



# Leisure-time and commuting physical activity and subsequent sickness absence among young and early midlife employees: a register-linked follow-up study 2017–2020

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## Abstract

**Purpose** We examined leisure-time physical activity (LTPA) and active commuting (AC) and their associations with subsequent sickness absence (SA) among young and early midlife employees.

**Methods** The 2017 Helsinki Health Study survey among employees of the City of Helsinki aged 19–39 was prospectively linked to register-based data on total, short- and long-term SA spells (2017–2020). LTPA (n=3618) and AC (n=3513) were assessed as weekly metabolic equivalent (MET) hours in 2017. LTPA was categorized into five groups based on intensity and weekly volume (inactivity, moderate, moderate-to-vigorous, vigorous and high vigorous) and AC into four groups (inactive, low moderate, moderate-to-vigorous, vigorous). Analyses were stratified by sex and adjusted for sociodemographic and lifestyle factors using negative binomial regression to estimate incidence rate ratios (IRRs) and their 95% confidence intervals (CIs).

**Results** Women had more SA than men (135 vs 97 days per 10 person-years;  $p < 0.001$ ). Women with moderate-to-vigorous LTPA had, compared to the inactive, lower rates of total SA (IRR 0.69, 95% CI 0.60–0.80) short SA and long SA after full adjustments for covariates. Men with vigorous LTPA remained protective in total SA days (IRR 0.60, 95% CI 0.44–0.81) and short SA spells after adjustment. For AC, protective associations were observed only among women.

**Conclusion** LTPA including vigorous-intensity activity was associated with lower SA over the follow-up, although patterns differed by sex and activity level. Associations for AC were weaker and confirmed for women only. Vigorous-intensity physical activity may be beneficial for reducing SA already in early working life.

**Keywords** Leisure-time physical activity · Active commuting · Gender · Sickness absence

## Introduction

Sickness absence (SA) represents a major public health, economical and societal challenge in Western countries. It imposes substantial costs on employees, workplaces, and society as a whole (Lallukka et al. 2020a, b; Virtanen et al. 2018). In addition, SA due to mental health problems have increased markedly, especially among women (Blomgren and Perhoniemi 2022). Overall, higher levels of SA have

been reported in female-dominated workplaces, suggesting that gender-related factors play an important role in shaping SA patterns (Haukenes and Hammarström 2024). Perceived work ability has declined among younger age groups in Finland during the last two decades and consequently work ability is projected to decline among middle-aged and older age groups in the coming decades (Lahti et al. 2025). Therefore, effective strategies to counteract declining work ability at the population level are urgently needed.

Recent evidence indicates that approximately 31% of the world's population does not meet the World Health Organization's (WHO) minimum recommendations for physical activity (2.5 h of moderate intensity physical activity per week), contributing to considerable economic burdens on healthcare and social welfare systems worldwide (Bull et al. 2020). Physical inactivity has been identified as a risk factor

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for numerous chronic diseases and is one of the leading contributors to global mortality (Ding et al. 2020). Regular leisure-time physical activity (LTPA) has been associated with 1–2 additional disease-free years, with the largest gains observed among individuals at elevated health risk, particularly those with lower socioeconomic position (Nyberg et al., 2025). A recent meta-analysis estimated that increasing moderate-to-vigorous LTPA by as little as 5 min per day could reduce population mortality by up to 10% (Ekelund et al. 2026). Active commuting (AC) has been associated with lower all-cause and cardiovascular mortality in meta-analyses, reduced cardiovascular disease risk and improved cardiorespiratory fitness and work ability (Dutheil et al. 2020; Hamer and Chida 2008; Kalliolahti et al. 2024).

Among Finnish employees, work ability has been observed to decline already between the ages of 31 and 46, emphasizing the importance of promoting work ability and identifying risk factors for its deterioration at an early stage (Punakallio et al. 2019). Evidence remains particularly limited regarding studies examining both LTPA and AC and risk of subsequent SA spells of different length. Addressing these gaps is important for informing early preventive strategies in the working-age population. Previous research has shown that LTPA is associated with a reduced risk of SA (Ketels et al. 2023; Lahti et al. 2012; López-Bueno et al. 2020; Proper et al. 2006) whereas there is less evidence regarding AC on relation to SA (Kalliolahti et al., 2025; Mytton et al. 2016). While physical activity is widely acknowledged as a determinant of health and work ability, little is known about how different domains, volumes, and intensities of activity translate into SA outcomes.

Health behaviors and health outcomes are unequally distributed across population groups. Individuals with lower socioeconomic position tend to report poorer perceived health and lower work ability compared to those with medium or higher socioeconomic position (Laaksonen et al. 2011). High mental and physical demands have been associated with a higher risk of SA (Andersen et al. 2016). In addition, factors that help maintain work ability include healthy lifestyle behaviors, and normal body weight (De Bortoli et al. 2021). The aim of this study was to examine how different volumes and intensities of LTPA and AC relate to subsequent SA (total SA days, and days of short and long SA spells, respectively), and whether these associations differ between women and men, controlling for key covariates such as age, occupational class, mental or physical strenuousness of work, smoking and body mass index (BMI).

## Methods

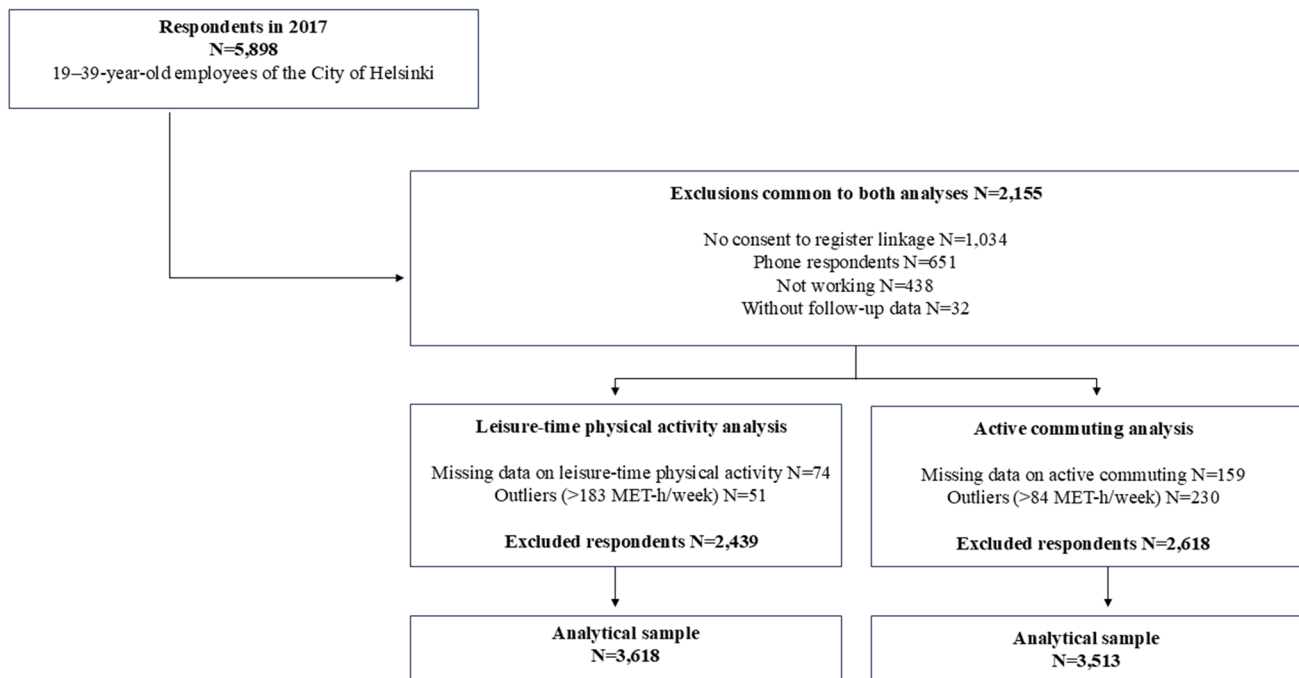
### Study population

This was a longitudinal prospective cohort study based on data collected between 2017 and 2020. The analyses utilized questionnaire data from the Helsinki Health Study (HHS) combined with prospectively linked register-based SA information from the City of Helsinki, Finland. The survey was conducted in autumn 2017 (Phase 1) among employees of the City of Helsinki aged 19–39 years who were eligible at the time of sampling, defined as having an employment contract of at least 50% for a minimum of four months prior to sampling. ( $n=11,459$ ) (Fig. 1). Data were gathered, including online questionnaires (58%), postal surveys (29%) and telephone interviews (13%) (Lallukka et al. 2020a, b). Participants with a registered email address were invited to complete the survey online, while paper questionnaires were sent to those without email access. All individuals who did not respond after the initial reminders were mailed a paper questionnaire containing login information in the cover letter, allowing them to select their preferred mode of response (online or via mail); postage costs were prepaid. The overall response rate was 51% ( $n=5898$ ), and women comprised 79% of the respondents, closely reflecting the sex distribution of the target population (and the Finnish municipal workforce) (Lallukka et al. 2020a, b). Consent to register linkage (81%,  $n=4864$ ) was required for inclusion in the study population. Participants who were interviewed by telephone ( $n=651$ ) were excluded, because the interview did not comprise the variable of interest of this study. Additionally, those who were not working full- or part-time at baseline ( $n=438$ ), without follow-up data ( $n=32$ ) and with missing LTPA ( $n=74$ ) or AC ( $n=159$ ) were excluded. The cut-off for removing the outliers was determined using the z-score method: a z-score of 3 was considered the threshold (Anusha et al. 2019). We chose the analyses to a common subset of respondents with complete data for both exposures, in order to maximize statistical power for each exposure-specific analysis. Therefore, as LTPA being the exposure, the final dataset consisted of 2850 women and 768 men. As for AC being the exposure, the final dataset consisted of 2773 women and 740 men.

### Exposures

#### Leisure-time physical activity and active commuting

Baseline (2017) weekly LTPA and AC were assessed separately with four items capturing activities at four intensity levels. Participants reported the number of hours per week



**Fig. 1** Flow chart of the Helsinki health study population 2017–2020

spent in each intensity category. The items corresponded to low-intensity activity (walking), moderate intensity (brisk walking or equivalent), vigorous intensity (such as jogging) and high vigorous intensity (running). Each intensity level was assigned a metabolic equivalent (MET) value (Kujala et al. 1998), which was used to calculate weekly MET-hours for the four intensity categories. The questionnaire items used to assess LTPA and AC are presented in Supplementary File 1. Following this, LTPA was categorized into five groups and AC into four groups based on distributional cut-offs with additional intensity conditions. LTPA groups were defined as: inactivity (<14.0 MET-h/week without vigorous activity), moderate (14.0–39.9 MET-h/week without vigorous), moderate-to-vigorous (14.0–39.9 MET-h/week with vigorous), vigorous (40.0–69.9 MET-h/week with vigorous) and high vigorous ( $\geq 70.0$  MET-h/week with vigorous). AC groups were defined as: inactivity (<3.0 MET-h/week without vigorous), moderate (3.0–8.9 MET-h/week without vigorous), moderate-to-vigorous (9.0–19.9 MET-h/week with vigorous) and vigorous ( $\geq 20.0$  MET-h/week with vigorous).

### Outcome measure: sickness absence

Information on SA was obtained from the City of Helsinki personnel register for employees who consented to record linkage (82%). SA data were obtained from the employer (the City of Helsinki) personnel register for the employees

who consented to record linkage, and that the register data were linked to questionnaire survey responses using unique personal identifiers assigned to each Finnish citizen at birth. Follow-up began on the day after the questionnaire was returned and continued through March 2020 (coinciding with the onset of the COVID-19 pandemic in Finland) or until the end of the employment contract, whichever occurred first (mean follow-up was 2.2 years). We analyzed total SA days and, in addition, differentiated short SA spells (1–7 days) from long SA spells ( $\geq 8$  days), as one week represents the maximum duration for self-certified absence spells recorded in the employer register, which could be approved by supervisors without a medical certificate. During the follow-up, SA of eight days or longer required a physician-approved medical certificate, and the same SA policy applied to all City of Helsinki employees. Additionally, we analyzed SA of all lengths combined.

### Covariates

Covariates were derived from the survey. Three age groups were used: 19–29, 30–34, and 35–39 years at Phase 1. We classified sex as women and men. Occupational class was classified into three categories: manual or routine non-manual workers' (e.g., care workers and underground train drivers), 'semi-professional' (e.g., nurses and technicians) and 'professional' (e.g., teachers, doctors, and managers).

The classification reflects occupational hierarchy and job characteristics rather than professional status. Physical and mental strenuousness of work were assessed using single-item questions asking participants to rate how physically or mentally strenuous their job was. Response options were "Very light", "Rather light", "Rather strenuous", and "Very strenuous". Responses were categorized into three levels for analyses: low (very/rather light), moderate (rather strenuous), and high (very strenuous). BMI was calculated from weight and height ( $\text{kg/m}^2$ ), and participants were categorized into four groups those with underweight ( $<1\%$ ) and healthy weight ( $\text{BMI} \leq 25.0 \text{ kg/m}^2$ ), those with overweight ( $25.0\text{--}29.9 \text{ kg/m}^2$ ), obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ), and a separate

category for missing BMI. Smoking was divided into smokers (daily and occasional) and non-smokers (non-smokers and ex-smokers).

## Statistical methods

Cross-tabulation with chi-squared tests were used to describe and compare the Phase 1 characteristics among women and men (Table 1). We used a negative binomial model to calculate incidence rate ratios (IRR) and their 95% confidence intervals (CI) to examine the association with SA to different volumes and intensities of LTPA and AC. Predicted marginal means per 10 person-years from

**Table 1** Descriptive statistics by sex, the Helsinki Health Study, 2017 between leisure-time physical activity ( $n=3618$ ) and active commuting ( $n=3513$ ).

|                                       | Leisure-time physical activity |                        |          | Active commuting         |                        |          |
|---------------------------------------|--------------------------------|------------------------|----------|--------------------------|------------------------|----------|
|                                       | Women<br>( <i>n</i> , %)       | Men<br>( <i>n</i> , %) | <i>p</i> | Women<br>( <i>n</i> , %) | Men<br>( <i>n</i> , %) | <i>p</i> |
| <i>Age</i>                            | 2850 (79)                      | 768 (21)               | <0.001   | 2773 (79)                | 740 (21)               | <0.001   |
| 19–29                                 | 966 (34)                       | 195 (25)               |          | 949 (34)                 | 193 (26)               |          |
| 30–34                                 | 941 (33)                       | 251 (33)               |          | 919 (33)                 | 246 (33)               |          |
| 35–39                                 | 943 (33)                       | 322 (42)               |          | 905 (33)                 | 301 (41)               |          |
| <i>Occupational class</i>             |                                |                        | <0.001   |                          |                        | <0.001   |
| Professional                          | 817 (29)                       | 231 (30)               |          | 783 (28)                 | 284 (30)               |          |
| Semi-professional                     | 1223 (43)                      | 243 (32)               |          | 1201 (43)                | 232 (31)               |          |
| Manual/routine non- manual            | 810 (28)                       | 294 (38)               |          | 789 (29)                 | 224 (39)               |          |
| <i>Mental strenuousness of work</i>   |                                |                        | <0.001   |                          |                        | <0.001   |
| Low                                   | 527 (19)                       | 225 (29)               |          | 509 (18)                 | 212 (29)               |          |
| Moderate                              | 1829 (64)                      | 409 (53)               |          | 1773 (64)                | 401 (54)               |          |
| High                                  | 494 (17)                       | 134 (18)               |          | 491 (18)                 | 127 (17)               |          |
| <i>Physical strenuousness of work</i> |                                |                        | <0.001   |                          |                        | <0.001   |
| Low                                   | 628 (22)                       | 200 (26)               |          | 615 (22)                 | 192 (26)               |          |
| Moderate                              | 1266 (44)                      | 374 (49)               |          | 1217 (44)                | 361 (49)               |          |
| High                                  | 956 (34)                       | 194 (25)               |          | 941 (34)                 | 187 (25)               |          |
| <i>Body mass index</i>                |                                |                        | <0.001   |                          |                        | <0.001   |
| <25.0 $\text{kg/m}^2$                 | 1753 (61)                      | 354 (46)               |          | 1706 (61)                | 345 (47)               |          |
| 25.0–29.9 $\text{kg/m}^2$             | 646 (23)                       | 292 (38)               |          | 634 (23)                 | 279 (38)               |          |
| $\geq 30.0 \text{ kg/m}^2$            | 418 (15)                       | 119 (16)               |          | 403 (15)                 | 113 (15)               |          |
| Missing                               | 33 (1)                         | 3 (0.4)                |          | 30 (1)                   | 3 (0.4)                |          |
| <i>Smoking</i>                        |                                |                        | 0.38     |                          |                        | 0.34     |
| No                                    | 2163 (76)                      | 571 (74)               |          | 2104 (76)                | 549 (74)               |          |
| Yes                                   | 687 (24)                       | 197 (26)               |          | 669 (24)                 | 191 (26)               |          |
| <i>Leisure-time physical activity</i> |                                |                        | <0.001   |                          |                        |          |
| High vigorous                         | 506 (18)                       | 182 (24)               |          | –                        | –                      |          |
| Vigorous                              | 734 (26)                       | 209 (27)               |          | –                        | –                      |          |
| Moderate-vigorous                     | 636 (22)                       | 165 (21)               |          | –                        | –                      |          |
| Moderate                              | 443 (15)                       | 88 (12)                |          | –                        | –                      |          |
| Inactive                              | 531 (19)                       | 124 (16)               |          | –                        | –                      |          |
| <i>Active commuting</i>               |                                |                        |          |                          |                        | 0.062    |
| Vigorous                              | –                              | –                      |          | 686 (25)                 | 196 (26)               |          |
| Moderate-vigorous                     | –                              | –                      |          | 721 (26)                 | 169 (23)               |          |
| Low moderate                          | –                              | –                      |          | 666 (24)                 | 161 (22)               |          |
| Inactive                              | –                              | –                      |          | 700 (25)                 | 214 (29)               |          |

*P*-values present differences between women and men

the crude negative binomial regression models represent expected values standardized for follow-up time (Table 2 & Supplementary Tables 1–2). The ‘exposure’ groups were formed based on LTPA or AC, separately. Inactive participants in LTPA and AC were used as reference group. All models in the main analysis were adjusted for age with an offset for follow-up time at work. Additional adjustments for individual covariates were performed (Supplementary Tables 3, 4, 5, 6). To avoid loss of individuals due to missing BMI and to retain comparability across models, individuals with missing BMI were included as a separate category in the adjusted analyses.

Neither of the interaction terms between LTPA or AC and sex reached statistical significance when formally tested (LTPA=0.08; AC=0.30). However, analyses were stratified by sex instead of pooled analyses to provide a clearer understanding of how physical activity may relate to SA separately in women and men.

We first present sex-stratified associations between physical activity and SA as the primary analyses. Interaction models were fitted next to formally assess effect modification by sex and to illustrate predicted marginal means. Predicted marginal means presented in Fig. 2 were estimated from models including interactions between sex and LTPA or AC to illustrate potential sex-specific patterns in SA per 10 person-years. Consequently, predicted means were higher than the descriptive averages, due to skewed distributions of SA days. As an additional analysis, potential interaction between LTPA and AC was examined with data available for both exposures ( $n=3488$ ) by including a multiplicative interaction term between the categorical LTPA and

AC variables in an age- and sex-adjusted negative binomial regression model.

The STROBE statement checklist is presented in Supplementary File 2.

Stata 19.5 (StataCorp LP; College Station, Texas, USA) statistical package was used for all analyses.

## Results

Women comprised approximately four-fifths of the study population (Table 1). Compared with men, women were younger, more often employed in semi-professional occupations, and reported lower levels of both mental and physical strenuousness of work ( $p<0.001$ ). Men were more frequently employed in manual or routine non-manual occupations and had higher BMI, with overweight being more common among men than women ( $p<0.001$ ). Smoking prevalence did not differ between women and men. Regarding physical activity, men more often reported high vigorous LTPA whereas women were more frequently inactive ( $p<0.001$ ). No statistically significant sex differences were observed in AC categories ( $p=0.062$ ).

Women reported higher levels of SA than men (Table 2), including total SA days as well as both short and long SA spells ( $p\leq 0.001$ ). More precisely, women had more SA days per 10 person-years than men in both LTPA (135.1 days [128.7–141.5] vs. 95.1 days [86.5–103.8]) and AC (134.8 days [128.3–141.3] vs. 95.8 [86.9–104.7]) datasets.

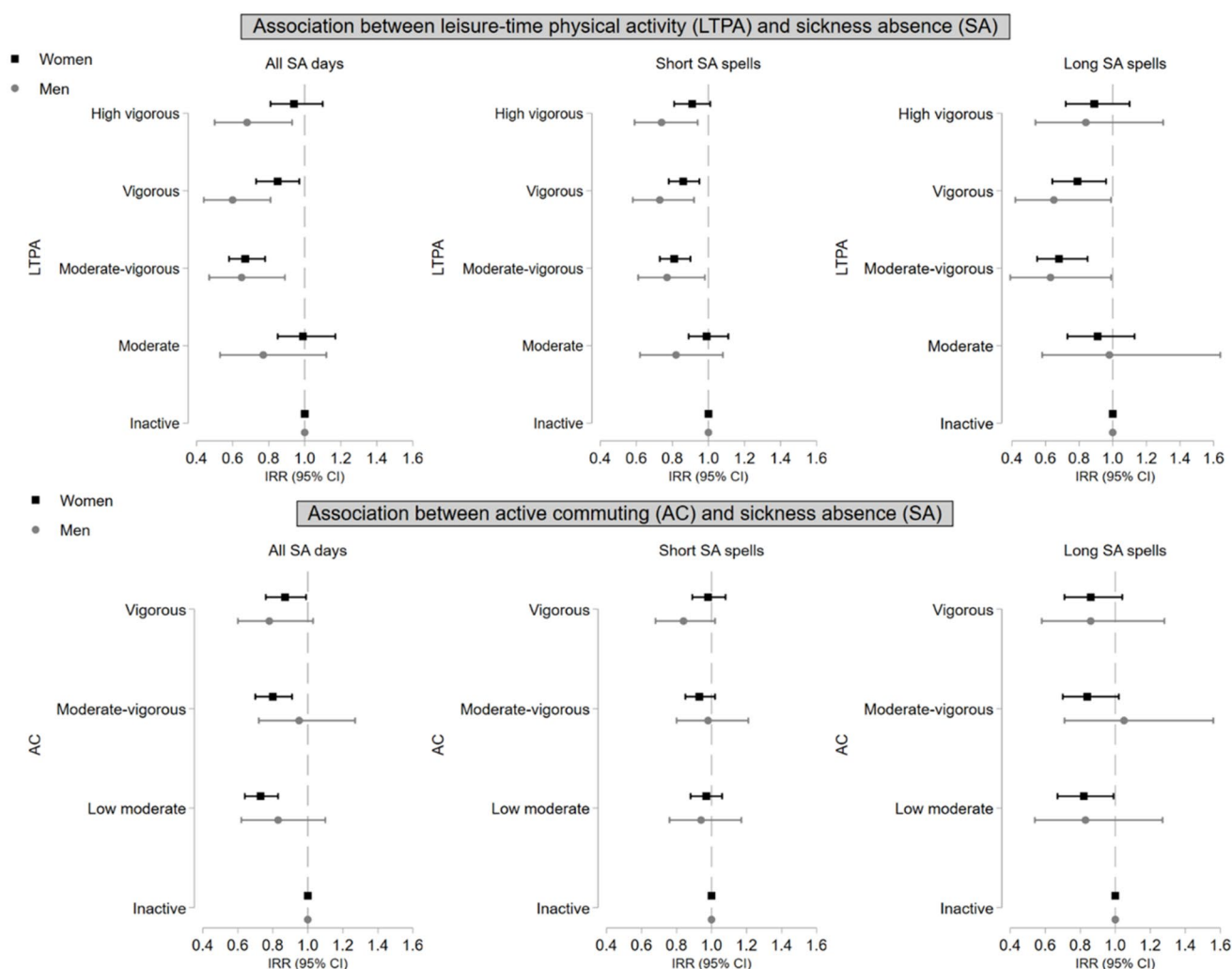
In the main analysis, among women (Fig. 2), moderate-to-vigorous LTPA was associated with significantly fewer SA days compared with inactivity (IRR 0.67, 95% CI 0.58–0.78) after adjusting for age. The association was weaker at vigorous activity levels (IRR 0.85, 95% CI 0.73–0.97) and was no longer evident at high vigorous LTPA, suggesting a non-linear association. Among men, moderate-to-vigorous and higher levels of LTPA were consistently associated with fewer SA days compared with inactivity (moderate-to-vigorous LTPA: IRR 0.65, 95% CI 0.47–0.89; vigorous LTPA: IRR 0.60, 95% CI 0.44–0.81; high vigorous LTPA: IRR 0.68, 95% CI 0.50–0.93), with no clear attenuation of the association at higher activity levels. Additionally, among women, the association between moderate-to-vigorous LTPA and SA, and among men, the association for vigorous LTPA, persisted after additional adjustment for individual covariates (Supplementary Tables 3 and 4). The overall pattern of associations was similar for short and long SA spells. However, the association between high vigorous LTPA and long SA spells did not persist for among men after adjustment for occupational class and BMI.

Among women, AC was associated with total SA, when compared with inactivity and adjusted for age (low moderate

**Table 2** Subsequent sickness absence (SA) days and spells by sex per 10 person-years, the Helsinki Health Study, 2017–2020 between leisure-time physical activity (LTPA) ( $n=3618$ ) and active commuting (AC) ( $n=3513$ ).

|      |                  | SA days |                     | SA spells             |                      |
|------|------------------|---------|---------------------|-----------------------|----------------------|
|      |                  | N       | Mean (95% CI)       | Shorter Mean (95% CI) | Longer Mean (95% CI) |
| LTPA | All participants | 3618    | 126.6 (121.2–131.9) | 27.2 (26.3–28.0)      | 2.3 (2.2–2.5)        |
|      | Women            | 2850    | 135.1 (128.7–141.5) | 28.7 (27.7–29.7)      | 2.5 (2.3–2.7)        |
|      | Men              | 768     | 95.1 (86.5–103.8)   | 21.6 (20.1–23.1)      | 1.8 (1.5–2.1)        |
| AC   | All participants | 3513    | 126.5 (121.1–131.9) | 27.1 (26.3–28.0)      | 2.3 (2.2–2.5)        |
|      | Women            | 2773    | 134.8 (128.3–141.3) | 28.6 (27.6–29.6)      | 2.5 (2.3–2.6)        |
|      | Men              | 740     | 95.8 (86.9–104.7)   | 21.7 (20.2–23.2)      | 1.8 (1.5–2.1)        |

Values are presented in means with 95% confidence intervals (CIs)



**Fig. 2** Incidence rate ratios (IRR) with 95% confidence intervals (CIs) from negative binomial regression models for the associations of leisure-time physical activity (LTPA) levels (upper panels) and active commuting (AC) levels (lower panels) with sickness absence (SA) out-

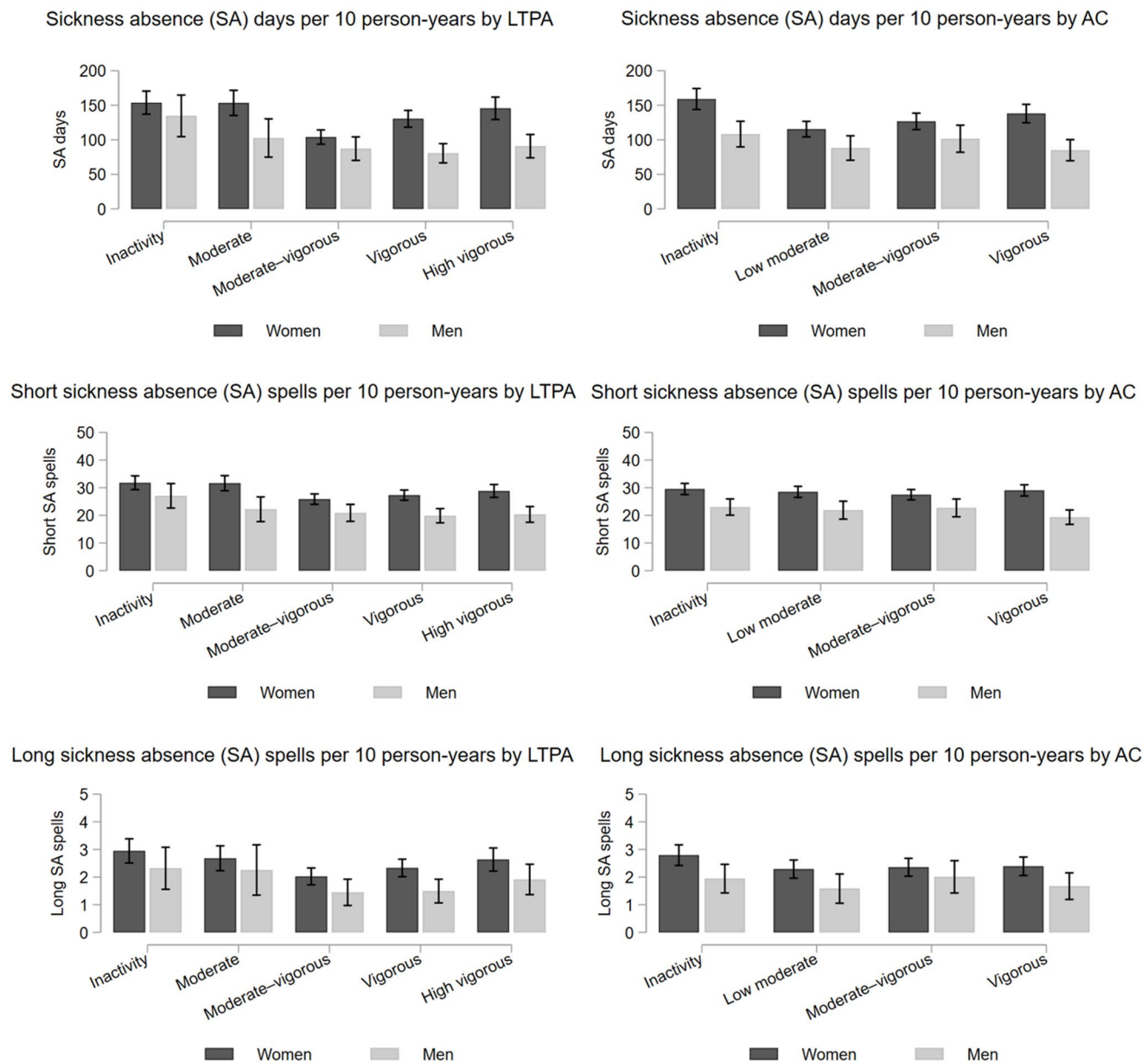
comes: total SA days (left column), short SA spells (middle column), and long SA spells (right column) between sex. Inactivity was used as the reference category. Estimates are derived from negative binomial regression models, adjusted for age and follow-up time (offset)

AC: IRR 0.73, 95% CI 0.63–0.83; moderate-vigorous AC IRR 0.80, 95% CI 0.70–0.91; vigorous AC IRR 0.87, 95% CI 0.76–0.99). The association between low moderate and moderate-to-vigorous AC persisted after additional adjustment for individual covariates (Supplementary Tables 4 and 5). No statistically confirmed associations were found among men (Supplementary Table 6).

Among women, when adjusted for age (Fig. 3), moderate-to-vigorous LTPA activity was associated with fewer SA days per 10 person-years compared with inactivity (moderate-to-vigorous: 104.0 days [95% CI 93.7–114.3] vs. inactivity: 145.6 days [95% CI 129.3–161.8]). Estimates at higher activity levels were closer to those of the inactive group, indicating attenuation of the association at higher LTPA levels (Supplementary Table 7). As for AC, low moderate (115.5 days [95% CI 104.3–126.7] and

moderate-to-vigorous (126.7 days [114.8–138.5]) AC were associated with fewer SA days per 10 person-years compared with inactivity (159.0 days [95% CI 143.9–174.2]) (Supplementary Table 8).

Among men (Fig. 3), moderate-to-vigorous and higher levels of LTPA were consistently associated with fewer SA days compared with inactivity (moderate-to-vigorous: 87.2 days [70.2–104.2]; vigorous: 80.5 days [95% CI 66.6–94.4] vs. inactivity: 145.6 days [95% CI 129.3–161.8]), with no clear attenuation of the association at higher activity levels (Supplementary Table 7). No significant associations emerged among men in AC. In an additional analysis (data not shown), there was evidence of an interaction between LTPA and AC in relation to SA ( $P$  for interaction = 0.007).



**Fig. 3** Model-predicted mean number of sickness absence (SA) days, short SA spells and long SA spells per 10 person-years by leisure-time physical activity (LTPA) and active commuting (AC) by sex. Esti-

mates are derived from negative binomial regression models including sex and LTPA or AC interactions, adjusted for age and follow-up time (offset). Error bars indicate 95% confidence intervals

## Discussion

Our study conducted among young and early midlife Finnish employees showed that vigorous LTPA, when compared to physical inactivity, was associated with lower rates of SA days during the follow up between 2017 and 2022. Among women, the association was weaker for higher LTPA volume, whereas in men it remained relatively stable across activity levels. After adjusting for covariates, moderate-to-vigorous LTPA among women and vigorous LTPA among men remained associated with lower rates of total, short and

long SA days. AC was also associated with fewer SA days among women compared with the inactive group, and these associations largely persisted after adjusting for covariates, although they attenuated in the most active group. No association could be confirmed among men.

Our findings are generally consistent with previous longitudinal studies showing that higher levels of LTPA are associated with fewer SA days (Holtermann et al. 2012; Laaksonen et al. 2009). Some previous studies also suggest that increasing moderate-to-vigorous or vigorous LTPA contribute to lower SA among older working-age adults (Lahti

et al. 2012; López-Bueno et al. 2020), including those in the same age range as in our study (Ketels et al. 2023; Proper et al. 2006).

The MET-based estimates reflect both weekly intensity and duration. The finding that moderate-to-vigorous, but not moderate, LTPA was associated with fewer SA days—despite similar total volumes—suggests that intensity may be an important aspect of the relationship. Vigorous activity induces greater physiological adaptations per unit time and may be more accurately reported than moderate or light activity, reducing exposure misclassification (Quinlan et al. 2021; Saint-Maurice et al. 2018). Furthermore, a recent study has shown that the validity of physical activity questionnaires varies by fitness level, with lower-fit individuals being more prone to over-reporting, and BMI acting as a useful proxy for fitness in epidemiological studies (Meh et al. 2023). This mechanism could partly explain why adjusting for BMI attenuated the associations in our data. In an occupational context, vigorous LTPA may more effectively enhance resilience and work ability, which are critical for preventing SA.

The association between LTPA and SA showed sex-specific differences. Among men, the protective association persisted across higher activity categories, which resembles the plateau pattern reported in large dose–response analyses of LTPA and mortality, where health benefits increased up to three to five times the recommended minimum, after which additional volume conferred only modest further benefit, with no evidence of harm and no indication of additional protective effect (Arem et al. 2015). In contrast, among women the strongest association emerged at moderate-to-vigorous levels and attenuated at the highest category, with estimates returning close to unity. This non-monotonic pattern at very high volumes is compatible with large, pooled dose–response study on non-occupational physical activity and major health outcomes, where relative risk reductions tend to flatten and become statistically imprecise at the highest exposure levels (Garcia et al. 2023). This pattern among women may also relate to evidence that women derive comparable or greater survival benefits from lower LTPA doses than males. In a large US cohort analysis, women achieved maximal mortality risk reduction at ~140 min/week of moderate-to-vigorous LTPA, whereas men achieved a similar benefit only at 300 min/week; for both women and men, the benefits plateaued thereafter (Ji et al. 2024). However, recent dose–response meta-analyses similarly suggest broadly comparable shapes of the LTPA–mortality curve in men and women, implying that the attenuation observed among women in our study may not be attributable to biological intensity-response differences alone (Ekelund et al. 2024). It is also possible that higher levels of LTPA could have led to increased injury rates (Gabbett 2016), which

may partly explain the weaker association between LTPA and SA among women. In addition, women tend to use health care services more frequently than men (Lehto et al. 2024), which may also contribute to higher detection and reporting of health issues, and thus influence SA patterns in our study. Nevertheless, our findings suggest working-age women may reach optimal LTPA benefits at moderate volumes, particularly when accounting for their higher total physical activity load across household and occupational domains (Ainsworth et al. 1993; Harryson et al. 2016). This interpretation aligns with evidence that high occupational physical activity without sufficient recovery can attenuate the health benefits otherwise observed for LTPA (Holtermann et al. 2012). Yet, biological differences in intensity responses (Quinlan et al. 2021), as well as methodological factors including measurement error, residual confounding, and selection, cannot be ruled out as explanations for the observed attenuation among women.

AC displayed a similar pattern of association with SA, although the associations were generally weaker. Among women, low to moderate levels of active commuting were associated with fewer SA days compared with inactivity, whereas no associations could be confirmed among men. AC is typically performed on most workdays and is therefore integrated into daily routines, which means that even relatively short walking or cycling trips can accumulate to a meaningful weekly dose of light-to-moderate physical activity (Dutheil et al. 2020). Previous studies have shown that AC, particularly cycling, is associated with better health, work ability and reduced SA (Kalliolahti et al. 2024, 2025; Mytton et al. 2016). Moreover, our findings are consistent with evidence suggesting that even lower-intensity forms of AC are associated with reduced health risks. A recent systematic review and meta-analysis concluded that AC is associated with all-cause and cardiovascular mortality, with a dose–response relationship particularly evident for walking, which typically reflects light-to-moderate intensity activity (Dutheil et al. 2020). Another meta-analysis reported that walking and cycling-based active commuting was associated with an overall 11% reduction in cardiovascular risk, with stronger associations among women (Hamer and Chida 2008). Thus, the apparent difference between AC and LTPA may reflect differences in regularity and classification of activity rather than differences in the effects of walking or cycling per se.

## Methodological considerations

Some limitations should be acknowledged. Since the study population, and public sector employees in general, consist predominantly of women, statistical power for male-specific estimates was limited. Findings should be only

cautiously generalized to male employees outside the municipal sector. However, there is no particular reason to assume why the associations between physical activity and SA would be notably different or inverse in different sectors in Finland. For short, self-certified SA, there are minor differences between companies what is allowed before requiring a medical certificate. However, it is always required for longer absence, and same rules apply across Finland, since the Social Insurance Institution of Finland covers for the employer the cost of long SA in the same way in entire Finland. Furthermore, self-reported measures are prone to misclassification, and physical activity levels are often overestimated due to recall-related inaccuracies. In addition, responses may be influenced by social desirability, whereby participants report behaviors they perceive as appropriate or health-promoting (Corder et al. 2019). Furthermore, self-reported physical activity may distort dose-response relationships compared to objective measures (Niemelä et al. 2019). Although non-response analysis suggested that the respondents broadly represented the target population (Lallukka et al. 2020a, b) and the response rate was acceptable, non-response and potential healthy worker selection remain limitations. In addition, although LTPA and AC were analyzed separately because they represent different domains of physical activity, it is possible that their combined effects or interactions influence SA. Future studies should examine the joint contribution of different physical activity domains. Our additional analysis indicated an interaction between LTPA and AC in relation to SA. This suggests that the association of one physical activity domain with SA may vary according to the level of activity in the other domain, as the nature and potential relevance of this interaction need further investigation.

A major strength of this study is the use of a large employee cohort including young and midlife workers across a wide range of occupations. Another strength is the use of employer register data on SA and not self-reported, periods and the longitudinal design. The data included all SA periods, also short and long spells. This is important because total SA days and short spells are rarely included in national registers and therefore less studied. An additional strength is that both LTPA and AC were examined within the same cohort using the same outcome and follow-up, and the analyses were conducted separately.

These findings add to the growing body of evidence that, compared with inactivity, both LTPA and AC are associated with SA already in early and mid-adulthood. However, the observed sex differences and attenuation of associations at higher activity levels highlight the need for further research to better understand optimal activity patterns for preventing SA across different population groups.

## Conclusion

Our findings highlight the importance of considering both the volume and intensity of physical activity, as well as differences in work and recovery contexts between women and men, when examining associations with SA. Taken together, the results emphasize the potential of promoting physical activity in everyday life as part of workplace health promotion. Such efforts may be especially relevant for young and mid-career employees, for whom early prevention of SA could yield long-term benefits. Moreover, the findings emphasize the relevance of vigorous LTPA for younger working-age adults. Similar associations between vigorous LTPA and reduced SA have previously been observed among midlife and older employees, suggesting that vigorous activity may play an important role for work ability across different stages of working life.

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**Data availability** The Helsinki Health Study survey data (and the register data of the City of Helsinki) cannot be made publicly available due to strict data protection statutes and regulations. The data can only be used for scientific research. More information on the survey data can be requested from the Helsinki Health Study research group ([kthhs@helsinki.fi](mailto:kthhs@helsinki.fi)).

## Declarations

**Conflict of interest** The authors declare no competing interests.

**Ethical approval** Ethical approval The Helsinki Health Study protocol of young and early midlife employees has been approved by the ethics committees of the Faculty of Medicine, University of Helsinki, Finland (01/2017), and the health authorities of the City of Helsinki, Finland (HEL 2017- 004490T 13 02 01). Appropriate ethical aspects have been followed in all phases of the study, according to the 1964 Helsinki Declaration. In line with the GDPR, all participants were informed about the study and its purposes; voluntary participation; data

confidentiality, use, and processing; data protection statement; and contact details. Written informed consent to participate to both questionnaire survey and its register linkages was obtained from all study participants. The data protection statement is available at the Helsinki Health Study website: <https://www.helsinki.fi/en/researchgroups/helsinki-health-study/dataprotection-statement>.

**Consent to participate** All participants of this study gave their written informed consent to participate. Register data on sickness absence were obtained from the employer's register for those participants who provided informed consent for register linkage.

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