Title

The pPhysical activity paradox in relation to work ability and health-related productivity loss

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Running title: PA paradox in work ability and productivity

Ethics statement

All participants signed a consent form, and anonymity and confidentiality were ensured. The study protocol was approved by the Institutional Review Board of Dong-A University (IRB number: 2-1040709-AB-N-01-202202-HR-017-06).

Conflict of interest

The authors have no conflicts of interest to declare for this study.

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Author Contributions

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ORIGINAL ARTICLE

The p~~P~~hysical ~~Activity Paradox~~activity paradox in ~~Relation~~relation to ~~Work Ability~~work ability and ~~Health~~health-related ~~Productivity Loss~~productivity loss

Abstract

Objectives: ~~Occupational~~The physical activity paradox suggests that occupational physical activity (OPA), ~~contrary to~~unlike leisure-time physical activity (LTPA), may ~~adversely affect~~detrimentally impact health~~ through~~. We explored the ~~physical activity paradox. In this study, we investigated the relationship among~~relationships of OPA~~,~~ and LTPA with work ability (WA) and health-related productivity loss (HRPL).

Methods: ~~We incorporated~~This study included 5,501 workers in Korea who were recruited in 2021 through a web-based cross-sectional questionnaire~~ in 2021. Using the~~. The questionnaire~~,~~ was utilized to quantify OPA and LTPA ~~were quantified~~ in ~~Metabolic Equivalents, and~~metabolic equivalents, while WA and HRPL were also measured. Non-parametric regression, using a generalized additive model (GAM~~)~~), was ~~used~~employed to visualize the ~~relationship between~~relationships of LTPA and OPA ~~to~~with WA and HRPL. ~~The mean~~Mean differences in WA and HRPL~~ according~~, in relation to OPA and LTPA, were examined using linear regression models~~ after adjusting~~. These models were adjusted for covariates~~, such as~~ including sex, age, body mass index, education level, alcohol consumption, smoking history, insomnia, occupation, ~~working~~ hours worked, and income.

Results: ~~Both~~The GAM and linear regression ~~results showed~~analyses revealed that ~~an increase in~~ higher LTPA ~~resulted in an increase in~~corresponded with higher WA and ~~a decrease in~~lower HRPL. ~~The opposite was true for OPA. With an increase in OPA~~In contrast, as OPA increased, WA decreased~~,~~ and HRPL increased. However, within the ~~high OPA~~ group with high OPA, HRPL ~~did~~was not ~~decrease~~significantly lower in the high-LTPA~~ high group~~ subgroup relative to the low-LTPA~~ low group~~ subgroup (mean difference = ~~,~~ 1.92~~% point percentage points~~%; p~~-value~~ = 0.343). This ~~trend~~pattern was ~~exaggerated in the worker group~~especially pronounced among workers aged ≥60 years~~, resulting~~ and older, with an increase in ~~increased~~ HRPL

메모 포함[오전1]: Is this what you meant here? Please note that "%p" is also available as an abbreviated option.

observed with increasing LTPA ~~within~~among the respondents with high OPA ~~group~~.

Conclusions: High LTPA ~~was associated with increased WA and decreased HRPL. In contrast, high OPA~~ levels were associated with ~~decreased~~elevated WA and diminished HRPL. In contrast, higher levels of OPA were associated with lower WA and ~~increased~~higher HRPL ~~levels~~.

Keywords: Physical activity; Productivity; Work ability; Health-related productivity loss

Introduction

~~An~~ Health is frequently considered an individual's ~~health is often the~~ most valuable asset. ~~Without~~When health is less than optimal~~ health~~, basic ~~everyday~~daily activities, ~~such as~~including the ~~capacity~~ability to work, ~~are~~can be severely compromised. ~~According to~~Under the theoretical framework of the human capital model, a person's work ability (WA) and workplace productivity are directly proportional to ~~their~~that individual's health status [1]. ~~To maintain~~Therefore, promoting personal health is crucial to maintaining WA and ~~enable employees to increase~~enhancing labor productivity~~, people should invest in~~ among employees. Examples of personal health promotion~~. Healthy lifestyles, including~~ include the adoption of healthy lifestyle behaviors, such as engaging in regular exercise~~, are typical examples.~~ .

~~Considerable health benefits can be gained from regular~~Regular physical activity~~. It prevents diseases~~ can yield substantial health benefits, including the prevention of conditions such as cardiovascular disease, diabetes, cancer, and osteoporosis~~ and positively affects~~ . It also may have a positive impact on mental health [2-4]. However, not all physical activity ~~positively affects~~contributes favorably to health. The physical activity paradox is a phenomenon in which occupational physical activity (OPA) ~~adversely affects~~ can have detrimental effects on health ~~compared to~~ , in contrast to the beneficial impacts of leisure-time physical activity (LTPA). This phenomenon ~~implies~~suggests that LTPA and OPA should be considered separately. For ~~example~~instance, while higher LTPA is ~~related to~~associated with a lower prevalence of cardiovascular disease or diabetes, elevated OPA is correlated with a higher ~~OPA can increase the~~ prevalence of these diseases [5,6].

This pattern ~~probably~~may also ~~appears~~be evident in labor market performance. For ~~example,~~instance, a higher level of OPA is ~~associated~~linked with ~~a higher probability of~~an increased likelihood of experiencing burnout at work [7]. Conversely, a higher level of LTPA is ~~related to a higher~~associated with increased WA [8]. ~~In a~~A study ~~on~~examining long-term sickness absence ~~(LTSA)~~ and physical activity~~, –~~ found that higher OPA ~~increased the~~ corresponded to an elevated risk of ~~LTSA, whereas~~ such absence, while higher LTPA ~~decreased the~~was associated with reduced risk ~~of LTSA, exhibiting~~, thus demonstrating the physical activity paradox [9]. ~~As such~~Consequently, the ~~impact~~influence of LTPA and OPA on labor market performance can be ~~also~~ complex and ~~paradoxical.~~seemingly contradictory. Therefore, the paradoxical ~~association~~associations of LTPA and OPA with WA and health-related productivity loss (HRPL) ~~is~~constitute an important area of research ~~for~~, key to improving our understanding of these ~~complex~~intricate relationships and developing evidence-based interventions to promote ~~better~~improved health and productivity in the workplace. ~~This~~Such research can benefit workers, employers, policymakers, and society ~~as a whole~~at large by contributing to a healthier and more productive workforce.

However, research ~~has been limited~~ on the paradoxical ~~association~~associations of LTPA and OPA with WA and/or HRPL has been limited, although reports have described the physical activity health paradox ~~has been reported for~~ in the context of various health outcomes [10]. Therefore, the present study ~~aimed~~was conducted to explore the physical activity paradox in ~~the context of~~ relation to WA and HRPL. ~~In particular, since WA and HRPL are~~ Since these issues ~~among~~are relevant to aging workers, we also investigated whether effect modifications were present depending on ~~the~~ age group. ~~This information~~The findings from this study could ~~provide~~offer a scientific ~~basis~~foundation for practical ~~advice for~~guidance to help workers ~~to~~ maintain productivity and ~~work ability and promote~~WA, as well as enhance their overall health.

Materials and Methods

Study participants

We used ~~first~~the initial dataset from a ~~panel~~ survey ~~called~~known as the Korean ~~Worker's~~Workers Health and Sleep Study ~~(KWHSS), which is~~ , an ongoing ~~nation-wide~~nationwide panel study ~~from~~initiated in 2022. Participants were recruited in July 2022 ~~using~~via the online survey platform EMBRAIN. In brief, panelists were invited to participate in the survey ~~based on~~ through a process of random sampling, which was stratified by sex, age, and occupation. ~~A~~ The initial screening process was completed by a total of 5,517 participants ~~completed the initial screening process (~~, all of whom were wage earners~~, regardless~~ of ~~occupation,~~varying occupations and aged ≥19 years~~). Only those who answered~~ or older. Inclusion in the study was contingent upon participants providing complete responses to questions ~~completely~~designed to ~~obtain~~gather the necessary information ~~necessary for this study (e.g.,~~, including sex, age, body mass index ~~[~~(BMI~~],~~), education level, occupation, ~~working~~ hours worked, income, alcohol consumption, smoking status, and insomnia severity index, along with questions used to calculate physical activity, ~~questions to calculate~~ WA, and HRPL~~) were included in the study. Accordingly~~. Consequently, 16 ~~people who incompletely answered~~ individuals who did not provide complete answers to the questions ~~necessary~~required to ~~calculate the~~determine HRPL were excluded~~. Finally, we enrolled~~ from the study. Ultimately, a total of 5,501 participants were enrolled.

Independent ~~variable~~variables: OPA and LTPA

The Global Physical Activity Questionnaire (GPAQ) [11,12] was ~~used~~employed to measure OPA and LTPA. ~~It aimed~~Its purpose was to ~~gather information about~~collect data on an individual's levels of physical activity ~~levels~~in both ~~at~~ work and ~~during~~ leisure ~~time. It comprises~~ contexts. The questionnaire consists of 12 questions ~~regarding~~about the intensity, frequency, and durationsduration of both vigorous and moderate physical activity. TheThese questions coveredencompass activities performed at undertaken during work and leisure activitiestime. The reliability and concurrent validity of the GPAQ have been reported primarily in Asian and Europeandocumented in adult populations, with from Asia and Europe, as evidenced by 20 publications [13].

Metabolic equivalents (METs) were used to quantify the intensity of physical activity intensity. The MET is. METs reflect the ratio of a person'san individual's metabolic rate during physical activity compared to that during person's metabolic rate at rest. OneA single MET is defined as the energy costexpenditure of sitting quietly and is equivalent, which equates to a caloric consumption of 1 kcal/kg/h. Four and eight METs were assigned to the time spent on moderateModerate and vigorous activities were assigned values of 4 and 8 METs, respectively. Using theThe survey questions, were used to separately calculate OPA and LTPA were calculated separately in MET-min/minutes per week. If certain activities arewere not performed (e.g., no, such as vigorous-intensity sports),, the corresponding values arewere considered to be 0. ForTo calculate LTPA, the following formula was used: (days engaged in vigorous-intensity sports × minutes spent × 8) + (days engaged in moderate-intensity sports × minutes spent × 4). Similarly, for OPA, was computed using the following formula was used: (days involving vigorous-intensity activitiesactivity at work × minutes spent × 8) + (days involving moderate-intensity activitiesactivity at work × minutes spent × 4) [11].

PhysicalHigh physical activity >was defined as that exceeding 600 MET-min throughout a minutes per week was categorized as "high," which . This is equivalent to 150 minminutes of moderate-intensity and 75 minminutes of vigorous-intensity physical activity, or an equivalenta comparable combination of the two, for both OPA and LTPA separately. The criterion of 600 MET-min/minutes per week criteria were obtainedwas derived from the World

Health Organization recommendations on physical activity for health included, as outlined in the GPAQ questionnaire guidelines [11].

Dependent variable: work ability variables: WA and health-related productivity lossHRPL

WA was measuredevaluated using the work ability index (WAI) [14,15]. WAI is used], a tool frequently employed in clinical occupational health research. ItThe WAI has been usedutilized in manynumerous countries, and itshas demonstrated high reliability is high inwithin the Korean context [16]. The questionnaire used in this study assessed various aspectsfacets of WA, health status, and mental well-being. It comprised seven and was divided into 7 sections with, each containing specific questions related to work abilityWA. Participants ratedwere asked to rate their current work ability, evaluated WA, assess their work abilityWA in relation to job demands, identified presentidentify any existing diseases and diagnoses, estimatedestimate work impairment, reportedreport any days taken off work because ofdue to illness, predictedpredict their work ability inWA for the next 2 years, and reflectedprovide reflections on their mental capacities.

To compute the total score, the points from each section were added to certain summed, with specific items subject to specific considerations. Work demands (e.g.,receiving additional consideration. Factors such as work demand, with potential options including physically demanding, mentally demanding, or both physically and mentally demanding work), were considered. ForIn terms of current diseases, the scoring system considersincorporated only diagnoses providedconfirmed by physicians.

The scores can be summed uptallied to yield a range from a minimum of 7 points andto a maximum of 49 points, with higher scores indicating better work abilityWA. This score can be

~~used~~utilized to ~~interpret~~categorize a participant's WA as poor (7–27 points), moderate (28–36 points), good (37–43 points), or excellent (44–49 points).

HRPL was measured using the Work Productivity and Activity Impairment Questionnaire (WPAI), a general health version. The reliability and validity of ~~the~~this questionnaire ~~were tested in a previous study~~had been previously reported [17]. The Korean version is accessible online (http://www.reillyassociates.net/WPAI_Translations), and the translation process was ~~harmonized~~standardized through independent translations, back-translation, and expert reviews. ~~The~~This questionnaire ~~assessed~~was designed to evaluate the ~~work-related~~impact of health ~~impacts~~on work productivity and ~~productivity~~daily activities. It included ~~six~~6 questions about employment status, hours of work missed ~~from work because of~~due to health and other reasons, actual working hours, the ~~effect~~effects of health problems on work productivity, and the ~~impact~~influence of health issues on regular daily activities. The overall ~~decline~~decrease in work productivity, ~~such as~~including absenteeism and presenteeism, was determined ~~by~~based on the responses to these questions.

Absenteeism refers to the degree to which workers are absent from work. The productivity loss ~~resulting from~~ associated with absenteeism ~~was determined~~is calculated by ~~calculating~~determining the percentage of working hours missed ~~because of~~due to health-related issues within the ~~past~~preceding 7 days. Presenteeism, in contrast, is defined as being physically present at work but experiencing impairment ~~because of~~due to health problems. ~~Productivity~~The productivity loss attributed to presenteeism ~~was determined~~is calculated by ~~calculating~~determining the percentage of working hours lost ~~because of~~due to health ~~problems~~issues during the same 7-day period. The HRPL, expressed ~~in~~as a percentage, is ~~calculated~~computed by ~~summing~~adding the percentages of absenteeism and presenteeism ~~percentages~~. It ~~represents~~signifies the total percentage of work hours lost due to health-related absencesabsence and productivity loss over the past 7 days.

Covariates

Demographic variables, such as age and sex, lifestyle behaviors, such as including alcohol consumption and smoking status, education levelslevel, occupation, working hours worked, income, sleep quality of sleep, and BMI, were considered as covariates, considering due to their clinical importance and incorporationinclusion in previous studies [7,8,9]. Sleep quality was evaluated using the Insomnia Severity Index (ISI). The ISI), which ranges from 0 to 28 points, . Higher scores on the ISI indicate more severe insomnia, with higher scores indicating worse insomnia:0–7 points suggesting no clinically significantmeaningful insomnia, 0–7; 8–14 points; indicating subthreshold insomnia, 8–14; 15–21 points; representing moderate insomnia, 15–21 points; and severe insomnia, 22–28 points denoting severe insomnia [18].

Statistical analysis

Participants were allocated to groups according to theircategorized based on demographic characteristics. The , and the levels of LTPA, OPA, WA, and HRPL levels of were documented for each demographic group were recorded. Considering. Given the absence of evidence forof linear relationships in previousprior studies, a non-parametric regression approach using a generalized additive model (GAM) was usedemployed to visualizeillustrate the relationshipsassociations between LTPA and WA, LTPA and HRPL, OPA and WA, and OPA and HRPL. Generalized cross-validation scores and thin-plate regression splines were employedutilized [19]. SexAdjustments were made for factors including sex, age, BMI, education level, alcohol consumption, smoking status, insomnia, occupation, working hours worked, and income were adjusted. Furthermore. Additionally, the relationships between LTPA and WA and, as well as those between LTPA and HRPL in, within the high- and low-level OPA groups were visualizedillustrated using the same techniquemethod.

Differences Linear regression models were employed to investigate the differences in WA and HRPL between the LTPA and OPA groups were examined using linear regression models. LTPA was used to divide the participants. Participants were divided into high- and low-activity groups based on LTPA, using a cutoff of 600 MET-minminutes/week, and this was treated as a categorical variable. The same procedure was performed usingfollowed for OPA. Low LTPA and low OPA levels were used as reference points in the regression models.. Low, with low OPA and LTPA levels were used as references.reference points. This method testedapproach enabled examination of the mean differences and 95% confidence intervals (CIs) of WA and HRPL according to the levels of LTPA and OPA levels and, as well as their combinations. Three linear regression models were usedutilized: model 1, crude; model 2, adjusted for sex and age; and model 3, adjusted for sex, age, BMI, education level, alcohol consumption, smoking history, insomnia, occupation, working hours worked, and income. CovariatesWhen applicable, covariates were appliedincorporated for adjustment as continuous variables, if applicable (e.g.,including age, BMI, working hours worked, and income)..

AAn analysis stratified analysis according to theby age group was performedconducted to investigatedetermine whether the results changeddiffered for participants older than 60 years. All statistical analyses were conductedperformed using R version 4.2.2, and two (R Foundation for Statistical Computing, Vienna, Austria). A 2-tailed p-values <value of less than 0.05 were adoptedwas established as the criterionthreshold for statistical significance.

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Results

Table 1 ~~shows~~presents the levels of physical activity ~~levels of~~for each demographic subgroup ~~and~~, as well as the distribution of ~~the~~ participants within ~~each subgroup.~~these subgroups. Male workers ~~had~~exhibited higher levels of LTPA and OPA ~~levels~~ than their female~~, but there was~~ counterparts. However, no significant ~~difference~~sex-based disparity was observed in ~~workability~~ WA or HRPL ~~between them. Looking at the~~. When considering occupation, white-collar workers ~~had~~demonstrated the lowest OPA~~, while~~ levels. In contrast, pink~~-~~-collar and blue~~-~~-collar workers ~~had gradually increased~~exhibited progressively higher OPA levels.

Figure 1 ~~depicts~~illustrates the relationships between LTPA and WA, LTPA and HRPL, OPA and WA, and OPA and HRPL, as determined using the GAM. ~~WA decreased with increasing~~As OPA ~~and~~ increased~~ with increasing~~, WA tended to decrease, whereas an increase in LTPA~~. Conversely, HRPL increased with an increase in OPA and decreased~~ was associated with an increase in ~~LTPA~~WA. HRPL tended to increase with an increase in OPA, but decreased as LTPA increased.

Table 2 ~~depicts~~presents the results of the linear regression models for WA and HRPL ~~according~~in relation to LTPA and OPA. In the crude model (model 1), the high-LTPA subgroup demonstrated ~~an increase in~~a higher WA ~~of~~(mean difference, 1.503~~ relative to~~) than the low-LTPA subgroup, ~~and~~while the high-OPA subgroup ~~demonstrated~~exhibited a mean difference of ~~-~~−1.203 for WA in ~~WA relative~~relation to the low-OPA subgroup. Models 2 and 3, which were adjusted for covariates, also demonstrated higher WA in the high~~-~~-LTPA group (mean differences of 1.513 and 1.101 for models 2 and 3, respectively) and lower WA in the low~~-~~-OPA group (mean differences of ~~-~~−1.394 and ~~-~~−0.904 for models 2 and 3, respectively). In all models, HRPL was lower in the high~~-~~-LTPA group (mean differences of ~~-~~−4.567~~, -~~%, −5.019~~,~~%, and ~~-~~−3.970% for models 1, 2, and 3, respectively), ~~and~~while HRPL was higher in the high~~-~~-OPA group (mean differences of 6.564%, 7.184%, and 5.931% for models 1, 2, and

3, respectively). All differences were statistically significant.

Figure 2 ~~shows~~illustrates the relationship between LTPA and WA~~ and~~, as well as that between LTPA and HRPL, for the low- and high-OPA groups using a GAM adjusted for all covariates. Regardless of the OPA level, WA ~~increased~~was observed to increase with increasing LTPA. However, HRPL decreased with increasing LTPA only in the low-OPA group. ~~In~~Conversely, in the ~~group with ~~high~~-~~-OPA group, HRPL increased ~~as ~~in tandem with LTPA~~ increased~~.

Table 3 ~~presents~~displays the results of the linear regression models for WA and HRPL ~~according to ~~, based on the ~~combination~~various combinations of OPA and LTPA subgroups. ~~WA was ~~For all models, the highest WA was observed in the group with low OPA ~~+~~and high LTPA~~ group and~~, while the lowest was seen in the group with high OPA ~~+~~and low LTPA. These results were statistically significant. In model 3, the group ~~in all models, ~~with ~~statistical significance. The ~~high OPA ~~+~~and low LTPA ~~group demonstrated~~exhibited an average ~~of~~WA that was 2.036 (95% CI~~:~~, 1.280%–2.596%) lower ~~WA ~~than that of the group with low OPA ~~+~~and high LTPA~~ group in model 3.~~. Similarly, ~~in all models with statistical significance, ~~HRPL was ~~the ~~lowest in the group with low OPA ~~+~~and high LTPA ~~combination,~~across all models, a finding that was statistically significant. This was followed by the groups with low OPA ~~+~~and low LTPA, high OPA ~~+~~and high LTPA, and high OPA ~~+~~and low LTPA~~ combinations, which demonstrated~~, in that order. The group with high OPA and low LTPA exhibited the highest HRPL. ~~The~~In model 3, the group with high OPA ~~+~~and low ~~LPTA group demonstrated~~LTPA showed an average ~~of~~HRPL that was 8.719% (95% CI~~:~~, 5.513%–11.926%) higher ~~HRPL ~~than that of the group with low OPA ~~+~~and high LTPA~~ group in model 3~~.

A sensitivity analysis was conducted according to age~~: <~~, with participants divided into those younger than 60 years and ~~≥~~those 60 years or older. Table 4 ~~depicts~~presents the ~~results~~outcomes of the linear regression models ~~of~~for WA and HRPL within each age group

~~according to the~~, categorized by OPA and LTPA subgroups. Figure 3 ~~depicts~~illustrates the results of the non-parametric regression of LTPA on WA and HRPL within each age group and ~~the~~ OPA subgroup ~~for LTPA~~. In the ~~group <~~under-60 ~~years of~~ age group, both linear regression and GAM ~~demonstrated~~analyses showed trends ~~similar to~~consistent with those observed in the previous analysis. However, ~~in the group ≥~~among those 60 years and older, the high ~~LTPA group, in comparison to the low -~~-LTPA group~~,~~ did not ~~demonstrate a significant decrease in~~ display significantly lower HRPL in the linear regression model~~. Nevertheless~~ relative to the low-LTPA participants. In contrast, the high~~-~~-OPA group~~, in comparison with the low OPA group,~~ demonstrated a significant reduction in WA and an increase in HRPL~~, even~~ in comparison with the low-OPA group ~~aged ≥~~, even among those at least 60 years~~. Additionally~~ old. Furthermore, in ~~the~~that ≥60-year-old population, the WA of the high~~-~~-OPA group was decreased, ~~contrary to~~ which contradicted the trend observed in the younger subgroup~~, and~~. As shown in the GAM, HRPL also markedly increased ~~as~~with increasing LTPA ~~increased compared to~~, which differed from the ~~<~~pattern observed for the under-60 ~~year~~ age group ~~in GAM~~.

Discussion

~~We~~In this study, we explored the associations of OPA and LTPA with WA and HRPL among South Korean workers. ~~An increase in the~~ We found that higher LTPA ~~resulted in an increase in~~ corresponded to higher WA and ~~a decrease in~~ lower HRPL. ~~Conversely, an increase in~~In contrast, elevated OPA ~~resulted in a~~ was associated with decreased WA and increased HRPL. These ~~findings are consistent~~results align with the physical activity paradox ~~in the context of~~as it pertains to HRPL and WA [20,21].

The ~~results of~~findings from our analysis ~~are comparable to~~ resemble those of ~~earlier~~previous studies, although ~~the comparison~~drawing direct comparisons may be challenging ~~owing to different working circumstances~~due to differing work environments and methodologies. Notably, LTPA ~~increases~~has been shown to increase WA [8,21~~]; however~~]. However, workers ~~allocated~~assigned to physically demanding tasks ~~demonstrated decreased~~ have exhibited decreases in WA [22,23]. A systematic review of 31 randomized controlled trials and non-randomized controlled studies ~~investigated~~examined the ~~effects~~impact of workplace nutritional and physical activity interventions on employee productivity, work performance, and WA [24]. ~~There have been substantial~~ Substantial reductions in absenteeism, improvements in job performance, increased WA, and ~~increased~~improved productivity have been reported ~~across~~in studies focusing on physical activity interventions (i.e., nonoccupational physical exercise) ~~in~~within the workplace ~~environment~~ or at multiple levels (organizational and individual). ~~Conversely, it has been reported~~ In contrast, research indicates that workers in teaching hospitals experience a decrease in productivity ~~loss~~ and work limitations associated with mechanical workloads, ~~demonstrating that they have difficulty~~ indicating difficulties in performing ~~activities~~tasks during a ~~part~~portion of their work time [25]. However, ~~owing~~due to the ~~lack~~scarcity of studies ~~on~~investigating the effects of OPA on HRPL, definitive conclusions cannot be ~~firm~~drawn.

The health ~~status of workers might be an important underlying~~condition of employees may serve as a key factor in ~~enhancing~~~~improving~~ sustaining or improving ~~maintaining~~~~sustaining~~ WA and productivity in the ~~labor force~~workforce [26]. ~~A person's~~ WA ~~depends on~~is determined by the ~~balance~~equilibrium between ~~their physical or mental resources, and work demands [22]. While LTPA enhances~~ an individual's physical or mental resources and the work demands experienced by that person [22]. While LTPA can bolster an individual's resources, it ~~can reflect~~may also indicate high ~~levels of work demand, causing the opposite~~work demands, potentially leading to adverse effects. ~~Likewise~~Similarly, in the context of HRPL, LTPA could ~~be beneficial to~~ enhance the health ~~levels~~status of workers, ~~but~~whereas OPA ~~could be harmful to health with regard~~may be detrimental due to the physical demands of work. ~~Therefore~~Consequently, these ~~two~~types of physical activities ~~seem~~appear to ~~have paradoxical~~exert contradictory effects on HRPL.

~~However, it is noteworthy that~~ Notably, however, LTPA does not always ~~have beneficial effects. Workers aged >~~yield favorable outcomes. Unlike their younger counterparts, workers over 60 years old did not ~~benefit from~~ experience benefits of increased LTPA in the WA and HRPL~~, unlike younger workers.~~ categories. This ~~trend~~pattern was also ~~observed~~evident in the high-OPA group. ~~This suggests~~ These findings imply that ~~in~~for older adults, excessive exercise may ~~mitigate~~reduce work productivity~~ in~~, particularly for those who already ~~perform large amounts of~~ engage in substantial physical activity ~~in the workplace. Although~~at work. While LTPA in ~~older age~~later life is beneficial ~~to~~for health and ~~decreases~~reduces the risk of ~~developing~~ various diseases [27], ~~it~~this may not ~~be in~~ hold true for those with physically demanding jobs. This ~~finding is consistent~~observation aligns with the ~~results~~findings of previous ~~studies with~~research that incorporated coronary heart disease as an outcome variable [28]. When ~~considering~~ sociodemographic and conventional coronary risk factors were considered, the incidence of coronary events was increased by approximately ~~four times higher~~ 4-fold among workers ~~whose jobs required heavy physical demands and~~ with physically demanding jobs who ~~engaged~~also participated in moderate-to-vigorous physical exercise during their leisure time. ~~These results~~This can be ~~explained by~~attributed to the fact that the combination of strenuous work and excessive exercise ~~lead to~~results in prolonged cardiovascular overload [29]. ~~Furthermore, given~~ On the other hand,~~Moreover~~, considering the cross-sectional nature of ~~this~~these data, it is important to acknowledge the possibility that poor physical condition or work ability could have contributed to lower levels of LTPA.

The phenomenon ~~of divergent health outcomes~~ wherein LTPA and OPA are associated with ~~LTPA and OPA~~ differing health outcomes is commonly ~~known~~described as the ~~PA~~physical activity health paradox [30]. Holtermann et al. ~~postulated~~proposed a ~~set~~series of hypotheses to ~~elucidate probable~~clarify the potential underlying mechanisms ~~contributing to the PA health~~of this paradox~~.~~ [6~~]:~~]. The authors suggested that OPA may (a) ~~is~~be of too low ~~in~~ intensity or too long in duration, (b) ~~elevates~~cause an increase in the 24-~~h~~hour heart rate, (c) ~~elevates~~lead to an elevation in the 24-~~h~~hour blood pressure, (d) ~~is~~ often ~~performed~~ be undertaken without ~~sufficient~~adequate recovery time, (e) ~~is often~~frequently be performed ~~with~~under conditions of low worker control, and (f) exacerbates inflammation.

Our study, which involved a large database of 5,517 workers~~ and~~, was unique in ~~that it explored~~its exploration of the physical activity paradox ~~in~~within the context of WA and HRPL. ~~Additionally, we demonstrated~~We found that the effects of physical activity on ~~the~~ WA and HRPL ~~were~~exhibited both ~~similar~~similarities and ~~different~~differences. However, ~~because this was a~~ due to the cross-sectional ~~study,~~nature of this study, we were unable to directly identify causal relationships~~ could not be directly identified. Longitudinal studies should be conducted to validate~~. To confirm the causal ~~relationship~~association between physical activity and its impact on WA and HRPL~~ to suggest~~, future longitudinal studies are recommended. This research would aid in the development of appropriate clinical guidelines for OPA and LTPA. ~~Additionally, the~~ Furthermore, we observed a large variance in ~~the~~ OPA and LTPA~~ was large, and the~~, with values ~~were not evenly~~unevenly distributed. ~~Therefore, as the~~Consequently, the 95% CI of the GAM expanded with increases in OPA and LTPA~~ increased, the CI of the GAM widened. Additionally, the~~. The criterion of 600-MET ~~min~~minutes/week~~ criterion~~, used to ~~divide~~categorize OPA and LTPA into high/low ~~categorical~~ variables, was derived from the total physical activity recommended by the World Health Organization [12~~] and is not necessarily an~~]. Importantly, however, this does not reflect separate cutoffs established ~~separate~~

~~cutoff~~ for OPA and LTPA. ~~In addition~~Additionally, potential confounding factors ~~(e.g., the longevity~~such as duration of work, family ~~responsibility~~responsibilities, and hobbies~~)~~ may ~~confound~~influence the associations~~, but we could not include them in our analytical model because of~~. However, due to the lack of this information in our survey data~~. Further~~, we were unable to incorporate these factors into our analytical model. Future research should be conducted to determine the appropriate levels of OPA and LTPA ~~levels~~ for maintaining healthy and productive workers.

In conclusion, the ~~results~~findings of ~~our~~this study suggest ~~that~~a positive correlation between LTPA ~~is positively correlated with WA and~~and WA, as well as labor productivity~~, whereas~~. In contrast, OPA ~~has~~appears to have a negative association, ~~implying~~indicating a paradoxical effect between ~~the two~~these types of physical activities. ~~Additionally, in~~Furthermore, among older adults with ~~high physical demands~~physically demanding jobs, LTPA may ~~be~~ negatively ~~correlated~~correlate with labor productivity~~, indicating~~. This suggests the need for advice tailored ~~advice according~~ to the individual's work situation and age. For ~~example~~instance, it is generally ~~advisable~~ recommendable to ~~engage~~participate in LTPA to ~~enhance~~improve WA and prevent HRPL. However, ~~it seems advisable that aging~~for older workers ~~with~~in physically demanding ~~jobs should not overly engage~~roles, it may be prudent to avoid excessive engagement in LTPA during non-~~work~~working hours. We ~~hope~~anticipate that ~~follow-up~~future studies ~~would generate more~~will provide additional evidence ~~that can be applied in diverse~~applicable to a variety of situations.

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Key Message

Occupational physical activity (OPA), contrary to leisure-time physical activity (LTPA), may have adverse effects on health through a phenomenon known as the physical activity paradox. This study investigated the relationship of OPA and LTPA with work ability (WA) and health-related productivity loss (HRPL). The results showed that a high LTPA was associated with increased WA and decreased HRPL. In contrast, a high OPA was associated with decreased WA and increased HRPL.

Key Summary (Korean)

직업적 신체활동은 여가시간 신체활동과 달리 건강에 악영향을 미칠 수 있다. 이는 신체활동 패러독스로 알려진 현상으로, 본 연구에서는 직업적 신체활동은 여가시간 신체활동가 업무능력(work ability) 및 건강관련 노동생산성손실과의 관계에 대해 직장인 5501 명을 대상으로 조사하였다. 분석 결과, 여가시간 신체활동이 높을수록 업무능력은 좋아지고 건강관련 노동생산성손실은 감소하였다. 그에 반해 직업적 신체활동이 높을수록 업무능력은 낮아지고 건강관련 노동생산성손실은 증가하는 양상을 보였다. 그런데, 직업적 신체부담이 많은 고연령 노동자의 경우, 여가시간 신체활동이 증가하면, 오히려 건강관련 노동생산성손실은 증가할 수 있어, 작업 상황 및 연령에 따른 맞춤형 조언이 필요함을 나타냈다. 후속 연구를 통해 다양한 상황에 적용할 수 있는 근거가 더 많이 제시되기를 기대한다.

Tables

Table 1. Physical activity, work ability, and health-related productivity loss ~~levels of~~among ~~the~~ study participants according to ~~their~~ demographic characteristics

	Total n (%)	Leisure-~~-~~time physical activity MET-min/week Mean (SD)	Occupational physical activity MET-min/week Mean (SD)	Work ability Mean (SD)	Health-related productivity loss (%) Mean (SD)
Overall	5501	788.02 (1307.31)	369.75 (1451.91)	37.64 (5.43)	29.26 (25.89)
Sex					
Male	3000 (54.5)	912.53 (1408.06)	507.51 (1724.66)	37.96 (5.44)	29.11 (25.72)
Female	2501 (45.5)	638.67 (1157.86)	204.52 (1009.69)	37.26 (5.41)	29.45 (26.10)
Age (years)					
20–39	2117 (38.5)	854.87 (1323.99)	330.75 (1387.83)	37.38 (5.50)	32.84 (26.53)
40–49	1306 (23.7)	746.81 (1278.98)	384.34 (1402.52)	38.01 (5.40)	25.62 (24.69)
50–59	1393 (25.3)	622.91 (1060.65)	377.91 (1523.36)	37.10 (5.23)	31.33 (26.17)
60+	685 (12.5)	980.00 (1654.68)	445.08 (1597.04)	38.72 (5.48)	21.68 (23.13)
Education l~~L~~evel					
≤~~-~~12 years of education	859 (15.6)	793.82 (1452.15)	555.40 (2008.20)	37.79 (5.47)	26.62 (25.28)
>~~-~~12 years of education	4642 (84.4)	786.94 (1278.88)	335.40 (1321.02)	37.61 (5.43)	29.75 (25.98)
Occupation					
White-~~-~~c~~C~~ollar	3718 (67.6)	790.72 (1275.14)	200.54 (845.57)	37.80 (5.28)	29.48 (25.93)
Pink-~~-~~c~~C~~ollar	720 (13.1)	803.10 (1408.90)	592.55 (1962.71)	36.93 (5.91)	30.60 (26.04)
Blue-~~-~~c~~C~~ollar	1063 (19.3)	768.34 (1347.48)	810.70 (2340.58)	37.58 (5.60)	27.61 (25.59)
Alcohol					
Low	4643 (84.4)	795.19 (1322.39)	360.88 (1389.02)	37.61 (5.46)	29.52 (25.96)
High	858 (15.6)	749.23 (1222.49)	417.76 (1753.73)	37.80 (5.31)	27.89 (25.50)
Smoking					
Never	2995 (54.5)	756.35 (1256.62)	263.64 (1160.49)	37.87 (5.26)	28.86 (25.67)
Ever s~~S~~moker	2506 (45.6)	825.86 (1364.82)	496.58 (1728.94)	37.37 (5.62)	29.75 (26.16)
Insomnia					
No	4314 (78.4)	810.64 (1333.73)	455.23 (1782.08)	38.58 (4.99)	25.24 (24.38)
Yes	1187 (21.6)	705.80 (1203.38)	346.24 (1346.23)	34.21 (5.59)	43.89 (25.97)
BMI (kg/m^2)					
<~~-~~25	3696 (67.2)	788.08 (1313.52)	359.32 (1430.72)	37.80 (5.40)	29.14 (25.89)
≥~~-~~25	1805 (32.8)	787.90 (1294.87)	391.13 (1494.53)	37.31 (5.49)	29.53 (25.90)
~~Working~~ H~~H~~ours worked (hours/week)					
<~~-~~40 h	1144 (20.8)	822.02 (1316.23)	370.12 (1434.79)	37.65 (5.46)	29.37 (25.76)
40-52	3606 (65.6)	784.47 (1305.13)	308.96 (1168.91)	37.77 (5.36)	28.28 (25.62)
≥~~-~~52	751 (13.7)	753.25 (1304.73)	661.12 (2377.23)	37.01 (5.71)	33.85 (26.93)
Income (KRW)*					
<~~-~~2,500,000	1926 (35.0)	685.09 (1220.82)	354.66 (1498.88)	36.98 (5.61)	29.48 (26.24)
<~~-~~5,000,000	2981 (54.2)	825.98 (1334.65)	386.27 (1488.67)	37.82 (5.31)	29.46 (25.79)
≥~~-~~5,000,000	594 (10.8)	931.26 (1413.99)	355.80 (1057.70)	38.88 (5.19)	27.59 (25.25)

BMI,~~:~~ body mass index; SD,~~:~~ standard deviation; KRW, Korean won.
*~~-~~Net monthly salary.

Table 2. Mean difference and 95% confidence interval of work ability and health-related productivity loss according to occupational and leisure~~-~~time physical activity

Work a~~A~~bility		Model 1		Model 2		Model 3	
Leisure~~-~~t~~T~~ime p~~P~~hysical a~~A~~ctivity	Low	reference		reference		reference	
	High	1.503	(1.199, 1.808)	1.513	(1.209, 1.817)	1.101	(0.824, 1.377)
Occupational p~~P~~hysical a~~A~~ctivity	Low	reference		reference		reference	
	High	−~~-~~1.203	(−~~-~~1.618, −~~-~~0.788)	−~~-~~1.394	(−~~-~~1.810, −~~-~~0.977)	−~~-~~0.904	(−~~-~~1.286, −~~-~~0.523)

Health-r~~R~~elated p~~P~~roductivity l~~L~~oss (%)		Model 1		Model 2		Model 3	
Leisure~~-~~t~~T~~ime p~~P~~hysical a~~A~~ctivity	Low	reference		reference		reference	
	High	−~~-~~4.567	(−~~-~~6.025, −~~-~~3.110)	−~~-~~5.019	(−~~-~~6.462, −~~-~~3.575)	−~~-~~3.970	(−~~-~~5.319, −~~-~~2.621)
Occupational p~~P~~hysical a~~A~~ctivity	Low	reference		reference		reference	
	High	6.564	(4.580, 8.548)	7.184	(5.207, 9.161)	5.931	(4.074, 7.789)

Estimated using~~by~~ linear regression and ~~contrast~~ compared to the reference (low leisure~~-~~time or low occupational physical activity).~~,~~
Model 1 was the crude model;~~;~~ m
~~M~~odel 2 was adjusted for sex and age; and m
~~M~~odel 3 was adjusted for sex, age, body mass index, education level, alcohol consumption, smoking status, insomnia, occupation, ~~working~~ hours worked, and income.

Table 3. Mean difference and 95% confidence interval of work ability and health-related productivity loss within each subgroup for occupational and leisure-–time physical activity

Work aAbility (oOccupational pPhysical aActivity, lLeisure-t-Time pPhysical aActivity)	Model 1		Model 2		Model 3	
(Low, High)	reference		reference		reference	
(Low, Low)	−-1.549	(−-1.879, −-1.220)	−-1.555	(−-1.883, −-1.226)	−-1.120	(−-1.418, −-0.821)
(High, High)	−-1.316	(−-1.833, −-0.799)	−-1.496	(−-2.013, −-0.979)	−-0.952	(−-1.422, −-0.482)
(High, Low)	−-2.548	(−-3.270, −-1.827)	−-2.763	(−-3.483, −-2.043)	−-1.938	(−-2.596, −-1.280)

Health-rRelated pProductivity lLoss (%) (oOccupational pPhysical aActivity, lLeisure-t-Time pPhysical aActivity)	Model 1		Model 2		Model 3	
(Low, High)	reference		reference		reference	
(Low, Low)	5.016	(3.441, 6.592)	5.492	(3.931, 7.053)	4.310	(2.855, 5.765)
(High, High)	7.670	(5.197, 10.142)	8.340	(5.887, 10.793)	6.766	(4.474, 9.058)
(High, Low)	9.583	(6.132, 13.034)	10.576	(7.159, 13.993)	8.719	(5.513, 11.926)

Estimated usingby linear regression and contrast compared to the reference (low occupational and high leisure-time physical activity).;
Model 1 was the crude model;
mModel 2 was adjusted for sex and age; and m
Model 3 was adjusted for sex, age, body mass index, education level, alcohol consumption, smoking status, insomnia, occupation, working hours worked, and income.

Table 4. Mean difference and 95% confidence interval of work ability and health-related productivity loss ~~according to the level of~~within each leisure-~~-~~time and occupational physical activity subgroup~~s~~ ~~for different~~by age group~~s.~~

Work a~~A~~bility		Age <~~-~~60 years		Age ≥~~-~~60 years	
Leisure-t~~-T~~ime p~~P~~hysical a~~A~~ctivity	Low	reference		reference	
	High	1.104	(0.808, 1.399)	1.150	(0.332, 1.969)
Occupational p~~P~~hysical a~~A~~ctivity	Low	reference		reference	
	High	−~~-~~0.789	(−~~-~~1.202, −~~-~~0.375)	−~~-~~1.555	(−~~-~~2.570, −~~-~~0.540)

Health-r~~R~~elated p~~P~~roductivity l~~L~~oss (%)		Age <~~-~~60 years		Age ≥~~-~~60 years	
Leisure-t~~-T~~ime p~~P~~hysical a~~A~~ctivity	Low	reference		reference	
	High	−~~-~~4.276	(−~~-~~5.737, −~~-~~2.815)	−~~-~~1.979	(−~~-~~5.497, 1.539)
Occupational p~~P~~hysical a~~A~~ctivity	Low	reference		reference	
	High	5.677	(3.631, 7.723)	7.406	(3.043, 11.768)

Estimated ~~by the~~via linear regression and ~~contrast~~ compared to the reference (low leisure-~~-~~time physical activity). The m~~M~~odel was adjusted for~~by~~ sex, age, body mass index, education level, alcohol consumption, smoking history, insomnia, occupation, ~~working~~ hours worked, and income.

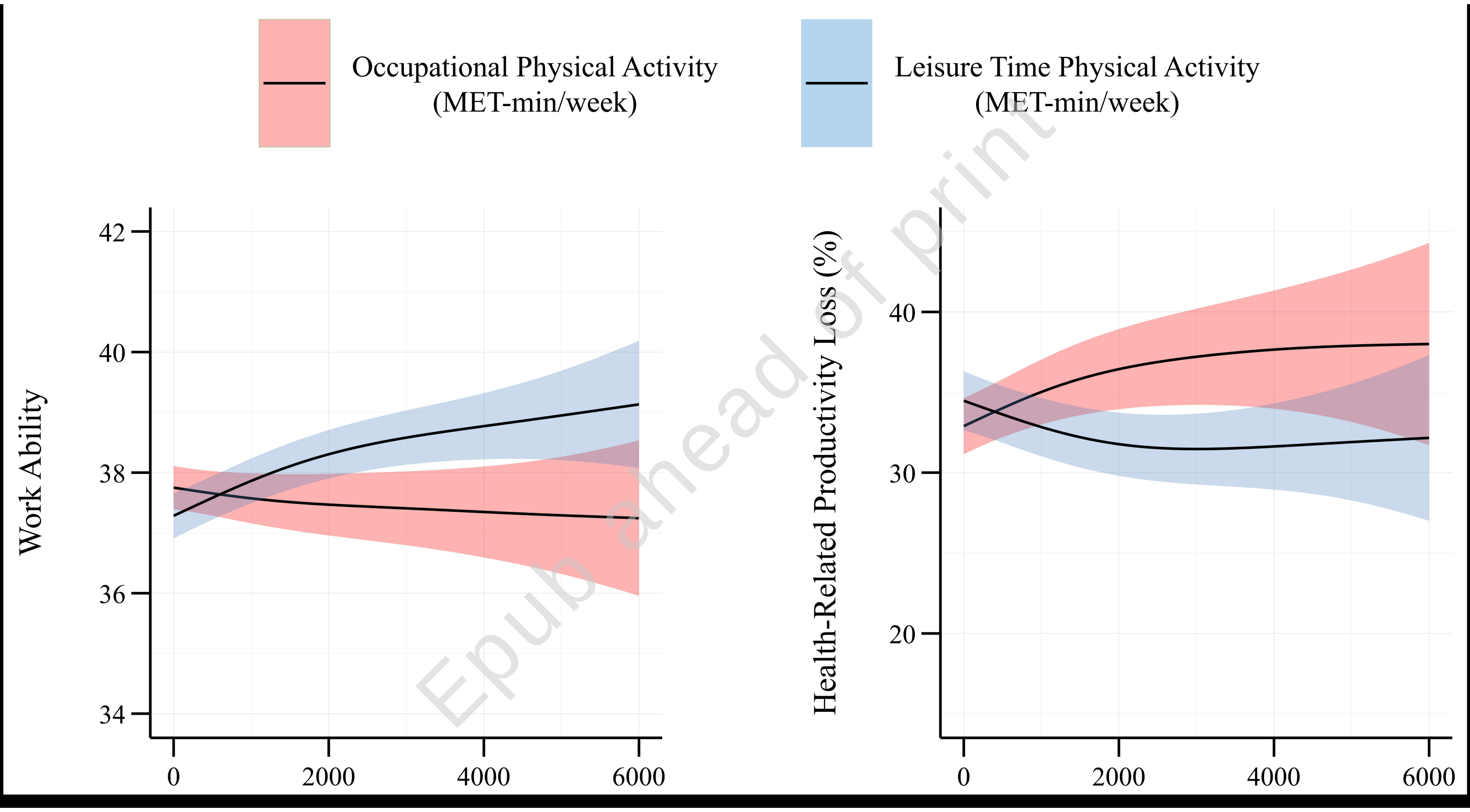
Figures

Figure 1. Generalized additive model of work ability and health-related productivity loss according to occupational and leisure-time physical activity.

Figure 2. Generalized additive model of leisure-time physical activity according to work ability and health-related productivity loss within each occupational physical activity subgroup.

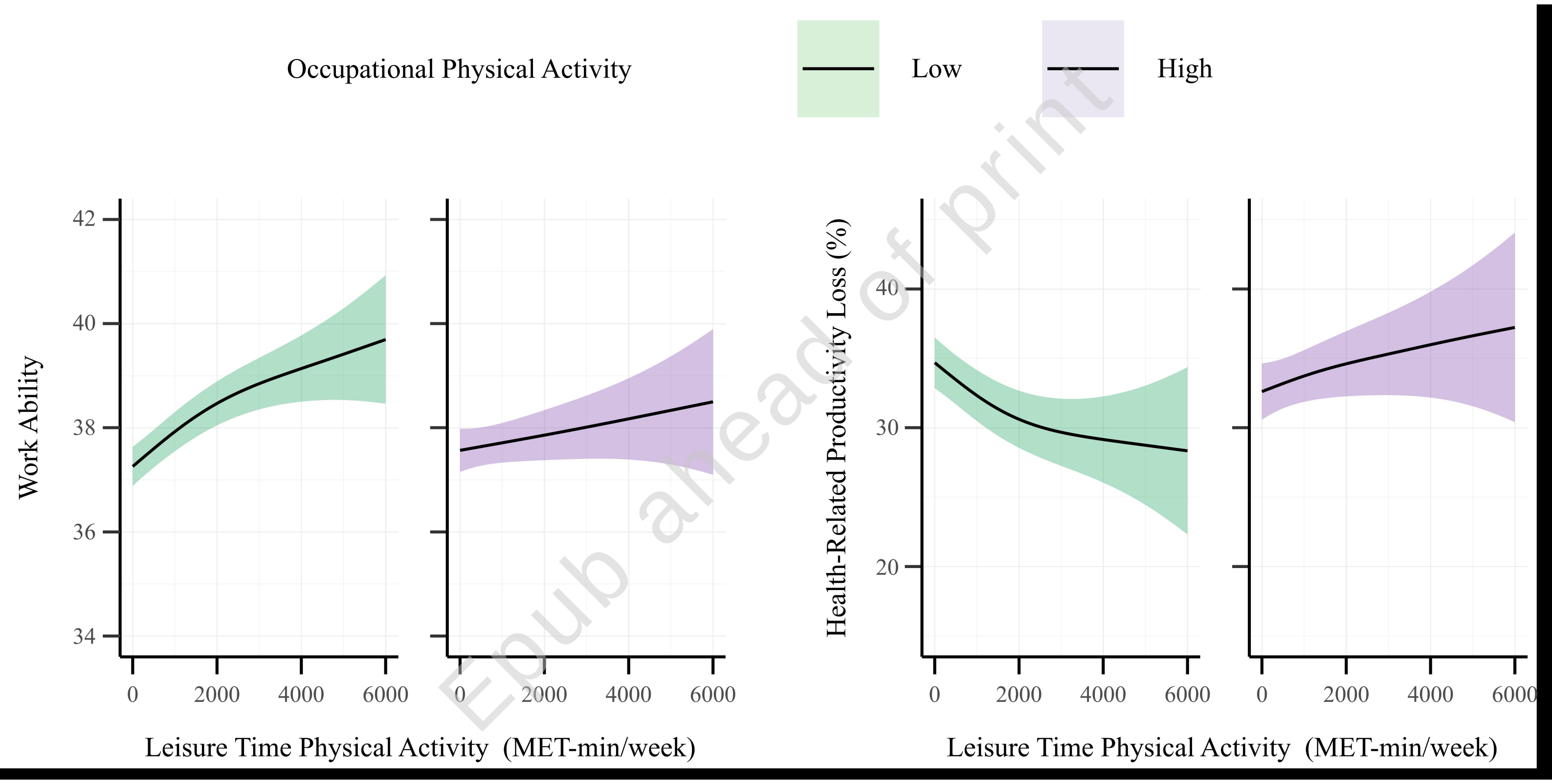
Figure 3. Generalized additive model of leisure-time physical activity within each occupational physical activity subgroup ~~for different~~by age group~~s~~.

Figure 1



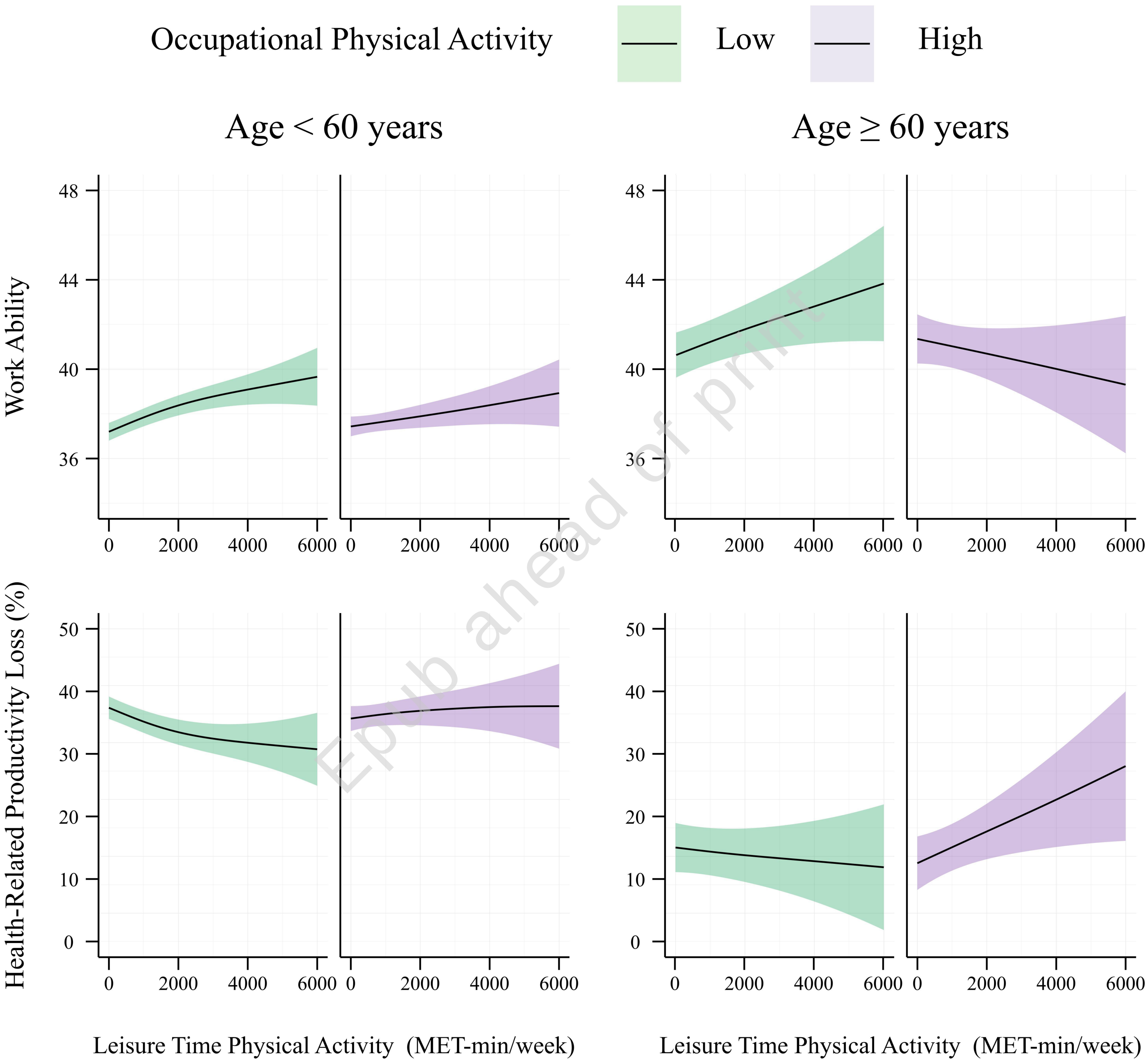
Occupational Physical Activity (MET-min/week)
Leisure Time Physical Activity (MET-min/week)
Work Ability
42
40
38
36
34
0
2000
4000
6000
Health-Related Productivity Loss (%)
40
30
20
0
2000
4000
6000

Figure 2



Occupational Physical Activity
Low
High
Work Ability
42
40
38
36
34
0
2000
4000
6000
Leisure Time Physical Activity (MET-min/week)
Health-Related Productivity Loss (%)
40
30
20
Leisure Time Physical Activity (MET-min/week)

Figure 3



Occupational Physical Activity
Low
High
Age < 60 years
Age ≥ 60 years
Work Ability
48
44
40
36
0
2000
4000
6000
Health-Related Productivity Loss (%)
50
40
30
20
10
Leisure Time Physical Activity (MET-min/week)