

## PEER REVIEW HISTORY

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### ARTICLE DETAILS

<b>TITLE (PROVISIONAL)</b>	Domain-specific physical activity patterns and cardiorespiratory fitness among the working population – Findings from the cross-sectional German health interview and examination survey
<b>AUTHORS</b>	Zeiber, Johannes; Duch, Maurice; Kroll, Lars; Mensink, Gert; Finger, Jonas D.; Keil, Thomas

### VERSION 1 – REVIEW

<b>REVIEWER</b>	Mette Korshøj The National Research Centre for the Working Environment, Denmark
<b>REVIEW RETURNED</b>	22-Nov-2019

<b>GENERAL COMMENTS</b>	<p>Reviewer comments for BMJ Open 2019-034610</p> <p>Domain-specific physical activity pattern and cardiorespiratory fitness among the working population. Findings from the German health interview and examination survey.</p> <p>Thanks for the possibility to review this interesting paper, investigating the relations between level of OPA and CRF. The findings are in line with the assumptions in relation the physical activity health paradox and ads important results in the disentangling of physiologic health effects of OPA. However, I find that a revision of the manuscript is needed before acceptance may be advised, due to the lack of proper discussion of the practical implications of the findings and background physiologic mechanisms needed for understanding.</p> <p><b>Article summary</b></p> <ol style="list-style-type: none"><li>1. Please state how the OPA was assed</li><li>2. Please include the cross sectional design of the study and thus lack of possibility for causality</li></ol> <p><b>Background</b></p> <ol style="list-style-type: none"><li>3. Please consider to support the argument given in page 4, line 55, regarding the insufficient intensity etc. of OPA in</li></ol>
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relation to increase CRF. Preferably a reference including technical measures of intensity of OPA, e.g. by heart rate measures, as Korshøj et al 2013, ergonomics.

4. The meaning of the sentence in page 5, line 5, would be more specific by adding not yet been analyzed ... in relation to CRF.
5. Are the explorative approach chosen based on an assumed lack of literature to support testing of hypothesis? It seems surprising, based on the literature review in the background, that the authors feel a need for explorative analysis as primary and not primary hypothesis testing followed by secondary explorative analysis, as explorative testing may seem hard to conclude upon.

### **Methods**

6. Please add the criteria for inclusion and exclusion.
7. Please include the name of the fitness test and a reference.
8. Please check the references for the fitness test, as both 15-17 and 20 are referred to as references for the fitness test.
9. Please elaborate on the scaling and background for scaling of the perceived physical work demands, and include a reference for the used method.
10. There is a punctuation too much in page 7, line 26.
11. Please make sure to explain what the abbreviation DEGS1 stands for.
12. Please elaborate on the arguments for dichotomizing the OPA.
13. Please make sure that the references are referenced correctly, different brackets are used ( ) [], page 7, line 41.
14. Page 7, line 45-55, it would make more sense if the response categories were described firstly and secondly a description of the categorization.
15. Throughout the method paragraph, there is a need to report the name, manufacturer and reference for the used monitors for measuring ex. body weight.
16. Please include argumentation for why it have been chosen to both include BMI and WC.
17. Please consider to include adjustment for use of medication that affects the VO2max, as use of these medications would imply a moderating effect of the relation between PA and CRF.
18. Please revise whether sex imply a bias or a moderation to the relation under investigation. Additionally, does it seem to lack some logically arguing, as it seems unnecessary to adjust for sex distribution in an analysis stratified on sex – unless you operate with more than two sexes? Also if sex were considered as a moderator and the interaction was significant, the argument for sex-stratification would be straightforward.
19. Please make sure to report the reference categories for the logistic regressions.

## Results

20. I cannot find the result of the interaction between OPA and LTPA, as described at page 8, line 4. Please make sure to report the interaction to generate argumentation for moderating effects from LTPA in the relation between OPA and CRF – which this version of the manuscript lacks.
21. The external validity are not in any way mentioned neither reported, thus as a minimum a description of where and how
22. The flow chart should not be placed in the additional files, but be a part of the main manuscript.
23. Please be more concise in the wording of the results, thus chance – page 10, line 32 – should be replaced by prevalence.

## Discussion

24. There seems to be some errors in the reporting of the results, as no LTPA and high OPA, were reported to have the highest OR for low CRF in the results. However, in the discussion, it is reported that it is no LTPA and no OPA that have the highest OR for low CRF. Please revise both tables, and text in results and discussion to make sure there is consistence in the reported results.
25. Please include references for the historical perspective in health effects from OPA, page 11, line 32, such as Morris et al 1953, lancet.
26. Overall, the discussion lacks proper reflection on the sex differences, both from a perspective on the work task in line with sex distribution of occupational titles as well as the physiological background explaining the sex differences in the investigated relation.
27. Please include what the described intensity are sufficient for in page 12, line 24, and remember to include relevant references.
28. Also, include an explanation for what the recovery should be sufficient for in page 12, line 33, and remember to include relevant references.
29. In order to be able to draw the link between recovery and CRF, an explanation of the physiologic background for the link between CRF and intensity of OPA are needed.
30. Please elaborate on how the associations in table 4 vary and revise page 12, line 38 accordingly.
31. Add the physiological mechanism explaining the reason for increased CRF to decrease CVD risk in relation to OPA, page 13, line 5.
32. Elaborate the last paragraph at page 13, line 8-26, with the practical implications – discussing who these results are relevant for, what they may be used for in a practical sense, ex guidelines or such, and how they feed into the improvement of public health.

	<p>33. Please include an explanation on how reversed causality would affect the overall conclusion in this manuscript.</p> <p>34. Please reflect upon whether these results could be affected by selection bias, such as the healthy worker bias.</p> <p>35. Please elaborate on how the fact those JEMs are not able to account for the variability of exposures within job may affect the overall conclusion in this manuscript.</p> <p><b>Conclusion</b></p> <p>36. Due to the fact that PA data are compositional by nature, the combined OPA and LTPA should be considered as the best estimate to relate to CRF, and should therefore be presented in the conclusion to feed into information and qualification of future PA guidelines/interventions etc.</p>
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<b>REVIEWER</b>	Margo Ketels Ghent University, Belgium
<b>REVIEW RETURNED</b>	12-Dec-2019

<b>GENERAL COMMENTS</b>	<p>General comments</p> <p>This is a very well-written and nicely structured paper with a highly relevant approach to domain-specific physical activity in relation to cardiorespiratory fitness in a population of workers. Overall, it is an important paper, which should be accepted for publication after some revisions. I will discuss these revisions in my comments below.</p> <p>Comments throughout the manuscript</p> <p>Please check the manuscript carefully for grammatical errors and typos. For example: page 5 OPA, and LTPA and CRF; page 6, line 10 the participants initially completed; page 6, line 46 (quintile 3-5); page 7, line 25 two full stops; page 12, line 8 cardio vascular needs to be 1 word; page 12, line 47 two blank spaces between the and service.</p> <p>Abstract</p> <p>The sentence “further investigation ... identified populations groups at risk” in the conclusion section is quite difficult to read, please rephrase this sentence.</p> <p>Introduction</p> <p>The introduction is overall nicely structured and contains the relevant references. However, some points are difficult to read and get lost because of the way the introduction is written. For example, on page 4 ‘Even if manual and physical demanding...’; on page 5 ‘Notably, the interplay between these different... Following an explorative approach...’.</p> <p>Methodology</p> <p>The paragraph on page 5, line 45 ‘Two hundred and four participants...’ until ‘had valid information on VO2max, OPA and LTPA’ is rather difficult to read. Please rephrase.</p>
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	<p>I would recommend to give some more information regarding the Physical Activity Readiness Questionnaire. What exactly does it measure?</p> <p>The hierarchic multilevel analyses adjusted for sex, age, job experience and part time employment used to determine the physical demand index should be better explained.</p> <p>The paragraph concerning the age-specific maximal heart rate is not clear. First, the abbreviation “HRmax” should be given earlier. Second, the formula used in this manuscript to calculate the age-predicted HRmax is “<math>208 - 0.7 \times \text{Age}</math>”, which is not the same used in the paper of Finger and colleagues (2013) where the following formula was given: “<math>0.85 \times (220 - \text{age})</math>”. Please clarify your use formula and change it if necessary.</p> <p>The last sentence of the ‘outcome variable’ paragraph, i.e. ‘that individuals in the low fitness group compared to the ...’ does not belong in the method section. Please remove or replace this part.</p> <p>In the first sentence of ‘occupational physical activity: a physical work demands index’ the verb ‘developed’ was used, but I don’t believe that the authors of the mentioned paper developed this method. Please provide more clarity on this issue.</p> <p>The paragraph about ‘leisure time physical activity: physical exercise’ needs to be restructured/rephrased: replace the word “as a proxy”; what is the difference between the first three groups and the last three groups?; the authors refer to “the categories of the five-point scale”, but there are only 4 options mentioned in the text. In summary, it is not clear to the reader how LTPA is assessed and which questions were used, so please make this more clear.</p> <p><b>Results</b>  Explain the unweighted and weighted percentages more extensive in the method section.</p> <p>All the results distinguish between men and women, but this strategy has not been introduced in the method section, nor are the reason for doing so explained. Some explanations in the method and if possible in the introduction section are required.</p> <p>The statistical method used to calculate the results in table 2 is not mentioned in the method section, please adapt.</p> <p>In the statistical model in table 4, the author adjusted for OPA and LTPA, however this is not mentioned in the methods section.</p> <p>Please make sure that the numbers add up to 100%, e.g. LTPA percentages of women: <math>24.7 + 49.9 + 25.3 = 99.9</math>; also check the consistency in layout, for example the paragraph about the multivariable analyses: sometimes there is a blank space between noLTPA/ low OPA, and sometimes there is not &lt;2hLTPA/lowOPA.</p> <p><b>Discussion</b>  Correction for reference number 41: the positive association between CRF and OPA was found among young men.</p> <p>In general “physical activity” refers to activities such as running, walking, cycling etc. If we distinguish PA into LTPA and OPA, we</p>
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	<p>assume that LTPA still includes the activities like mentioned above, but it is a different story for OPA. Objectively measured OPA normally refers to MVPA during work including walking, running, stair climbing and cycling. However, self-reported occupational physical activity normally refers to physically demanding tasks such as lifting, manual handling, repetitive movements etc. In summary, there is a conceptual issue around what occupational physical activity precisely is. This needs to be discussed and clarified because this has a big impact on CRF.</p> <p>The discussion section is nicely structured with valuable comparisons to findings from other studies. However, these studies all used self-reported measures to assess physical activity, which has to be emphasized more as a limitation in the discussion.</p> <p>Page 12: the assumption that intensity during work would be too low is not in line with other studies that showed that the intensity of work related PA was higher compared to LTPA (Coenen et al., 2018; Gram et al., 2016; Ruzic et al., 2003). Please have a closer look at these references and discuss.</p> <p>Page 13: The article recommends more LTPA to increase CRF, which seems logical. However, a few studies showed that high LTPA in combination with high OPA levels can lead to a higher risk of developing CVD (Clays et al., 2013; Korshoj et al., 2015). Please look into this papers and adjust your claims accordingly.</p> <p>Please provide some recommendations for further research, especially with regard to the need of objective measurements of PA.</p>
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## VERSION 1 – AUTHOR RESPONSE

### Review #1

1. Thanks for the possibility to review this interesting paper, investigating the relations between level of OPA and CRF. The findings are in line with the assumptions in relation the physical activity health paradox and ads important results in the disentangling of physiologic health effects of OPA. However, I find that a revision of the manuscript is needed before acceptance may be advised, due to the lack of proper discussion of the practical implications of the findings and background physiologic mechanisms needed for understanding.  
We would like to thank Ms. Korshøj for the detailed, objective and insightful comments and recommendations.

### Article Summary

2. Please state how the OPA was assed  
The abstract was written according to the BMJ Open guidelines for research articles which do not include a methods section. However, we included the requested information in the objectives section:  
*“This study aims to investigate the associations of patterns of 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 the German working population.”* (page 2, line3)

3. Please include the cross sectional design of the study and thus lack of possibility for causality. The cross-sectional design is mentioned in the 'design' subsection in the abstract. To highlight the study design, we added this information to the title as well (see comment #60).

## Background

4. Please consider to support the argument given in page 4, line 55, regarding the insufficient intensity etc. of OPA in relation to increase CRF. Preferably a reference including technical measures of intensity of OPA, e.g. by heart rate measures, as Korshøj et al 2013, ergonomics. We now support argument with further literature:

13. Korshoj M, Krustrup P, Jespersen T, Sogaard K, Skotte JH, Holtermann A. A 24-h assessment of physical activity and cardio-respiratory fitness among female hospital cleaners: a pilot study. *Ergonomics*. 2013;56(6):935-43.

5. The meaning of the sentence in page 5, line 5, would be more specific by adding not yet been analyzed ... in relation to CRF.

We followed the reviewer's suggestion to make this statement more precise:

*"However, data on the association of different domains of PA and CRF for Germany is limited. In particular, the interplay between these different domains has not yet been analyzed in relation to CRF. Thus, this study aims to investigate the associations between patterns of OPA and LTPA with CRF among the German working population."* (page 5, line 1)

6. Are the explorative approach chosen based on an assumed lack of literature to support testing of hypothesis? It seems surprising, based on the literature review in the background, that the authors feel a need for explorative analysis as primary and not primary hypothesis testing followed by secondary explorative analysis, as explorative testing may seem hard to conclude upon.

The first part of the sentence on page 5, line 8 that we "followed an explorative approach" is misleading as we conducted a cross-sectional data analysis based on a national health survey data set. Our hypotheses indeed were developed based on the body of evidence identified with a previous systematic review on correlates and determinants of CRF. We have thus erased the first part the sentence stating the study aim at the end of the background section.

## Methods

7. Please add the criteria for inclusion and exclusion.

We expanded on the inclusion and exclusion criteria (see also comment #9 and #43):

*"DEGS1 participants were included in the ergometer test if they were aged 18-64 years, signed an informed consent, and were categorized as test-qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q) (21, 22). Participants were consulted by a physician if any PAR-Q contraindications were reported and the physician decided whether or not the participant should be enrolled into the exercise test."* (page 6, line 18)

8. Please include the name of the fitness test and a reference.

The exercise test followed an incremental test protocol which was recommended by the World Health Organization for cycle ergometer tests which has, to our knowledge, no specific name. The reference (now reference #23) is already provided on page 7, line 2.

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

9. Please check the references for the fitness test, as both 15-17 and 20 are referred to as references for the fitness test.

We checked the references and dropped Reference 17(now reference 35) as it is in this context not relevant. References 15 and 16 (now references 19 and 20) refer to the DEGS1 exercise test measurement and reference 20 (now 23) refers to the WHO incremental test protocol used within the DEGS test proceedings (see also answer on comment #8). To avoid confusion, we removed the reference for the WHO test protocol from the first sentence and restructured the paragraph (see also comment #7 and #43):

*“DEGS1 participants were included in the ergometer test if they were aged 18-64 years, signed an informed consent, and were categorized as test-qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q) (21, 22). Participants were consulted by a physician if any PAR-Q contraindications were reported and the physician decided whether or not the participant should be enrolled into the exercise test. CRF was assessed using the test protocol recommended by the World Health Organization (WHO) (23): [...]”*(page 6, line 18)

10. Please elaborate on the scaling and background for scaling of the perceived physical work demands, and include a reference for the used method.

We followed the reviewer’s request and added information on the assessment of the physical work demands and included a reference.

*“The Overall Job Index and specific indexes are already described and applied elsewhere (29-31). In this study, we used a specific sub-index of perceived physical work demands. To construct the index we used data regarding the frequency of lifting and carrying heavy loads (men  $\geq 20$  kg, women  $\geq 10$  kg). The item was assessed with a frequency scale with four answer categories: “often”, “sometimes”, “rarely” and “never” (27, 28).”* (page 8, line 1)

27. Kroll, L.E. Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten anhand von ISCO-88 und KldB-92 [Construction and validation of a general index for job demands in occupations based on ISCO-88 and KldB-92]. Methoden — Daten — Analysen 5, 63-90 (2011).
28. Rohrbach-Schmidt, D. & Hall, A. BIBB/BAuA employment survey 2012. BIBB-FDZ Data and Methodological Reports. Federal Institute for Vocational Education and Training. Bonn, Germany (2013).

11. There is a punctuation too much in page 7, line 26.  
Corrected.

12. Please make sure to explain what the abbreviation DEGS1 stands for.

We added the full German study title on page 5, line12:

*“We used data from the nationwide cross-sectional German Health Interview and Examination Survey for Adults (Studie zur Gesundheit Erwachsener in Deutschland; DEGS1).”*

13. Please elaborate on the arguments for dichotomizing the OPA.

The dichotomization was conducted to enable the construction of a straight-forward combined OPA/LTPA variable. As, to our knowledge, this is the first time, that such an index-based approach was used, there is no reference for defining a specific cut-off. Thus, following the



distribution-based CRF dichotomization, we defined a high OPA as the 4<sup>th</sup> & 5<sup>th</sup> quintile (= index values 7-10) and low OPA as the 1<sup>st</sup> – 3<sup>rd</sup> quintile (= index values 1-6).

Please note that there was a typo regarding the cut-off values: index values 1-6 were considered as 'low OPA' and index values 7-10 as a 'high OPA'. We corrected this mistake:

*“To create a combined OPA/LTPA variable, this index was then dichotomized in a ‘low OPA’ (index values 1-6) and a ‘high OPA’ category (index values 7-10)”* (page 8, line 14)

14. Please make sure that the references are referenced correctly, different brackets are used ( ) [], page 7, line 41.  
Corrected.

15. Page 7, line 45-55, it would make more sense if the response categories were described firstly and secondly a description of the categorization.  
We followed the reviewer’s suggestion and rearranged the paragraph:  
*“For the analyses, the categories of the five-point scale “less than 1 h a week” and “regularly 1-2 h a week”, “regularly up to 4 h” and “regularly more than 4 h” were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.”* (page 8, line 25)

16. Throughout the method paragraph, there is a need to report the name, manufacturer and reference for the used monitors for measuring ex. body weight.  
We added the missing information regarding the instruments used for measuring:

*CRF was measured using a standardized, submaximal cycle ergometer test (Ergosana Sana Bike 350/450 [Ergosana, Germany], heart rate monitor [Polar, Finland], blood pressure cuffs [Ergosana, Germany], a heart rate transmitter [Oregon Scientific, USA] and a notebook with ergometer software [Dr Schmidt GmbH, Germany]).* (page 6, line 14)

*“Body height and weight were measured by standardized procedures using portable electronic scales (SECA, Germany) and stadiometer (Holtain, UK).”* (page 9, line 16)

*“Waist circumference was measured at the smallest site between the lowest rib and the superior border of the iliac crest with flexible, non-stretchable measurement tape (Sibner Hegner, Switzerland) and categorized as ‘normal’, ‘increased’ and ‘strongly increased’ according to international guidelines (37).”* (page 9, line 18)

17. Please include argumentation for why it have been chosen to both include BMI and WC. Studies suggest that both parameters are independent related to CRF [1-3]. Moreover, in previous analyses of the DEGS1 dataset, increased waist circumference was – independent of body mass index – strongly associated with lower CRF in men and women [4]. While body mass index might be a more general marker of body composition and could be affected by adjustment of  $\dot{V} O_{2max}$  for body weight [5], waist circumference is closer related to abdominal adiposity [3]. We added this argument to the manuscript:

*“As body mass index and waist circumference have been shown to be independently related with CRF in previous studies (34, 35) we included both parameters as covariates.”* (page 9, line 15)

18. Please consider to include adjustment for use of medication that affects the VO<sub>2</sub>max, as use of these medications would imply a moderating effect of the relation between PA and CRF. Thank you for bringing up this interesting point. During the initial PAR-Q screening all participants answered a question on cardiorespiratory-related medications (“Has a doctor ever prescribed you drugs for high blood pressure or heart or breathing problems?”). If this question was answered with “yes” (n = 192) the participant was interviewed by a physician,

who was instructed to exclude all participants using antihypertensive drugs such as beta blockers from the exercise test. As a result, more than 85 % of these participants were categorized as testunqualified. Since by this procedure it was justified for the remaining participants by a trained physician that the medication did not affect their ability to perform the exercise test, we decided to not include the use of medication as a covariate. However, as this holds only true for medications “for high blood pressure or heart or breathing problems”, there is a possibility that the use of other medications might have affected the results. We discuss this potential effect in the limitation section:

*“Second, due to the use of the PAR-Q screening questionnaire, our sample consists of a relatively healthy study-population. This implies the exclusion of most study participants using cardiorespiratory related medications. However, it cannot be ruled out that the use of other medications (e.g. psychotropic or antidiabetic drugs) act as a source of bias in our investigations”* (page 16, line 11)

19. Please revise whether sex imply a bias or a moderation to the relation under investigation. Additionally, does it seem to lack some logically arguing, as it seems unnecessary to adjust for sex distribution in an analysis stratified on sex – unless you operate with more than two sexes? Also if sex were considered as a moderator and the interaction was significant, the argument for sexstratification would be straightforward. The term “sex bias” was maybe misleading and was thus replaced with “effect modification by gender”:

*“All analyses were conducted separately for men and women to identify gender-specific physical activity patterns associated with CRF and to detect a potential effect modification by gender”* (page 10, line 8)

In addition, we used a weighting factor which to correct for deviations in the study sample from the true German population, to improve the representativeness and generalizability. This considers also gender but as a distribution combined with age and other characteristics. So this weighting is more complex than just a correction for the gender distribution.

## Results

20. Please make sure to report the reference categories for the logistic regressions. The reference categories for the logistic regression models were added in the statistical analyses section:  
*“Multivariable logistic regression models were computed to estimate the associations between domains of PA and low  $V O_{2max}$  (reference category: intermediate to high  $V O_{2max}$ ).”* (page 10, line 1)
21. I cannot find the result of the interaction between OPA and LTPA, as described at page 8, line 4. Please make sure to report the interaction to generate argumentation for moderating effects from LTPA in the relation between OPA and CRF – which this version of the manuscript lacks. In this sentence, we refer to the combined OPA/LTPA variable. We changed the wording to avoid misinterpretation:  
*“To analyze the combined relationship of OPA and LTPA on CRF, we generated a combined variable containing the categories no LTPA/low OPA, no LTPA/high OPA, <2h LTPA/low OPA, <2h LTPA/high OPA, ≥2h LTPA/low OPA, and ≥2h LTPA/high OPA.”* (page 9, line 4)
22. The external validity are not in any way mentioned neither reported, thus as a minimum a description of where and how  
We discuss measures to enhance the external validity in the statistical analyses section:

*“Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA). To enhance the external validity of the results, weighting factors were used to adjust for distribution of the sample by gender, age, education, and region to match the German population. Stata’s survey procedures were applied to account for the clustered sampling design.” (page 10, line 12)*

In addition, please see also comment #49 where we address the results from table 1.

23. The flow chart should not be placed in the additional files, but be a part of the main manuscript.

The flow chart was moved to the main manuscript (Figure 1).

24. Please be more concise in the wording of the results, thus chance – page 10, line 32 – should be replaced by prevalence.

We revised the sentence to make it more concise:

*“Men and women with no or less than 2 hours LTPA per week were more likely to have a low VO<sub>2</sub>max compared to those with 2 hours or more LTPA per week.” (page 11, line 21)*

## Discussion

25. There seems to be some errors in the reporting of the results, as no LTPA and high OPA, were reported to have the highest OR for low CRF in the results. However, in the discussion, it is reported that it is no LTPA and no OPA that have the highest OR for low CRF. Please revise both tables, and text in results and discussion to make sure there is consistency in the reported results.

Thank you for pointing this out! This was based on a copy-paste mistake in Table 4 (fully-adjusted model for men and age-adjusted model for women were exchanged). We corrected this mistake in Table 4 and adapted the manuscript.

26. Please include references for the historical perspective in health effects from OPA, page 11, line 32, such as Morris et al 1953, lancet.

We added the landmark article by Morris et al. to underpin the given argument.

40. Morris JN, Heady JA, Raffle PAB, Roberts CG, Parks JW. Coronary Heart Disease and Physical Activity of Work. The Lancet. 1953;262(6796):1111-20.

27. Overall, the discussion lacks proper reflection on the sex differences, both from a perspective on the work task in line with sex distribution of occupational titles as well as the physiological background explaining the sex differences in the investigated relation.

We expanded on the typical work tasks in the potential working mechanisms section, where we already elaborate on the effect of typical high OPA occupations mainly performed by men or women:

*“The observed results suggest, that the association of domain-specific PA and CRF vary between men and women. Among women with low levels of LTPA, high OPA is associated with lower fitness. As Table S1 shows, men with physically demanding occupation mainly work in manual and technical professions (e.g., electricians, plumbers, mechanics) while women in physically demanding jobs work mainly in the service sector (e.g. nursing/care, catering, and cleaning). The latter jobs, mainly performed by females, are particularly affected by limited work control and higher job-strain, which may be a possible explanation for these gender-specific patterns. For example, health care workers in Germany report very high level of job demands compared with the average level of all occupations while having a low decision-making autonomy (55) (56, p. 7684). This can be of special concern as studies have shown, that high strain-jobs can lead to lower LTPA (57) whereas high occupational stress in*

*combination with low CRF has been shown to considerably increase the cardiovascular risk (58). Furthermore, the potential physiological mechanisms described above hold especially true for the prevalent high work demand professions among women: studies have shown, that e.g. among cleaners OPA is often of long duration, but with insufficient intensity and goes along with an high relative workload (13).” (page 14, line 17)*

28. Please include what the described intensity are sufficient for in page 12, line 24, and remember to include relevant references.

We added the requested information, but did not insert an additional reference, as this is by our understanding already covered by Ross et al.:

*“To increase  $V_{O_{2max}}$ , exercise should ideally be performed at PA intensities of at least 50% of the maximal aerobic capacity for rather untrained individuals (10).” (page 13, line 23)*

29. Also, include an explanation for what the recovery should be sufficient for in page 12, line 33, and remember to include relevant references.

We expanded regarding the physiological mechanisms in the potential working mechanisms section:

*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)” (page 13, line 25)*

Please see also comment #57

30. In order to be able to draw the link between recovery and CRF, an explanation of the physiologic background for the link between CRF and intensity of OPA are needed. Please see comment #29

31. Please elaborate on how the associations in table 4 vary and revise page 12, line 38 accordingly. Again, thank you for pointing out this discrepancy. As the mistake in table 4 was corrected (see comment #25), no further adjustment was necessary.

32. Add the physiological mechanism explaining the reason for increased CRF to decrease CVD risk in relation to OPA, page 13, line 5.

Please see comment #29 where we elaborate on the physiological mechanisms regarding the relation of CRF, OPA/LTPA and CVD risk.

33. Elaborate the last paragraph at page 13, line 8-26, with the practical implications – discussing who these results are relevant for, what they may be used for in a practical sense, ex guidelines or such, and how they feed into the improvement of public health. In addition to implications for further research addressed in comment #58, we expanded on the practical implications for public health professionals:

*“Finally, it is recommended that policy makers and public health experts involved in the development of PA recommendations consider specifying these recommendations according to the level of OPA, as recent guidelines do not make a distinction between activity levels during work.”* (page 15, line 22)

34. Please include an explanation on how reversed causality would affect the overall conclusion in this manuscript.

We included the following:

*“First, the cross-sectional design of the study does not permit a causal inference of the observed relationship between PA pattern and CRF. Even if it is well established that regular PA can enhance CRF, reversed causality for instance that individuals who have inherited a low CRF tend to be less active, cannot be ruled out (66). Thus, it cannot be drawn from our study, that a higher CRF can be traced to high LTPA levels.”* (page 16, line 6)

35. Please reflect upon whether these results could be affected by selection bias, such as the healthy worker bias.

We expanded on a potential selection bias based on a relatively healthy study-population in the limitation section:

*“Second, due to the use of the PAR-Q screening questionnaire, our sample consists of a relatively healthy study-population. This implies the exclusion of most study participants using cardiorespiratory related medications. However, it cannot be ruled out that the use of other medications (e.g. psychotropic or antidiabetic drugs) act as a source of bias in our investigations. Furthermore, the use of a relatively healthy study-sample may have hampered the generalizability of our results. In addition, it cannot be ruled out that our results are affected by the so called healthy worker effect describing a specific form of selection bias in terms that more healthy individuals are more likely to work in physically demanding occupations.”* (page 16, line 11)

See also comment #18.

36. Please elaborate on how the fact those JEMs are not able to account for the variability of exposures within job may affect the overall conclusion in this manuscript. We expanded on this in the limitation section:

*“Even though these JEMs were based on a very large sample and the use of hierarchical linear regression models, controlling for age, gender, working hours and job experience, reducing the likelihood of confounding, JEMs are generally not able to account for variability of exposures within jobs (69). If the prevalence of high physical demands within occupations varies widely, this could have led to biased results regarding the observed OPA levels, which would tend to reduce the magnitude of the observed associations.”* (page 17, line 3)

## Conclusion

37. Due to the fact that PA data are compositional by nature, the combined OPA and LTPA should be considered as the best estimate to relate to CRF, and should therefore be presented in the conclusion to feed into information and qualification of future PA guidelines/interventions etc. We thank the reviewer for this helpful suggestion. We revised the conclusions and now elaborate on the main results of our study regarding the combined OPA/LTPA variable and the consequences for future research and PA guidelines.

*“This study showed a strong association between patterns of PA during leisure time and work and CRF among men and women in the working population in Germany. For example, women without LTPA are likely to have a low CRF, especially if they work in physically demanding jobs. Hence, these findings contribute to the increasing body of evidence of different domain-specific effects of PA on health outcomes and emphasize the importance of considering different domains of PA in future studies. Moreover, as current guidelines do not distinguish between PA during work and leisure time, specifying LTPA recommendations according to the OPA level should be considered. Further research is needed to elucidate the pathways through which different domains of PA lead to divergent health effects and to confirm these findings with objective measures of PA.”* (page 17, line 10)

## Review #2:

38. This is a very well-written and nicely structured paper with a highly relevant approach to domainspecific physical activity in relation to cardiorespiratory fitness in a population of workers. Overall, it is an important paper, which should be accepted for publication after some revisions. I will discuss these revisions in my comments below.  
We would like thank Ms. Ketels for her detailed, objective and insightful comments on our manuscript.

39. Please check the manuscript carefully for grammatical errors and typos. For example: page 5 OPA, and LTPA and CRF; page 6, line 10 the participants initially completed; page 6, line 46 (quintile 3-5) quintile); page 7, line 25 two full stops; page 12, line 8 cardio vascular needs to be 1 word; page 12, line 47 two blank spaces between the and service.  
We corrected the mentioned mistakes and again proof read the manuscript carefully.

## Abstract

40. The sentence “further investigation ... identified populations groups at risk” in the conclusion section is quite difficult to read, please rephrase this sentence.  
We followed the suggestion and rephrased this section to make it easier to read:

*“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.”* (page 2, line 25)

## Background

41. The introduction is overall nicely structured and contains the relevant references. However, some points are difficult to read and get lost because of the way the introduction is written. For example, on page 4 ‘Even if manual and physical demanding...’; on page 5 ‘Notably, the interplay between these different... Following an explorative approach...’.  
We rephrased the mentioned parts to make the introduction more concise and easier to read:

*“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).”* (page 4, line 15)  
*“However, data on the association of different domains of PA and CRF for Germany is limited. In particular, the interplay between these different domains has not yet been analyzed in relation to CRF. Thus, this study aims to investigate the associations between patterns of OPA and LTPA with CRF among the German working population.”* (page 5, line 1)



## Methods

42. The paragraph on page 5, line 45 'Two hundred and four participants...' until 'had valid information on VO2max, OPA and LTPA' is rather difficult to read. Please rephrase. We rephrased the paragraph:

*"Two hundred and four participants terminated the test before reaching this heart rate. As a result, VO2max could be calculated for 2.826 participants. Further cases were excluded based on missing data on the PA variables. Overall, valid information on VO2max, OPA and LTPA was available for 1,296 women and 1,199 men"* (page 5, line 25)

43. I would recommend to give some more information regarding the Physical Activity Readiness Questionnaire. What exactly does it measure?

We expanded on the PAR-Q in the methods section (see also comment #7 and #9):

*"DEGS1 participants were included in the ergometer test if they were aged 18-64 years, signed an informed consent, and were categorized as test-qualified based on a modified German version of the Physical Activity Readiness Questionnaire (PAR-Q) (21, 22). This screening test includes questions on medical conditions, medical supervision, pregnancy or contradictions regarding physical activity. Participants were consulted by a physician if any of PAR-Q contraindications were reported and the physician decided whether or not the participant should be enrolled into the exercise test."* (page 6, line 18)

44. The hierarchic multilevel analyses adjusted for sex, age, job experience and part time employment used to determine the physical demand index should be better explained. We followed the reviewer's suggestion and expanded on this paragraph:

*Based on hierarchic multilevel analyses adjusted for gender, age, job experience and part time employment, the physical demand index was assigned to the occupations. In contrast to the use of occupations-specific means, this procedure allows to adjust for further variables that could influence the level of demands besides the specific occupation (e.g., the gender ratio or the level of part time employment). The levels for the multi-level estimation were defined by the 2-, 3- and 4-digit codes of the ISCO-88 classification. These JEMs were then classified into deciles."* (page 8, line5)

45. The paragraph concerning the age-specific maximal heart rate is not clear. First, the abbreviation "HRmax" should be given earlier. Second, the formula used in this manuscript to calculate the age-predicted HRmax is "208-0.7xAge", which is not the same used in the paper of Finger and colleagues (2013) where the following formula was given: "0.85 x (220-age)". Please clarify your use formula and change it if necessary.

"0.85 x (220 – age)" (a) was used by the ergometer software during the exercise test to terminate the test and "208 – 0.7 · Age" (b) was used during the indicator calculation of estimated

*V O<sub>2</sub>max.*

- (a) The formula  $0.85 \times (220 - \text{age})$  was used to calculate the individual submaximal target heart rate for each test person to terminate the exercise test. If the target heart rate was exceeded for 30 seconds the test was terminated at the end of the current 2-minutes workload level.
- (b) The "Tanaka formula" of  $208 - 0.7 \cdot \text{age}$  was use to predict the physical work capacity at HRmax (PWC100%) in order to calculated the estimated VO<sub>2</sub> max according to the metabolic equation of the ACSM.

No changes in the manuscript were conducted.

The abbreviation “HRmax” is now given the first time it appears in the manuscript.

46. The last sentence of the ‘outcome variable’ paragraph, i.e. ‘that individuals in the low fitness group compared to the ...’ does not belong in the method section. Please remove or replace this part.

We followed the suggestion and removed this sentence from the manuscript.

47. In the first sentence of ‘occupational physical activity: a physical work demands index’ the verb ‘developed’ was used, but I don’t believe that the authors of the mentioned paper developed this method. Please provide more clarity on this issue.

The wording of this sentence was maybe misleading – thank you for pointing that out. Of course, “developed” was referring to the specific JEMs used in our analyses and not to this method in general. We rephrased the sentence avoid misinterpretation:

*“To assess PA at work we used an indirect method and computed specific job exposure matrices (JEMs) that can distinguish the participant’s occupation by the criterion of physical demands.”*  
(page 7, line 18)

48. The paragraph about ‘leisure time physical activity: physical exercise’ needs to be restructured/rephrased: replace the word “as a proxy”; what is the difference between the first three groups and the last three groups?; the authors refer to “the categories of the five-point scale”, but there are only 4 options mentioned in the text. In summary, it is not clear to the reader how LTPA is assessed and which questions were used, so please make this more clear. We rephrased the whole paragraph, added the missing category and removed the redundant parts (see also comment #15):

*“LTPA was assessed by asking participants “How often do you engage in physical exercise?” (32). Even though LTPA is usually referring to all PA in their freely disposable time, sport and exercise constitute the core area of LTPA (29) and are therefore used in this study. For the analyses, the categories of the five-point scale “no physical exercise”, “less than 1 h a week” and “regularly 1-2 h a week”, “regularly up to 4 h” and “regularly more than 4 h” were categorized into three groups: no physical exercise, < 2 hours/week, ≥ 2 hours/week.”* (page 8, line 21)

## Results

49. Explain the unweighted and weighted percentages more extensive in the method section. We expanded on the unweighted and weighted percentages and moved this paragraph to the method section:

*“Overall, valid information on  $V_{O2max}$ , OPA and LTPA was available for 1,296 women and 1,199 men. Table 1 illustrates demographic, anthropometric and health behavior variables from this representative sample of the adult working population of Germany. Women comprised 48.0 % of the sample, the mean age of the participants was 39.6 years (range 18-64years). Generally, unweighted and weighted percentage did not differ substantially. In detail, weighting lead to slightly smaller share of participants in the older age groups and a smaller share of participants in the high socioeconomic status group.”* (page 6, line 2)

50. All the results distinguish between men and women, but this strategy has not been introduced in the method section, nor are the reason for doing so explained. Some explanations in the method and if possible in the introduction section are required.



We added a justification for the stratification at the end of the introduction:

*“In particular, the interplay between these different domains has not yet been analyzed in relation to CRF. Thus, this study aims to investigate the associations between patterns of OPA and LTPA with CRF among the German working population. As men and women are differently exposed to physical demands at work (14), work in different occupations (15), and may respond differently to PA (16), our analyses were performed stratified by gender.”* (page 5, line 1).

15. Hobbler, D., Pfahl, S. & Spitznagel, J. Horizontale Segregation des Arbeitsmarktes 2017. WSI GenderDatenPortal [horizontal segregation of the labor market]. (2020).
16. Hands, B., Parker, H., Larkin, D., Cantell, M. & Rose, E. Male and Female Differences in Health Benefits Derived from Physical Activity: Implications for Exercise Prescription. Journal of Womens Health, Issues and Care 5(2016).
17. Clays, E., et al. The association between leisure time physical activity and coronary heart disease among men with different physical work demands: a prospective cohort study. European journal of epidemiology 28, 241-247 (2013)

Please note that we harmonized the wording and now use the term ‘gender’ rather than ‘sex’ throughout the manuscript.

Please see also comment #19.

51. The statistical method used to calculate the results in table 2 is not mentioned in the method section, please adapt.

We added a sentence referring the method used to calculate the results in table 2:

*“To show the association of the domain-specific activity levels LTPA was cross-tabulated with OPA. Prevalence and 95% confidence intervals (CI) of low  $V_{O_2max}$  were calculated for OPA, LTPA and covariates.”* (page 9, line 25)

52. In the statistical model in table 4, the author adjusted for OPA and LTPA, however this is not mentioned in the methods section.

We thank the Reviewer for pointing that out. We added the additional adjustment in the statistical analyses section:

*“In a first step, separate models for OPA and LTPA were fitted, in a second step the combined variable of OPA and LTPA was used. In both steps an age-adjusted model and a model adjusting for body mass index, waist circumference, smoking, alcohol intake and SES were fitted. The separate models for OPA and LTPA were additionally adjusted for LTPA and OPA, respectively. Finally, we computed predicted margins (39) from the final logistic regression model to plot adjusted prevalences of low  $V_{O_2max}$  according to domain specific PA.”* (page 10, line 2)

53. Please make sure that the numbers add up to 100%, e.g. LTPA percentages of women: 24.7 + 49.9 + 25.3= 99.9; also check the consistency in layout, for example the paragraph about the multivariable analyses: sometimes there is a blank space between noLTPA/ low OPA, and sometimes there is not <2hLTPA/lowOPA. We checked for consistency in the layout.

## Discussion

54. Correction for reference number 41: the positive association between CRF and OPA was found among young men.

We added the mentioned restriction to the sentence:

*“...and a study from Finland found a positive association of CRF and self-reported OPA even after adjustment for LTPA among young men (47).”* (page 13, line 12)

55. In general “physical activity” refers to activities such as running, walking, cycling etc. If we distinguish PA into LTPA and OPA, we assume that LTPA still includes the activities like mentioned above, but it is a different story for OPA. Objectively measured OPA normally refers to MVPA during work including walking, running, stair climbing and cycling. However, self-reported occupational physical activity normally refers to physically demanding tasks such as lifting, manual handling, repetitive movements etc. In summary, there is a conceptual issue around what occupational physical activity precisely is. This needs to be discussed and clarified because this has a big impact on CRF.

Thank you for bringing up this important and helpful remark. We decided to discuss this in the limitation section, were we already elaborate on the limitations of self-reported (O)PA:

*“In the case of OPA, in contrast to objectively measured activity levels, which usually includes general activities during work, self-reports are often restricted to specific task, such as lifting of heavy loads. This is particularly important, because such physically demanding task influence CRF in a different way than general activities.”* (page 16, line 25)

56. The discussion section is nicely structured with valuable comparisons to findings from other studies. However, these studies all used self-reported measures to assess physical activity, which has to be emphasized more as a limitation in the discussion.

We now elaborate on this issue in the strengths and limitations section:

*“Fourth, self-reports on PA levels are prone to recall and social desirability bias (67, 68). Thus, we cannot exclude the possibility that the level of PA was over- or underreported. This holds true not only for this study, but also for most of the studies cited in the discussion.”* (page 16, line 21)

In addition, we added the information regarding the method of PA assessment wherever applicable in the discussion.

57. Page 12: the assumption that intensity during work would be too low is not in line with other studies that showed that the intensity of work related PA was higher compared to LTPA (Coenen et al., 2018; Gram et al., 2016; Ruzic et al., 2003). Please have a closer look at these references and discuss.

Thank you for bringing up these interesting findings. We adjusted the paragraph taking into account the results of the named studies (Please see also comment #29):

*“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 to 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).”* (page 14, line 2)

Regarding Ruzic et al [6], we were not able to identify the association mentioned. However, we are very happy to add this if the reviewer can help us here.

58. Page 13: The article recommends more LTPA to increase CRF, which seems logical. However, a few studies showed that high LTPA in combination with high OPA levels can lead to a higher risk of developing CVD (Clays et al., 2013; Korshoj et al., 2015). Please look into this papers and adjust your claims accordingly.

Thank you for pointing out these relevant studies. We know elaborate on these contradictory results at the end of the potential working mechanisms section and conclude this paragraph with some recommendations regarding further research:

*“When recommending higher levels of LTPA, one should consider the embedded and dependent relationship of the different domains of PA: First, OPA and LTPA are not the exclusive domains of PA; transportation and domestic activities are also relevant. This is of importance because, like OPA, both of these domains can also be described as non-discretionary time (59) with limited autonomy by the individual. Second, performing PA in all of these domains does depend on structures at the societal, environmental and individual level (60). As individuals face varying obstacles to engage in more LTPA like cultural temporal structures (e.g., public-transport timetables) or individual responsibilities (e.g. parenthood), measures and policies aiming to create an activity friendly environment are needed rather than blaming the individual (1). In addition, it has to be noted that some studies found that a moderate to high level of LTPA was associated with adverse health outcomes among those exposed to high OPA (61, 62). Thus, the interrelationships between OPA and LTPA remains not fully understood and there is a need for further research to explain these partly contradictory results in the literature. To take into account the observed gender differences, it is highly recommended that future studies should investigate both men and women separately. Furthermore, a high share of the research on this topic is based on self-reported PA with a high heterogeneity among the instruments used. Thus, future research investigating the domains-specific effects of PA using objective measures is necessary (63). Finally, it is recommended that policy makers and public health experts involved in the development of PA recommendations consider specifying these recommendations according to the level of OPA, as recent guidelines do not make a distinction between activity levels during work.” (page 15, line 6)*

59. Please provide some recommendations for further research, especially with regard to the need of objective measurements of PA.  
Please see comment #58.

#### VERSION 2 – REVIEW

<b>REVIEWER</b>	Mette Korshøj Department of Occupational and Social Medicine, Holbæk Hospital a part of Copenhagen University Hospital, Denmark
<b>REVIEW RETURNED</b>	18-Feb-2020
<b>GENERAL COMMENTS</b>	Dear authors The manuscript have greatly improved by your revision, however there are a few comments that would improve the communication and interpretation of the results. Thus, please consider to revise the manuscript based on the following comments.  #19

	<p>Please consider to replace gender with sex, as this is more correct due to the link to the biological sex (male/female) than to the culturally gender (presently 71 acknowledged, ex poly-gender, bi-gender, cis etc.).</p> <p>#23 There seems to be something wrong with the flow chart, as it is mainly black in my version, please make sure that it is readable.</p>
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<b>REVIEWER</b>	Margo Ketels Ghent University
<b>REVIEW RETURNED</b>	06-Feb-2020

<b>GENERAL COMMENTS</b>	<p>General comments Replying to the combined feedback of reviewer 1 and 2 has led to various changes throughout the manuscript. While each change taken by itself proves to be a valuable addition, the general structure of the paper has, unfortunately, suffered by all these adjustments. Therefore I don't have many additional comments regarding the content of the article, but the general structure of the manuscript and the writing needs further improvement. I would invite the authors to rethink the organisation of the article based on the new additions, rather than keeping the old organisation of the article while trying to force the new additions into the old structure. More attention needs to be given to inserting more linking words and phrases between the paragraphs and the overall cohesiveness of the text. Given the mediocre quality of the language used, I would strongly suggest to have the text read by a native speaker.</p> <p>Abstract Objectives: Change "Patterns occupational physical activity" =&gt; "occupational physical activity patterns" Conclusion: The sentence "Further investigation... lead to divergent health effect." needs rewriting.</p> <p>Introduction Aim: Please describe more clearly what you mean specifically by "patterns" of OPA and LTPA. Put also more emphasis on the difference between the main effects of LTPA and OPA separately, and interaction effects, i.e. LTPA/OPA.</p> <p>Methodology Outcome variable: what were the reasons that the study staff would have terminated the exercise test? Statistical analyses: this section needs more improvement. It is not entirely clear which statistical methods are used for which analyses. This is especially the case for the data that are represented in the result tables.</p> <p>Discussion The explanation about the potential working mechanisms is definitely of added value. However it feels like this part is forced between two parts, which disrupts the flow of text. Please carefully reread the general discussion part and restructure this section. Strengths and limitations: please rewrite some parts, some parts do not flow well: for example, two times "it cannot be ruled out"; "This holds true not only...".</p>
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## VERSION 2 – AUTHOR RESPONSE

### Reviewer #1

The manuscript have greatly improved by your revision, however there are a few comments that would improve the communication and interpretation of the results. Thus, please consider to revise the manuscript based on the following comments.

1. Please consider to replace gender with sex, as this is more correct due to the link to the biological sex (male/female) than to the culturally gender (presently 71 acknowledged, ex poly-gender, bi-gender, cis etc.).

We have replaced the word 'gender' with 'sex' throughout the manuscript.

2. Here seems to be something wrong with the flow chart, as it is mainly black in my version, please make sure that it is readable.

We apologize for this and have double-checked that we have now uploaded the correct file. We have also pasted the figure into this response letter for ease of reference:

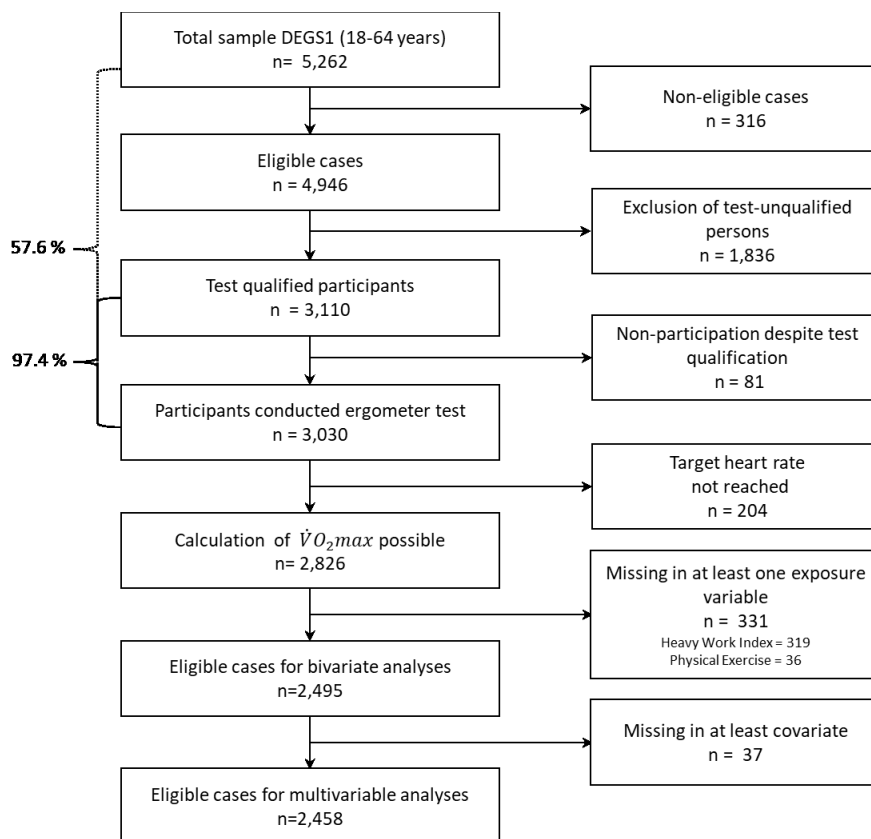


Figure 1: Flow diagram of participants. DEGS1: German National Health Interview and Examination Survey for adults;  $\dot{V}O_2max$ : maximal oxygen consumption

### Review #2:

3. Replying to the combined feedback of reviewer 1 and 2 has led to various changes throughout the manuscript. While each change taken by itself proves to be a valuable addition, the general structure of the paper has, unfortunately, suffered by all these adjustments. Therefore I don't have many additional comments regarding the content of the article, but the general structure of the manuscript and the writing needs further improvement. I would invite the authors to rethink the organisation of the article based on the new additions, rather than keeping the old organisation of the article while trying to force the new additions into the old structure. More attention needs to be given to inserting more linking words and phrases between the paragraphs and the overall cohesiveness of the text. Given the mediocre quality of the language used, I would strongly suggest to have the text read by a native speaker.

We have restructured the discussion to include further subheadings. The main discussion is now divided into four sections. First, as in the previous version, we compare our results with findings from previous studies. Second, we discuss the potential mechanisms of action. Third, we discuss the different findings for men and women and the potential underlying mechanisms. Fourth, we discuss the practical implication of our results and recommendations for further research. We have not added to or changed the arguments in the discussion, but we hope that this has improved the flow of the text. As you suggested, we have looked again at the flow. We have also had the paper edited by a native English speaking language editor, who has checked the manuscript for flow and consistency. I hope that you will agree that it is much improved.

#### *Abstract*

4. Objectives: Change "Patterns occupational physical activity" => "occupational physical activity patterns"

We have revised this sentence as suggested.

5. Conclusion: The sentence "Further investigation... lead to divergent health effect." needs rewriting.

We have revised the sentence to read:

*"However, further investigation is needed to understand the relationships between activity and fitness in different domains."* (page 3, line 2)

#### *Background*

6. Aim: Please describe more clearly what you mean specifically by "patterns" of OPA and LTPA. Put also more emphasis on the difference between the main effects of LTPA and OPA separately, and interaction effects, i.e. LTPA/OPA.

We have amended the manuscript to differentiate between the main and interactional effects in the study objectives. The section now reads:

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

#### *Methods*

7. Outcome variable: what were the reasons that the study staff would have terminated the exercise test?

General indications for stopping an exercise test were used, e.g. physical or verbal manifestations of severe fatigue, excessive rise in blood pressure etc. Please see ACSM's Health-Related Physical Fitness Assessment Manual, Box 7.3; p. 118 [1]

1. American College of Sports Medicine. ACSM's health-related physical fitness assessment manual. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2014.

8. Statistical analyses: this section needs more improvement. It is not entirely clear which statistical methods are used for which analyses. This is especially the case for the data that are represented in the result tables.

We have revised the statistical analyses section, and also added additional information to the results tables to make clear which statistical methods were used.

*“Leisure time and occupational physical activity were cross-tabulated to show the association of the domain-specific activity levels. Prevalence and 95% confidence intervals (CI) of low  $\dot{V}O_{2max}$  were calculated by occupational and leisure time physical activity and covariates. Multivariable logistic regression models were computed to estimate the associations between domain-specific physical activity (exposure) and low  $\dot{V}O_{2max}$  (outcome). In a first step, the main effects of occupational and leisure time physical activity were investigated, in a second step the combined activity variable was used. In both steps, we fitted an age-adjusted model and one adjusting for age, body mass index, waist circumference, smoking, alcohol intake and socioeconomic status. Finally, we computed predicted margins[39] from the fully adjusted logistic regression model investigating the combined physical activity variable to plot adjusted prevalence of low  $\dot{V}O_{2max}$  by domain-specific physical activity. All analyses were performed separately for men and women to identify sex-specific physical activity patterns associated with cardiorespiratory fitness and to detect potential effect modification by sex. Analyses were performed with Stata 15.1 (Stata Corp., College Station, TX, USA). To enhance the external validity of the results, weighting factors were used to adjust for distribution of the sample by sex, age, education, and region, to match the German population. Stata’s survey procedures were applied to account for the clustered sampling design..” (page 9, line 14)*

**Discussion**

9. The explanation about the potential working mechanisms is definitely of added value. However it feels like this part is forced between two parts, which disrupts the flow of text. Please carefully reread the general discussion part and restructure this section.

Please see comment #3.

10. Strengths and limitations: please rewrite some parts, some parts do not flow well: for example, two times “it cannot be ruled out”; “This holds true not only...”.

We have removed the repetitions and revised this section. Our editor has also suggested some revisions to improve the flow of this section.

We have also revised the document for wording and notation, resulting in a few small changes. Other changes were made during the English language editing.

**VERSION 3 – REVIEW**

<b>REVIEWER</b>	Margo Ketels Ghent University, Belgium
<b>REVIEW RETURNED</b>	12-Mar-2020

<b>GENERAL COMMENTS</b>	<p>I would like to congratulate the authors on the end result of this manuscript. All feedback points have been nicely adjusted, which you notice when reading the manuscript. The paper reads much more fluently and all substantive aspects are clearly presented. I would say that this manuscript is suitable for publication after correcting two minor comments.</p> <p>1. Use “occupational physical activity” consistent in the introduction. Thus change “occupational activity” to “occupational physical activity”.</p> <p>2. Throughout the manuscript, many commas were forgotten before “and” in a list of three or more items.</p>
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