The physical activity paradox: The main and interactive effects of occupational physical activity and leisure-time physical activity on physical and mental health

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The main and interactive effects of occupational physical activity and leisure-time physical activity on physical and mental health

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Abstract

Objective Recent research has found conflicting interactions between health and different domains of physical activity (PA). Occupational physical activity (OPA) seems to negatively impact health, whereas leisure-time physical activity (LTPA) positively impacts health, a phenomenon known as the physical activity paradox. What remains unclear is how these different domains of PA interact with each other and how their interaction influences health. Therefore, this study aims to investigate the main and interactive effects of OPA and LTPA on physical and mental health. A better understanding of these relations can contribute to more accurate PA advice, indirectly contributing to the closure of socioeconomic health inequalities. Based on previous studies, it was expected that higher OPA would relate to higher physical and mental health problems, while higher LTPA would relate to lower physical and mental health problems. Additionally, this study aimed to answer the research question whether LTPA functions as a buffer for the negative effects of high OPA on health or as an accelerator.

Methods To investigate the hypotheses and research question, data from a longitudinal panel study were used. Two data measurement points were used with a one-year time lag. The sample was heterogeneous and consisted of Dutch employees working ≥ 24-hours a week ($N = 1578$).

Results It was found that OPA and LTPA independently did not affect physical or mental health outcomes differently. Additionally, different combinations of OPA and LTPA did not lead to an increase or decrease in both physical mobility or mental health problems one year later. However, the results did show that individuals who had high levels of both OPA and LTPA had the highest chance on developing physical health problems one year later (b = 0.393, p = <0.001).

Conclusion This study shows that OPA and LTPA may have different effects on the development of physical health problems, like headache and sleeping problems. The findings suggest that the health benefits of LTPA are affected by the extent of OPA and that a combination of both high OPA and LTPA is the most unfavourable combination. This combination is associated with an increase in physical health problems. Theoretical and practical implications are discussed.

Layman's abstract

Objective Recent scientific studies show mixed results about the influence of different types of physical activity (PA) on health. Physical activity at work (OPA) seems to harm health, while physical activity during free time (LTPA) seems to improve health. This study looks into how these types of PA interact with each other and impact health. Understanding this interaction could help improve PA advice and reduce health inequalities. It was expected that more OPA would lead to more health problems, while more LTPA would lead to fewer health problems. The study also aimed to find out if LTPA could reduce the negative effects of high OPA on health, or if LTPA might make them worse.

Methods To investigate this, the study used data measured at two moments in time, one year apart. The study included 1,578 Dutch citizens, who worked at least 24 hours per week.

Results The study found that OPA and LTPA did not have different effects on physical or mental health. Next to that, different combinations of OPA and LTPA did not change the chances of developing physical mobility problems or mental health problems one year later. However, the study did find that a combination of high OPA and high LTPA increased the chances of developing physical health problems one year later.

Conclusion This study suggests that OPA and LTPA may affect physical health problems differently. Combining high levels of OPA and LTPA is linked to an increase in physical health problems, such as headaches or sleep issues.

Introduction

Physical activity (PA) is generally known to improve health. According to the World Health Organization (2022) PA refers to all movement within various life domains: leisure time, household activities, transportation, and work. WHO's definition implicates that all domains of PA are alike and beneficial for physical and mental health. However, research findings from the last decade question this claim.

Specifically, it appears that occupational physical activity (OPA) differs from leisure-time physical activity (LTPA) in its impact on physical and mental health, forming the foundation of the physical activity paradox (Holtermann, 2018). The idea is that OPA does not contribute to and can even damage one's physical and mental health, whereas LTPA improves it. There is a growing body of evidence that supports this idea (Hall et al., 2019; Karihtala et al., 2023; Wang et al., 2019). However, what remains unclear is if OPA and LTPA interact and - if so - how this interaction affects physical and mental health. In other words, what happens to an individuals' health when high or low levels of OPA are combined with either high or low levels of LTPA? Studies that looked at the interaction of OPA and LTPA and how it affects physical and mental health found contradictory results (Allesøe et al., 2015; Hallman et al., 2017; Holtermann et al., 2013). A clear answer to this question is not yet found, which will be the main objective of this study.

In the present study, the effect of OPA on LTPA and the main and interactive effects of OPA and LTPA on physical and mental health are investigated. This will contribute to the literature in three ways. First, it enhances understanding of the possible different effects of OPA and LTPA on mental health. Scientific evidence of the effects on physical health are widely published (Ketels et al., 2020; Holtermann et al., 2013; Clays et al., 2014), whereas the understanding of the effects on mental health is mainly based on general knowledge and common sense (De Vries & Bakker, 2022; Gallagher & Carr, 2021). This study will help determine if the physical activity paradox applies to mental health as well. Second, this study addresses the question whether engaging in LTPA is a wise choice when someone already performs higher levels of OPA. Specifically, does LTPA function as a buffer against detrimental effects of OPA or does it increase the detrimental effects of OPA on health? To date, most studies have investigated whether OPA and LTPA independently influence health outcomes, but seldom studied the interaction between OPA and LTPA. Hence, the present study investigates the interaction between OPA and LTPA on both physical and mental health. This knowledge could help to provide more tailored and nuanced PA advice for employees in various contexts. If LTPA works as an accelerator of the negative health effects, interventions should be aimed at improving the working conditions, increasing the available equipment and primarily focusing on organizational aspects. Conversely, if LTPA works as a buffer, interventions should aim to identify barriers and facilitators for individuals to engage in LTPA. Third, this study provides more clarity in whether individuals with high OPA, are more or less inclined to be physically active during leisure time. Understanding this relationship, along with the studied effects of LTPA and OPA on health, will teach us whether employees with high OPA should be actively stimulated to engage in LTPA. Using a longitudinal design with two time moments (T1 and T2), the study aims to provide the basis for more nuanced PA advice. This study could provide explanations for employees' PA patterns and better tools for targeted interventions. Furthermore, this knowledge could also indirectly contribute to the closure of the socioeconomic health gap, as more people with a low socioeconomic status have jobs including high OPA and are therefore more susceptible to health issues (Holtermann, 2022; Craike et al., 2019). Thus, the present study helps to understand how employees with high OPA could be supported in improving their physical and mental health.

Theoretical background

Definitions

OPA is generally defined as all physical activities performed during working hours. Previous research included both walking, running and standing as well as lifting, carrying, climbing and kneeling during worktime (Wang et al., 2019; Allesøe et al., 2015). In the present study, physical job demands serve as an indicator of OPA, referring to the physical aspects of a job that require sustained physical effort, cost considerable energy and bear the risk of being unhealthy (De Vries & Bakker, 2022). Thus, typically, these physical job demands constitute OPA, because they require effortful PA during worktime, such as lifting heavy objects, repetitive movements, and sustained exertion.

LTPA consists of all physical activities during leisure time, such as hiking, walking and biking. In this study, sport engagement serves as an indicator of LTPA, including activities like field hockey, fitness or rowing. Sport engagement does not reflect all forms of LTPA, but provides an indication of all planned, effortful and organised physical activity that is considered to contribute to health.

OPA influencing LTPA

Additionally, to the idea that LTPA and OPA impact health, exposure to high physical job demands can also reduce employees' engagement in LTPA. Häusser & Mojzisch (2017) provided an overview of empirical evidence and suggested mechanisms regarding the link between job demands, including high OPA, and LTPA. They suggested that self-regulatory fatigue and decreased motivation explain why high job demands negatively influence employees' engagement in LTPA. In other words, due to high job demands, an individuals' capacity to initiate and maintain effortful behaviours, is exceeded. Self-regulation is a limited source, resulting in fatigue and decreased motivation at the end of the workday, leading to less engagement in LTPA (Häusser & Mojzisch, 2017). Furthermore, previous studies found that high strain jobs (high demands and low job control) were associated with lower levels of self-reported LTPA (Kouvonen et al., 2005; Fransson et al., 2012) and that long working hours were also associated with less LTPA (Kirk & Rhodes, 2011). Lastly, Nakayama et al. (2024) found that adults working high-activity jobs were less likely to meet the Physical Activity Guidelines during leisure time than adults working in low-activity or medium-activity jobs.

Overall, research points to a negative relationship between OPA and LTPA. Therefore, I propose:

Hypothesis 1: OPA at T1 will negatively affect LTPA at T2, adjusting for LTPA at T1.

Physical activity paradox predicting physical and mental health

In the present study, the proposition that LTPA is beneficial and OPA is not beneficial for health is tested, which is suggested in the physical activity paradox (Holtermann, 2018). Holtermann proposed several explanations for the different observed effects of LTPA and OPA on cardiovascular health. It is, however, plausible that the same mechanisms play a role in other physical health outcomes as well, based on recent research (Gupta et al., 2020; Karihtala et al., 2023). Holtermann (2018) proposed the following explanations:

(1) OPA is of insufficient intensity or duration to maintain or improve physical fitness and physical health,
(2) OPA elevates 24-hour heart rate. Prolonged elevated heart rate can lead to arteriosclerosis (the arteries harden, which restricts blood flow to organs and tissues), which in turn is a risk factor for cardiovascular disease (CVD) and mortality (Korshøj et al., 2015),

(3) OPA including heavy lifting or static posture elevates 24-hour blood pressure, due to muscle contractions during manual material handling and prolonged static work. Prolonged elevated blood pressure is identified as an important CVD risk factor (Fuchs & Whelton, 2020),
(4) OPA is often performed without sufficient recovery time, leading to fatigue, exhaustion and increased risk of CVD,
(5) OPA frequently involves low worker control over work tasks, speed, protective clothing, stressors and the environment (e.g. sun, shade, hydration). This can lead to over exhaustion, increased heat stress, risk of fatal heart stroke and increased CVD risk (Holtermann et al., 2018),
(6) OPA increases levels of inflammation, which remain elevated until adequate recovery occurs. Prolonged inflammation can cause arteriosclerosis, which, as mentioned, is a risk factor for CVD (Korshøj et al., 2015; Holtermann, 2018).

OPA thus has a limited possibility of tailoring the duration, intensity and variation according to the individual needs and preferences. Consequently, OPA can lead to excessive exertion and fatigue, without adequate recovery time. Over time, this can lead to impaired health and long-term sickness absence (Gupta et al., 2020). In contrast, LTPA is characterized by high control over the physical activity dose and can be adjusted to individuals' needs. Gallagher & Carr (2021, p. 777) explain the paradox as follows: "…these characteristics [of OPA and LTPA] may result in differential physiological responses that contribute uniquely to long-term disease risk. OPA may result in wear and tear and increased systemic inflammation while LTPA may have the opposite effect: reducing inflammation and improving cardiovascular fitness."

Additional to the idea that OPA negatively influences physical health, OPA may also negatively affect mental health. Holtermann (2018) attributes these negative effects of OPA on mental health to the prolonged nature of physical demands during working hours and the absence of control over PA characteristics and breaks. The absence of control can result in failure to meet the physical demands (Schaufeli & Taris, 2014), causing feelings of frustration, annoyance, tension (Gyurak et al., 2011), emotional exhaustion and a tendency to mentally and physically withdraw from work (Boksem & Tops, 2008). Furthermore, PA of excessively high intensity can elevate cortisol levels, triggering an overreaction in the stress system, leading to increased stress and anxiety. Prolonged PA (> 30 min) can also result in fatigue and trigger withdrawal responses (Chan et al., 2019).

Conversely, LTPA can improve mental health through various mechanisms (Werneck et al., 2022). It has been proposed that LTPA reduces inflammatory cells (i.e. inflammation) (Holtermann, 2018; Werneck et al., 2022), while psychological distress is associated with increased inflammation. LTPA is also linked to lower cortisol levels, which are responsible for reported stress and anxiety, and enhanced hippocampal structure and functioning. A meta-analysis found that aerobic exercise led to retention of hippocampal volume in healthy older adults, thereby leading to conservation of cognitive functions (Firth et al., 2018). The last proposed mechanism entails that LTPA facilitates social connections and support networks (through team sports for example), improving psychological distress and well-being both directly and as stress buffers. Several possible mechanisms are proposed, including social influence, social comparison, social control, role-based purpose and meaning (mattering), self-esteem, sense of control, belonging and companionship, and perceived support availability (Thoits, 2011). Thus, whereas OPA reduces mental health, LTPA has many pathways to enhance it.

Empirical support for the main effects of OPA and LTPA on physical health

The aforementioned mechanisms of the physical activity paradox are increasingly supported by empirical findings. For instance, Ketels et al. (2020) demonstrated that OPA does not improve cardiorespiratory fitness (CRF), which is defined as "the ability of the cardiovascular and respiratory systems to supply oxygen to the muscles per kilogram of bodyweight" (Ketels et al., 2020, p.2). Using cross-sectional and accelerometer-assessed data, they found a positive association between moderate-to-vigorous LTPA and CRF, while no association was observed for moderate-to-vigorous OPA. Low CRF levels are related to various health-problems, such as CVD and all-cause mortality (Ketels et al., 2020). Previous studies also showed the different impacts of OPA and LTPA on CVD and all-cause mortality. LTPA showed beneficial impact and lower risk on these outcomes, whereas OPA did not show similar benefits (Holtermann et al., 2013; Clays et al., 2014).

In line with Holtermann's proposition (2018), research also identified other health problems following high OPA. A systematic review focusing on healthcare workers showed that OPA and LTPA differ in intensity, duration, and their influence on cardiovascular parameters (Janssen & Voelcker-Rehage, 2023). OPA also had a negative impact (in contrast to LTPA) on parameters like heart rate variability (Hallmann et al., 2017), need for recovery (Karihtala et al., 2023), cardiovascular diseases (Holtermann et al., 2013; Allesøe et al., 2015; Hall et al., 2019) and long-term sickness absence (Gupta et al., 2020).

In contrast, LTPA has been linked to many beneficial physical health outcomes, both in non-clinical and clinical populations (Gallagher & Carr, 2021; Bonekamp et al., 2023). Whereas OPA negatively affects or shows no influence on health outcomes such as heart rate variability (HRV, a physiological recovery marker. The higher the value of HRV, the stronger and more resilient the heart is), cardiovascular diseases, obesity and long-term sickness absence, LTPA improves them (Hallman et al., 2017; Holtermann et al., 2013; Petermann-Rocha et al., 2019; Gupta et al., 2020). Overall, empirical evidence suggests that OPA does not improve and may even damage physical health, while LTPA shows positive impacts on physical health.

Empirical support for the main effects of OPA and LTPA on mental health

In contrast to the extensive research on OPA and its effects on physical health outcomes, empirical studies on the relation between OPA and mental health remain scarce. De Vries & Bakker (2022) demonstrated a positive cross-sectional association between high physical demands at work and burnout symptoms. Furthermore, Gallagher & Carr (2021) found that LTPA positively influenced superior mood, whereas OPA did not. Finally, a meta-analysis by White et al. (2017) found that OPA was associated with mental ill-health.

In comparison, the same meta-analysis found that LTPA was positively associated with mental health and inversely associated with mental ill-health (White et al., 2017). These findings underscore the large body of evidence supporting the positive influence of LTPA on mental health. For example, higher LTPA is associated with positive affect and life satisfaction (Wiese et al., 2018), reduced risk of depression (Mikkelsen et al., 2010), lower feelings of exhaustion (Wolff et al., 2021), reduced risk of unhappiness after 2 years and 4 years (Wang et al., 2012) and lower psychological distress and higher psychological well-being (Werneck et al., 2022). Similar findings were done by Eather et al. (2023) in a systemic review. They found that participating in sports contributes to better mental health, including lower psychological ill-being (e.g. decreased levels of depression, anxiety and stress), increased psychological well-being (e.g. higher self-esteem and life-satisfaction) and improved social outcomes (e.g. improved self-control, pro-social behaviour, fostering a sense of belonging and interpersonal communication).

Given the aforementioned empirical findings regarding the main effects of OPA and LTPA on physical and mental health outcomes, I propose:

Hypothesis 2a: OPA at T1 will positively affect physical and mental health problems at T2, adjusting for physical and mental health problems at T1.

Hypothesis 2b: LTPA at T1 will negatively affect physical and mental health problems at T2, adjusting for physical and mental health problems at T1.

Interactive effects of OPA and LTPA on health outcomes

While the main effects of OPA and LTPA on physical and mental health are becoming clearer, there may also be interactive effects of OPA and LTPA on physical and mental health.

Contradictory findings are done regarding the interactive effects of OPA and LTPA on physical and mental health. Some propose that employees' LTPA should be tailored based on employees' OPA (see de Vries & Bakker, 2022). De Vries & Bakker (2022) suggest that high LTPA is not beneficial for burnout symptoms when OPA is already high, as the overall physical activity level is already too demanding. In other words, the psychophysiological stress system is active for too long, both during work and leisure time, leading to insufficient recovery time and quality, which can result in impaired health and sickness-absence (Gupta et al., 2020). Conversely, others suggest that high LTPA functions as a buffer against the detrimental health effects of OPA (Holtermann et al., 2013). For instance, individuals with good physical fitness, may cope with the demands at work more adequately, thereby experiencing the physical demands as less demanding and reducing the psychophysiological costs.

The interaction between OPA and LTPA remains under-researched and the empirical evidence on whether LTPA functions as a buffer or an accelerant remains mixed. Hallman et al. (2017) show that the combination of both high OPA and LTPA has a detrimental effect on resting heart rate and HRV. De Vries & Bakker (2022) found a stronger positive relationship between OPA and burnout among employees with high LTPA. Additionally, Allesøe et al. (2015) found a higher risk of ischaemic heart disease with high OPA levels, irrespective of the levels of LTPA, indicating that LTPA does not work as a buffer. Holtermann et al. (2013) found contradicting results, showing that high levels of LTPA decreases risk of all-cause mortality and cardiovascular mortality, independent from the levels of OPA.

To summarize, De Vries (2022), Hallman et al. (2017) and Allesøe et al. (2015) observed that LTPA is not able to counteract or buffer the negative effects OPA has on health, while Holtermann et al. (2013) showed that high LTPA leads to the highest survival benefit, irrespective of the levels of OPA. These findings are contradictory, which raises new questions. This suggests that the effects on physical and mental health depend on the extent to which one engages in both OPA and LTPA. Thus, it is not clear whether high LTPA functions as a potential buffer for high levels of OPA or as an accelerant (De Vries & Bakker, 2022). Given this unclarity, I aim to answer the following research question:

Research question 3: Do employees' OPA and LTPA have interactive effects on changes in physical and mental health?

Methods

Design

This study used a two-wave longitudinal design with a one-year time-lag, using data from wave 15 (2022) and wave 16 (2023) of the LISS panel (Longitudinal Internet studies for the Social Sciences), which is managed by the non-profit research institute Centerdata (Tilburg University, The Netherlands).

Procedure

The LISS panel collects data using online surveys (https://www.lissdata.nl/about-us). Annually, circa 7500 Dutch citizens complete online surveys, covering subjects like housing, work, education, leisure, background and personality. The sample is heterogenous in age, sex, gender and other demographic variables, and representative of the Dutch population. Participants are invited to participate and cannot self-register. When participants agree to participate, they receive a confirmation letter and access to the first questionnaire. When completed, participants have to read and agree to the LISS informed consent. They can only become a LISS panel member when they agree to the LISS informed consent. Households that are not able to participate due to the absence of a computer or internet are provided with the equipment. Monthly, the participants complete online questionnaires for which they receive a monetary incentive for each completed questionnaire (LISS panel, n.d.).

Participants

Participants (N = 1578; 20% of the original sample) were included in the current study if they were working (paid, unpaid or voluntary) ≥ 24 hours per week in 2022 (T1) and 2023 (T2). The final sample consisted of N = 1578 participants. Of this final sample, most participants were male (n = 851, 53.9%), the mean age was 53.86 (SD = 18.37) and the mean educational level was 'Post-secondary non-tertiary education'. All participants were Dutch citizens and worked (paid, unpaid or voluntary) at the time of the measurements.

Dropout analysis

A drop-out analysis was carried out to see if there was specific drop-out. T-tests (for age, OPA, LTPA, physical and mental health indicators) and Chi-square tests (for gender and educational level) were used to see if participants who were excluded on the basis of the inclusion criteria significantly differed from the participants who were included.

The t-tests showed that participants who were included in de data-analysis reported less OPA, LTPA and health problems than the participants who were excluded. They did not differ in age. Chi-square tests also showed that the participants differed in gender ($X^2 = 61{,}855$ (2), $p < 0.001$) and educational level ($X^2 = 519{,}497$ (27), $p < 0.001$). More males were included (26% of the males versus 18% of the females) and participants who were included were higher educated than the excluded participants.

Measures

OPA was measured by several questions in the online surveys: '[Is / Was] your work physically demanding?', '[Do / Did] you need to lift heavy objects?' and '[Do / Did] you need to kneel or stoop?'. Items could be answered on a 3-point scale from 1 (Often) to 3 (Never), which was rescaled to 1 (Never) – 3 (Often) and a mean was calculated so that higher mean scores would reflect higher OPA. These questions were self-developed by Centerdata, but largely mimic questions relating to physical job demands in the Karasek Job Content Questionnaire (Karasek, 1985), the TNO National Survey of Working Conditions (Van den Heuvel et al., 2023) and the VBBA 2.0 (SKB, 2014), which have been found reliable and valid. The Cronbach's alpha for the three items on T1 was 0.906 and on T2 was 0.901.

LTPA was measured by the question 'How many hours do you spend on sports per week, on average?'. The question could be answered by hours spent on sports, ranging from 0.0 (*min*) to 168.0 (*max*). LTPA is a continuous variable. Although sports might not reflect all physical activities that are performed during leisure time (e.g., walking the dog is not taken into account), it gave an indication to what extent one is moderately and vigorously physically active during leisure time, as discussed in the theoretical background.

Physical health was measured by two indicators. The 23-item Physical Health/Mobility Index (PHI) (Green & Young, 2001) captures problems with different activities in daily life. The items were introduced as follows: "Can you indicate, for each activity, whether you can perform it" and could be answered on a 5-point scale: 1 (without any trouble), 2 (with some trouble), 3 (with a lot of trouble), 4 (only with the help of others), 5 (not at all). A sum variable of the 23 items was calculated and a higher score reflected more physical mobility problems.

The Cronbach's alpha for the 23 items on T1 was 0.953 and on T2 was 0.950. Additionally, factual health problems were measured. Respondents were asked to select from a list of 11 possible health problems in response to the question 'Do you regularly suffer from the following diseases/problems. Participants could choose either 0 (no) or 1 (yes). A sum variable of the health problems was calculated, and a higher score reflected more physical health problems. The Cronbach's alpha for the 11 items on T1 was 0.680 and on T2 was 0.674.

Mental health was measured using the Revised Mental Health Inventory-5 (MHI-5) (Rivera-Riquelme, Piqueras & Cuijpers, 2019). The items were: 'I felt very anxious', 'I felt so down that nothing could cheer me up, 'I felt calm and peaceful', 'I felt depressed and gloomy' and 'I felt happy'. The items could be answered on a 6-point scale: 1 (never), 2 (seldom), 3 (sometimes), 4 (often), 5 (mostly) and 6 (continuously). The third item ('I felt calm and peaceful') and the fifth item ('I felt happy') are 'positively' framed and were thus rescaled to 1 (continuously) – 6 (never). The sum score of the five items was calculated and a higher score reflected more mental health problems. The Cronbach's alpha for the five items on T1 was 0.882 and on T2 was 0.874.

Control variables

Age, gender and educational level were included as control variables, due to their influence on physical and mental health (Hugh-Jones et al., 2023; The Lancet Public Health, 2020).

Statistical approach

Before the actual analyses, several assumptions were checked: linearity, homoscedasticity, multicollinearity, normality of residuals, and absence of extreme outliers. Linearity and homoscedasticity were checked using scatterplots plotting standardized residuals against unstandardized predicted values and the assumptions were met when the points are randomly scattered. The normality of residuals was checked by using a Normal Probability plot and was met when the plot of residuals is approximately linear. Multicollinearity were checked by inspecting the VIF. There is no multicollinearity if the VIF is lower than 10. Lastly, outliers were checked using boxplots. Variables were considered outliers if they were 3*SD* above or under the mean.

Hierarchical regression analyses were used to test all hypotheses and the research question. Three models were computed, separately for the two physical health components and mental health. The first model included the control variables (age, gender and educational level). The second model included the control variables and the outcome variable at baseline as a control variable. The third model included the control variables, the outcome variable at baseline as a control variable and the predictor variables (OPAT1, LTPAT1 or OPAxLTPAT1).

Results

Descriptive statistics

Table 1 shows the mean (*M*), standard deviation (*SD*) and correlation (*r*) of all outcome variables. Educational level has negative significant correlations with OPA at T1 and physical mobility problems at T1 and T2, meaning that employees with a lower educational level show higher OPA and more physical mobility problems. Additionally, educational level has positive significant correlations with mental health problems at T1 and T2, meaning that a higher educational level is related to more mental health problems.

What's notable, is that the correlations between outcome variables at T1 and T2 are significantly strong (e.g. physical mobility problems T1 and physical mobility problems T2). The correlation between LTPA at T1 and T2 is 0.67, between physical mobility problems 0.92, between physical health problems 0.87 and between mental health problems 0.70, meaning that there is high stability in the assessed health outcomes over the one-year period.

Assumptions

In all the analyses the assumptions of multicollinearity and extreme outliers were met. Due to the violation of the assumption's normality, linearity and homoscedasticity in the sample, the variables were transformed into log-variables. Thereupon, the analyses were carried out as planned.

OPA predicting LTPA

See Table 2 for the results of testing Hypothesis 1 (OPA at T1 negatively influences LTPA at T2). The first model showed that the control variables minimally affect the variance in LTPA; gender, age and educational level were not related to LTPA. Adding LTPA at T1 in the second model significantly improved the prediction of LTPA at T2, explaining nearly half of the variance in LTPA at T2 (β = 0.681). However, including OPA at T1 in the third model did not improve the prediction of LTPA at T2 (β = 0.04). Thus, as OPA at T1 was not related to LTPA at T2, Hypothesis 1 is not supported.

Table 1

Correlation table

		M (SD)	1	2	3	4	5	6	7	8	9	10	11	12
1.	Gender	n/a												
2.	Age	n/a	-0.009											
3.	Educational level	n/a	-0.131***	-0.033										
4.	OPA T1	1.55 (0.65)	-0.048	0.007	-0.323***									
5.	LTPA T1	2.20 (2.45)	-0.098**	-0.016	-0.013	0.038								
6.	LTPA T2	2.12 (2.40)	-0.062	-0.036	-0.019	0.022	0.669***							
7.	OPA x LTPA T1	3.26 (4.30)	-0.007	-0.038	-0.201***	0.850***	0.396***	0.271***						
8.	Physical mobility problems T1	25.3 (3.66)	0.125***	-0.007	-0.118***	0.141***	-0.025	-0.087*	0.067*					
9.	Physical mobility problems T2	25.5 (3.87)	0.141***	-0.021	-0.118***	0.154***	-0.028	-0.107**	0.063*	0.919***				
10.	Physical health problems T1	1.38 (1.58)	0.095**	-0.014	-0.043	0.017	-0.061	-0.094*	-0.046	0.364***	0.353***			
11.	Physical health problems T2	1.45 (1.66)	0.127***	-0.031	-0.044	0.047	-0.033	-0.048	0.023	0.335***	0.359***	0.867***		
12.	Mental health problems T1	10.9 (3.58)	0.104**	-0.013	0.061*	0.045	-0.041	-0.047	-0.010	0.238***	0.218***	0.300***	0.286***	
13.	Mental health problems T2	10.8 (3.59)	0.081**	-0.020	0.073**	0.033	-0.002	-0.050	-0.004	0.213***	0.228***	0.305***	0.321***	0.699***

*$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

Table 2

Hierarchical regression models predicting LTPA at T2 from OPA at T1

	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	1.177	0.247	<0.001	0.126	0.199	0.527	0.066	0.215	0.759
Gender	-0.112	0.078	0.151	0.056	0.059	0.344	0.058	0.059	0.333
Age	-0.001	0.002	0.566	-0.001	0.002	0.524	-0.001	0.002	0.580
Educational level	0.012	0.009	0.162	0.011	0.007	0.082	0.013	0.007	0.059
LTPA T1				0.682	0.051	<0.001	0.680	0.051	<0.001
OPA T1							0.063	0.083	0.450
F	1.524			47.629			38.144		
R^2	0.20			0.463			0.464		
Adjusted R^2	0.007			0.453			0.452		
$\Delta R2$	0.20			0.443			0.001		

OPA predicting more health problems

OPA and physical mobility problems

See Table 3 for the results of testing Hypothesis 2a (OPA at T1 will positively affect physical mobility problems at T2, adjusting for physical mobility problems at T1). The first model showed that the control variables account for a small amount of variance in physical mobility problems; gender (β = 0.152) and educational level (β = -0.154) significantly predict physical mobility problems. This indicates that women and lower-educated participants tend to experience more physical mobility problems. Age was not related to physical mobility problems. Adding physical mobility problems at T1 in the second model significantly improved the prediction of physical mobility problems at T2, explaining nearly three quarters of the variance in physical mobility problems at T2 (β = 0.879). However, adding OPA at T1 in the third model did not improve the prediction of physical mobility problems at T2 (β = 0.024). Thus, as OPA at T1 was not related to more physical mobility problems at T2, Hypothesis 2a regarding physical mobility problems is not supported.

OPA and physical health problems

See Table 4 for the results of testing Hypothesis 2a (OPA at T1 will positively affect physical health problems at T2, adjusting for physical health problems at T1). The first model showed that the control variables minimally affect physical health problems; none of the control variables are a significant predictor of physical health problems at T2. Adding physical health problems at T1 in the second model, significantly improved the prediction of physical health problems at T2. Almost three quarters of the variance in physical health problems at T2 was

Table 3

Hierarchical regression models predicting physical mobility problems at T2 from OPA at T1

Physical mobility problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	3.239	0.032	<0.001	0.218	0.075	0.004	0.218	0.075	0.004
Gender	0.042	0.012	<0.001	0.011	0.006	0.059	0.011	0.006	0.051
Age	<-0.001	0.000	0.880	0.000	0.000	0.300	0.000	0.000	0.286
Educational level	-0.004	0.001	<0.001	-0.001	0.001	0.271	0.000	0.001	0.484
Physical mobility problems T1				0.934	0.023	<0.001	0.932	0.023	<0.001
OPA T1							0.008	0.008	0.218
F	7.029			448.291			358.99		
R^2	0.042			0.787			0.788		
Adjusted R^2	0.036			0.786			0.786		
$\Delta R2$	0.042			0.746			0.001		

Table 4

Hierarchical regression models predicting physical health problems at T2 from OPA at T1

Physical health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	0.601	0.191	0.002	0.210	0.099	0.035	0.153	0.105	0.147
Gender	0.135	0.075	0.072	0.004	0.039	0.920	0.002	0.038	0.958
Age	0.001	0.002	0.704	-0.001	0.001	0.490	-0.001	0.001	0.423
Educational level	-0.007	0.007	0.270	-0.003	0.003	0.459	-0.001	0.004	0.877
Physical health problems T1				0.879	0.031	<0.001	0.879	0.031	<0.001
OPA T1							0.077	0.031	0.119
F	1.340			206.425			166.465		
R^2	0.014			0.742			0.744		
Adjusted R^2	0.003			0.738			0.740		
$\Delta R2$	0.014			0.728			0.002		

explained by physical health problems at T1 (β = 0.861). However, adding OPA at T1 in the third model did not improve the prediction of physical health problems at T2 (β = 0.050). Thus, as OPA at T1 was not related to physical health problems at T2, Hypothesis 2a regarding physical health problems is not supported.

OPA and mental health problems

See Table 5 for the results of testing Hypothesis 2a (OPA at T1 will positively affect mental health problems at T2, adjusting for mental health problems at T1). The first model showed that the control variables minimally affect mental health problems; none of the control variables appear to be a significant indicator of mental health problems at T2. Adding mental health problems at T1 in the second model significantly improved the prediction of mental health problems at T2, explaining more than half of the variance in mental health problems (β = 0.694).

Table 5

Hierarchical regression models predicting mental health problems at T2 from OPA at T1

Mental health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	9.798	0.860	<0.001	2.867	0.700	<0.001	2.572	0.739	<0.001
Gender	0.407	0.333	0.222	0.057	0.241	0.812	0.074	0.241	0.760
Age	-0.001	0.009	0.951	-0.003	0.006	0.637	-0.003	0.006	0.617
Educational level	0.024	0.030	0.420	0.017	0.022	0.432	0.026	0.023	0.253
Mental health problems T1				0.707	0.033	<0.001	0.705	0.033	<0.001
OPA T1							0.389	0.314	0.215
F	0.801			114.397			91.928		
R^2	0.005			0.484			0.486		
Adjusted R^2	-0.001			0.480			0.480		
$\Delta R2$	0.005			0.479			0.002		

However, adding OPA at T1 in the third model, did not improve the prediction of mental health problems at T2 ($\beta = 0.043$). Thus, as OPA at T1 was not related to mental health problems at T2, Hypothesis 2a regarding mental health problems is not supported.

LTPA predicting less health problems

LTPA and physical mobility problems

See Table 6 for the results of testing Hypothesis 2b (LTPA at T1 will negatively affect physical mobility problems at T2, adjusting for physical mobility problems at T1). The first model showed that the control variables minimally affect physical mobility problems; none of the control variables appear to be a significant indicator of physical mobility problems at T2. Adding physical mobility problems at T1 in the second model significantly improved the prediction of physical mobility problems at T2, explaining nearly three quarters of the variance in physical mobility problems at T2 ($\beta = 0.832$). However, adding LTPA at T1 in the third model did not improve the prediction of physical mobility problems at T2 ($\beta = -0.024$). Thus, as LTPA at T1 was not related to physical mobility problems at T2, Hypothesis 2b regarding physical mobility problems is not supported.

LTPA and physical health problems

See Table 7 for the results of testing Hypothesis 2b (LTPA at T1 will negatively affect physical health problems at T2, adjusting for physical health problems at T1). The first model showed that the control variables minimally affect the variance in physical health problems; none of the control variables appear to be a significant indicator of physical health problems at T2. Adding physical health problems at T1 in the second model significantly improved the prediction of physical health problems at T2; explaining nearly three quarters of the variance in physical health problems at T2 ($\beta = 0.862$). However, adding LTPA at T1 in the third model did not improve the prediction of physical health problems at T2 ($\beta = 0.052$). Thus, as LTPA at T1 was not related to physical health problems at T2, Hypothesis 2b regarding physical health problems is not supported.

Table 6

Hierarchical regression models predicting physical mobility problems at T2 from LTPA at T1

Physical mobility problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	3.192	0.043	<0.001	0.439	0.115	<0.001	0.439	0.116	<0.001
Gender	0.037	0.014	0.011	0.014	0.008	0.091	0.013	0.008	0.121
Age	0.000	0.000	0.510	0.000	0.000	0.461	0.000	0.000	0.489
Educational level	-0.002	0.002	0.115	0.000	0.001	0.694	0.000	0.001	0.679
Physical mobility problems T1				0.852	0.035	<0.001	0.854	0.035	<0.001
LTPA T1							-0.005	0.007	0.486
F	3.095			156.349			124.932		
R^2	0.034			0.705			0.705		
Adjusted R^2	0.023			0.700			0.700		
$\Delta R2$	0.034			0.671			0.001		

Table 7

Hierarchical regression models predicting physical health problems at T2 from LTPA at T1

Physical health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	0.271	0.309	0.383	-0.100	0.154	0.517	-0.190	0.169	0.264
Gender	0.193	0.103	0.062	0.095	0.051	0.065	0.103	0.051	0.046
Age	0.001	0.003	0.789	0.000	0.001	0.800	0.000	0.001	0.880
Educational level	0.005	0.011	0.614	0.004	0.005	0.406	0.005	0.005	0.357
Physical health problems T1				0.887	0.042	<0.001	0.884	0.042	<0.001
LTPA T1							0.055	0.044	0.207
F	1.346			114.377			92.214		
R^2	0.027			0.763			0.766		
Adjusted R^2	0.007			0.756			0.758		
$\Delta R2$	0.027			0.736			0.003		

LTPA and mental health problems

See Table 8 for the results of testing Hypothesis 2b (LTPA at T1 will negatively affect mental health problems at T2, adjusting for mental health problems at T1). The first model showed that the control variables minimally affect health problems; none of the control variables appear to be a significant indicator of mental health problems at T2. Adding mental health problems at T1 in the second model significantly improved the prediction of mental health problems at T2, explaining nearly half of the variance in mental health problems at T2 (β = 0.693). However, adding LTPA at T1 in the third model did not improve the prediction of mental health problems at T2 (β = -0.036). Thus, as LTPA at T1 was not related to mental health problems at T2, Hypothesis 2b regarding mental health problems is not supported.

Table 8

Hierarchical regression models predicting mental health problems at T2 from LTPA at T1

Mental health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	10.165	1.330	<0.001	3.319	1.062	0.002	3.670	1.149	0.002
Gender	0.483	0.444	0.278	-0.091	0.324	0.779	-0.128	0.328	0.696
Age	0.007	0.012	0.579	0.002	0.009	0.852	0.001	0.009	0.886
Educational level	-0.017	0.047	0.722	-0.007	0.034	0.840	-0.006	0.034	0.853
Mental health problems T1				0.713	0.046	<0.001	0.711	0.046	<0.001
LTPA T1							-0.219	0.272	0.422
F	0.522			60.239			48.255		
R^2	0.006			0.479			0.480		
Adjusted R^2	-0.005			0.471			0.470		
$\Delta R2$	0.006			0.473			0.001		

Interaction of OPA and LTPA predicting health problems

OPAxLTPA and physical mobility problems

See Table 9 for the results of testing research question 3 (Do employees' OPA and LTPA have interactive effects on changes in physical mobility problems?). The first model showed that the control variables minimally affect physical mobility problems; none of the control variables appear to be a significant indicator of physical mobility problems at T2. Adding physical mobility problems at T1 in the second model significantly improved the prediction of physical mobility problems at T2, explaining nearly three quarters of the variance in physical mobility problems at T2 ($\beta = 0.839$). However, adding OPA T1, LTPA T1 and the interaction between OPA and LTPA T1 in the third model did not improve the prediction of physical mobility problems at T2 ($\beta = 0.063$, $p = 0.470$). This means that there are no interactive effects of OPA and LTPA on physical mobility problems.

OPAxLTPA and physical health problems

See Table 10 for the results of testing research question 3 (Do employees' OPA and LTPA have interactive effects on changes in physical health problems?). The first model showed that the control variables minimally affect physical health problems; none of the control variables appear to be a significant indicator of physical health problems at T2. Adding physical health problems at T1 in the second model significantly improved the prediction of physical health problems at T2, explaining more than three quarters of the variance in physical health problems at T2 ($\beta = 0.861$). In the third model, OPA T1, LTPA T1 and OPAxLTPA T1 were added to the regression models, which also lead to an improvement of the model. Results revealed that the interaction term OPAxLTPAT1 (β = 0.357, p = <0.001) was a significant predictor of physical health problems at T2.

Simple slope test showed that for 1 *SD* below the mean of LTPA, the relationship between OPA at T1 and physical health problems at T2 was negative (b = -0.487, t = -2.970, p = 0.003). Additionally, simple slope test showed that for 1 *SD* above the mean of LTPA the relationship between OPA at T1 and physical health problems at T2 was positive (b = 1.438, t = 2.887, p = 0.004). This means that at higher levels of LTPA, OPA is related to an unfavourable change in physical health problems (i.e., more physical health problems) from T1 to T2. Engaging in LTPA is thus not beneficial for employees higher in OPA regarding their physical health problems.

Table 9

Hierarchical regression models predicting physical mobility problems at T2 from OPAxLTPA at T1

Physical mobility problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	3.189	0.044	<0.001	0.357	0.116	0.002	0.359	0.117	0.002
Gender	0.035	0.015	0.017	0.015	0.008	0.063	0.014	0.008	0.095
Age	0.000	0.000	0.387	<0.001	0.000	0.642	0.000	0.000	0.576
Educational level	-0.002	0.002	0.119	0.000	0.001	0.641	0.000	0.001	0.607
Physical mobility problems T1				0.878	0.035	<0.001	0.880	0.036	<0.001
OPA T1							-0.012	0.026	0.640
LTPA T1							-0.008	0.008	0.314
OPAxLTPA T1							0.013	0.018	0.470
F	2.908			162.507			92.371		
R^2	0.033			0.716			0.717		
Adjusted R^2	0.021			0.711			0.709		
Δ*R2*	0.033			0.683			0.001		

Table 10

Hierarchical regression models predicting physical health problems at T2 from OPAxLTPA at T1

Physical health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	0.245	0.311	0.432	-0.096	0.156	0.538	-0.165	0.180	0.360
Gender	0.180	0.104	0.085	0.097	0.052	0.065	0.097	0.051	0.058
Age	0.001	0.003	0.623	0.000	0.001	0.726	0.001	0.001	0.596
Educational level	0.006	0.011	0.610	0.004	0.005	0.415	0.006	0.006	0.307
Physical health problems T1				0.891	0.043	<0.001	0.905	0.042	<0.001
OPA T1							-0.389	0.152	0.320
LTPA T1							-0.052	0.053	0.011
OPAxLTPA T1							0.393	0.114	<0.001
F	1.195			110.036			70.446		
R^2	0.025			0.760			0.784		
Adjusted R^2	0.004			0.753			0.773		
Δ*R2*	0.025			0.735			0.024		

OPAxLTPA and mental health problems

See Table 11 for the results of testing research question 3 (Do employees' OPA and LTPA have interactive effects on changes in mental health?). The first model showed that the control variables minimally affect mental health problems; none of the control variables appear to be a significant indicator of mental health problems at T2. Adding mental health problems at T1 in the second model significantly improved the prediction of mental health problems at T2, explaining more than half of the variance in mental health problems at T2 ($\beta = 0.695$). However, adding OPA T1, LTPA T1 and OPAxLTPA T1 in the third model did not improve the prediction of mental health at T2 ($\beta = -0.010$, $p = 0.934$). This means that there are no interactive effects of OPA and LTPA on mental health problems.

Table 11

Hierarchical regression models predicting mental health problems at T2 from OPAxLTPA at T1

Mental health problems	Model 1			Model 2			Model 3		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Constant	10.089	1.329	<0.001	3.212	1.059	0.003	3.087	1.232	0.013
Gender	0.398	0.446	0.373	-0.104	0.324	0.748	-0.150	0.328	0.648
Age	0.010	0.012	0.415	0.002	0.009	0.810	0.003	0.009	0.753
Educational level	-0.017	0.047	0.716	-0.008	0.034	0.815	0.010	0.037	0.782
Mental health problems T1				0.724	0.047	<0.001	0.718	0.047	<0.001
OPA T1							0.691	1.042	0.397
LTPA T1							-0.282	0.332	0.508
OPAxLTPA T1							-0.062	0.745	0.934
F	0.514			60.246			34.784		
R^2	0.006			0.483			0.488		
Adjusted R^2	-0.006			0.475			0.474		
$\Delta R2$	0.006			0.477			0.006		

Discussion

The primary goal of this study was to shine more light on the main and interactive effects of OPA and LTPA on each other and on health outcomes. No evidence was found that OPA predicted less LTPA one year later. Additionally, neither OPA nor LTPA predicted more physical and mental health problems one year later. Concerning the interaction of OPA and LTPA, there was no evidence found that certain combinations affected physical mobility problems and mental health problems one year later. Thus it did not matter for the individuals' physical mobility or mental health problems whether they had high levels of OPA combined with either low or high levels of LTPA. The study did observe an effect of the interaction between OPA and

LTPA on physical health problems one year later. Specifically, high levels of both OPA and LTPA were found to be the most detrimental combination for developing physical health problems.

Thus, levels of OPA (i.e., physical job demands) were unrelated to employees' LTPA. This finding contradicts previous research suggesting that job demands predict the amount of LTPA employees engage in (Häusser & Mojzisch, 2017; Nakayama et al., 2024; Kouvonen et al., 2005). Nevertheless, the empirical evidence for this relationship remains mixed. It may be possible that OPA, when combined with other job characteristics, affects the amount of LTPA. A study identified that, in addition to high OPA, also shiftwork, nightwork and job insecurity decreased LTPA (Mutz, Abdel Hadi & Häusser, 2020). This would mean that, instead of OPA alone, rather OPA combined with shiftwork or long working hours would unfavourably impact LTPA. However, OPA in combination with favourable job characteristics, like autonomy, could buffer the negative impact of OPA on LTPA. Since OPA was studied in isolation, potential interactive effects of job characteristics – which could counteract each other, resulting in a null-finding – remain unknown. Future research should consider examining the combinations of different job demands and their influence on LTPA. Another explanation for the lack of association between of OPA and changes in LTPA is that sports participation functioned as an indicator of LTPA. Many individuals play organized (team) sports, which means that social influences or the organized format influence sport participation. For instance, individuals make agreements within the sports team to train twice a week, which creates a higher threshold for cancelling participation. Thus, by using sports participation as an indicator of LTPA, fatigue and failed self-regulation potentially play a smaller role than looking at all forms of LTPA. In addition, it is also possible that individuals' total LTPA duration does not change, but rather the nature of the LTPA changes. For instance, individuals who are tired from work might choose to go for a walk instead of going to the gym, which is not adequately captured by sports duration alone.

Furthermore, it was hypothesized that higher levels of OPA would lead to more physical and mental health problems. However, there was no effect of OPA on all indicators of physical and mental health, which contradicts previous empirical findings (Holtermann et al., 2013; Karithala et al., 2023; Gallagher & Carr, 2021; White et al., 2017). It also contradicts the assumed working mechanisms, describing how excessive exertion and fatigue negatively impacts the duration and quality of an individual's recovery time, harming one's physical health (Gupta et al., 2020) and how due to the lack of control and prolonged nature of OPA, one can develop feelings of frustration, annoyance, emotional exhaustion and withdrawal (Holtermann, 2018; Gyurak et al., 2011; Boksem & Tops, 2008). An explanation why OPA was unrelated to health, is perhaps because this study only measured lifting and kneeling as an indicator of OPA. The study did not assess the duration and intensity of the physically demanding activities at work. That is, there was no insight into activities such as standing, walking or climbing the stairs. Even though these activities can be perceived as an easy and light form of PA, these can be exhausting when performed for extended periods. Prolonged standing, for example, can have adverse effects on health outcomes, like lower back pain, cardiovascular problems and fatigue (Waters & Dick, 2015). Besides the substantive explanations, the unexpected results could be attributed to the one-year time-lag used in this study. Perhaps OPA is more likely to have an accumulative effect on health outcomes and require more time than one year to see adverse outcomes. Longitudinal research preferably has a time lag that corresponds to the time it takes for the cause to lead to an effect (Taris & Kompier, 2014). It was shown that PA behaviour and health remained quite stable over one year (as is reflected by across-time correlations ranging from 0.669 to 0.919), explaining a significant portion of the variance in the models. This means that previous behaviour and health are the strongest predictors for future behaviours and health. Previous research investigating the effects of OPA on the development of various medical conditions used time lags varying from 4 years (Gupta et al., 2020) to 22.4 years (Holtermann et al., 2013) and in between (Allesøe et al., 2015; Bonekamp et al., 2023). Thus probably, profound chances in physical or mental health problems, like depression, high cholesterol or heart complaints, may need more time than one year to really be significant. Research showed the ideal time lag for a longitudinal study is 2-year (Taris & Kompier, 2003). However, shorter intervals (i.e., weeks or months) also have the benefit to reveal the across-time development of the process of the researched variables (Taris & Kompier, 2003). It is thus important that future longitudinal research takes the correct time lag into account. Based on aforementioned research, it may be relevant to obtain measurement in a more frequent time interval, but for a longer time period than one year. This way, more insight in the across-time development of physical and mental health (problems) can be obtained.

It was also hypothesized that higher levels of LTPA would lead to fewer physical and mental health problems. However, there was no effect of LTPA on all indicators of physical and mental health. Similar to OPA, it is possible that the one-year timeframe in this study was insufficient to detect changes in physical and mental health outcomes. Another explanation could be that this study did not assess the intensity of the performed PA. On average, participants engaged in 2.2 hours of LTPA per week, which may have predominantly consisted of light PA (LIPA). Previous research found that LIPA has mixed and limited effects on mental health outcomes (Felez-Nobrega et al., 2021). However, other research found that LIPA did have an effect on health, even after adjustment for moderate- to vigorous PA (MVPA). These findings indicate that it remains unclear whether various PA intensities affect health differently and what could be beneficial for health improvements. In addition, muscle and bone strengthening exercises, recommended at least twice a week for health maintenance and improvement (RIVM, 2020), were not considered in this study and may not have been met by the sample.

The research question contained investigating the effects of the interaction of OPA and LTPA on physical and mental health problems. Would LTPA work as a buffer or as an accelerator on the negative effects from OPA on physical and mental health? Evidence was found that the interaction of OPA and LTPA predicted more physical health problems one year later. The combination of high OPA and high LTPA appeared to be the most detrimental combination for the development of physical health problems one year later. This indicates that LTPA does not generate a buffering effect when combined with high OPA, but rather an accelerating effect. This finding aligns with previous studies, reporting negative effects on resting heart rate and HRV, burnout symptoms and risks of ischaemic heart disease (Hallman et al., 2017; De Vries & Bakker, 2022; Allesøe et al., 2015). Insufficient recovery may be the underlying mechanisms of this phenomenon, overstressing the psychophysiological system and potentially resulting in impaired health and sickness-absence (Gupta et al., 2020).

However, no evidence was found regarding the effects of the interaction on physical mobility problems and mental health problems. An explanation could be that physical mobility problems, such as carrying groceries, tying your shoes and making a phone call takes a longer time than one year to emerge. Due to the accessible nature of the activities, even the majority of individuals with poor(er) health could perform them. The development of mobility issues is a prolonged and gradual process, which is often being caused by aging and chronic diseases (Grimmer et al., 2019). This differs from other indicator of physical health, namely physical health problems, like headache, heart complaints and high blood pressure, which can be developed within a shorter period of time. Headache, for example, can be developed within a period of 24 hours by causes such as dehydration, lack of sleep and stress (Rizzoli & Mullally, 2018). A possible explanation for the lack of observed effects regarding mental health, may be due to individual perceptions of PA. For some, PA provides relaxation and distraction, while for others, PA can be stressful. This variation in experience may explain why no consistent differences are found in studies (Chen, 2024).

Strengths, limitations, and suggestions for future research

This study has several strengths. A longitudinal design was used with two measurement points, providing more insight in changes over time and more chances to identify causal relationships compared to a cross-sectional design. Additionally, a large, non-convenience sample of participants was used (N = 1578), which is representative for the Dutch population. With this, the generalizability of the findings is enhanced, along with the validity and reliability of the study. Another strength of this study is its recognition and inclusion of the relation between PA and mental health. Much of the scientific research on the physical activity paradox focuses on physical health and little is found on mental health. In addition, this study looks at the interaction of two domains of physical activity and their effect on physical and mental health, unlike most scientific research. This is beneficial for the understanding of complex relations, because science tends to isolate concepts.

This study also had some limitations. First, physical activity and physical health were assessed using self-report, increasing the chances of biases, by imperfect recall or answering incorrectly. This could lead to an over- or underestimation of the effects. Future research could use devices to measure physical activity and physical health. Perhaps participants can wear them 24 hours, to provide a comprehensive and accurate view. Second, the healthy worker effect could be present, which could lead to an underestimation of the effects. The healthy worker effect is the phenomenon that a study includes healthier individuals, because the unhealthier individuals drop out of the study or are absent from work. An inclusion criterion of this study was that individuals worked more than 24 hours a week, both at T1 and T2. It is therefore possible that individuals dropped out due to ill-health, thus being neglected in the analysis. The third limitation covers the possibility of reversed causation, where individuals who are physically healthier, experience their jobs as less demanding. Future research could cover this limitation by testing reverse causation. Using a longitudinal design, preferably with more than 2 time points, may help determine the direction of causation, though it cannot definitively verify it. Lastly, as mentioned, this study used certain operationalizations of OPA and LTPA. This does not give a complete view on individuals' complete movement patterns, thereby overlooking other kinds of PA which could influence physical and mental health. Future research could measure OPA and LTPA more comprehensively. For instance, previous studies measured steps and speed of walking, using accelerometer data, which provided knowledge about the length and intensity of PA during the whole day (Gupta et al., 2020). Additionally, it could be interesting to map different activity domains, like household physical activity and commute physical activity, as it has been shown that these differently impact (mental) health (De Vries

& Bakker, 2022; White et al., 2017). Investigating main and interactive effects of different kinds or categories of PA on (mental) health could provide more knowledge and handles for nuanced and accurate physical activity guidelines.

Theoretical and practical implications

The present study has several theoretical and practical implications. First, the study highlights the importance of examining the combined effects of OPA and LTPA on health. According to the physical activity paradox, OPA is considered unhealthy while LTPA is beneficial. However, our findings suggest that the health benefits of LTPA may be influenced by the extent of OPA and that LTPA can have adverse effects on health for individuals with high OPA levels. Therefore, it is crucial to consider an individual's overall PA pattern over a 24-hour period to accurately assess the type and amount of physical activity that is truly beneficial. Second, the study's findings can contribute to improved and nuanced PA advice for employees. For individual with high OPA, it is important to prioritize sufficient and qualitative recovery, such as ensuring a good night's sleep, taking a walk through nature and detaching yourself from work (Walkowiak et al., 2010; Sonnentag & Fritz, 2007). If an individual really wants to be active, perhaps a milder form of physical activity would more suitable (e.g. walking or yoga), rather than running long distances or interval training. Employers can also benefit from these findings, by improving working conditions, ensuring sufficient breaks, and providing ergonomic equipment for employees with high OPA. Regarding employees with low OPA, it can be beneficial to implement more LTPA and tailor this based on their OPA, should their OPA levels change.

Conclusion

This study shows that the combination of PA during and outside work may have different effects on the development of physical health problems, like headache, sleeping problems, or heart complaints. Findings indicate that a combination of high OPA and high LTPA is the least favourable combination, leading to an increase in physical health problems. This cautiously suggests that employees with highly-active occupations benefit from adequate and qualitative recovery, while employees with low-active jobs can engage in more LTPA. PA advice should thus be tailored based on individuals' physical activity during work and leisure-time. In addition, no main effects from OPA and LTPA on physical and mental health, nor any interaction effects on physical mobility problems and mental health, were found. For a comprehensive understanding of the interaction between different PA domains and health, I suggest that future longitudinal research differentiates between types of PA, the duration and intensity of the PA, considers all the PA domains, uses longer time intervals between measurement points and uses device-based physical activity measures.

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