). The levels for the multi-level estimation
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1
2
3 were defined by the 2-, 3- and 4-digit codes of the ISCO-88 classification. These JEMs were then
4
5 classified into deciles. Occupations with the lowest level of physical work demands have a value of 1
6
7 (first decile), and those with the highest level have a value of 10 (tenth decile). Using the
8
9 International Classification of Occupations of 1988 (ISCO-88), the JEMs were matched to DEGS1. To
10
11 create a combined OPA/LTPA variable, this index was then dichotomized in a 'low OPA' (index values
12
13 1-6) and a 'high OPA' category (index values 7-10). A list of the most frequent occupations in DEGS1
14
15 according to OPA level for men and women is presented in Table S1 (Online Supplemental Material).
16
17

18 19 *Leisure time physical activity: physical exercise*

20 LTPA was assessed by asking participants "How often do you engage in physical exercise?" (32). Even
21
22 though LTPA is usually referring to all PA in their freely disposable time, sport and exercise constitute
23
24 the core area of LTPA (33) and are therefore used in this study. For the analyses, the categories of
25
26 the five-point scale "no physical exercise", "less than 1 h a week" and "regularly 1-2 h a week",
27
28 "regularly up to 4 h" and "regularly more than 4 h" were categorized into three groups: no physical
29
30 exercise, < 2 hours/week, ≥ 2 hours/week.
31
32
33

34 35 *Combined variable of occupational and leisure time physical activity*

36 To analyse the combined relationship of OPA and LTPA on CRF, we generated a combined variable
37
38 containing the categories no LTPA/low OPA, no LTPA/high OPA, <2h LTPA/low OPA, <2h LTPA/high
39
40 OPA, ≥2h LTPA/low OPA, and ≥2h LTPA/high OPA.
41
42

43 44 *Covariates*

45 Relevant covariates were selected based on evidence in the literature (34, 35). Age was categorised
46
47 into five groups: 18-24 years, 25-34 years, 35-44 years, 45-54 years and 55-64 years. Smoking was
48
49 grouped into daily, occasionally, former and never smoking. Alcohol intake was estimated by
50
51 multiplying the calculated quantity of each alcoholic beverage, assessed by a food frequency
52
53 questionnaire, with standard ethanol content (beer: 4.8%; wine: 11%, spirits: 33%) and classified into
54
55 low alcohol consumption (quintile 1), medium alcohol consumption (quintile 2-4), and high alcohol
56
57 consumption (quintile 5) using gender-specific quintiles. As body mass index and waist circumference
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2
3 have been shown to be independently related with CRF in previous studies (34, 35) we included both
4 parameters as covariates. Body height and weight were measured by standardized procedures using
5 portable electronic scales (SECA, Germany) and stadiometer (Holtain, UK). Body mass index (kg/m^2)
6 was categorized according to WHO guidelines (36). Waist circumference was measured at the
7 smallest site between the lowest rib and the superior border of the iliac crest with flexible, non-
8 stretchable measurement tape (Sibner Hegner, Switzerland) and categorized as 'normal', 'increased'
9 and 'strongly increased' according to international guidelines (37). Socioeconomic status (SES) was
10 determined using a composite additive index, based on information about participants' education,
11 occupational position and net equivalent income (38).
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23 **Statistical Analyses**

24
25 To show the association of the domain-specific activity levels LTPA was cross-tabulated with OPA.
26 Prevalence and 95% confidence intervals (CI) of low $\dot{V}O_2\text{max}$ were calculated for OPA, LTPA and
27 covariates. Multivariable logistic regression models were computed to estimate the associations
28 between domains of PA and low $\dot{V}O_2\text{max}$ (reference category: intermediate to high $\dot{V}O_2\text{max}$). In a
29 first step, separate models for OPA and LTPA were fitted, in a second step the combined variable of
30 OPA and LTPA was used. In both steps an age-adjusted model and a model adjusting for body mass
31 index, waist circumference, smoking, alcohol intake and SES were fitted. The separate models for
32 OPA and LTPA were additionally adjusted for LTPA and OPA, respectively. Finally, we computed
33 predicted margins (39) from the final logistic regression model to plot adjusted prevalences of low \dot{V}
34 $O_2\text{max}$ according to domain specific PA. All analyses were conducted separately for men and women
35 to identify gender-specific physical activity patterns associated with CRF and to detect a potential
36 effect modification by gender. Analyses were performed with Stata 15.1 (Stata Corp., College Station,
37 TX, USA). To enhance the external validity of the results weighting factors were used to adjust for
38 distribution of the sample by gender, age, education, and region to match the German population.
39 Stata's survey procedures were applied to account for the clustered sampling design.
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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 >>>

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3 Men and women with no or less than 2 hours LTPA per week were more likely to have a low $\dot{V}O_2max$
4 than participants with 2 hours or more LTPA per week. The effect size did not change considerably
5 when adjusting for OPA and other controls.
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10 Multivariable analyses of the combined OPA/LTPA variable (fully-adjusted model) showed, that less-
11 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
12 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
13 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
14 LTPA /low OPA compared to men with ≥2h LTPA /high OPA. The corresponding ORs for women were
15 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
16 7.60), 1.93 (95% CI 0.90 to 4.13), indicating the highest likelihood of low fitness for women working
17 in physically demanding jobs and not engaging in LTPA.
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28 Based on the final model with the combined OPA/LTPA variable, we plotted predicted probabilities of
29 having a low $\dot{V}O_2max$ to illustrate these different patterns between men and women (Figure 2).
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34 35 36 **DISCUSSION**

37 38 **Summary of results**

39 This cross-sectional study showed a strong association between low LTPA and low estimated $\dot{V}O_2$
40 max , but not between OPA and $\dot{V}O_2max$. Furthermore, the association of domain-specific PA
41 patterns with low $\dot{V}O_2max$ varied according to gender: After adjustment for potential confounding,
42 women not participating in LTPA and working in highly physically demanding occupations showed
43 the highest likelihood of having a low $\dot{V}O_2max$. In contrary, men that did not engage in LTPA and not
44 working in physically demanding occupations showed the highest risk of low $\dot{V}O_2max$.
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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 $\geq 50\%$ 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

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3 may be a possible explanation for these gender-specific patterns. For example, health care workers
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5 in Germany report very high level of job demands compared with the average level of all occupations
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7 while having a low decision-making autonomy (55) (56, p. 76-84). This can be of special concern as
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9 studies have shown, that high strain-jobs can lead to lower LTPA (57) whereas high occupational
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11 stress in combination with low CRF has been shown to considerably increase the cardiovascular risk
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13 (58). Furthermore, the potential physiological mechanisms described above hold especially true for
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15 the prevalent high work demand professions among women: studies have shown, that e.g. among
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17 cleaners OPA is often of long duration, but with insufficient intensity and goes along with an high
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19 relative workload (13).
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24 When recommending higher levels of LTPA, one should consider the embedded and dependent
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26 relationship of the different domains of PA: First, OPA and LTPA are not the exclusive domains of PA;
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28 transportation and domestic activities are also relevant. This is of importance because, like OPA, both
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30 of these domains can also be described as non-discretionary time (59) with limited autonomy by the
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32 individual. Second, performing PA in all of these domains does depend on structures at the societal,
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34 environmental and individual level (60). As individuals face varying obstacles to engage in more LTPA
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36 like cultural temporal structures (e.g., public-transport timetables) or individual responsibilities (e.g.
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38 parenthood), measures and policies aiming to create an activity friendly environment are needed
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40 rather than blaming the individual (1). In addition, it has to be noted that some studies found that a
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42 moderate to high level of LTPA was associated with adverse health outcomes among those exposed
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44 to high OPA (61, 62). Thus, the interrelationships between OPA and LTPA remains not fully
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46 understood and there is a need for further research to explain these partly contradictory results in
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48 the literature. To take into account the observed gender differences, it is highly recommended that
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50 future studies should investigate both men and women separately. Furthermore, a high share of the
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52 research on this topic is based on self-reported PA with a high heterogeneity among the instruments
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54 used. Thus, future research investigating the domains-specific effects of PA using objective measures
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56 is necessary (63). Finally, it is recommended that policy makers and public health experts involved in
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3 the development of PA recommendations consider specifying these recommendations according to
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5 the level of OPA, as recent guidelines do not make a distinction between activity levels during work.
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8 **Strengths and Limitations**

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10 A major strength of this study is the use of a large population-based nationally representative sample
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12 of the non-institutionalized, resident adult working population, which allows the generalizability of
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14 our findings.
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18 However, even though in DEGS1 great efforts have been taken to reduce potential sources of bias
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20 (64, 65), the results of our study need to be interpreted in the context of some limitations. First, the
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22 cross-sectional design of the study does not permit a causal inference of the observed relationship
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24 between PA pattern and CRF. Even if it is well established that regular PA can enhance CRF, reversed
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26 causality for instance that individuals who have inherited a lower CRF tend to be less active, cannot
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28 be ruled out (66). Thus, it cannot be drawn from our study, that a higher CRF can be traced to high
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30 LTPA levels. Second, due to the use of the PAR-Q screening questionnaire, our sample consists of a
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32 relatively healthy study-population. This implies the exclusion of most study participants using
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34 cardiorespiratory related medications. However, it cannot be ruled out that the use of other
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36 medications (e.g. psychotropic or antidiabetic drugs) act as a source of bias in our investigations.
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38 Furthermore, the use of relatively healthy study-population may have hampered the generalizability
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40 of our results. In addition, it cannot be ruled out that our results are affected by the so called healthy
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42 worker effect describing a specific form of selection bias where more healthy individuals are more
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44 likely to work in physically demanding occupations. Third, as in most large-scale epidemiological
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46 studies (10, 34), $\dot{V}O_{2max}$ was estimated based on a submaximal ergometer test in a highly
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48 standardized and quality assured procedure (19) and not directly assessed by breath gas analysis.
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50 Fourth, self-reports on PA levels are prone to recall and social desirability bias (67, 68). Thus, we
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52 cannot exclude the possibility that the level of PA was over- or underreported. This holds true not
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54 only for this study, but also for most of the studies cited in the discussion. Furthermore, LTPA was
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3 assessed based on information about the duration per week but not about intensity. The latter may
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5 have an additional impact on CRF (10). In the case of OPA, in contrast to objectively measured
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7 activity levels, which usually includes general activities during work, self-reports are often restricted
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9 to specific task, such as lifting of heavy loads. This is particularly important, because such physically
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11 demanding task influence CRF in a different way than general activities. Fifth, OPA was assessed
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13 indirectly via JEMs. Even though these JEMs were based on a very large sample and the use of
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15 hierarchical linear regression models, controlling for age, gender, working hours and job experience,
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17 reducing the likelihood of confounding, JEMs are generally not able to account for variability of
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19 exposures within jobs (69). If the prevalence of high physical demands within occupations varies
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21 widely, this could have led to biased results regarding the observed OPA levels, which would tend to
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23 reduce the magnitude of the observed associations.
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27 28 **CONCLUSIONS**

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

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3 **FIGURES & TABLES**
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8 **Figure 1:** Flow diagram of participants. DEGS1: German National Health Interview and Examination
9 Survey for adults; $\dot{V}O_{2max}$: Maximal oxygen consumption
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16 **Figure 2:** Predicted probabilities (with 95 % confidence intervals) of low $\dot{V}O_{2max}$ according to
17 domain specific physical activity among men and women who participated in the nationwide German
18 Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference,
19 body mass index, smoking status, alcohol consumption, SES index. LTPA Leisure time physical activity,
20 OPA Occupational physical activity.
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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	-

¹Percentage of the sample (unweighted) ²Weighted 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

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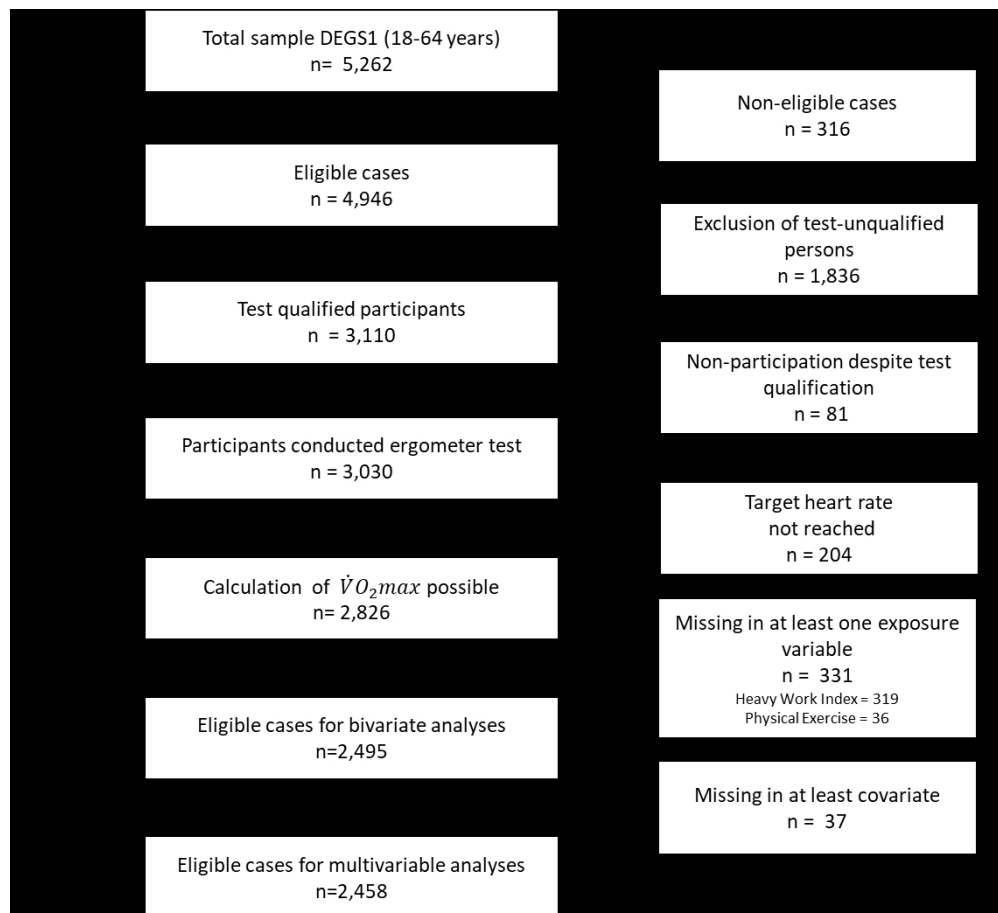
Table 4: Domain-specific physical activity and low estimated $\dot{V}O_{2max}$ among male and female DEGS1 participants

	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	

¹adjusted for age; ²adjusted 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

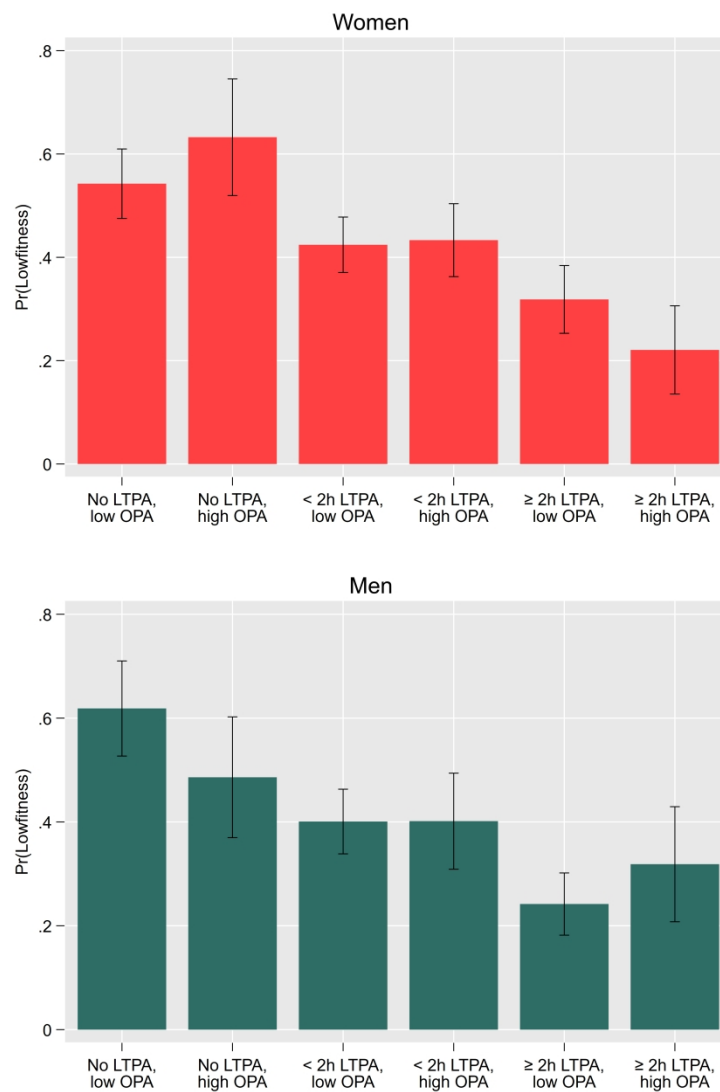
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36 Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey
37 for adults; VO2max: Maximal oxygen consumption

38 193x176mm (150 x 150 DPI)



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

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5 **Online Supplemental Material 1: Supplementary tables**
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9 **Additional file to:** Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity
10 patterns and cardiorespiratory fitness among the working population. Findings from the German
11 cross-sectional health interview and examination survey
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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:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034610.R2
Article Type:	Original research
Date Submitted by the Author:	06-Mar-2020
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Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Occupational and environmental medicine
Keywords:	cardiorespiratory fitness, adults, physical activity, physical fitness, occupational physical activity

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3 1 Research article
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5 2 **Domain-specific physical activity patterns and cardiorespiratory fitness among the working**
6 3 **population – Findings from the cross-sectional German health interview and examination survey**
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9 4

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57 32 Word count (main text): 4,375 words
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3 1 **ABSTRACT**

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6 2 **Objectives:**

7 3 This study aimed to investigate associations between occupational physical activity patterns (physical
8 4 work demands linked to job title) and leisure time physical activity (assessed by questionnaire) with
9 5 cardiorespiratory fitness (assessed by exercise test) among men and women in the German working
10 6 population.

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14 7 **Design:**

15 8 Population-based cross-sectional study

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18 9 **Setting:**

19 10 Two-stage cluster-randomized general population sample selected from population registries of 180
20 11 nationally-distributed sample points. Information was collected from 2008 to 2011.

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23 12 **Participants:**

24 13 1,296 women and 1,199 men aged 18–64 from the resident working population.

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27 14 **Outcome measure:**

28 15 Estimated low maximal oxygen consumption ($\dot{V}O_{2max}$), defined as first and second sex-specific
29 16 quintile, assessed by a standardized, submaximal cycle ergometer test.

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32
33 17 **Results:**

34 18 Low estimated $\dot{V}O_{2max}$ was strongly linked to low leisure time physical activity, but not occupational
35 19 physical activity. The association of domain-specific physical activity patterns with low $\dot{V}O_{2max}$
36 20 varied by sex: women doing no leisure time physical activity with high occupational physical activity
37 21 levels were more likely to have low $\dot{V}O_{2max}$ (odds ratio (OR) 6.54; 95% confidence interval (CI) 2.98–
38 22 14.3) compared with women with ≥ 2 hours of leisure time physical activity and high occupational
39 23 physical activity. Men with no leisure time physical activity and low occupational physical activity had
40 24 the highest odds of low $\dot{V}O_{2max}$ (OR 4.37; 95% CI 2.02–9.47).

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47 25 **Conclusion:**

48 26 There was a strong association between patterns of leisure time and occupational physical activity
49 27 and cardiorespiratory fitness within the adult working population in Germany. Women doing no
50 28 leisure time physical activity were likely to have poor cardiorespiratory fitness, especially if they
51 29 worked in physically-demanding jobs. However, further investigation is needed to understand the
52 30 relationships between activity and fitness in different domains. Current guidelines do not distinguish
53 31 between activity during work and leisure time, so specifying leisure time recommendations by
54 32 occupational activity level should be considered.

1
2
3 **1 KEYWORDS**

4 2 cardiorespiratory fitness; adults; physical activity; physical fitness; occupational physical activity
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6

7 **3 ARTICLE SUMMARY**
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9 **4 Strengths and limitations of this study**
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11
12 5 1. This is among the first studies to examine the association between leisure time and
13 6 occupational physical activity patterns and cardiorespiratory fitness in Germany.

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16 7 2. We used a large nationally-representative population-based sample of the resident adult
17 8 working population, to allow our findings to be generalized.

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20 9 3. Leisure time physical activity was assessed by self-reports, which may be prone to recall and
21 10 social desirability bias.
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1 BACKGROUND

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

15 Manual and physically-demanding occupations have been declining for decades, but occupational
16 physical activity still accounts for a large part of many people’s daily activity.[4] The beneficial effects
17 of leisure time physical activity are well established, but the effect of occupational activity is
18 inconclusive. Studies in the past often argued that occupational activity should also be considered to
19 improve health,[5] but recent studies suggest that it is not health-enhancing and may even have the
20 opposite effect.[6, 7] As a possible explanation for this ‘health paradox’, the domain-specific effects
21 of physical activity on cardiorespiratory fitness have come to attention.[8, 9] Defined as the ability of
22 circulatory, respiratory and muscular systems to supply oxygen during prolonged physical exercise,[3]
23 cardio respiratory fitness can be enhanced by regular endurance exercise[10] and is a strong
24 predictor of adverse health outcomes.[11] It has been argued, that occupational physical activity
25 rarely has the adequate intensity, duration, and volume to increase cardiorespiratory fitness.[8, 9,
26 12, 13]

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3 1 However, research on the association between different activity domains and cardiorespiratory
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5 2 fitness in Germany is limited. In particular, the interplay between different domains has not yet been
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7 3 analysed for cardiorespiratory fitness. This study therefore aimed to investigate the associations
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9 4 between leisure time and occupational physical activity with cardiorespiratory fitness among the
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11 5 German working population. Furthermore, in addition to the direct effects of the domain-specific
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13 6 physical activity, their interactional effects on cardiorespiratory fitness are investigated. The analyses
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15 7 were stratified by sex because men and women may vary in their exposure to physical demands at
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17 8 work,[14] type of occupations,[15] and response to physical activity.[16]
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21 9 **METHODS**

22 10 **Study design**

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27 11 We used data from the nationwide cross-sectional German Health Interview and Examination Survey
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29 12 for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1). DEGS1 is part of the Federal
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31 13 Health Monitoring System administered by the Robert Koch Institute.[17] In detail, the study design
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33 14 is described elsewhere.[18] Briefly, the study is based on a two-stage cluster randomized sampling
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35 15 procedure. First, 180 sample points were sampled from a list of German communities stratified to
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37 16 represent the regional distribution. Second, within these units, adult individuals were randomly
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39 17 drawn from local population registries stratified by 10-year age groups. The response rate was 42%.
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41 18 A total of 5,262 participants aged 18–64 years took part in the physical measurements component
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43 19 from November 2008 to December 2011. Of these, 3,110 individuals were test-qualified for the
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45 20 exercise test (Figure 1).
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50 21 <<< Figure 1 about here >>>

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52 22 Overall, 3,030 participants completed the exercise test (participation rate 97.4%). $\dot{V}O_{2max}$ was
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54 23 estimated for all participants reaching at least 75% of the age-predicted maximum heart rate (HR_{max}).
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56 24 In total, 204 participants terminated the test before reaching this heart rate, so $\dot{V}O_{2max}$ could be
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58 25 calculated for 2,826 participants. Further cases were excluded from this analysis because of missing
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3 1 physical activity data. Overall, valid information on VO_{2max} and occupational and leisure time
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5 2 physical activity was available for 1,296 women and 1,199 men. Table 1 shows demographic,
6
7 3 anthropometric and health behaviour variables from this representative sample of the adult working
8
9 4 population of Germany. Women made up 48.0% of the sample, and the mean age of the participants
10
11 5 was 39.6 years (range 18–64 years). The unweighted and weighted percentages did not differ
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13 6 substantially, although weighting led to a slightly smaller proportion of participants in the older age
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15 7 groups and a smaller proportion in the high socioeconomic status group.
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19 8 <<< Table 1 about here >>>

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22 9 *Patient and public involvement*

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24 10 This research was done without patient involvement. Patients were not invited to comment on the
25
26 11 study design and were not consulted to develop patient-relevant outcomes or interpret the results.
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28 12 Patients were not invited to contribute to the writing or editing of this document for readability or
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30 13 accuracy.
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33 14 **Outcome variable**

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36 15 Cardiorespiratory fitness was measured using a standardized, submaximal cycle ergometer test
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38 16 (Ergosana Sana Bike 350/450 [Ergosana, Germany], heart rate monitor [Polar, Finland], blood
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40 17 pressure cuffs [Ergosana, Germany], a heart rate transmitter [Oregon Scientific, USA] and a notebook
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42 18 with ergometer software [Dr Schmidt GmbH, Germany]). Test methodology, protocol, and exclusion
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44 19 criteria have been described elsewhere.[19, 20] DEGS1 participants were included in the ergometer
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46 20 test if they were aged 18–64 years, gave informed consent, and were test-qualified based on a
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48 21 modified German version of the Physical Activity Readiness Questionnaire (PAR-Q).[21, 22] If any
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50 22 PAR-Q contraindications were reported, the participant was seen by a physician, who decided
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52 23 whether they should be enrolled into the exercise test. Cardiorespiratory fitness was assessed using
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54 24 the test protocol recommended by the WHO.[23] Beginning at 25 watts, the workload was increased
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56 25 by 25 watts every two minutes until 85% of the estimated age-specific maximal heart rate was
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58 26 exceeded, a maximum level of 350 watts was achieved or the study staff terminated the test. Heart
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1 rate was monitored continuously throughout the test. The formula $208 - 0.7 \times Age$ was used to
2 calculate the age-predicted maximum heart rate.[24] To derive physical work capacity at HR_{max}
3 ($PWC_{100\%}$), the measured heart rate (beats per minute) during the incremental phase was regressed
4 against corresponding workload in watts for each participant. Assuming a linear relationship between
5 heart rate and workload, $PWC_{100\%}$ was obtained by extrapolation using the individual regression
6 equation $PWC_{100\%} = intercept + HR_{max} \times slope$. [25] $PWC_{100\%}$ was converted to $\dot{V}O_2max$ using a
7 metabolic equation provided by the American College of Sports Medicine: $3.5 ml/min/kg + 12.24 \times$
8 $(PWC_{100\%}) / (body\ weight)$. [26] Estimated $\dot{V}O_2max$ was categorized into low (sex-specific quintiles 1–
9 2) and intermediate to high (quintiles 3–5).

10 **Exposure variable**

11 *Occupational physical activity: a physical work demands index*

12 To assess occupational physical activity, we used an indirect method and computed specific job
13 exposure matrices to distinguish participants' occupation by level of physical demand. These
14 matrices are an established methodological tool to allow inclusion of specific occupational exposure
15 in analyses, drawing on studies that assess information about job titles. They are constructed using
16 available secondary data to determine exposure profiles for each occupation. These profiles are
17 matched to primary data using standardised job classifications. In our case, such matrices were
18 constructed using data from a large-scale representative study on working conditions of 20,000
19 employees in Germany, [27, 28] which was part of the European Working Conditions Survey regularly
20 conducted in member states of the European Union. The overall job index and specific indexes have
21 been described and applied elsewhere. [29–31] In this study, we used a specific sub-index of
22 perceived physical work demands. To construct the index, we used data on the frequency of lifting
23 and carrying heavy loads (men ≥ 20 kg, women ≥ 10 kg). The item was assessed with a frequency
24 scale with four answer categories: "often", "sometimes", "rarely" and "never". [27, 28] The physical
25 demand index was assigned to the occupations based on hierarchic multilevel analyses adjusted for
26 sex, age, job experience and part time employment. In contrast to the use of occupation-specific

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3 1 means, this procedure allows adjustment for other variables besides the specific occupation that
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5 2 could also influence the level of demand (e.g., the sex ratio or the level of part time employment).
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7 3 The levels for the multi-level estimation were defined by the 2-, 3- and 4-digit codes of the
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9 4 International Classification of Occupations of 1988 (ISCO-88) classification. These matrices were then
10
11 5 classified into deciles. Occupations with the lowest level of physical work demands had a value of 1
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13 6 (first decile), and those with the highest level had a value of 10 (tenth decile). Using the ISCO-88, the
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15 7 matrices were matched to DEGS1. To create a combined physical activity variable, this index was
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17 8 then dichotomized into low (index values 1–6) and high occupational physical activity (index values
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19 9 7–10). A list of the most frequent occupations in DEGS1 by occupational activity level for men and
20
21 10 women is shown in Table S1 (Online Supplemental Material).

22 23 24 25 26 11 *Leisure time physical activity: physical exercise*

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28 12 Leisure time physical activity was assessed by asking participants “How often do you engage in
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30 13 physical exercise?”.[32] Leisure time physical activity usually refers to all physical activity in freely
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32 14 disposable time, but sport and exercise are the main elements[33] so were used in this study.
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34 15 Responses were on a five-point scale of “no physical exercise”, “less than 1 h a week” and “regularly
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36 16 1–2 h a week”, “regularly up to 4 h” and “regularly more than 4 h”, and were categorized into three
37
38 17 groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.

39 40 41 42 18 *Combined occupational and leisure time physical activity*

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44 19 To analyse the combined relationship of occupational and leisure time physical activity on
45
46 20 cardiorespiratory fitness, we generated a combined variable by grouping no, < 2 hours, and ≥ 2 hours
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48 21 leisure time physical activity with each of low and high occupational physical activity, giving six
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50 22 possible categories.

51 52 53 23 *Covariates*

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55 24 Relevant covariates were selected from the literature.[34, 35] Age was categorised into five groups:
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57 25 18–24 years, 25–34 years, 35–44 years, 45–54 years and 55–64 years. Smoking was grouped into
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59 26 daily, occasionally, former and never. Alcohol intake was estimated by multiplying the calculated
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1 quantity of each alcoholic beverage, assessed by a food frequency questionnaire, with standard
2 ethanol content (beer: 4.8%; wine: 11%, spirits: 33%) and classified into low (quintile 1), medium
3 (quintile 2–4), and high (quintile 5) alcohol consumption using sex-specific quintiles. Body mass index
4 and waist circumference have been shown to be independently related to cardiorespiratory
5 fitness,[34, 35] so we included both parameters as covariates. Body height and weight were
6 measured by standardized procedures using portable electronic scales (SECA, Germany) and
7 stadiometer (Holtain, UK). Body mass index (kg/m²) was categorized using WHO guidelines.[36] Waist
8 circumference was measured at the smallest site between the lowest rib and the superior border of
9 the iliac crest with flexible, non-stretchable measurement tape (Sibner Hegner, Switzerland) and
10 categorized as ‘normal’, ‘increased’ and ‘strongly increased’ using international guidelines.[37]
11 Socioeconomic status was determined using a composite additive index, based on information about
12 participants’ education, occupational position and net equivalent income.[38]

13 **Statistical Analyses**

14 Leisure time and occupational physical activity were cross-tabulated to show the association of the
15 domain-specific activity levels. Prevalence and 95% confidence intervals (CI) of low $\dot{V}O_2max$ were
16 calculated by occupational and leisure time physical activity and covariates. Multivariable logistic
17 regression models were computed to estimate the associations between domain-specific physical
18 activity (exposure) and low $\dot{V}O_2max$ (outcome). In a first step, the main effects of occupational and
19 leisure time physical activity were investigated, in a second step the combined activity variable was
20 used. In both steps, we fitted an age-adjusted model and one adjusting for age, body mass index,
21 waist circumference, smoking, alcohol intake and socioeconomic status. Finally, we computed
22 predicted margins[39] from the fully adjusted logistic regression model investigating the combined
23 physical activity variable to plot adjusted prevalence of low $\dot{V}O_2max$ by domain-specific physical
24 activity. All analyses were performed separately for men and women to identify sex-specific physical
25 activity patterns associated with cardiorespiratory fitness and to detect potential effect modification
26 by sex. Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA). To enhance

1 the external validity of the results, weighting factors were used to adjust for distribution of the
2 sample by sex, age, education, and region, to match the German population. Stata's survey
3 procedures were applied to account for the clustered sampling design.

4 RESULTS

5 Occupational and leisure time physical activity levels

6 Prevalence of high occupational physical activity was 40.3% among men and 33.0% among women
7 (Table 1). In total, 24.9% of men and 24.7% of women engaged in no leisure time physical activity,
8 39.8% and 49.9% in less than two hours per week, and 35.3% and 25.3% in two hours or more per
9 week. Leisure time physical activity did not vary with occupational activity level among men, but
10 women with high occupational physical activity were less likely to engage in two hours or more
11 leisure time physical activity per week than women with low occupational activity (Table 2).

12 <<< Table 2 about here >>>

13 low $\dot{V}O_2max$

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

21 <<< Table 3 about here >>>

22 Multivariable analyses (Table 4) showed that women in jobs with high levels of occupational physical
23 activity were more likely to have a low estimated $\dot{V}O_2max$ when adjusting only for age (odds ratio
24 [OR] 1.71; 95% CI 1.23–to 2.36). This association disappeared when controlling for leisure time

1 physical activity and other covariates (OR 1.06; 95% CI 0.75–1.49). Neither model showed any
2 association between low $\dot{V}O_{2max}$ and occupational physical activity for men (OR 1.05; 95% CI 0.75–
3 1.46 and OR 0.95; 95% CI 0.64–1.42).

4 <<< Table 4 about here >>>

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

8 Multivariable analyses of the combined physical activity variable (fully-adjusted model) showed that
9 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
10 leisure time/low occupational physical activity, 2.34 (95% CI 1.08–5.07) for no leisure time/high
11 occupational physical activity, 1.54 (95% CI 0.77–3.06) for < 2 h leisure time/low occupational
12 physical activity, 1.54 (95% CI 0.75–3.16) for < 2 h leisure time/high occupational physical activity,
13 and 0.64 (95% CI 0.32–1.27) for ≥ 2 h leisure time/low occupational physical activity compared with
14 men with ≥ 2 h leisure time/high occupational physical activity. The corresponding ORs for women
15 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–
16 7.60), and 1.93 (95% CI 0.90–4.13), indicating women were most likely to have a low fitness if they
17 worked in physically-demanding jobs and did not engage in leisure time physical activity.

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

20 <<< Figure 2 about here >>>

21 DISCUSSION

22 Summary of results

23 This cross-sectional study showed a strong association between low leisure time physical activity and
24 low estimated $\dot{V}O_{2max}$, but not between occupational physical activity and $\dot{V}O_{2max}$. The

1
2
3 1 association between domain-specific physical activity and low $\dot{V}O_2max$ also varied by sex. After
4
5 2 adjustment for potential confounding, women working in physically-demanding occupations who did
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7 3 not participate in leisure time physical activity had the highest likelihood of having a low $\dot{V}O_2max$.
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10 4 However, the men with the highest risk of low $\dot{V}O_2max$ were those who did not engage in leisure
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12 5 time physical activity and were not working in physically-demanding occupations.
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14

15 6 **Comparison with other studies**

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18 7 The strong association between leisure time physical activity and cardiorespiratory fitness has been
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20 8 shown in numerous studies.[34] However, evidence of the association between occupational physical
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22 9 activity and cardiorespiratory fitness is inconclusive. Historically, occupational physical activity has
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24 10 been seen as a way to improve health in behavioural medicine, but as a potential health hazard in
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26 11 occupational medicine.[6, 40] Recent studies agree that occupational physical activity does not lead
27
28 12 to increased cardiorespiratory fitness.[41-44] A Swiss study among adults reported no association
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30 13 between the amount of objectively-assessed steps during work-time and $\dot{V}O_2max$, and a lower $\dot{V}O_2$
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32 14 max among participants doing manual work than those doing sedentary work (according to reported
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34 15 job title), while controlling for leisure time physical activity and various other covariates.[41] A cross-
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36 16 regional study in Germany also found higher levels of $\dot{V}O_2max$ among participants with high levels of
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38 17 leisure time physical activity, but $\dot{V}O_2max$ was lower among participants with higher levels of
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40 18 occupational physical activity (assessed by questionnaire).[43] A study among the Danish working
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42 19 population observed that self-reported work and leisure sitting time had different associations with
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44 20 $\dot{V}O_2max$: there was a strong negative association between sitting leisure time and $\dot{V}O_2max$, but no
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46 21 similar association with sitting time at work.[45] However, a study among male workers in Japan
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48 22 found higher levels of $\dot{V}O_2max$ among those with self-reported high occupational physical activity
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50 23 than low[46] and a study from Finland found a positive association between cardiorespiratory fitness
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52 24 and self-reported occupational physical activity even after adjustment for leisure time physical
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54 25 activity among young men.[47]
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3 1 Occupational physical activity has been linked to negative health outcomes: in a meta-analysis, Li and
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5 2 colleagues[6] found evidence that it might increase the risk of cardiovascular disease, although
6
7 3 leisure time physical activity considerably reduced the risk. Another meta-analysis found that men
8
9 4 with high occupational physical activity had an increased risk of preliminary mortality, but women did
10
11 5 not.[7] In particular, the combination of high occupational physical activity with low cardiorespiratory
12
13 6 fitness seems to be associated with a higher risk of adverse cardiovascular outcomes.[48, 49]

7 **Potential mechanisms**

8 Regular aerobic exercise induces biological changes, such as increased stroke volume and decreased
9
10 9 venous oxygen content, both of which lead to increased individual cardiorespiratory fitness.[10] To
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12 10 increase $\dot{V}O_{2max}$, exercise should ideally be performed with sufficient intensity at $\geq 50\%$ of the
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14 11 maximal aerobic capacity for untrained individuals.[10] Cardiorespiratory fitness is determined by
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16 12 the cardiac output and arteriovenous oxygen difference, so it can be enhanced by an increase in
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18 13 stroke volume, oxygen difference, or both.[10] Leisure time physical activity, especially sport, is
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20 14 usually relatively short duration but high intensity, and provides sufficient recovery time between
21
22 15 occasions. This is important, because this type of activity can achieve a training effect of the
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24 16 myocardium. This reduces the heart rate, the heart muscle remains longer in diastole and the stroke
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26 17 volume increases.[50] In contrast, physical activity without recovery leads to prolonged elevation of
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28 18 heart rate and blood pressure.[51] This can result in erosion of the endothelium, which can provoke
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30 19 atherosclerosis.[52] This prolonged activity is typically observed in occupational physical activity,
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32 20 where workers also have limited control of work speed and duration.[9, 50] Sufficient recovery is
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34 21 therefore not possible, because individuals are unable to decide for themselves how to perform their
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36 22 work, and when to pause. Assuming average occupational physical activity as a constant,
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38 23 monotonous but low intensity activity, it has also been proposed that its intensity might be too low
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40 24 to increase individual fitness.[9] However, this might not hold true for all occupations. Studies among
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42 25 blue-collar workers found that directly-assessed intensity of physical activity was higher during work
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44 26 than leisure time,[53] especially among those with low fitness levels.[54]

1 **Differences between men and women**

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

17 **Recommendations for further research and practical implications**

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

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3 1 physical activity with high heterogeneity among the instruments used. Future studies should
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5 2 investigate the domain-specific effects of physical activities using objective measures.[61]
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8 3 When recommending higher levels of leisure time physical activities, it is important to consider the
9
10 4 embedded and dependent relationship of the different domains of physical activity. Occupational
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12 5 and leisure time activity are not the only areas of physical activity. Transportation and domestic
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14 6 activities are also relevant. This is important because both these domains can also be described as
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16 7 non-discretionary time[62] with limited individual autonomy. Second, physical activity in all these
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18 8 domains depends on structures at the societal, environmental and individual level.[63] Individuals
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20 9 face obstacles in engaging in more leisure time physical activity, such as cultural temporal structures
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22 10 (e.g., public transport timetables) or individual responsibilities (e.g. parenthood). Thus, measures and
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24 11 policies to create an activity-friendly environment are needed, rather than blaming individuals for
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26 12 lack of exercise.[1] Finally, we recommend that policy-makers and public health experts involved in
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28 13 the development of physical activity recommendations consider specifying these recommendations
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30 14 by level of occupational physical activity, because recent guidelines do not make this distinction.
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35 **Strengths and Limitations**

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38 16 A major strength of this study is its use of a large population-based nationally-representative sample
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40 17 of the non-institutionalized, resident adult working population. This allows the findings to be
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42 18 generalized. Significant efforts were made to reduce potential sources of bias in DEGS1,[64, 65] but
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44 19 our study still needs to be interpreted in the context of some limitations. First, the study's cross-
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46 20 sectional design does not permit any causal inferences to be drawn about the observed relationship
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48 21 between physical activity patterns and cardiorespiratory fitness. It is well-known that regular physical
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50 22 activity can increase cardiorespiratory fitness, but reversed causality cannot be ruled out: for
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52 23 example, individuals who have inherited a lower cardiorespiratory fitness may tend to be less
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54 24 active.[66] We therefore cannot conclude that a higher cardiorespiratory fitness can be traced to
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56 25 higher leisure time physical activity levels. Second, due to the use of the PAR-Q screening
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3 1 questionnaire, our sample consists of a relatively healthy study-population. This implies the exclusion
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5 2 of most study participants using cardiorespiratory-related medication. However, it is possible that
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7 3 the use of other medications (e.g. psychotropic or antidiabetic drugs) may act as a source of bias. The
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10 4 use of a relatively healthy study population may also have hampered the generalizability of our
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12 5 results. The results might also be affected by the so-called healthy worker effect, a specific form of
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14 6 selection bias where more healthy individuals are more likely to work in physically-demanding
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16 7 occupations. Third, as in most large-scale epidemiological studies,[10, 34] $\dot{V}O_{2max}$ was estimated
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18 8 using a submaximal ergometer test in a highly standardized and quality-assured procedure[19] and
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20 9 not directly assessed by breath gas analysis. Fourth, self-reports on physical activity levels are prone
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22
23 10 to recall and social desirability bias.[67, 68] We cannot exclude the possibility that the level of
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25 11 physical activity was over- or underreported. This is also true for most of the studies cited. Leisure
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28 12 time physical activity was assessed based on information about the duration per week, but not
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30 13 intensity, although intensity may have an additional impact on cardiorespiratory fitness.[10] In the
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32 14 case of occupational physical activity, self-reports are restricted to specific task, such as lifting of
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34 15 heavy loads. In contrast, objectively-measured activity levels usually include general activities at
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37 16 work. This is particularly important, because this type of task influences cardiorespiratory fitness in a
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39 17 different way from general activities. Fifth, occupational physical activity was assessed indirectly via
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41 18 job exposure matrices. These were based on a very large sample and the use of hierarchical linear
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43 19 regression models, controlling for age, sex, working hours and job experience, reduced the likelihood
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45 20 of confounding. However, they are generally not able to account for variability of exposure within
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47 21 jobs.[69] If the prevalence of high physical demands within occupations varied widely, this could
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49 22 have led to biased results on observed occupational physical activity levels, which would reduce the
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51 23 magnitude of the observed associations.

54 24 **CONCLUSIONS**

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57 25 This study showed a strong association between patterns of physical activity during leisure time and
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59 26 work and cardiorespiratory fitness among men and women in the working population in Germany.

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3 1 For example, women doing little or no leisure time physical activity were likely to have low
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5 2 cardiorespiratory fitness, especially if they worked in physically-demanding jobs. These findings
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7 3 therefore contribute to the increasing body of evidence about different domain-specific effects of
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9 4 physical activity on health outcomes. They also emphasize the importance of considering different
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11 5 domains of physical activity in future studies. Current guidelines do not distinguish between work
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13 6 and leisure time physical activity, and it may be helpful to specify leisure time physical activity
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15 7 recommendations by occupational physical activity levels. Further research is needed to understand
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17 8 the pathways through which different domains of physical activity lead to divergent health effects
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19 9 and to confirm these findings with objective measures of physical activity.
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3 **1 STATEMENTS**
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6 **2 Author Contributions**
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8 GBMM and JDF were involved in the design and conduct of DEGS1, JDF in particular for the
9
10 ergometer testing. JZ, LEK, and JDF conceptualized the current study. JZ, MD and LEK conducted the
11
12 analysis. JZ drafted the manuscript. GBMM, JDF and TK contributed to the analysis plan and
13
14 interpretation of the results. MD, GBMM, JDF and TK critically revised it. All authors contributed to
15
16 the interpretation of findings, reviewed, edited and approved the final manuscript.
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19
20 **8 Acknowledgements**
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22
23 We thank Melissa Leffler for editing a draft of this manuscript.
24

25
26 **10 Funding**
27

28 No external funding was received. The study was financed by the Robert Koch Institute which is a
29
30 federal institute within the portfolio of the German Federal Ministry of Health.
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32

33
34 **13 Competing interests**
35

36 None declared.
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40 **15 Patient consent**
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42 Participants signed an informed written consent prior to participation.
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45
46 **17 Ethics approval**
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48 DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité
49
50 – Universitätsmedizin Berlin ethic committee (no EA2/047/08).
51

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53 **20 Data sharing statement**
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55 A dataset of DEGS1 is available via Public Use File
56 ([https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node](https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html)
57 [.html](https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/application/application_node.html) [accessed 23 Sep 2019]).
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3 1 **FIGURES & TABLES**
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8 3 **Figure 1:** Flow diagram of participants. DEGS1: German National Health Interview and Examination
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10 4 Survey for adults; $\dot{V}O_{2max}$: Maximal oxygen consumption
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16 6 **Figure 2:** Predicted probabilities (with 95% confidence intervals) of low $\dot{V}O_{2max}$ by domain-specific
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18 7 physical activity among men and women who participated in the nationwide German Health
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20 8 Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body
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22 9 mass index, smoking status, alcohol consumption, and socioeconomic status index. LTPA: leisure time
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24 10 physical activity, OPA: occupational physical activity.
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1 **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	-

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

1 Examination Survey for Adults, $\dot{V}O_{2max}$: maximal oxygen consumption, LTPA: leisure time physical activity, OPA:
2 occupational physical activity

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

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31 8 DEGS1: German Health Interview and Examination Survey for Adults, CI: confidence intervals, LTPA: leisure time physical
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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

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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.

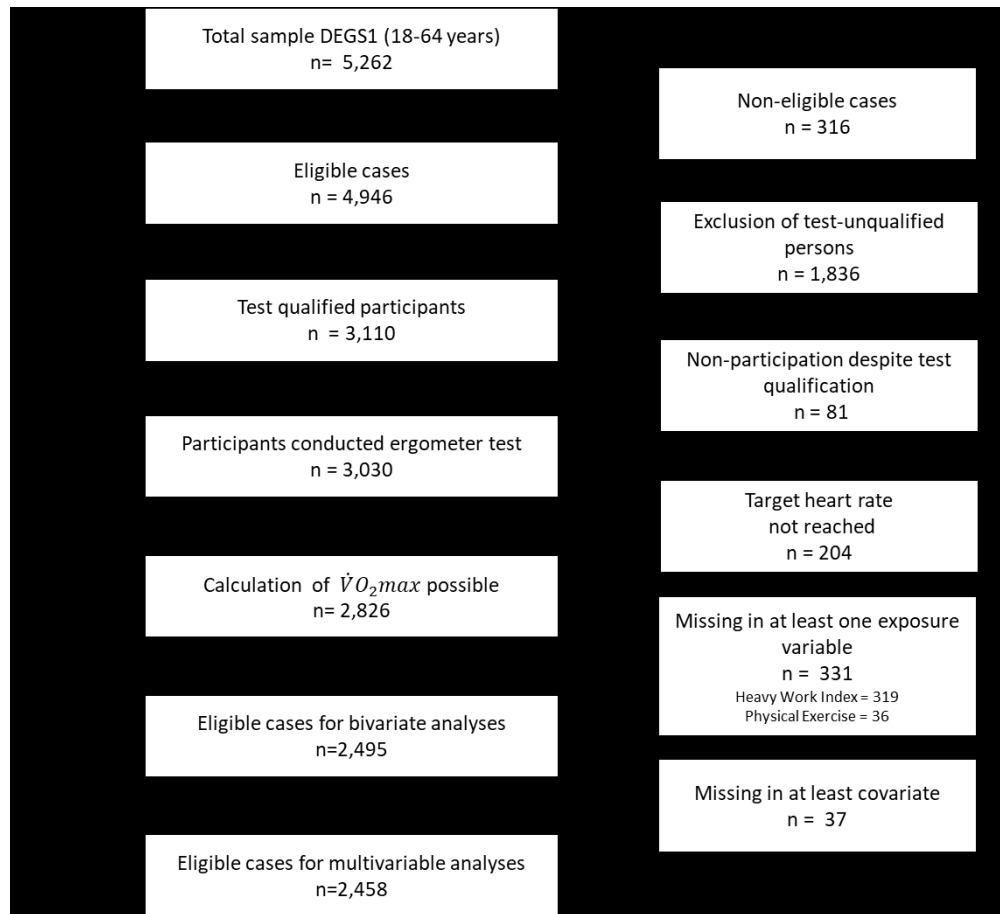
	Men				Women			
	OR ¹	(95 % CI)	OR ²	(95 % CI)	OR ¹	(95 % CI)	OR ²	(95 % CI)
Main effects model								
OPA								
low OPA	(ref.)		(ref.)		(ref.)		(ref.)	
high OPA	1.05	(0.75 - 1.46)	0.95	(0.64 - 1.42)	1.71	(1.23 - 2.36)	1.06	(0.75 - 1.49)
LTPA								
no LTPA	4.97	(3.47 - 7.13)	4.46	(2.89 - 6.89)	4.96	(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	

¹Adjusted for age; ²adjusted 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

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

38 193x176mm (150 x 150 DPI)

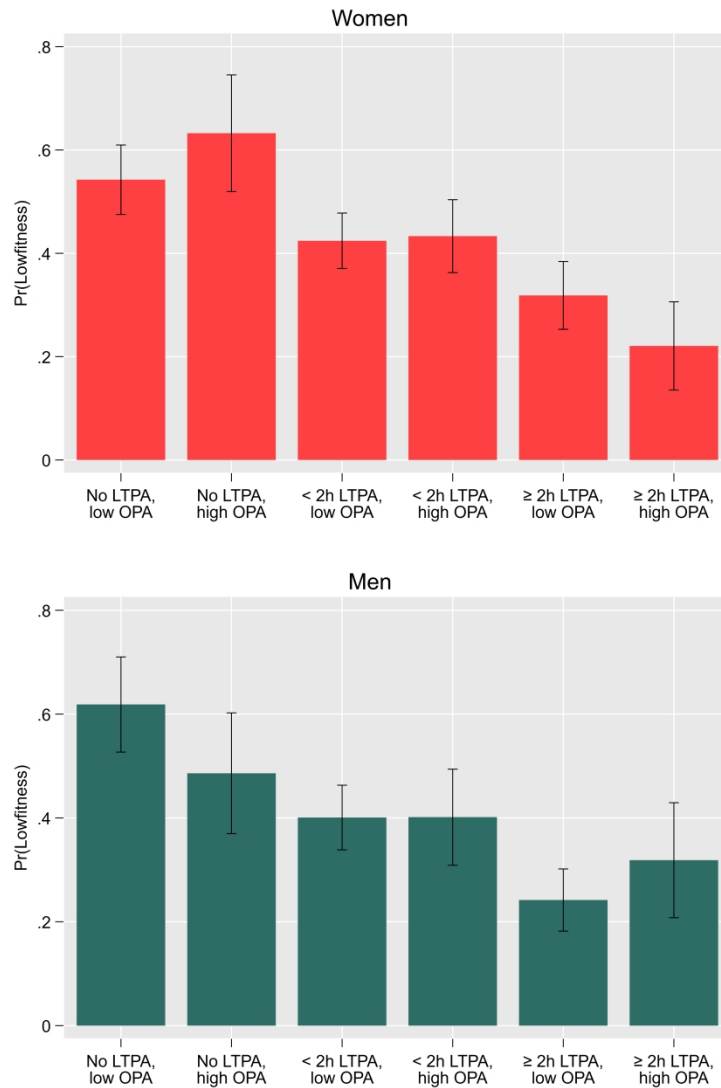


Figure 2: Predicted probabilities (with 95 % confidence intervals) of low VO₂max according to domain specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults (DEGS1). Adjusted for age, waist circumference, body mass index,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

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5 **Online Supplemental Material 1: Supplementary tables**
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9 **Additional file to:** Zeiher J, Duch M, Mensink GBM, Finger JD, Keil T. Domain-specific physical activity
10 patterns and cardiorespiratory fitness among the working population. Findings from the German
11 cross-sectional health interview and examination survey
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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

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60STROBE 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.