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

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To cite: Zeiher J, Duch M, Kroll LE, et al. Domain-specific physical activity patterns and cardiorespiratory fitness among the working population: Findings from the cross-sectional German Health Interview and Examination Survey. BMJ Open 2020;10:e034610. doi:10.1136/bmjopen-2019-034610  

ABSTRACT

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

Design Population-based cross-sectional study.

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

Participants 1296 women and 1199 men aged 18–64 from the resident working population.

Outcome measure Estimated low maximal oxygen consumption ($\hat{VO}_2\text{max}$), defined as first and second sex-specific quintile, assessed by a standardised, submaximal cycle ergometer test.

Results Low estimated $\hat{VO}_2\text{max}$ was strongly linked to low leisure time physical activity, but not occupational physical activity. The association of domain-specific physical activity patterns with low $\hat{VO}_2\text{max}$ varied by sex: women doing no leisure time physical activity with high occupational physical activity levels were more likely to have low $\hat{VO}_2\text{max}$ (OR 6.54; 95% CI 2.98 to 14.3) compared with women with ≥2 hours of leisure time physical activity and high occupational physical activity. Men with no leisure time physical activity and low occupational physical activity had the highest odds of low $\hat{VO}_2\text{max}$ (OR 4.37; 95% CI 2.02 to 9.47).

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

BACKGROUND

Physical activity is crucial for health and the unfavourable effects of an increasingly sedentary lifestyle are acknowledged as a major public health challenge. Physical activity is defined as all bodily movement produced by skeletal muscles that require energy expenditure. It has a positive influence on physical and mental health and contributes to the prevention of non-communicable diseases and premature mortality. It can also take different forms and happen in different domains of individual daily routines and life courses. For example, people may participate in sports during their leisure time (leisure time physical activity) or be active at work (occupational physical activity). To date, physical activity in any form and setting has been considered beneficial and recent recommendations do not distinguish between domains. The current WHO guideline recommends...
at least 150 min of moderate intensity aerobic physical activity per week, stating that “[...] Physical activity includes leisure time physical activity, transportation (eg, walking or cycling), occupational (ie, work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities”.(3, p8)

Manual and physically demanding occupations have been declining for decades, but occupational physical activity still accounts for a large part of many people’s daily activity.4 The beneficial effects of leisure time physical activity are well established, but the effect of occupational physical activity is inconclusive. Studies in the past often argued that occupational physical activity should also be considered to improve health,5 but recent studies suggest that it is not health enhancing and may even have the opposite effect.6 7 As a possible explanation for this ‘health paradox’, the domain-specific effects of physical activity on cardiorespiratory fitness have come to attention.8 9 Defined as the ability of circulatory, respiratory and muscular systems to supply oxygen during prolonged physical exercise,3 cardiorespiratory fitness can be enhanced by regular endurance exercise10 and is a strong predictor of adverse health outcomes.11 It has been argued that occupational physical activity rarely has the adequate intensity, duration and volume to increase cardiorespiratory fitness.8 9 12 13

However, research on the association between different activity domains and cardiorespiratory fitness in Germany is limited. In particular, the interplay between different domains has not yet been analysed for cardiorespiratory fitness. This study therefore aimed to investigate the associations between leisure time and occupational physical activity with cardiorespiratory fitness among the German working population. Furthermore, in addition to the direct effects of the domain-specific physical activity, their interactional effects on cardiorespiratory fitness are investigated. The analyses were stratified by sex because men and women may vary in their exposure to physical demands at work,14 type of occupations15 and response to physical activity.16

**METHODS**

**Study design**

We used data from the nationwide cross-sectional German Health Interview and Examination Survey for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1). DEGS1 is part of the Federal Health Monitoring System administered by the Robert Koch Institute.17 In detail, the study design is described elsewhere.18 Briefly, the study is based on a two-stage cluster randomised sampling procedure. First, 180 sample points were sampled from a list of German communities stratified to represent the regional distribution. Second, within these units, adult individuals were randomly drawn from local population registries stratified by 10-year age groups. The response rate was 42%. A total of 5262 participants aged 18–64 years took part in the physical measurements component from November 2008 to December 2011. Of these, 3110 individuals were test qualified for the exercise test (figure 1).

Overall, 3030 participants completed the exercise test (participation rate 97.4%). VO2 max was estimated for all participants reaching at least 75% of the age-predicted maximum heart rate (HR max). In total, 204 participants terminated the test before reaching this heart rate, so VO2 max could be calculated for 2826 participants. Further cases were excluded from this analysis because of missing physical activity data. Overall, valid information on VO2 max and occupational and leisure time physical activity was available for 1296 women and 1199 men.

**Table 1** shows demographic, anthropometric and health behaviour variables from this representative sample of the adult working population of Germany. Women made up 48.0% of the sample, and the mean age of the participants was 39.6 years (range 18–64 years). The unweighted and weighted percentages did not differ substantially, although weighting led to a slightly smaller proportion of participants in the older age groups and a smaller proportion in the high socioeconomic status group.

**Patient and public involvement**

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

**Outcome variable**

Cardiorespiratory fitness was measured using a standardised, submaximal cycle ergometer test (Ergosana...
## Table 1: Characteristics of study participants in German Health Interview and Examination Survey for Adults

|                        | Men       | Women     | Total     |
|------------------------|-----------|-----------|-----------|
|                        | n %*      | n %†      | n %* %†   |
| **\( \dot{V}O_2 \text{max} \)** |           |           |           |
| Low                    | 494 41.2  | 546 42.1  | 1040 41.7 |
| Intermediate/high      | 705 58.8  | 750 57.9  | 1455 58.3 |
| Missing                | 0 0.0     | 0 0.0     | 0 0.0     |
| **LTPA**               |           |           |           |
| No                     | 297 24.8  | 309 23.8  | 606 24.3  |
| <2 hours               | 492 41.0  | 647 49.9  | 1139 45.7 |
| ≥2 hours               | 410 34.2  | 340 26.2  | 750 30.1  |
| Missing                | 0 0.0     | 0 0.0     | 0 0.0     |
| **OPA**                |           |           |           |
| Low                    | 750 62.6  | 895 69.1  | 1645 65.9 |
| High                   | 449 37.4  | 401 30.9  | 850 34.1  |
| Missing                | 0 0.0     | 0 0.0     | 0 0.0     |
| **Age**                |           |           |           |
| 18–24 Years            | 137 11.4  | 138 10.6  | 275 11.0  |
| 25–34 Years            | 277 23.1  | 250 19.3  | 527 21.1  |
| 35–44 Years            | 287 23.9  | 338 26.1  | 625 25.1  |
| 45–54 Years            | 308 25.7  | 369 28.5  | 677 27.1  |
| 55–64 Years            | 190 15.8  | 201 15.5  | 391 15.7  |
| Missing                | 0 0.0     | 0 0.0     | 0 0.0     |
| **Waist circumference**|           |           |           |
| Normal                 | 719 60.0  | 702 54.2  | 1421 57.0 |
| Increased              | 256 21.4  | 289 22.3  | 545 21.8  |
| Strongly increased     | 224 18.7  | 303 23.4  | 527 21.1  |
| Missing                | 0 0.0     | 2 0.2     | 2 0.1     |
| **Body mass index**    |           |           |           |
| Underweight            | 9 0.8     | 32 2.5    | 41 1.6    |
| Normal weight          | 467 38.9  | 748 57.7  | 1215 48.7 |
| Overweight             | 548 45.7  | 348 26.9  | 896 35.9  |
| Obese                  | 171 14.3  | 164 12.7  | 335 13.4  |
| Missing                | 4 0.3     | 4 0.3     | 8 0.3     |
| **Smoking status**     |           |           |           |
| Daily                  | 349 29.1  | 268 20.7  | 617 24.7  |
| Occasionally           | 106 8.8   | 96 7.4    | 202 8.1   |
| Former                 | 323 26.9  | 354 27.3  | 677 27.1  |
| Never                  | 420 35.0  | 576 44.4  | 996 39.9  |
| Missing                | 1 0.1     | 2 0.2     | 3 0.1     |
| **Alcohol consumption**|           |           |           |
| Low                    | 180 15.0  | 151 11.7  | 331 13.3  |
| Moderate               | 760 63.4  | 821 63.3  | 1581 63.4 |
| High                   | 245 20.4  | 314 24.2  | 559 22.4  |
| Missing                | 14 1.2    | 10 0.8    | 24 1.0    |
| **Socioeconomic status**|         |           |           |

Continued
between heart rate and workload, PWC100% was obtained by extrapolation using the individual regression equation: 

\[ \text{PWC100\%} = \text{intercept} + \text{HR}_{\text{max}} \times \text{slope} \]

To derive physical work capacity at HR max (PWC100%), the measured heart rate (beats/min) during the incremental load was increased by 25 W every 2 min until 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 W was achieved or the study staff terminated the test. Heart rate was monitored continuously throughout the test. The formula 208−0.7×Age was used to calculate the age-predicted maximum heart rate. To derive physical work capacity at HR max (PWC100%), the measured heart rate (beats/min) during the incremental phase was regressed against corresponding workload in watts for each participant. Assuming a linear relationship between heart rate and workload, PWC100% was obtained by extrapolation using the individual regression equation:

\[ \text{PWC100\%} = \text{intercept} + \text{HR}_{\text{max}} \times \text{slope} \]

PWC100% was converted to \(\dot{V}O_2\text{max}\) using a metabolic equation provided by the American College of Sports Medicine: 3.5 mL/min/kg+12.24×(PWC100%)/body weight. Estimated \(\dot{V}O_2\text{max}\) was categorised into low (sex-specific quintiles 1–2) and intermediate to high (quintiles 3–5).

**Exposure variable**

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

To assess occupational physical activity, we used an indirect method and computed specific job exposure matrices to distinguish participants’ occupation by level of physical demand. These matrices are an established methodological tool to allow inclusion of specific occupational exposure in analyses, drawing on studies that assess information about job titles. They are constructed using available secondary data to determine exposure profiles for each occupation. These profiles are matched to primary data using standardised job classifications. In our case, such matrices were constructed using data from a large-scale representative study on working conditions of 20,000 employees in Germany, which was part of the European Working Conditions Survey regularly conducted in member states of the European Union. The overall job index and specific indexes have been described and applied elsewhere.

In this study, we used a specific subindex of perceived physical work demands. To construct the index, we used data on the frequency of lifting and carrying heavy loads (men≥20 kg, women≥10 kg). The item was assessed with a frequency scale with four answer categories: ‘often’, ‘sometimes’, ‘rarely’ and ‘never’. The physical demand index was assigned to the occupations based on hierarchical multilevel analyses adjusted for sex, age, job experience and part time employment. In contrast to the use of occupation-specific means, this procedure allows adjustment for other variables besides the specific occupation that could also influence the level of demand (eg, the sex ratio or the level of part-time employment). The levels for the multilevel estimation were defined by the 2-digit, 3-digit and 4-digit codes of the International Classification of Occupations of 1988 (ISCO-88) classification. These matrices were then classified into deciles. Occupations with the lowest level of physical work demands had a value of 1 (first decile), and those with the highest level had a value of 10 (tenth decile). Using the ISCO-88, the matrices were matched to DEGS1. To create a combined physical activity variable, this index was then dichotomised into low (index values 1–6) and high occupational physical activity (index values 7–10). A list of the most frequent occupations in DEGS1 by occupational physical activity level for men and women is shown in online supplementary table S1.

**Leisure time physical activity: physical exercise**

Leisure time physical activity was assessed by asking participants ‘How often do you engage in physical exercise?’ Leisure time physical activity usually refers to physical activity in freely disposable time, but sport and exercise are the main elements so were used in this study.

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**Table 1**

| Exposure variable | Men | | | Women | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | \(n\) | %* | %† | \(n\) | %* | %† | \(n\) | %* | %† |
| **Low** | | | | | | | | | |
| 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 | – |

Values shown are frequencies in percentages.

*Percentage of the sample (unweighted).

†Weighted percentage (weighting factors were used to adjust the distribution of the sample to match the German population for sex, age, education and region).

LTPA, leisure time physical activity; OPA, occupational physical activity; \(\dot{V}O_2\text{max}\), maximal oxygen consumption.

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Sana Bike 350/450 (Ergosana, Germany), heart rate monitor (Polar, Finland), blood pressure cuffs (Ergosana, Germany), a heart rate transmitter (Oregon Scientific, USA) and a notebook with ergometer software (Dr Schmidt GmbH, Germany). Test methodology, protocol and exclusion criteria have been described elsewhere. DEGS1 participants were included in the ergometer test if they were aged 18–64 years, gave informed consent and were test qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q). If any PAR-Q contraindications were reported, the participant was seen by a physician, who decided whether they should be enrolled into the exercise test. Cardiorespiratory fitness was assessed using the test protocol recommended by WHO. Beginning at 25 W, the workload was increased by 25 W every 2 min until 85% of the estimated age-specific maximal heart rate was exceeded, a maximum level of 350 W was achieved or the study staff terminated the test. Heart rate was monitored continuously throughout the test. The formula 208−0.7×Age was used to calculate the age-predicted maximum heart rate. To derive physical work capacity at HR max (PWC100%), the measured heart rate (beats/min) during the incremental phase was regressed against corresponding workload in watts for each participant. Assuming a linear relationship between heart rate and workload, PWC100% was obtained by extrapolation using the individual regression equation:

\[ \text{PWC100\%} = \text{intercept} + \text{HR}_{\text{max}} \times \text{slope} \]

PWC100% was converted to \(\dot{V}O_2\text{max}\) using a metabolic equation provided by the German College of Sports Medicine: 3.5 mL/min/kg+12.24×(PWC100%)/body weight. Estimated \(\dot{V}O_2\text{max}\) was categorised into low (sex-specific quintiles 1–2) and intermediate to high (quintiles 3–5).

**Leisure time physical activity: physical exercise**

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Zeitner J, et al. BMJ Open 2020;10:e034610. doi:10.1136/bmjopen-2019-034610
Responses were on a five-point scale of ‘no physical exercise’, ‘less than 1 hour a week’ and ‘regularly 1–2 hours a week’, ‘regularly up to 4 hours’ and ‘regularly more than 4 hours’, and were categorised into three groups: no physical exercise, <2 hours/week and ≥2 hours/week.

Combined occupational and leisure time physical activity

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

Covariates

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

Statistical analyses

Leisure time and occupational physical activity were cross tabulated to show the association of the domain-specific activity levels. Prevalence and 95% CIs of low VO₂max were calculated by occupational and leisure time physical activity and covariates. Multivariable logistic regression models were computed to estimate the associations between domain-specific physical activity (exposure) and low VO₂max (outcome). In a first step, the main effects of occupational and leisure time physical activity were investigated; in a second step, the combined activity variable was used. In both steps, we fitted an age-adjusted model and one adjusting for age, body mass index, waist circumference, smoking, alcohol intake and socioeconomic status. Finally, we computed predicted margins from the fully adjusted logistic regression model investigating the combined physical activity variable to plot adjusted prevalence of low VO₂max by domain-specific physical activity. All analyses were performed separately for men and women to identify sex-specific physical activity patterns associated with cardiorespiratory fitness and to detect potential effect modification by sex. Analyses were performed with Stata V.15.1 (Stata Corp.). To enhance the external validity of the results, weighting factors were used to adjust for distribution of the sample by sex, age, education and region, to match the German population. Stata’s survey procedures were applied to account for the clustered sampling design.

RESULTS

Occupational and leisure time physical activity levels

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

Low

Overall, the prevalence of estimated low VO₂max was 41.2% (95% CI 37.6 to 44.8) for men and 40.5% for women (95% CI 37.1 to 44.0). Table 3 shows the prevalence of low VO₂max by domain-specific physical activity and sociodemographic, health behaviour and anthropometric variables. Binary analyses showed that men and women with higher leisure time activity levels had substantially lower prevalence of low VO₂max. There were no relevant differences in low VO₂max by occupational physical activity among men, but women with high occupational

| Table 2 | Association of leisure time and occupational physical activity among male and female German Health Interview and Examination Survey for Adults participants |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|         | Low OPA | % (95% CI) | High OPA | % (95% CI) |
| Men     |          |            |          |            |
| No LTPA | 24.0     | (20.1 to 28.3) | 26.2   | (21.4 to 31.5) |
| < 2 hours LTPA | 39.4 | (35.2 to 43.7) | 40.4 | (34.9 to 46.2) |
| ≥ 2 hours LTPA | 36.6 | (32.7 to 40.7) | 33.4 | (27.7 to 39.7) |
| Women   |          |            |          |            |
| No LTPA | 21.6     | (17.9 to 25.9) | 31.1   | (25.6 to 37.3) |
| < 2 hours LTPA | 49.6 | (44.8 to 54.3) | 50.6 | (44.9 to 56.4) |
| ≥ 2 hours LTPA | 28.8 | (25.1 to 32.8) | 18.2 | (14.4 to 22.9) |

Values shown are frequencies in percentages with 95% CIs. LTPA, leisure time physical activity; OPA, occupational physical activity.
Table 3  Prevalence and 95% CIs of low estimated $\dot{V}O_2\text{max}$ by domain-specific physical activity, health behavioural, anthropometric and sociodemographic characteristics among male and female German Health Interview and Examination Survey for Adults participants

|                     | Men                  | Women                |
|---------------------|----------------------|----------------------|
|                     | % (95% CI)           | % (95% CI)           |
| **Total**           | 41.2 (37.6 to 44.8)  | 40.5 (37.1 to 44.0)  |
| LTPA                |                      |                      |
| No                  | 63.2 (56.4 to 69.4)  | 56.1 (49.1 to 62.9)  |
| <2 hours            | 42.2 (36.5 to 48.0)  | 41.2 (36.6 to 45.9)  |
| ≥2 hours            | 24.7 (19.8 to 30.5)  | 24.1 (19.0 to 30.1)  |
| OPA                 |                      |                      |
| Low                 | 41.5 (36.8 to 46.4)  | 37.2 (33.0 to 41.6)  |
| High                | 40.8 (35.0 to 46.8)  | 47.4 (41.5 to 53.4)  |
| OPA/LTPA            |                      |                      |
| No LTPA, low OPA    | 68.5 (59.2 to 76.4)  | 48.0 (39.7 to 56.3)  |
| No LTPA, high OPA   | 56.0 (44.9 to 66.5)  | 67.7 (56.7 to 77.0)  |
| <2 hours LTPA, low OPA | 42.6 (35.8 to 49.7)  | 39.3 (33.5 to 45.5)  |
| <2 hours LTPA, high OPA | 41.6 (32.3 to 51.5)  | 44.9 (37.5 to 52.5)  |
| ≥2 hours LTPA, low OPA | 22.8 (17.1 to 29.6)  | 25.4 (19.0 to 33.0)  |
| ≥2 hours LTPA, high OPA | 28.0 (19.1 to 39.0)  | 19.9 (11.6 to 32.1)  |
| Age                 |                      |                      |
| 18–24 Years         | 28.0 (19.9 to 37.7)  | 25.8 (17.9 to 35.7)  |
| 25–34 Years         | 36.0 (28.9 to 43.8)  | 29.2 (23.3 to 35.9)  |
| 35–44 Years         | 41.9 (34.9 to 49.2)  | 36.1 (30.3 to 42.3)  |
| 45–54 Years         | 47.2 (40.9 to 53.7)  | 48.5 (42.1 to 55.1)  |
| 55–64 Years         | 51.9 (42.3 to 61.4)  | 68.7 (60.2 to 76.1)  |
| Waist circumference |                      |                      |
| Normal              | 27.1 (23.2 to 31.4)  | 26.9 (23.0 to 31.1)  |
| Increased           | 54.6 (46.2 to 62.8)  | 46.4 (38.5 to 54.6)  |
| Strongly increased  | 74.2 (66.7 to 80.4)  | 72.5 (66.3 to 77.9)  |
| Body mass index     |                      |                      |
| Underweight         | 19.8 (3.3 to 64.1)   | 18.9 (7.7 to 39.4)   |
| Normal weight       | 21.7 (16.9 to 27.4)  | 27.1 (23.4 to 31.2)  |
| Overweight          | 47.5 (42.3 to 52.8)  | 53.7 (46.4 to 60.8)  |
| Obese               | 71.1 (62.4 to 78.4)  | 83.1 (75.3 to 88.8)  |
| Smoking status      |                      |                      |
| Daily               | 40.7 (34.9 to 46.8)  | 38.8 (31.6 to 46.7)  |
| Occasionally        | 31.7 (22.3 to 42.9)  | 33.5 (22.9 to 46.0)  |
| Former              | 49.6 (42.3 to 56.9)  | 46.7 (40.0 to 53.6)  |
| Never               | 37.5 (31.4 to 44.0)  | 39.0 (34.0 to 44.3)  |
| Alcohol consumption |                      |                      |
| Low                 | 45.7 (38.0 to 53.7)  | 50.2 (40.8 to 59.5)  |
| Moderate            | 39.1 (34.9 to 43.6)  | 41.1 (36.6 to 45.8)  |
| High                | 43.4 (35.1 to 52.2)  | 33.2 (26.7 to 40.5)  |
| Socioeconomic status|                      |                      |
| Low                 | 39.9 (30.7 to 49.8)  | 56.3 (45.8 to 66.3)  |
| Medium              | 43.3 (38.7 to 48.1)  | 43.4 (39.3 to 47.5)  |
| High                | 36.8 (30.8 to 43.2)  | 28.2 (22.4 to 34.9)  |

LTPA, leisure time physical activity; OPA, occupational physical activity; $\dot{V}O_2\text{max}$, maximal oxygen consumption.
Table 4: Domain-specific physical activity and low estimated \( \dot{V}O_2_{\text{max}} \) among male and female German Health Interview and Examination Survey for Adults participants

|                  | Men                              | Women                             |
|------------------|----------------------------------|-----------------------------------|
|                  | OR* (95% CI)                     | OR† (95% CI)                      |
| **Main effects model** |                                  |                                   |
| OPA Low OPA      | (Ref.)                           | (Ref.)                            |
| High OPA         | 1.05 (0.75 to 1.46)              | 0.95 (0.64 to 1.42)               |
| OPA LTPA No LTPA | 4.97 (3.47 to 7.13)              | 4.46 (2.89 to 6.89)               |
| <2 hours LTPA    | 2.17 (1.48 to 3.19)              | 2.04 (1.32 to 3.15)               |
| ≥2 hours LTPA    | (Ref.)                           | (Ref.)                            |
| OPA/LTPA model   |                                  |                                   |
| No LTPA, low OPA | 4.92 (2.56 to 9.46)              | 4.45 (2.14 to 9.23)               |
| No LTPA, high OPA| 2.86 (1.47 to 5.58)              | 2.34 (1.08 to 5.07)               |
| <2 hours LTPA, low OPA | 1.69 (0.94 to 3.06)           | 1.54 (0.77 to 3.06)               |
| <2 hours LTPA, high OPA| 1.70 (0.91 to 3.17)          | 1.54 (0.75 to 3.16)               |
| ≥2 hours LTPA, low OPA | 0.67 (0.35 to 1.27)           | 0.64 (0.32 to 1.27)               |
| ≥2 hours LTPA, high OPA| (Ref.)                      | 1.37 (0.64 to 2.92)               |
| n                | 1199                             | 1181                              |

Different adjustment criteria were used in multivariable logistic regression analyses.

*Adjusted for age.
†Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption and socioeconomic status index.

LTPA, leisure time physical activity; OPA, occupational physical activity; \( \dot{V}O_2_{\text{max}} \), maximal oxygen consumption.

physical activity had a higher prevalence of low \( \dot{V}O_2_{\text{max}} \) than women with low occupational physical activity.

Multivariable analyses (table 4) showed that women in jobs with high levels of occupational physical activity were more likely to have a low estimated \( \dot{V}O_2_{\text{max}} \) when adjusting only for age (OR 1.71; 95% CI 1.23 to 2.36). This association disappeared when controlling for leisure time physical activity and other covariates (OR 1.06; 95% CI 0.75 to 1.49). Neither model showed any association between low \( \dot{V}O_2_{\text{max}} \) and occupational physical activity for men (OR 1.05; 95% CI 0.75 to 1.46 and OR 0.95; 95% CI 0.64 to 1.42).

Men and women who did no or less than 2 hours leisure time physical activity per week were more likely to have a low \( \dot{V}O_2_{\text{max}} \) than participants who did 2 hours or more. The effect size did not change considerably when adjusting for occupational physical activity and other controls.

Multivariable analyses of the combined variable (fully adjusted model) showed that less-active men were more likely to have a low \( \dot{V}O_2_{\text{max}} \) with ORs of 4.45 (95% CI 2.14 to 9.23) for no leisure time/low occupational physical activity, 2.34 (95% CI 1.08 to 5.07) for no leisure time/high occupational physical activity, 1.54 (95% CI 0.77 to 3.06) for <2 hours leisure time/low occupational physical activity, 1.54 (95% CI 0.75 to 3.16) for <2 hour leisure time/high occupational physical activity and 0.64 (95% CI 0.32 to 1.27) for ≥2 hours leisure time/low occupational physical activity compared with men with ≥2 hours leisure time/high occupational physical activity. The corresponding ORs for women were 6.54 (95% CI 2.98 to 14.3), 10.5 (95% CI 4.39 to 24.9), 3.52 (95% CI 1.75 to 7.09) and 3.69 (95% CI 1.80 to 7.60). However, the men with the highest risk of low \( \dot{V}O_2_{\text{max}} \) were those who did not participate in leisure time physical activity and were not working in physically demanding occupations.

**DISCUSSION**

**Summary of results**

This cross-sectional study showed a strong association between low leisure time physical activity and low estimated \( \dot{V}O_2_{\text{max}} \), but not between occupational physical activity and \( \dot{V}O_2_{\text{max}} \). The association between domain-specific physical activity and low \( \dot{V}O_2_{\text{max}} \) also varied by sex. After adjustment for potential confounding, women working in physically demanding occupations who did not participate in leisure time physical activity had the highest likelihood of having a low \( \dot{V}O_2_{\text{max}} \). However, the men with the highest risk of low \( \dot{V}O_2_{\text{max}} \) were those who did not engage in leisure time physical activity and were working in physically demanding occupations.
among participants with high levels of leisure time physical activity, but \( VO_2_{max} \) was lower among participants with higher levels of occupational physical activity (assessed by questionnaire).\(^{43}\) A study among the Danish working population observed that self-reported work and leisure sitting time had different associations with \( VO_2_{max} \): there was a strong negative association between sitting leisure time and \( VO_2_{max} \), but no similar association with sitting time at work.\(^{45}\) However, a study among male workers in Japan found higher levels of \( VO_2_{max} \) among those with self-reported high occupational physical activity than low \(^{46}\) and a study from Finland found a positive association between cardiorespiratory fitness and self-reported occupational physical activity even after adjustment for leisure time physical activity among young men.\(^{47}\)

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

**Potential mechanisms**

Regular aerobic exercise induces biological changes, such as increased stroke volume and decreased venous oxygen content, both of which lead to increased individual cardiorespiratory fitness.\(^{10}\) To increase \( VO_2_{max} \), exercise should ideally be performed with sufficient intensity at \( \geq 50\% \) of the maximal aerobic capacity for untrained individuals.\(^{10}\) Cardiorespiratory fitness is determined by the cardiac output and arteriovenous oxygen difference, so it can be enhanced by an increase in stroke volume, oxygen difference or both.\(^{10}\) Leisure time physical activity, especially sport, is usually relatively short duration but high intensity, and provides sufficient recovery time between occasions. This is important, because this type of activity can achieve a training effect of the myocardium. This reduces the heart rate, the heart muscle remains longer in diastole and the stroke volume increases.\(^{50}\) In contrast, physical activity without recovery leads to prolonged elevation of heart rate and blood pressure.\(^{51}\) This can result in erosion of the endothelium, which can provoke atherosclerosis.\(^{52}\) This prolonged activity is typically observed in occupational physical activity, where workers also have limited control of work speed and duration.\(^{53}\) Sufficient recovery is therefore not possible, because individuals are unable to decide for themselves how to perform their work, and when to pause. Assuming average occupational physical activity as a constant, monotonous but low intensity activity, it has also been proposed that its intensity might be too low to increase individual fitness.\(^{9}\) However, this might not hold true for all occupations. Studies among blue-collar workers found that directly assessed intensity

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**Figure 2** Predicted probabilities (with 95% CIs) of low \( VO_2_{max} \) by domain-specific physical activity among men and women who participated in the nationwide German Health Interview and Examination Survey for Adults. Adjusted for age, waist circumference, body mass index, smoking status, alcohol consumption and socioeconomic status index. LTPA, leisure time physical activity; OPA, occupational physical activity.

**Comparison with other studies**

The strong association between leisure time physical activity and cardiorespiratory fitness has been shown in numerous studies.\(^{34}\) However, evidence of the association between occupational physical activity and cardiorespiratory fitness is inconclusive. Historically, occupational physical activity has been seen as a way to improve health in behavioural medicine, but as a potential health hazard in occupational medicine.\(^{6,40}\) Recent studies agree that occupational physical activity does not lead to increased cardiorespiratory fitness.\(^{41-44}\) A Swiss study among adults reported no association between the amount of objectively assessed steps during work-time and \( VO_2_{max} \), and a lower \( VO_2_{max} \) among participants doing manual work than those doing sedentary work (according to reported job title), while controlling for leisure time physical activity and various other covariates.\(^{44}\) A cross-regional study in Germany also found higher levels of \( VO_2_{max} \)
of physical activity was higher during work than leisure time, especially among those with low fitness levels. Differences between men and women

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

Recommendations for further research and practical implications

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

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

Strengths and limitations

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

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

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Acknowledgements
The authors thank Melissa Leffler for editing a draft of this manuscript.

Contributors
GBMM and JDF were involved in the design and conduct of DEGS1, JDF in particular for the ergometer testing. JZ, LEK and JDF conceptualised 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
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 for publication
Not required.

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).

Provenance and peer review
Not commissioned; externally peer reviewed.

Data availability statement
Data are available upon reasonable request. 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 September 2019)).

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