Author's response to reviews

Title: Physical Activity and Sleep Profiles in Finnish Men and Women

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Author's response to reviews: see over
**Reviewer 1:**
This paper does address an essential question, which is how leisure, occupational and commuting physical activity may be related to sleep patterns and different chronotypes. The sample size is also very large, which allows for good generalizability of the results. Please find some comments below that need to be addressed before a decision on accepting this manuscript for publication can be made.

**Major Compulsory Revisions**
1-The assessment of chronotype is questionable because it is not specified whether the chronotype is based on the subjects' willingness to go to bed at a certain time, or on the fact that they have to go to bed at a certain time due to work, social activities, etc. If certain subjects are forced to go to bed at a certain time, then this is not their true chronotype. Please address.

**Response:** Our measure of chronotype is based on 6 items derived from the original Morningness-eveningness questionnaire (Horne and Östberg 1976) that correlated best with the sum score of the original Morningness-eveningness questionnaire accounting for 83% of the total variance in a Finnish population-based study (Hätönen et al. 2008), and had good psychometric properties (Cronbach coefficient alpha of 0.80) in another Finnish population-based study (Merikanto et al. 2012), and thereby our measure of chronotype covered reliably the most important aspects of the original Morningness-eveningness questionnaire. We emphasize that the original Morningness-eveningness questionnaire and our 6 items instructed the individual to concern only his subjective “feeling best” rhythm for scheduling a range of daily activities irrespective of social zeitgebers. We have added the following to our discussion (see the Strengths and limitations section): “The assessment of chronotype was based on a commonly used instrument, only on self-reports, which is considered a limitation.”

2-Discussion, paragraph 4: The authors discuss the link between different sleep patterns with age. Was age assessed? If so, it is suggested that age also be added to the model, or as a mediator in the model.

**Response:** Age was assessed and we have now added the mean age ±SD of each profile in the results section (see p. 9): In men, the mean age (with standard deviation, SD), respectively for profiles 1-4 was: 46.6 (11.6), 64.6 (8.4), 44.5 (11.1), and 59.5 (10.9) years. The corresponding mean age in women’s profiles 1 to 4 was: 45.5 (11.2), 61.6 (12.2), 45.2 (10.9), and 58.8 (13.4) years. We emphasize that our aim was to define the specific characteristics that identify a physical activity and sleep profile, in other words, what are the important behavioral indicators of these profiles. In this respect, age is background information (covariate) which may be related to the probability of membership in each latent class but is assumed to be otherwise unrelated to individuals’ responses to indicator items. Consequently, age is not considered as an indicator of a latent profile that determines its interpretation. As our results show, ageing is associated with the probability of membership in latent profiles 2 and 4 but does not “create” these profiles. The profiles per se exist independently of age but with ageing people are more likely to be members of some of them. Therefore age was not included in our LCA models.

3-Was shift work taken into consideration? The authors discuss the potential differences in sleep patterns between working days and days off, and these may
be quite different in those who work shifts, as briefly discussed by the authors in the last paragraph of the discussion. This would be a relevant employment status category to add, if the authors have this information.

Response: We agree with the reviewer that shift work imposes a whole different sleep and PA rhythm than people with normal working hours. We do unfortunately not have information on whether people work in shifts or not and we cannot therefore include this information in our study.

Minor Essential Revisions
4-Grammar and spelling revisions are needed in some parts of the text. Please revise.
Response: The revised manuscript has been proof-read by a professional text editor.

Abstract:
5-Please specify what you mean by different types of physical activity and sleep.
Response: Different types of PA in this study mean occupational, commuting and leisure time PA. Different types of sleep refer to the different lengths, sufficiency and quality of sleep and also daytime sleeping or napping behavior. We have now changed the abstract as follows: “The interrelationship between these behaviors has been studied, but there remain questions regarding the association of different types of PA, such as occupational, commuting, and leisure time to sleep, including quality, duration and sufficiency. It is unclear to what extent sleep modifies the effects of PA on health, and vice versa.”

6-In the methods section, the final sentence is quite vague and does not say very much. I would recommend explaining in more detail or rewording.
Response: We have now specified the final sentence as follows: “Models with one through five latent profiles were fitted to the data. Based on fit indicators, a four-class model for men and women, respectively, was decided to be the best fitted model.”

7-What is considered "sufficient sleep"? Please define. What is considered sufficient sleep for one, may be insufficient for another. I would suggest using another term, such as "recommended sleep".
Response: By sufficient sleep we refer to the question “Do you sleep enough?” that assess the subjective feeling of sleeping sufficiently enough. Sleep durations on free days and those on workdays were assessed with a separate question. We have now specified this in the text as follows: “sleep, subjectively rated as sufficient, as well as sleep duration of 7-7.9 hours.”

8-The authors mention that “high levels of occupational physical activity is associated with shorter and worse sleep”, however there is no mention of this in the results. The results suggest that physical inactivity is linked with short sleep and evening type. Please address this discrepancy.
Response: Thank you for pointing out this discrepancy. We have now tried to correct this by adding in the results a sentence as follows: “There was also one profile in both genders
characterized by likelihood for both high occupational PA and subjectively experienced insufficient sleep.”

9-I would suggest using the term "poor sleep" rather than "worst sleep".

Response: It was assumed that this comment meant the last sentence of the abstract and it has now been changed to “poorer sleep” instead of “worse sleep”.

Introduction:
10-1st paragraph: Please add a direction to the link between sleep duration and sleep quality with CVD risk.

Response: This has been corrected as follows: “…too short or long sleep duration and poor sleep quality are suggested to be associated with higher CVD risk as well [7-9].”

11-Please define "good sleep" in terms of duration and quality.

Response: We have changed “good sleep” into “enough sleep”, as we in this first sentence of the introduction, refer to the findings that sleep quality and sleep duration associate with a risk of CVD. The optimal sleep duration has been addressed later in the introduction, see paragraph 6.

12-5th paragraph: Please define "eveningness" and morningness".

Response: The introduction has been modified: “Eveningness, or a late chronotype, is directly associated with both sleep complaints [27], shorter sleep during work days [28], and sedentary time [29], whereas morningness, or an early chronotype, has been associated with higher PA [30].”

13-Please define the term "re-entrainment of circadian rhythm”. Also, please explain in what way the circadian rhythm can be altered by physical activity.

Response: We have now modified the text so that the term re-entrainment has been explained in other words and the role of PA as a zeitgeber for the circadian clock has been added: “It has also been suggested that regular PA can facilitate a re-entrainment or a change in the phase of the circadian rhythms, a possible advantage, for example, for shift-workers. PA acts as a non-photic zeitgeber for the human biological clock, maybe because of the changes it evokes in body temperature or in the general arousal level [31].”

14-6th paragraph: Is it that a long time spent in bed predicts decreases in physical performance and immobility incidence or vice versa? It would seem that some individuals may be more predisposed to spending more time in bed because of physical immobility or other physical problems, and not that the long time spend in bed necessarily causes this. Please address.

Response: It is true that people with physical immobility may be predisposed to more time in bed, but according to the reference Stenholm et al. 2011, long time in bed predicted the decrease seen in physical performance and increased immobility. In the study by Stenholm et al. 2011, subjects were followed up to 6 years and persons with physical immobility at baseline were not included in the follow-up analyses.
15-7th paragraph: Please add hypotheses that were tested.

**Response:** The hypothesis tested has been included in the last sentence of the introduction. “We assumed that people with higher leisure time PA would also have longer and better sleep than inactive persons but, also, that being physically active in other domains would be related to longer and better sleep.”

**Methods:**
16-Paragraph 5: Is the defined chronotype based on the subjects’ willingness to go to bed at a certain time, or is it based on the fact that they have to go to bed at a certain time due to work, social activities, etc. This would be important to specify.

**Response:** This point has been addressed earlier by the reviewer 1 in page 1, as a major compulsory revision 1. See the corresponding response.

**Results:**
17-Paragraph 2: Please clarify the difference between the "evening-type" and "more evening-type". The authors mention that the "evening-type" report a likelihood for increased morning tiredness, while the "more evening-type" report a poor morning alertness. It is difficult to understand the difference between the 2 sub-groups, based on these explanations alone. Additionally, please use another term to describe the "more evening types" and "more morning types". These terms may lead to confusion.

**Response:** The text has been modified to more explicitly address this difference (see paragraph 2 in results section). “The first chronotype class (17.5%) was characterized by likelihood for morning tiredness and self-reported eveningness, and a preference to work hours between 14 and 16 o’clock. This group was called “evening types.” The fourth chronotype class (30.2%) was characterized by likelihood for self-reported eveningness more than morningness and poor morning alertness, but still feeling quite rested and able to easily to get up in the morning. These were called the “more evening-than-morning types.”

18-Paragraph 2: The midpoint of sleep is a measure of sleep timing and not sleep chronotype. This may be different in the case where someone is forced to go to bed earlier or later because of work, social demands, etc. Please address.

**Response:** According to the studies by Roenneberg et al (2007) and Roenneberg et al (2004), the midpoint of sleep is calculated by taking into account for the difference between sleep on workdays and freedays, and thus it corrects the estimation of chronotype. We used the corrected midpoint of sleep to check whether our chronotype classification separated the chronotypes. In other words, it was used as an additional validity criterion for LCA defined chronotypes.

**Discussion:**
19-Paragraph 1: Do the authors mean "poor sleep quality" when saying "not sleeping enough"? They mention "not sleeping enough" and "short sleep" as different profiles, but these are the same. Please address.
Response: We used two separate questions, not one. Not sleeping enough refers to the question “Do you sleep enough?” that assesses the subjective feeling of sleeping sufficiently. By short sleep we mean self-reported sleep duration less than 7 hours. Self-reported sleep duration and sufficiency of sleep do correlate, however, they are not redundant (see e.g. Merikanto et al. 2012). We have now specified the text in the Discussion, paragraph 1 as follows: “subjective feeling of not sleeping enough”

Discretionary Revisions

Abstract:

20-The 2nd sentence is quite long. Please restructure the sentence.

Response: This has been restructured: “The interrelationship between these behaviors has been studied, but there remain questions regarding the association of different types of PA, such as occupational, commuting, and leisure time to sleep, including quality, duration and sufficiency. It is unclear to what extent sleep modifies the effects of PA on health, and vice versa.”

21-Please replace "of variety of" by "between".
Response: This has been changed.

22-Please replace "for" this study by "in" this study.
Response: This has been changed.

23-In results, add leisure time physical activity "and" sufficient sleep.
Response: This has been changed.

Introduction:

24-2nd paragraph: Please remove the term "physical fitness", as the relationships that you are describing in the next line are based on physical activity participation and not fitness level.

Response: The term has been removed, thank you for pointing it out.

Level of interest: An article of importance in its field
Quality of written English: Needs some language corrections before being published
Statistical review: Yes, but I do not feel adequately qualified to assess the statistics.
Reviewer 2
This is a well conducted paper on the association between various self-reported types of physical activity and sleep characteristics. The authors have conducted novel statistical analyses appropriately. Furthermore, analyses have been performed in a large dataset, which adds to the quality of the paper.

Major Compulsory Revisions (in order of importance):
- Higher levels of activity in leisure time (LTPA) and lower levels of activity (OPA) during work cluster in the same profile as “better” sleep behaviors. As is, I am not convinced that people with moderate to high OPA actually sleep shorter or worse sleep or about the correlations between LTPA and sleep. It would support these conclusions to do additional analyses on the sleep characteristics stratified by activity level category (for OPA and LTPA). For OPA, and possibly also for LTPA, analyses may have to be done separately for the employed and the unemployed.

Response: In order to assess the interrelationship between PA and sleep, we decided to include these variables in the LCA model instead of using traditional regression analysis with LTPA, OPA and CPA separately. Previous studies have reported on independent associations of different types of PA with sleep, thus our novelty values lies in the idea of defining “combinations in real life”. LCA is not a variable-oriented model but a person-oriented approach, with the emphasis on the individual as a whole. Our profiles describe people who share the same patterns of individual characteristics regarding PA and sleep. The profiles do not indicate that there are linear relations between the indicator variables or that these relations hold for all people. In our profiles we have found combinations of characteristics, for example people with high physical activity at work that are reporting insufficient sleep and shorter sleep. We cannot conclude that increases in for example LTPA results in better or longer sleep. This discussion has now also been added to the manuscript (See Strengths and limitations, p.12)

- You found that individuals with a more psychically active occupation sleep worse. I think a major confounder could be social economic status, which could be related to other parameters like obesity and smoking and could also influence sleep. Have you collected information about SES? If not, at least the possibility of confounding should be discussed.

Response: We have data on educational years and this has been added to the results as follows: “Mean years of schooling for men in profiles 1 to 4 was: 14.2 (3.6), 11.2 (3.8), 13.7 (3.5), and 11.3 (3.8), and for women in profiles 1 to 4: 14.9 (3.8), 12.1 (4.1), 14.8 (3.4), and 12.3 (4.2) years. There were no statistically significant differences in educational years between profiles 1 and 3, neither in men nor in women.”

- As indicated by the authors in the discussion, age influences sleep duration, chronotype and physical activity; yet it is not included in the analyses. Associations could potentially be quite different in the younger vs. older individuals. Especially since the age range is big (25-74 years), I would suggest including age in the LCA, or at least supply the average age of each Profile.

Response: This comment is analogous with the comment of reviewer 1 (comment 2 in major compulsory revisions). See corresponding response.
- Individuals in profiles 2 and 4 are unemployed; could you specify whether they are retired or unemployed for other reasons?

**Response:** Obviously we had forgotten to mention this in the methods, thank you for pointing this out. Information on working status has now been added in the methods (page 4, paragraph 2): “Employment status was dichotomized into working or not working. Those not working included the retired, unemployed (without work), or homemakers.”

- Could you provide p-values for table 1 and 2? You mention in the discussion that men and women fundamentally differ in sleep and PA behaviors, so it would be good to see this confirmed in the tables.

**Response:** p-values (chi-square tests and t-test) for differences between men and women in PA and sleep indicator variables have now been added to tables 1 and 2.

- Could you specify which percentage of individuals you excluded because they had a history of CVD and which percentage because they did not participate in the health examination? Do you think there could be a selection bias in selecting only the individuals that participated in a health examination?

**Response:** To clarify the selection criteria, we added more numbers and modified the text: “The participation rate was 64% (n=6,424). Participants with any history of CVD (including myocardial infarction, stroke, bypass surgery, angioplasty, angina pectoris, and heart failure) and had missing information on any of the used variables (n=1,388) were excluded from the analyses. The final sample was 4,470 (1,947 men and 2,523 women).”

It is commonly reported that those not participating in population-based health examination surveys are lower educated and male and suffer from poorer health, which also is the case in the FINRISK Study. The inclusion criteria for the analyses in our manuscript purposefully excluded people with CVDs and also people with missing responses in any of the used variables. We believe that most of the missing values in the questionnaires appear at random and the risk of selection bias is low. Therefore we believe that our sample represents the healthy Finnish population fairly well.

- Since you based the classification of chronotype on a LCA of a questionnaire, it would be good if you could show the midpoints of sleep of the four categories of chronotypes, so that the reader can compare how extreme the “morning” and the “evening” types in your particular study are.

**Response:** This is true. We have added this information to the results. The text has also been modified to more explicitly address the difference between the different chronotypes (see paragraph 2 in results section): “The first chronotype class (17.5%) was characterized by likelihood for morning tiredness and self-reported eveningness, and a preference to work hours between 14 and 16 o’clock. This group was called “evening types.” The second chronotype class (26.9%) was characterized by likelihood for strong morning alertness and self-reported morningness, called the “morning types.” The third latent chronotype class (25.3%) was characterized by likelihood for self-reported more morningness than eveningness, with fair morning alertness. This group was called “more-morning-than-evening types.” The fourth chronotype class (30.2%) was characterized by likelihood for self-reported eveningness more than morningness and poor morning alertness, but still feeling quite rested and able to easily to get up in the morning. These
were called the “more evening-than-morning types.” All 4 latent chronotype classes were well identified and the average posterior probabilities were over 0.8 respectively, describing good class separation [37]. Furthermore, the four classes were tested in the data by comparing the distributions in midpoint of sleep, a suggested measure of chronotypes [28]. The four classes differed, as was expected, in their midpoint of sleep as follows: morning types, 2:49; more-morning-than-evening types, 3:14; more-evening-than-morning types, 3:45; and evening types, 4:25. This supported the validity of chronotype classification obtained by the LCA, which was used in analyses for this study.”

Minor Essential Revisions:
- It would make it easier for the reader to label the figures with “men” and “women”. Also the legends (“inactive”, “light”, and “moderate to high”) are not well aligned with the appropriate category (e.g. “commuting PA”) so they should be somewhat adjusted.

Response: The figures have been modified to make them easier to be interpreted.

- In the last sentence in Methods in the Chronotype paragraph “The shortened … original items”, please include “so” after the comma, or “Since” at the start of the sentence, and change “doesn’t” into “does not”.

Response: This has been corrected.

- Please insert name of the authors before “[47]”.

Response: The name of the authors has been included.

- Could you specify how you classified education into low, middle and high?

Response: In each birth cohort of the sample, education was classified into thirds, based on self-reported educational years in total. This accounts for the change in the Finnish education system that is biased by birth cohort, as younger generations go to school longer than older birth cohorts.

- In table 2, please also supply the three significant digits for the height of women.

Response: This has been corrected.

- In the 6th paragraph of the introduction, in the sentence “Long time … in elderly.” please change “predict” to “predicts”.

Response: This has been corrected.

Discretionary Revisions:
- I am not sure whether the term “sleep debt” is appropriate to describe the discrepancy between sleep duration on weekdays or on weekends. This implies that the underlying reason for sleeping longer is a shortage of sleep, while it could be caused by many factors. Maybe “sleep duration discrepancy” would be
a better term to use?

Response: We agree in that the term “sleep duration difference” is more accurate here. We have replaced the term “sleep debt” with the term “sleep duration difference”.

- In category 2) of using sleep medication you included all individuals that are currently using sleep medication or have used in the past, including usage over a month and even over a year ago. Would it be better to dichotomize it a bit less strict – e.g. include answers 1) to 2) (or 1) to 3) if you prefer) in “Yes”, and 3) to 5) in “No, or over a month ago” (or (“No, or over a year ago”)?

Response: The use of sleeping pills was dichotomized, because we thought that those who sometimes have used sleeping pills have had some problems with sleep, and thus may be prone to sleeping disorders (the use of sleeping pills thus being a proxy) or short sleep or has different PA than those who never have taken sleeping medication.

- It might make it easier for the reader to label the profiles on the figures (e.g. for Profile 1 of the men “physically active, normal range sleepers”) and to indicate more clearly that individuals in Profile 2 and 4 are almost always unemployed, which explains the “inactive” OPA and CPA.

Response: The figures have been modified to make them easier to interpret.

Level of interest: An article of importance in its field
Quality of written English: Acceptable
Statistical review: No, the manuscript does not need to be seen by a statistician.