

# Does high occupational physical activity hamper the beneficial health effects of leisure time physical activity? Evidence of the physical activity health paradox from a prospective study on compositional accelerometry data and long-term sickness absence

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# Abstract

**Background:** The 'physical activity health paradox' advocates that leisure physical activity (PA) promotes health while occupational PA impairs health. However, this paradox can be explained by methodological limitations of the previous studies—self-reported PA measures, socioeconomic confounding or not addressing the compositional nature of PA. Therefore, this study investigated the association between compositions of accelerometer-based moderate to vigorous PA (MVPA) time at work and leisure and onset of long-term sickness absence (LTSA).

**Methods:** Time spent on MVPA and remaining physical behaviours (sedentary behaviour, standing, light PA and time in bed) at work and leisure was measured for 929 workers using thigh accelerometry and expressed as isometric log-ratios (ilrs). LTSA was register-based events of  $\geq 6$  consecutive weeks during 4-year follow-up. The association between ilrs and LTSA was analysed using a Cox proportional hazards model adjusted for remaining physical behaviours and potential confounders, then separately adjusting for and stratifying on education and type of work.

**Results:** During the follow-up, 21% workers experienced LTSA. During leisure, more relative MVPA time was negatively associated with LTSA (20% lower risk with 20 minutes higher MVPA,  $P=0.02$ ). At work, more relative MVPA time was positively associated with LTSA (15% higher risk with 20 minutes higher MVPA,  $P=0.02$ ). Beneficial association between MVPA at leisure and LTSA was only observed for the lowest tertile of MVPA at work ( $P=0.03$ ). Results remained unchanged when adjusted for or stratified on education and type of work.

**Conclusion:** These findings provide further support to the 'PA health paradox'.

**Key words:** physical activity, sedentary behavior, accelerometers, sick leave, occupational health, time-use epidemiology, register-based sickness absence

## Background

Physical activity (PA) prevents chronic diseases and mortality (1). However, research indicating the health benefits of PA is predominantly limited to the leisure domain (2). Adults engage in PA at work—a domain where individuals spend half of their awake time. However, there is no consistent documentation of a beneficial health effect of occupational PA (OPA) (3–6). Rather, a recent meta-analysis of almost 200,000 participants observed an increased risk of all-cause mortality among males with high OPA (7). This potential contrasting health effect of PA during leisure and work domains is termed 'the physical activity paradox', which has recently received extensive attention in the field of PA and health (8, 9).

In particular, researchers have suggested that the PA paradox is merely a result of methodological limitations of existing studies (9). One such limitation lies in the measurements of PA, like the use of questionnaires that has been found to be imprecise and potentially biased (10, 11). Besides this, existing prospective studies on the PA paradox have disregarded the compositional nature of time-use data like

PA (12–15). The compositional nature of PA data means that the longer time spent on a specific PA, such as moderate-to-vigorous PA (MVPA), will consequentially require less time spent on other physical behaviors, such as light PA (LIPA), sedentary behavior or sleep. To counter this challenge, the time-use data on PA should be analysed using a Compositional Analysis (CoDA) approach (12–14, 16). Another limitation is the potentially inadequate adjustments for socioeconomic status (SES) confounding, where analyses of homogeneous groups with respect to socioeconomic characteristics are preferable (9).

The PA paradox has been shown to be associated with long-term sickness absence (LTSA) – an established predictor of all-cause mortality (17), chronic disease (18), and early exit from the labour market (19–22) with considerable economic burdens on companies and society (23, 24). Studies have shown that high levels of OPA increases risk of prospective LTSA (3, 25) while high levels of leisure time PA decreases this risk (3). However, the present study addresses, for the first time, the previous limitations of these studies by using better measurement methods of PA at work and leisure, addressing the compositional nature of PA data and adjusting for SES confounding.

## Methods

### Data and study population

The present study is based on the prospective data from the ‘technically measured compositional Physical wOrk DEmands and Prospective register-based Sickness Absence study (PODESA) cohort (15). This cohort was formed by harmonizing two cohorts, the ‘Danish Physical ACTivity cohort with Objective measurements’ (DPHacto) (26) and the ‘New method for Objective Measurements of physical Activity in Daily living’ (NOMAD) cohort (27). Both cohorts used similar procedures of 24-hour time accelerometry and comprised mainly blue-collar workers in Denmark, enabling the harmonization. More details on the setting, locations, recruitment, and inclusion and exclusion criteria in these cohorts and on the harmonizing procedures can be found elsewhere (15).

The baseline in PODESA included accelerometry and questionnaires administered between 2011 and 2013. The data on LTSA during four year follow-up from the date of completing the baseline was retrieved from the Danish national DREAM register (which is a Danish acronym for ‘the Register-based Evaluation of Marginalization’(19)).

Representatives for the participants, i.e., the management and worker unions, were actively involved in the planning, design, decision on measurements, recruitment of workplaces, data collection, feedback to participants, interpretation and the dissemination of the results.

### Accelerometry at work and leisure

Workers wore a thigh-based triaxial ActiGraph accelerometer (GT3X+, Florida, U.S.A) for 24 hours for up to five workdays (27, 28). Simultaneously, during those five days, workers also filled-in a diary reporting their time of starting and ending work and going to and out of the bed each day. The accelerometry data

were downloaded using Actilife Software version 5.5 (29) and further processed using a MATLAB program Acti4 (30, 31). Acti4 has previously shown a high sensitivity and specificity in detecting PA at work and leisure (32). Acti4 was used to determine time spent sedentary (sitting and/or lying), standing still, moving (standing with slight movements), walking slow (< 100 steps per min) and fast ( $\geq$  100 steps per min), running, cycling and stair climbing (32). For the analysis, time spent moving and slow walking was merged to calculate low-intensity physical activity (LIPA) while time spent on fast walking, stair climbing and running was merged to calculate moderate to vigorous physical activity (MVPA) (33). Leisure MVPA also included cycling time (33). Diary-based information was used to determine time in bed—a period between going to and out of the bed that were further visually checked for verification in the Acti4. A work period was defined as self-reported working hours spent on primary occupation while leisure period was defined as non-work periods, excluding time in bed.

All non-work days and accelerometry non-wear periods were excluded. Workers who had at least one day with valid work and leisure period were involved in further analyses. A work or a leisure period was considered valid if it comprised  $\geq$  4 h of wear time or  $\geq$  75% of the average wear-time across days, respectively (16, 26, 34, 35).

The mean time spent sedentary, standing and on LIPA, MVPA and median time spent in bed on all valid days were calculated to express average daily work and leisure physical behaviours (33, 36).

## **Prospective register-based long-term sickness absence**

Four-year prospective data on LTSA was retrieved from the DREAM register (37, 38). This register contains weekly information on granted subsidised sickness absence for each individual in Denmark. The sickness absence compensation is given to the employer who can claim a refund from the state after 30 days of sickness absence. Therefore, DREAM contains information on sickness absence periods of  $\geq$  5 consecutive weeks. LTSA was defined as the occurrence of the first (if any)  $\geq$  6 consecutive weeks of sickness absence period during the 4-year follow-up from the date of completing the baseline measurements. We selected this cut off point based on previous research (39). Previous research has shown the accuracy of DREAM register-based LTSA (40).

## **Potential confounders**

Potential confounders included age, sex, Body Mass Index (BMI), smoking status, duration of occupational lifting and carrying, and education and type of work as proxy indicators of socioeconomic status (SES). Age was determined using workers' unique civil registration number. Sex of the workers was determined using single item 'are you male or female?' Workers' height and weight were objectively measured to determine their BMI ( $\text{kg}/\text{m}^2$ ). Smoking status was determined using a single item with response categories summarized to smokers (smoking daily or sometimes) and non-smokers (ex-smokers and never smoked). Occupational lifting and carrying duration was determined using a single item with 6 responses ranging from 'almost all the time' to 'never'(33). The information on workers' education and type of work was included as indicators of SES (41–43). The education of the workers was determined using a single item 'are you skilled or unskilled?' The information on type of work was

collected using single item 'are you a worker engaged in administrative work tasks [white collar] or in production [blue-collar]'. Later, the information on these two measures was summarized in three categories - white-collar, blue-collar skilled, and blue-collar unskilled.

## Statistical analyses

The statistical analyses were performed using R software (version [3.5.1]) using the software package 'robcompositions'(44) and 'survival'(45).

The data were analyzed in the CODA approach (46). First, the four-part time composition of work (MVPA, sedentary, standing, and LIPA) and five-part time composition of leisure (MVPA, sedentary, standing, LIPA, and time in bed) were expressed as isometric log-ratios (ilrs). The first ilr coordinate for the work and leisure composition represents time spent on MVPA relative to the geometric mean of remaining behaviors. In subsequent ilrs, the numerator of the first ilr was further split to create remaining ilrs (47)

The Cox proportional hazards regression model was then fitted by maximizing the partial likelihood function to the ilrs (i.e. the log-transformed work and leisure compositions) and the onset of LTSA (48). We censored 47 workers who were pregnant or going on maternity leave within 8 months during the study period, or either emigrated, became deceased, entered retirement or early retirement. The Cox regression model was adjusted for age, sex, BMI, smoking status, occupational lifting/carrying duration, and MVPA and other physical behaviors in the mutual domain (set of ilrs at work and leisure were entered together in the model). The assumptions of proportional hazards were met when tested by visual inspection and using the Grambsch-Therneau test (49). The model coefficient associated with ilrs were assessed using Wald test statistics (z) and associated significance (P), considering  $P < 0.05$  statistically significant.

Due to many missing in SES data (three categories: white-collar, blue-collar-skilled, and blue-collar-unskilled; missing = 118), we performed separate analyses to test if the main results were independent of SES. Therefore, we performed two separate analyses without and with additional adjustment for SES on 811 workers, who had data on SES. We also stratified the analyses on the three categories of SES.

## Effect size interpretation

To interpret the strength of the association, procedures explained in previous studies was used (33). First, sample compositional mean of all physical behaviours at work and leisure was calculated (Table 1). Based on the means, new work and leisure time compositions of MVPA and other behaviours were created by incrementally increasing/decreasing the time spent on MVPA and other behaviours while keeping the total time at work and leisure constant. Thereafter, the Cox parameter estimates were used to predict the difference in risk of LTSA expressed as a hazard ratio (HR) of the new work and leisure time compositions relative to the sample compositional mean. Finally, the predicted HRs associated with reallocating time between MVPA and remaining behaviours within work and leisure were plotted. The corresponding 95% CI of the differences in predicted HR are presented in Appendix A.

To test the combined association of relative MVPA at work and leisure and sickness absence, we stratified the population based on the tertiles (rounded to the closest bound) of the work MVPA. The Cox proportional hazards regression model, as explained above, was re-fitted separately on each of these sub-groups. Thereafter predicted new HRs corresponding to 20, 40, 60 minutes of relative MVPA at leisure were plotted for the sub-groups with low, moderate and high MVPA at work.

The sample size in this manuscript was derived from the a priori calculation made for the PODESA project. Based on a statistical significance of 0.05, LTSA prevalence of 20%, and an effect size corresponding to a 7% (or higher) change in HR per 10 minutes of MVPA, we require 850 workers for the analyses to achieve a statistical power of 80%.

## Results

Out of the 2,498 eligible participants, 929 (37%) workers had sufficient data to be involved in the analyses. A detailed flow chart is shown in Fig. 1.

Table 1 shows the descriptive of the workers involved in the analysis. The participants were on average 45 years old with a BMI of 27 kg/m<sup>2</sup>, 55% were men, and 30% smoked.

Table 1  
Descriptive of 929 workers involved in the analyses.

<b>Variables</b>	<b>N</b>	<b>Mean (SD)</b>	<b>%</b>
Age (years)	929	44.9 (9.7)	
Females	418		45
BMI (kg/m <sup>2</sup> )	929	27.1 (4.8)	
Non-smokers	646		70
White-collar	154		17
Occupational lifting/carrying duration (1–6) <sup>±</sup>	929	3.9 (1.5)	
Influence at work (0-100%)	929	60.7 (27.4)	
Social support at work (0-100%)	929	78.4 (16.3)	
SES			
White-collar	154		19
Blue-collar skilled	320		39
Blue-collar unskilled	337		42
Compositional means of time spent on physical behaviors (mins)			
Work			
MVPA	929	64	
Sedentary	929	176	
Standing	929	137	
LIPA	929	74	
Leisure			
MVPA	929	33	
Sedentary	929	311	
Standing	929	77	
LIPA	929	41	
Time in bed	929	429	
BMI = Body mass index, LIPA = Light physical activity, LTSA = Long-term sickness absence, MVPA = moderate to vigorous physical activity, LIPA = light physical activity; <sup>±</sup> 1 = almost all the time, 6 = never			

Of the 929 workers included in the analyses, 191 (21%) experienced LTSA in the 4-year follow-up. The average (median) time to an LTSA event was 94.3 (SD = 60.6) weeks. Forty-seven (5%) workers were censored over the 4-year follow-up period with an average follow-up time of 94.3 (SD = 59.5) weeks.

The results of the Cox proportional hazards models are shown in Appendix B. Specifically, more time spent on MVPA at work, relative to other work behaviors, was significantly positively associated ( $z = 2.27$ ,  $P = 0.02$ ) while more time spent on MVPA at leisure relative to other leisure behaviors was significantly negatively associated ( $z = -2.26$ ,  $P = 0.02$ ) with LTSA. Figure 2 shows that, for example, reallocating 20 minutes to MVPA at work from the remaining work behaviors was associated with  $\approx 15\%$  higher risk of LTSA while reallocating 20 minutes to MVPA at leisure from remaining leisure behaviors was associated with  $\approx 20\%$  lower risk of LTSA.

Figure 3 indicates the association of relative MVPA at leisure and risk for LTSA among those with low (0-40 minutes), moderate (>40-70 minutes) and high (>70 minutes) MVPA at work. We observed a significant dose-response relation between relative leisure time MVPA and LTSA with a reduction in LTSA risk for greater amount of leisure time MVPA but only in the low work MVPA tertile ( $P = 0.03$ ). In the high work MVPA tertile, the corresponding association was attenuated and not significant.

Results of the sensitivity analysis are shown in Appendix C. Adjusting for SES did not change the main results of the association between relative MVPA during both domains and LTSA (without adjusting for SES; work,  $z = 2.68$ ,  $P = 0.01$ , leisure,  $z = -2.02$ ,  $P = 0.04$ , with adjustment for SES; work,  $z = 2.73$ ,  $P = 0.01$ , leisure,  $z = -2.04$ ,  $P = 0.04$ ). Additionally, the direction of the estimates similar to the primary analysis when stratifying on the three categories of SES.

## Discussion

Our study showed that relative time spent on MVPA during leisure reduces the risk of LTSA while relative time spent on MVPA during work increases the risk. Beneficial association between MVPA at leisure and LTSA was only observed for the low work MVPA group. These results support the existence of the 'PA paradox'.

At leisure, more time spent on MVPA relative to other physical behaviors (sedentary, stand, LIPA and time in bed) was significantly associated with lower risk of LTSA ( $z = -2.26$ ,  $P = 0.02$ ). For example, reallocating 20 minutes to MVPA from other leisure behaviors was associated with 20% lower risk of LTSA. This observation of a beneficial association of PA at leisure with LTSA is in accordance with the results of existing studies using self-reported measures of PA (50) and not applying the CoDA approach (7). The potential mechanisms behind benefits of leisure time PA could be the increase of both improving health and physical capacity (51, 52), making the workers better perform their work tasks. Overall, we observed that reallocating just a little duration, say 5 minutes, to MVPA from other behaviours seem to lower risk of LTSA. Increasing a little duration of MVPA (defined as time spent fast walking, stair climbing, running, and cycling) could be feasible for many workers and can be facilitated by modifying the structural environment (eg, more bike lanes) or work environment (eg, work tasks offering restitution, likely giving

energy and motivation to workers to perform leisure MVPA (53)) making it more MVPA friendly for workers. A slight lowered risk for LTSA can have enormous effects on reducing economic costs for companies and the society, as well as for the individual since LTSA often leads to unemployment and further aggravation of health and life-situation crisis (54, 55).

At work, more time spent on MVPA relative to other physical behaviors was positively associated with LTSA ( $z = 2.27, P = 0.02$ ). For example, reallocating 20 minutes to work MVPA from other behaviors was associated with 15% higher LTSA risk. No previous studies on the association between work PA and LTSA have used technically measured PA, like accelerometers, and a CoDA approach with prospective register-based LTSA. Thus, we cannot directly compare the estimates of our study with previous studies (3, 7). Nevertheless, the overall finding of an increased risk for future LTSA with higher levels of work PA is in line with the some studies based on self-reports (3, 7). The potential mechanism behind our finding could be that work MVPA is influenced by different constraints and comprise different characteristics than leisure PA (56). Work PA is performed mainly to complete working tasks and compared with leisure, there is limited possibility of tailoring the duration, intensity, and variation of the PA according to the individual needs and preferences. Because of these constraints, the work PA can lead to excessive exertion and fatigue without sufficient possibility for recovery (57), which over time can increase risk of impaired health and LTSA (58, 59).

We also observed that our results were robust when the analyses were adjusted for SES indicators. Studies testing the PA paradox have been criticized for not adjusting for or removing the socioeconomic confounding (9). To address this limitation, we performed the analyses without and with adjustment for a proxy measure of SES (three categories: white-collar, blue-collar-skilled, and blue-collar-unskilled) and even stratified the analyses on these categories. We still observed the PA paradox even after these adjustments and stratifications based on SES, confirming that PA paradox exist independent of SES of workers.

When we stratified the workers in three groups, low, moderate and high work MVPA, the negative association between relative leisure MVPA and LTSA was clear among those with low work MVPA. This negative association was weak and non-significant among those with low and moderate work MVPA. These results show that leisure MVPA is of particular importance among those with low work MVPA, for example administrative workers or the drivers. Conversely, too much work MVPA time seem to reduce the beneficial effect of leisure MVPA.

## Strengths and limitations

The main strengths of the study are the thigh-worn accelerometry-based physical behaviors data, shown to be highly reliable and valid (32, 60). Another strength is the CoDA approach applied for the analyses of the study, handling the compositional structure of time-use data of PA (46, 61). Additionally, this study adjusted for remaining physical behaviors (sedentary behaviours, standing and LIPA and time in bed) within 24 hours. Another strength was the usage of national register data with valid prospective

measures of LTSA (37). Finally, the opportunity to remove/adjust for possible SES confounding when testing the PA paradox supports our main findings.

One limitation of the study is the relatively small study sample (n = 929) based on workplace recruitment, limiting generalizability of the results of the study to the general population. Thus, similar future studies should be conducted on larger and more representative working populations. We used proxy measure of education and type of work indicating workers' SES. Therefore, a better measure of SES confounding [such as data from national registers on household income, job group, and education (Statistics Denmark (62))] are needed in the future to confirm these findings. Similar future studies should also focus on testing the PA paradox in relation to other outcomes such as mortality.

## **Practical recommendations**

LTSA is an early precursor for impaired health with an extensive economic burden on workplaces and society (23, 24). Moreover, LTSA can have enormous consequences for the individual workers as LTSA is a strong predictor of premature exit from the labor market (19, 21) and mortality (63). Because PA at work and leisure are modifiable factors, the findings of the present study can be of importance for better prevention of LTSA with systemic interventions at both work and leisure environments.

## **Conclusion**

In conclusion, our study suggests that MVPA during leisure reduces the risk of LTSA, while MVPA during work increases the risk of LTSA. This finding supports the PA paradox.

## **List Of Abbreviations**

BMI Body mass index

CODA Compositional data analysis

DPhacto Danish Physical ACTivity cohort with Objective measurements

HR Hazard ratio

LIPA Light physical activity

LTSA Long-term sickness absence

MVPA Moderate to vigorous physical activity

NOMAD New method for Objective Measurements of physical Activity in Daily living

OPA Occupational physical activity

PA Physical activity

## Declarations

### Ethics approval and consent to participate and for publication

The PODESA study has been approved by the Danish Data Protection Agency (file number 2013-10-11/104); this approval includes the use of register data. The DPhacto cohort was approved by the Danish Data Protection Agency and the local Ethics Committee (file number H-2-2012-011)(64). The NOMAD cohort was approved by the Ethics Committee for the Capital Region of Denmark (file number H-2-2011-047)(27). All participants in the NOMAD and DPhacto studies received written and oral information about the projects, the practicalities of participating, potential risks of participating and having the possibility of withdrawal from the project without giving a specific reason with sufficient time for considerations of their participation. The persons agreeing to participate gave a written consent to participate in the study and the use of the data for research studies.

### Availability of data and materials

The fully anonymized data from the baseline in NOMAD and DPHACTO from each participant involved in the main analysis of this study are available in a Danish public repository DPhacto: (<http://dda.dk/catalogue/28618?lang=en>, NOMAD: <http://dda.dk/catalogue/28617?lang=en>).

The fully anonymized data on prospective long-term sickness absence is available upon request from statistics Denmark (A Central Authority on Danish Statistics)(62).

### Competing interests

The Danish Working Environment Research Fund had no role in study design, collection, analysis, data interpretation, manuscript writing, or decision to submit the manuscript for publication. The authors declare no conflicts of interest.

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### Authors' contributions

AH and MBJ were the principal investigators of the PODESA cohorts. AH acquired funding for this project. SDL and AH initiated the study. CLR performed the merging of the two cohorts, prepared the data to be uploaded on Denmark Statistik server. SVT contributed in defining the LTSA. AHO, SDL and NG wrote the first draft of the manuscript. NG with help from DM, CLR, SC, SDL, and AH completed the statistical analysis and wrote the final draft of the manuscript. All authors have edited, reviewed, and approved

drafts of this manuscript, including the final version. All authors take full responsibility for and have read and approved this final version of this manuscript.

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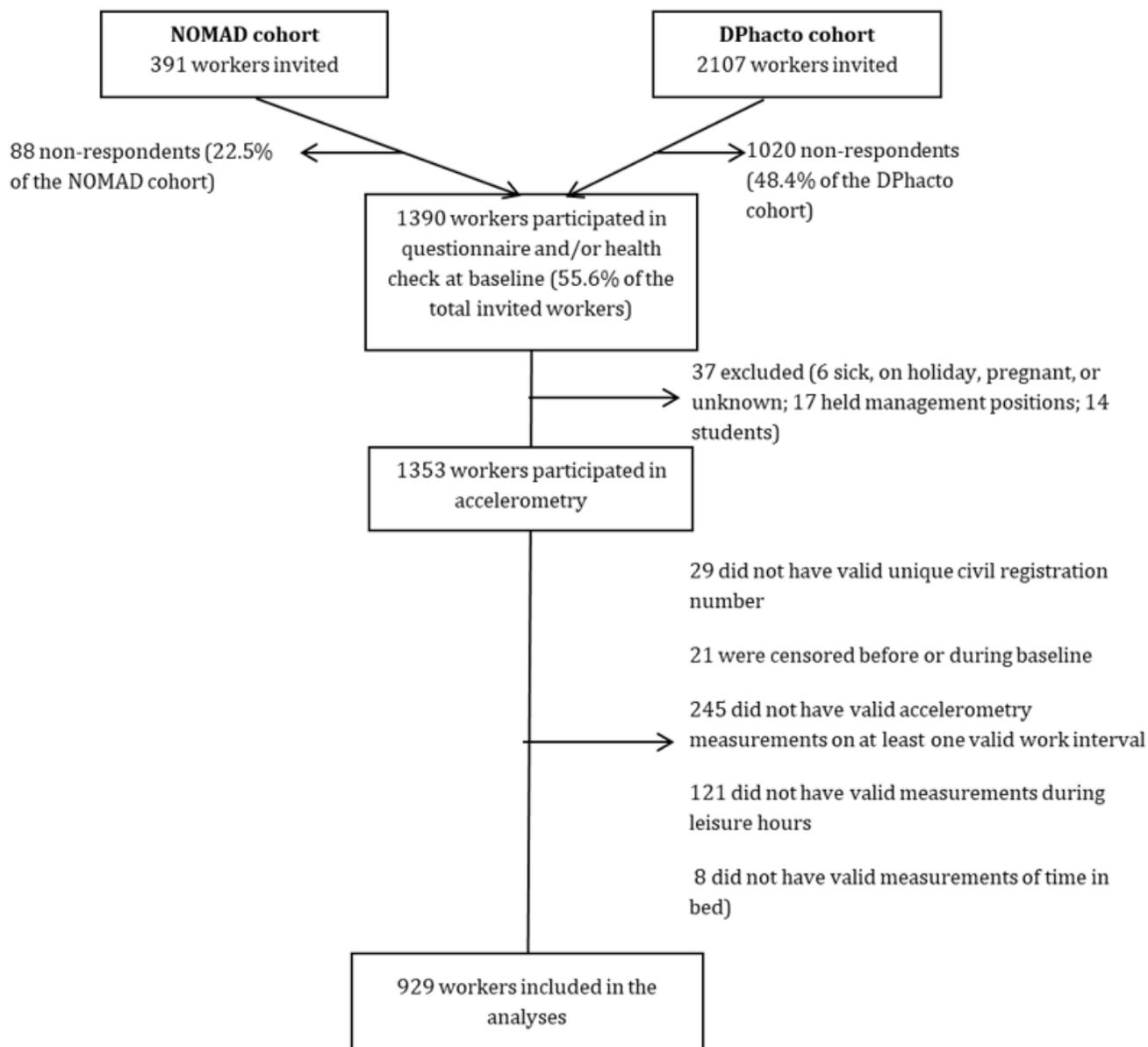
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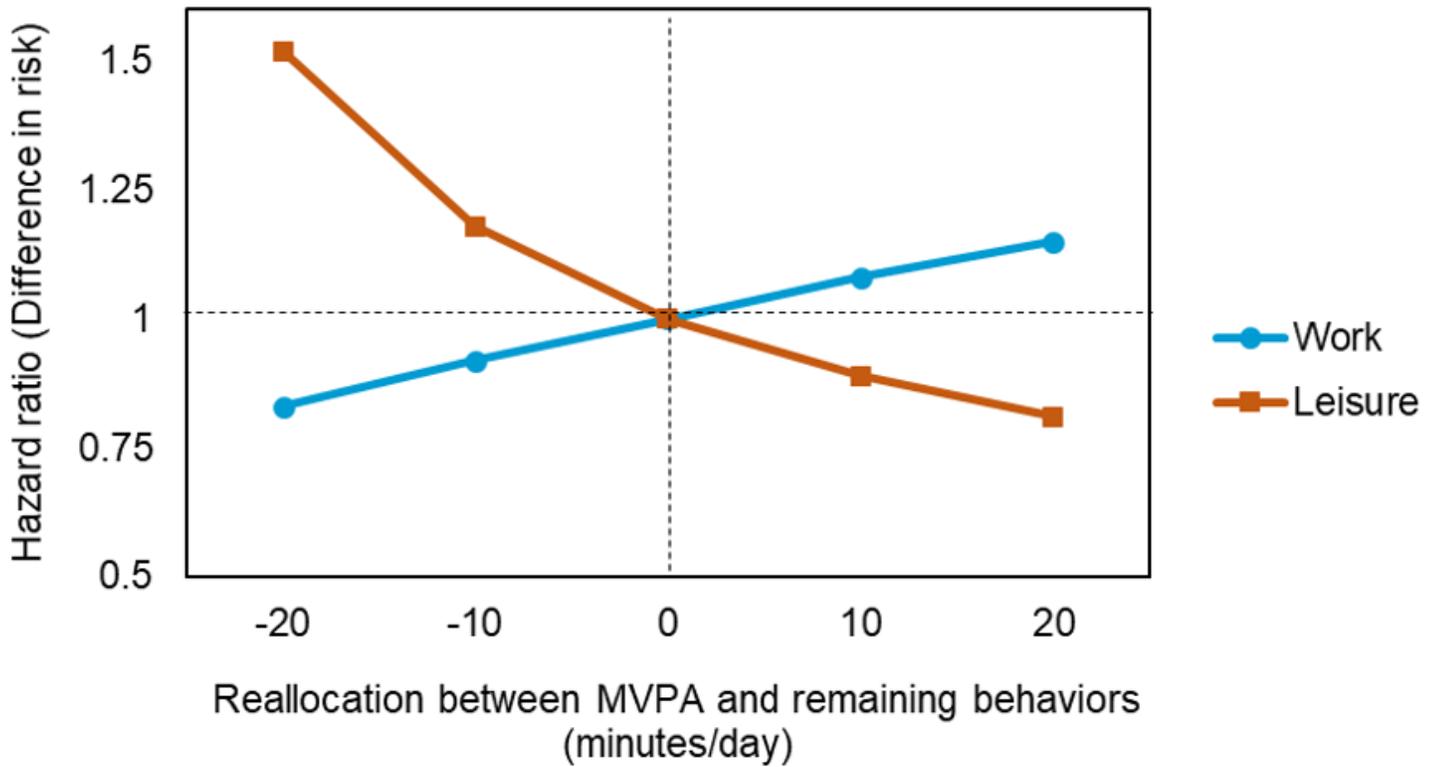
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## Figures



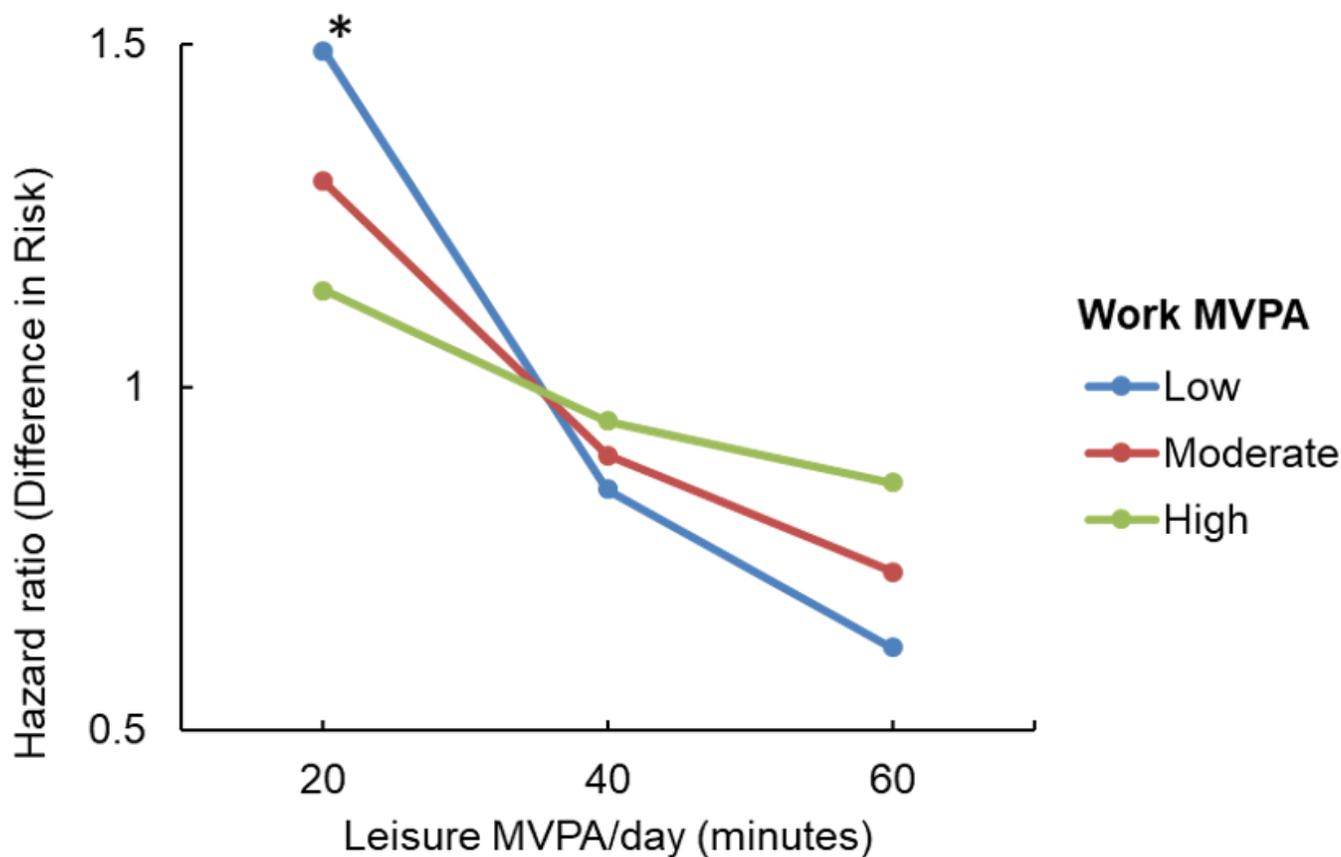
**Figure 1**

Flow of the participants in the study



**Figure 2**

Results of the Cox Proportional hazard ratio indicating the association between reallocating time between MVPA and remaining behaviors at work and leisure and risk of long-term sickness absence. '0' on the x axis represents the average composition (work: 64 minutes MVPA, 176 minutes sedentary, 137 standing and 74 minutes LIPA; leisure: 33 minutes MVPA, 311 minutes sedentary, 77 minutes standing, 41 minutes LIPA, and 429 minutes time in bed).



**Figure 3**

Results of the association between the relative MVPA at leisure and risk of the long-term sickness absence, stratified on the low (0-40 minutes), moderate (>40-70 minutes) and high (>70 minutes) MVPA at work. Hazard ratio of 1 corresponds to average composition of time spent on MVPA and other behaviors at leisure (33 minutes MVPA, 311 minutes sedentary, 77 minutes standing, 41 minutes LIPA, and 429 minutes time in bed). \*results were significant (P=0.03).

## Supplementary Files

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