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Changes in active commuting and changes in work ability and recovery from work in 16,778 Finnish public sector employees

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ABSTRACT

Background: Promotion of active commuting by walking and cycling presents a feasible strategy to increase physical activity levels and improve employee health and wellbeing. Increasing evidence on the health benefits of active commuting exists, but little is known about longitudinal associations between active commuting and work ability, and recovery from work.

Methods: We conducted an observational cohort study of 16,778 public sector employees who responded to the Finnish Public Sector study surveys in 2020 and 2022. Within- and between-individual associations of changes in active commuting with changes in work ability and recovery from work were examined using hybrid modelling. Analyses were adjusted for sex and age at T1 (time-invariant confounders in the between-individual part of the analyses) and socio-economic factors, body mass index, health behaviours, and job strain (time-varying confounders in both parts).

Results: After adjustments, an increase in active commuting equivalent to 10 km per week was associated with small within-individual (unstandardized beta (B) = 0.016, 95% confidence interval (CI) 0.004–0.028) and between-individual (B = 0.028, 95% CI 0.019–0.038) improvements in work ability. In sex-stratified analyses, the positive within-individual effect on work ability was observed only among women (B = 0.026, 95% CI 0.001–0.040). With recovery from work, only between-individual positive association was observed (B = 0.032, 95% CI = 0.018–0.045).

Conclusions: It may be possible to improve work ability by increasing active commuting. However, it appears that a change corresponding to tens of weekly kilometres of active commuting is required to achieve a small improvement in work ability. No conclusive evidence supporting that an increase in active commuting enhances recovery from work was found.

1. Background

Extensive evidence underscores the physical and mental health benefits of physical activity, including walking and cycling (Kelly

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et al., 2014; World Health Organization, 2018, 2022b). Despite this, the global trend towards decreasing physical activity poses significant public health challenge (Guthold et al., 2018; World Health Organization, 2022a). As a part of the solution, governments and cities around the world are promoting active commuting to work (World Health Organization, 2022b). Active commuting by walking or cycling can increase the overall levels of weekly physical activity (Wanjau et al., 2023), and it is also better for the environment. For example, substituting motorized commuting with walking or cycling reduces greenhouse gas emissions from commuting traffic (Brand et al., 2021; European Environment Agency, 2022).

Active commuting may decrease, for example, the risk of diabetes, cardiovascular diseases (Dinu et al., 2018; Wu et al., 2021), and mortality (Dinu et al., 2018; Dutheil et al., 2020). Additionally, some earlier longitudinal research from the UK suggests that transitioning from passive to active commuting could lead to improvements in self-rated physical and mental health (Jacob et al., 2021) and that engaging more in active commuting may be beneficial for psychological wellbeing (Martin et al., 2014). Conversely, switching from active to passive commuting appears to have adverse effects on physical and mental health (Jacob et al., 2021). Long commutes– which are often undertaken passively – are also found to associate with adverse health-related effects such as poor self-rated health, fatigue (Hansson et al., 2011), sleep problems (Halonen et al., 2020; Hansson et al., 2011), and physical inactivity (Halonen et al., 2020). Consistent with earlier findings, a recent cross-sectional study showed that a greater time spent in commuting by walking or cycling was associated with better perceived health while longer commuting in general was associated with lower self-rated health status (Echeverría et al., 2023). In a recent study among Finnish public sector workers, an increase in active commuting was associated with improved self-rated health, but not with mental health-related outcomes (Haukka et al., 2023). Overall, the longitudinal effects of active commuting on mental health and subjective wellbeing remain unclear (Liu et al., 2022).

From employers' perspective, the potential of active commuting for improving work ability may also be of interest. Considering the established health benefits of active commuting, it is plausible to assume that increase in active commuting may improve work ability. This is also supported by some cross-sectional findings that have associated active commuting with better self-rated work ability (Kalliolahti et al., 2023; Phanprasit et al., 2022). In addition, a positive association between overall leisure-time physical activity and work ability has been shown, for example, among female white-collar workers (Nawrocka et al., 2019), among male workers with different occupational physical demands (Päivärinne et al., 2019), and in a Swedish cohort of predominately female health care workers (Arvidson et al., 2013). Yet, longitudinal associations between active commuting and work ability have not been previously studied.

To maintain good work ability and prevent work-related ill health, sufficient recovery from work is also essential (Sonnentag, 2018; Verbeek et al., 2019). Daily commute has potential for providing an important recovery-enhancing experience (McAlpine and Piszczek, 2022; van Hooff, 2015). However, it can also be a source of stress (Liu et al., 2022; van Hooff, 2015) and impede the recovery process (van Hooff, 2015). Whether the process is enhanced or hampered by the daily commute may depend largely on the person's subjective perceptions on the commute experience (McAlpine and Piszczek, 2022; van Hooff, 2015). Active commuters with typically shorter commute time (De Vos et al., 2022) and distance (Batista Ferrer et al., 2018) are found to experience less commute-related stress (Denstadli et al., 2017; Handy and Thigpen, 2019) and in general, they are more satisfied with their commute than passive commuters (De Vos et al., 2022; Handy and Thigpen, 2019; St-Louis et al., 2014; Willis et al., 2013). To best of our knowledge, longitudinal studies on whether recovery from work can be improved by increasing active commuting are non-existent.

We examined whether a change in active commuting (walking or cycling) was associated with changes in work ability and recovery from work in a cohort of 16,778 Finnish public sector employees. We hypothesised that an increase in weekly kilometres of active commuting and substituting passive commuting with walking or cycling would associate with beneficial changes in the outcomes. To test these, we examined the within- and between-individual associations of changes in active commuting (km/week; primary exposure

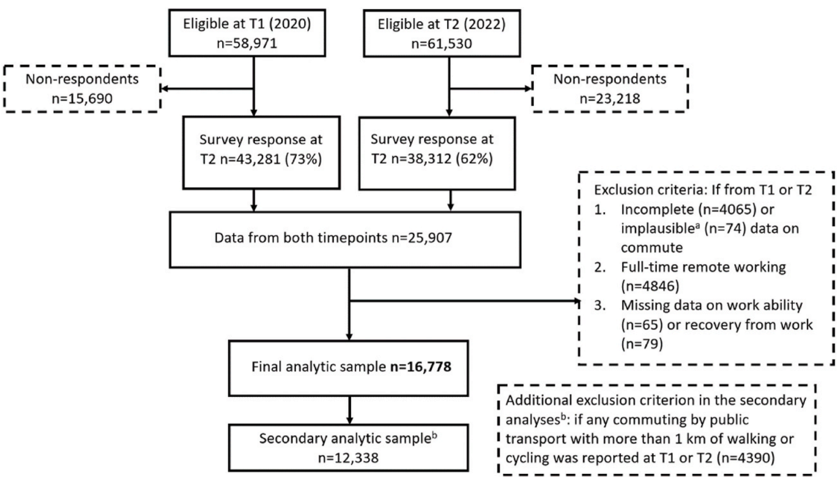

Fig. 1. Flow chart of the selection of study population. [a] Commute distance of >20 km if reported at least once per week walking or of >100 km if reported at least once per week cycling either during summer or winter. [b] Secondary analyses: change in the net amount of active commuting (days/week) as an exposure.

of interest) and changes in the net amount of active commute modes use (days/week; secondary exposure of interest) with changes in self-reported work ability and recovery from work.

2. Methods

2.1. Study design and participants

This was an observational cohort study utilising personnel wellbeing survey data from two waves of the ongoing Finnish Public Sector (FPS) study (Ervasti et al., 2021). Study participants were employees of four large Southern Finland cities who were asked to report their commuting behaviour as a part of the FPS surveys in autumn 2020 (T1) and autumn 2022 (T2). Response rate was 73% at T1 (n = 43,281) and 62% at T2 (n = 38,312). Of these, 25,907 participants had responded to the surveys at both time points. Participants without any information on their commute mode use or distance, and without information on work ability or recovery from work were excluded. Additionally, we excluded participants who reported working from home (full-time or almost full-time) and those with an unrealistic (or 0 km) response on commute distance. The final analytic sample (n = 16,778) consisted of participants with complete and plausible information on their commuting and data on both outcomes from both time points. In our secondary analyses (n = 12,388), participants who had reported any commuting by public transport with more than 1 km of walking or cycling (n = 4390) were additionally excluded. Flow chart of the selection of the study populations is shown in Fig. 1.

2.2. Commuting behaviour

At both time points, participants reported how often they used each commute mode during ‘summer conditions’ and ‘winter conditions’. Commute modes were walking, cycling, public transport with 1 km or more of walking or cycling (i.e. active public transport), public transport with less than 1 km of walking or cycling (i.e., passive public transport), and private car. If the participant reported using at least one commute mode during each season, the data on commuting behaviour was considered as complete and the missing values were imputed with ‘never’. Walking and cycling were considered as active commute modes and passive public transport and car as passive modes. Active public transport was not considered as either passive or active commute mode due to lack of information on how much of the commute was undertaken passively and actively.

The reported frequency of walking or cycling were converted to represent the average workdays per week of active commuting: ‘daily or almost daily’ = 5 days; ‘a few times a week’ = 3 days; ‘once a week’ = 1 day; ‘less than once a week’ = 0.5 days; ‘never’ = 0 days. As there were separate answers for summer and winter, we added up the days for both weather conditions and then divided it by two to produce the average weekly days of active commuting for the calendar year. The same procedures were done for the reported frequencies of passive commuting (car or passive public transport). At both time points, participants were also asked to report their one-way commute distance (km).

2.2.1. Primary exposure: change in active commuting (km/week)

To produce an exposure measurement for the kilometres per week of active commuting, average weekly days of active commuting were multiplied by the reported commute distance (km; two-way). To ease the interpretation of results, we further divided this by 10 so that in the regression analyses, one-unit change in the primary exposure represents a change in weekly active commuting equivalent to 10 km/week.

2.2.2. Secondary exposure: change in net amount of active commuting (days/week)

To produce an exposure measurement that represents the net amount of active commute modes use (days/week), average weekly days of passive commuting were subtracted from weekly days of active commuting. Thus, one-unit change in the secondary exposure represents a change in the net amount of active commuting equivalent to 1 day/week.

2.3. Work ability

Work ability was assessed with the first item from the validated instrument of Work Ability Index (WAI) (Ilmarinen et al., 1997): ‘Let’s assume that your work ability at its all-time best would be given 10 points, and 0 points would indicate that you are completely unable to work. How would you score your current work ability?‘. This measure, also called Work Ability Score (WAS) is similarly valid but simpler alternative for WAI (El Fassi et al., 2013). WAI is a subjective estimation of worker’s work ability in relation to health status, available resources, and work demands (Ilmarinen et al., 1997). Compared to WAI, WAS has similar associations with sickness absence and health (Ahlstrom et al., 2010) and they both predict the risk of disability pension (Jääskeläinen et al., 2016). In the analyses, we treated WAS as a continuous variable (scale from 0 = poor to 10 = excellent).

2.4. Recovery from work

Recovery from work was measured with a single item: ‘Let’s assume that 10 points indicates that you fully recover from work before the next workday, and 0 points that you do not recover at all. How would you score your recovery from work?’ The item was based on a measure developed and used by Kinnunen et al. (Kinnunen and Feldt, 2013; Kinnunen et al., 2011), and it has been shown to correlate with potential antecedents and consequences of poor recovery. In this study, instead of the original scale of 1–5, we used a scale similar to WAS from 0 (=not at all) to 10 (=completely) (Selander et al., 2023). The measure was treated as a continuous variable.

2.5. Covariates

We controlled for sex, age at T1, marital status (unmarried vs. cohabiting or married), type of job contract (permanent vs. fixed-term), type of employment (full-time vs. part-time), socio-economic status (SES; high vs. intermediate or low), body mass index (BMI; kg/m2), smoking (current vs. never or ex-smokers), alcohol use (no/moderate vs. at-risk use), and job strain.

SES was categorised into three groups according to 2001 International Standard Classification of Occupations (ISCO) codes: high (managers and senior specialists such as physicians and teachers), intermediate (e.g., specialists, office workers, and health and social care professionals) and low (manual workers, incl. e.g., practical nurses). Alcohol use was assessed with questions on weekly consumption of alcoholic beverages and drinks, converted to represent weekly grammes of pure alcohol and further dichotomised into no/moderate use and at-risk use. The cut-off value of at-risk alcohol use for women was more than 11 units or 140 g, and for men more than 23 units or 280 g of alcohol per week. One unit was 12 g of alcohol that is approximately equivalent to one 33 cl bottle of beer or equivalent drink, 12 cl glass of wine, or 4 cl of hard liquor (Ervasti et al., 2018). The assessment of job strain was based on the Job Demands and Control model (Karasek and Theorell, 1990) and executed with a modified Job Content Questionnaire (Karasek et al., 1998). Responses were given on Likert scale 1 = "very little" to 5 = "very much". The continuous measure for job strain (balance between job demands and job control; JD/JC) was constructed by dividing the mean response scores to questions on psychological job demands with mean response scores on skills discretion and decision authority (job control) so that higher value indicated higher strain. In the survey questionnaire, psychological job demands were assessed with five items and job control with nine items (Ruokangas et al., 2022).

In the secondary analyses with change in the net amount of weekly active commutes as an exposure, we additionally controlled for commute distance (one-way; km).

2.6. Statistical analyses

To visualize the potential linear associations, we plotted scatter graphs of the crude (i.e., uncontrolled) associations between changes in work ability and recovery from work by change in active commuting (km/week). The scatter plots were drawn from the entire analytic study population and further from the sex-stratified subpopulations.

To analyse the associations between the change in active commuting and changes in the outcomes, we used hybrid modelling. Hybrid model is a type of linear mixed effects model that can be used for longitudinal data analysis. It produces regression estimates for both within- and between-individual associations of the independent and the dependent variable over time. In the model, the within-individual part of the association is obtained by using the deviation score (i.e., differences between the observations and the individual mean value) as the independent variable, whereas the between-individual part is obtained by using the individual mean value over time as the independent variable (Twisk and de Vente, 2019). The advantage of the hybrid approach is that, unlike other mixed effects models or fixed-effect model, it enables to disentangle the within- and between-individual parts of the association (Bell et al., 2018; Twisk and de Vente, 2019). In addition, while the within-individual part allows to control for the effects of all time-invariant variables (e.g., sex, birth year, genetics, and personality) whether observed or not (as in the fixed-effect model), the hybrid model also allows to estimate their effects in the between-individual part (Twisk and de Vente, 2019). In this study, the between-individual part of the model was adjusted for sex and age at T1 (time-invariant) and both parts for marital status, type of job contract, type of employment, SES, BMI, smoking status, weekly alcohol use, and job strain (time-varying).

To analyse the associations between the change in the secondary exposure of interest (i.e., the net amount of weekly active commuting) and changes in the outcomes, similar hybrid models were run in a subpopulation from which the participants who had reported any commuting by public transport with more than 1 km of walking or cycling were excluded (n = 12,338). The models were adjusted as the main analyses except that we additionally included commute distance into the models as a time-variant confounder.

We tested for a potential interaction with 1) sex, 2) job strain at T1, and 3) passive vs. active commuting at T1. Interactions were tested separately by introducing an interaction term 1) 'sex × active commuting', 2) 'job strain at T1 × active commuting', or 3) 'passive vs. active commuting at T1 × active commuting' into the models. To test for job strain interaction, we first constructed a time-invariant confounder of job strain at T1 by dichotomising the level of job strain into high strain (n = 3070) and having no high strain (n = 12,808). Then, we introduced this into the models (instead of the time-variant job strain covariate) along with the interaction term. High strain was defined as reporting high job demands and low job control which were determined by study-specific median splits. All other combinations were defined as not having high strain (Heikkila et al., 2013). Interaction between entirely passive vs. any level of active commuting at T1 was tested by adding a binary time-invariant confounder and an interaction term into the models.

The strength of the associations is presented as unstandardized coefficient betas (B) with 95% CIs. To further elucidate the effect size of the associations, we additionally calculated standardized regression estimates (β) with 95% CIs. While the unstandardized coefficient B refers to the degree of change in the outcome variable for every one unit of change in the predictor variable (in our primary analyses: a 10 km change in weekly active commuting), the standardized coefficient β refers to how many standard deviations (SD) the outcome variable will change per a SD change in the predictor variable (Nieminen, 2022).

We conducted sensitivity analyses among two different subpopulations. First, to control for baseline level of overall physical activity, we repeated the main analyses including only participants who had reported low-to-moderate level of overall physical activity (7–29 MET-hours/week) at baseline. Second, to control for the potential independent effect of change in commute length, the models were run among the participants with unchanged commute distance at T2. Commute distance was considered unchanged if there was a maximum of 10% or 1 km (if the one-way commute distance at baseline was ≤10 km) difference in the reported distance at T1 and at T2.

For all the above-described statistical analyses, we used R version 4.2.2 (R Core Team, 2021). To run the hybrid models, we used an R package *panelr* (Long, 2023). The R code for the main models is provided as supplementary material.

To test the linearity assumption, we repeated the main analyses by modelling the outcomes as ordinal variables. We applied ordered logistic within- and between-individual regression models. The models were adjusted for the same confounders as the fully adjusted main models. For these analyses, we used Stata 17 (StataCorp, 2021) because no R package was available for this type of hybrid model analyses.

3. Results

Descriptive statistics in the entire study population (n = 16,778) at T1 (2020) and T2 (2022) and by sex (n of women = 13,375; n of men = 3403) at T1 are shown in Table 1. Mean of active commuting (km/week) was 13.0 at T1 and 12.3 at T2. Between the time points, there was a decline in self-rated work ability (from 8.1 to 7.8) as well as in self-rated recovery from work (from 6.5 to 6.2). Compared to men, women reported lower recovery from work (6.4 vs. 6.9) and higher job strain (0.93 vs. 0.87) (Table 1). Women also had shorter average commute distances compared to men (10.8 km vs. 14.9 km).

The distributions of the change in active commuting (km/week) and changes in work ability and recovery from work are shown as histograms in Appendix figures A1 and A2. The proportions of participants with changes in weekly active commuting and changes in the outcomes are shown in Appendix A3. The commute mode shares (i.e., the proportions of participants using each mode) by the reported weekly frequencies during summer and winter conditions at T1 are shown in Appendix A4.

3.1. Crude associations

The crude (uncontrolled) associations with linear regression lines between changes in work ability and recovery from work by change in active commuting (km/week) are shown in Fig. 2. The plots show that in the entire study population and among women, the

Table 1
The characteristics of the study population (n = 16,778) at T1 (2020) and T2 (2022) and by sex at T1. Values are counts and percentages unless otherwise stated.

Variable	Women (T1)	Men (T1)	Total (T1)	Total (T2)
Sex				
Women	13375 (80)		13375 (80)	13375 (80)
Men		3403 (20)	3403 (20)	3403 (20)
Age, Mean (SD [a])	46.5 (10.2)	45.9 (10.2)[c]	46.4 (10.2)	48.4 (10.2)
Marital Status				
Unmarried	4239 (32)	877 (26)[c]	5116 (31)	5066 (30)
Cohabiting	2514 (19)	765 (23)	3279 (20)	3191 (19)
Married	6564 (49)	1741 (51)	8305 (50)	8438 (51)
SES				
High	5671 (47)	1359 (42)[c]	7030 (46)	7136 (47)
Intermediate	3812 (31)	981 (30)	4793 (31)	4591 (30)
Low	2628 (22)	912 (28)	3540 (23)	3449 (23)
Job Contract				
Permanent	11612 (87)	2990 (88)	14602 (87)	12155 (73)[c]
Fixed term	1763 (13)	413 (12)	2176 (13)	4556 (27)
Employment Type				
Full-time	12742 (95)	3334 (98)[c]	16076 (96)	15940 (95)
Part-time	602 (5)	57 (2)	659 (4)	775 (5)
BMI, Mean (SD)	26.5 (5.2)	27.0 (4.2)[c]	26.6 (5.0)	26.9 (5.1)[c]
Smoking				
No	11740 (88)	2969 (88)	14709 (88)	14756 (88)
Yes	1568 (12)	424 (12)	1992 (12)	1925 (12)
Alcohol Use				
No/moderate use	12780 (96)	3246 (96)	16026 (96)	16120 (97)[c]
At-risk use	549 (4)	148 (4)	697 (4)	577 (4)
Job Strain (JD/JC), Mean (SD)	0.93 (0.3)	0.87 (0.3)[c]	0.92 (0.3)	0.98 (0.3)[c]
Weekly Active Commute (km), Mean (SD)[b]	12.2 (21.9)	16.3 (31.7)[c]	13.0 (24.3)	12.3 (23.7)
Work Ability, Mean (SD)	8.1 (1.5)	8.1 (1.7)	8.1 (1.5)	7.8 (1.7)[c]
Recovery from Work, Mean (SD)	6.4 (2.3)	6.9 (2.3)[c]	6.5 (2.3)	6.2 (2.4)[c]

The amount of missingness (counts) at T1 and T2 for marital status: 78 and 83, SES: 1415 and 1602, job contract: 0 and 67, employment type: 43 and 63, BMI: 554 and 678, smoking: 77 and 97, alcohol use: 55 and 81, and job strain: 10 and 12, respectively.

[a] Standard Deviation (SD).

[b] For statistical analyses, this was divided by 10. Reported by participants with any active commuting, the means and SDs were 25.1 (28.9) at T1 and 24.4 (28.6) at T2.

[c] P-value for difference (women vs. men or T1 vs. T2) <0.001 (Wilcoxon rank sum test).

positive association with work ability is evident but weak (Fig. 2A). With change in recovery from work, a very weak positive association can be observed and only among women (Fig. 2B).

3.2. Main results

3.2.1. Change in weekly km of active commuting and change in work ability

The fully adjusted within-individual part of the hybrid model showed that an increase in active commuting equivalent to 10 km/week was associated with a small improvement in work ability (B = 0.016, 95% CI 0.004–0.028). This result was replicated in the between-individual part of the model (B = 0.028, 95% CI 0.019–0.038) (Fig. 3A, Model 3). The adjustments only slightly attenuated the within-individual association, but the between-individual association was weakened after adjusting for time-varying confounders (Fig. 3A).

We detected a statistically significant (p = 0.012) interaction between change in active commuting and sex. We thus stratified the study population into women (n = 13,375) and men (n = 3403) and ran the models separately. Among women, after adjusting for age and time-varying confounders, we observed a small positive within-individual (B = 0.026, 95% CI 0.012–0.040) and a small between-individual (B = 0.030, 95% CI 0.018–0.042) association. Among men, no within-individual, but a small positive between-individual (B = 0.023, 95% CI 0.005–0.040), association was observed (Fig. 3A).

We observed a statistically significant (p = 0.001) interaction also between change in active commuting and passive vs. active commuting at baseline. Due this, the models were rerun separately in the populations stratified into entirely passive commuters at T1 (n = 8091) vs. not entirely passive commuters at T1 (n = 8687). Our main results for work ability were replicated among those who reported at least some active commuting at baseline. Of these, 31% reported more, and 51% reported less active commuting at T2. Among the participants who reported exclusively passive commuting at baseline, 85% remained passive commuters at follow-up and the analyses produced no significant associations with work ability (Supplementary Table S3).

No interaction between change in active commuting and job strain at baseline was detected. All unstandardized regression estimates for work ability in the entire study population are shown in Supplemental Table S1.

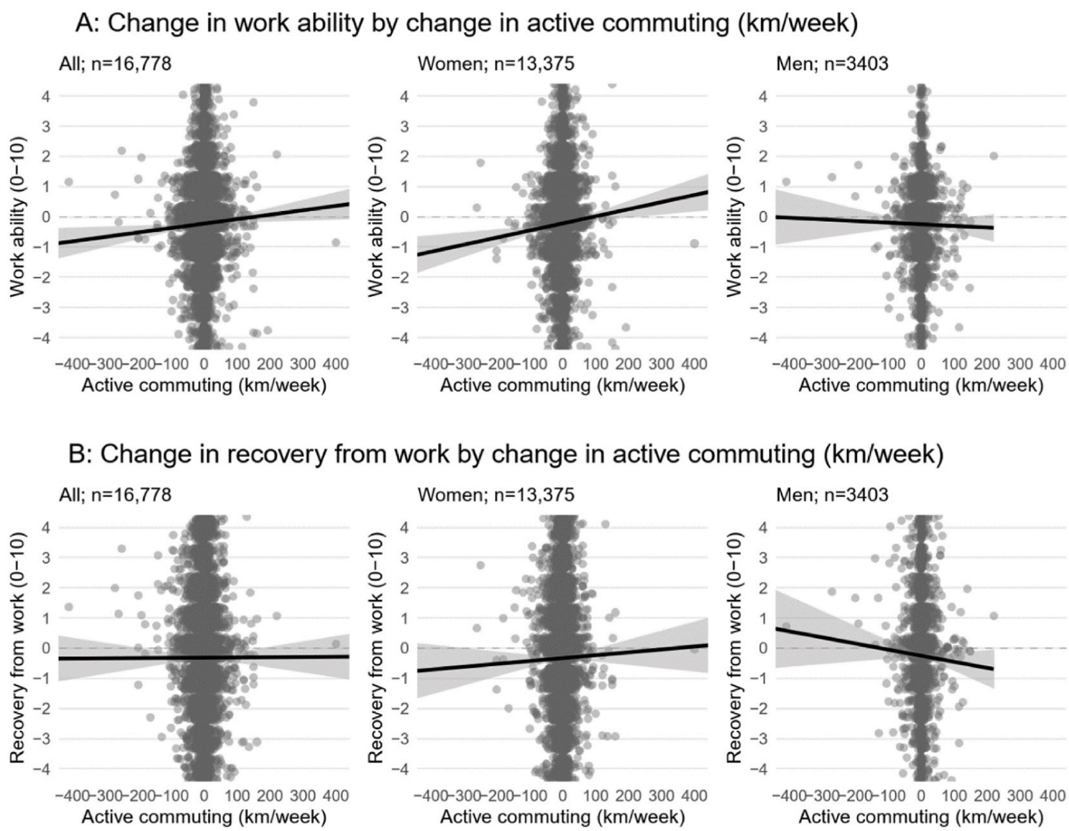

Fig. 2. Crude (uncontrolled) changes in work ability (2 A) and recovery from work (2 B) by change in active commuting between T1 and T2 in the entire study population and in the sex-stratified subsamples. Individual observations are shown with jittered grey dots and a black linear regression line is fitted to the data.

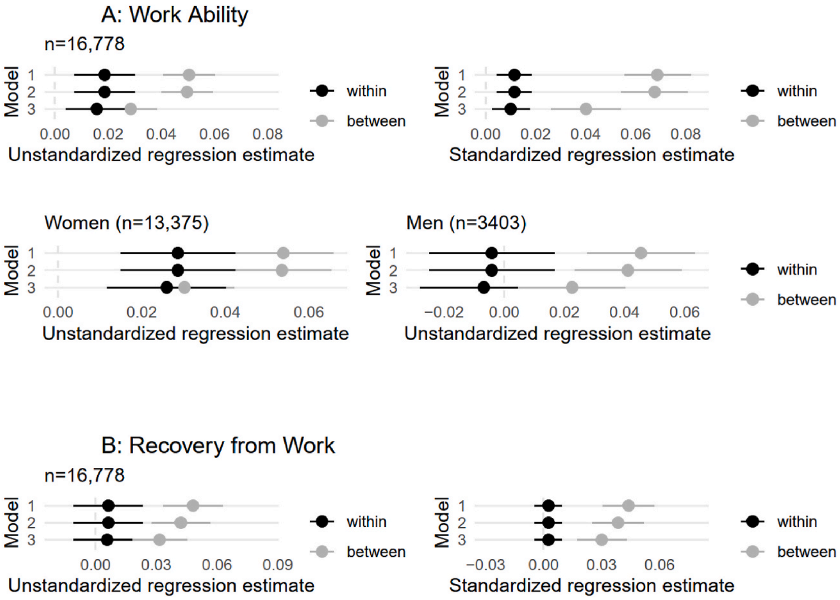

Fig. 3. Unstandardized and standardized regression estimates with 95 % CIs for the within- and between-individual associations of change in active commuting (km/week) with change in work ability (3 A) and change in recovery from work (3 B). Model 1 is unadjusted. Between-individual part of the Model 2 is adjusted for sex and age at T1 (time-invariant covariates). Model 3 is additionally adjusted for marital status, type of job contract, type of employment, SES, BMI, smoking status, weekly alcohol use, and job strain (time-varying covariates). For work ability, unstandardized regression estimates are additionally shown in the sex-stratified subsamples (3 A).

3.2.2. Change in weekly km of active commuting and change in recovery from work

With change in recovery from work, no within-individual (B = 0.006, 95% CI = −0.011–0.022), but a small positive between-individual association (B = 0.032, 95% CI = 0.018–0.045) was observed (Fig. 3B, Model 3). No interaction effects were detected. All unstandardized regression estimates for recovery from work in the entire study population are shown in Supplemental Table S2.

3.3. Secondary analyses: change in the net amount of active commuting (days/week)

An increase of one active commute day per week was associated with a small positive within-individual (B = 0.021, 95% CI 0.005–0.037) and between-individual (B = 0.016, 95% CI 0.008–0.024) effect on work ability, and with a small within-individual (B = 0.028, 95% CI 0.005–0.050) and between-individual (B = 0.020, 95% CI 0.009–0.030) improvement in recovery from work (Table 2). In the subpopulation used in these analyses (n = 12,388), 41% reported changes in their average weekly usage of active or passive commute modes. The distribution of changes in the net amount of active commuting (days/week) is shown as histograms in Appendix Figure A5.

3.4. Sensitivity analyses

3.4.1. Accounting for overall physical activity at baseline

Of the participants with low-to-moderate level of overall physical activity at baseline (n = 6606), 55% reported changing their commuting behaviour into more active at follow-up. In this subgroup, increase in commute activity was associated with a small within-

Table 2
Regression estimates (unstandardized) for the within- and between-individual associations of change in the net amount of active commuting (days/week; n = 12,388) and changes in work ability and recovery from work.

		Model 1		Model 2		Model 3	
		B	95% CI	B	95% CI	B	95% CI
Work ability	Within	0.036	0.022–0.051	0.036	0.022–0.051	0.022	0.006–0.038
	Between	0.019	0.013–0.026	0.018	0.011–0.025	0.014	0.006–0.021
Recovery from work	Within	0.049	0.027–0.071	0.049	0.027–0.071	0.027	0.005–0.049
	Between	0.008	−0.002–0.018	0.005	0.002–0.021	0.014	0.004–0.024

Model 1 is unadjusted. Between-individual part of the Model 2 is adjusted for sex and age at T1 (time-invariant covariates). Model 3 is additionally adjusted for marital status, type of job contract, type of employment, SES, BMI, smoking status, weekly alcohol use, job strain, and commute distance (time-varying covariates).

individual improvement in work ability (B = 0.025, 95% CI 0.001–0.049), but no between-individual association was observed. Neither within- or between-individual associations were observed for recovery from work (Supplementary Table S4).

3.4.2. Accounting for change in commute distance

The main results for both outcomes were replicated among the participants with unchanged commute distance (n = 10,787; 53% reported changes in active commuting). After adjusting for confounders, 10 km weekly increase in active commuting was associated with small within-individual (B = 0.018, 95% CI 0.002–0.035) and between-individual (B = 0.027, 95% CI 0.015–0.040) improvement in work ability. A statistically significant (p = 0.027) interaction between change in active commuting and sex was detected and we rerun the models in the sex-stratified samples. Among women (n = 8596), the observed positive within-individual (B = 0.033, 95% CI 0.012–0.053) and between-individual (B = 0.031, 95% CI 0.015–0.047) effects with work ability were of the same size as in the entire population. Among men (n = 2191), we observed no associations. With recovery from work, a small positive between-individual (B = 0.021, 95% CI 0.004–0.038) association was observed (Supplementary Table S5).

3.4.3. Testing the linearity assumption

The ordered logistic regression analyses produced similar results with the main analyses also in terms of the modest effect size. After adjustments, an increase equivalent to 10 km per week of active commuting was associated with higher odds of reporting a one unit increase in work ability in the within-individual (odds ratio (OR) = 1.03, 95% CI 1.00–1.05) and the between-individual model (OR = 1.07, 95% CI 1.05–1.09). Similar increase in active commuting was associated with higher odds of reporting a one unit increase in recovery from work in the between-individual model (OR = 1.05, 95% CI 1.03–1.06), but not in the within-individual model (OR = 1.01, 95% CI 0.99–1.03).

4. Discussion

In this cohort study, we used repeated measures from two time points (2020 and 2022) to examine whether a change in active commuting was associated with changes in work ability and recovery from work in a Finnish cohort of public sector employees. These associations were simultaneously analysed within and between individuals using hybrid modelling.

4.1. An increase in active commuting may improve work ability

Our results for work ability align with previous research demonstrating the strong link between health outcomes and work ability (Ahlstrom et al., 2010; El Fassi et al., 2013). Commuting by cycling has also shown to associate with lower sickness absenteeism from work (Hendriksen et al., 2010; Mytton et al., 2016). Overall, our findings suggesting that an increase in active commuting may improve work ability are consistent with broader evidence of the health benefits of active commuting reviewed in this study. Furthermore, the findings are supported by a previous cross-sectional study conducted within the same Finnish study population, utilising FPS data from 2020 (Kalliolahti et al., 2023). In that study, regular use of active commute modes – cycling in particular – was associated with a lower risk of suboptimal self-rated work ability (Kalliolahti et al., 2023). Similarly, in another available cross-sectional study involving food industry workers in Thailand (Phanprasit et al., 2022), the average self-ratings of work ability were higher among active compared to non-active commuters (Phanprasit et al., 2022). However, our results suggest that achieving even a modest improvement in work ability may require a relatively large increase in weekly kilometres of active commuting.

While alterations in commute distance are likely to arise from changes in residence or workplace (Clark et al., 2016), such changes may influence health, wellbeing, and the available resources, and consequently, have an impact on work ability and recovery from work. Our results among participants with unchanged distance did not differ from the main results which suggests that the observed positive effect on work ability was more likely stemming from engaging more in active commuting rather than changes in commute distance.

Our findings imply that the beneficial effect of increasing active commuting on work ability may be restricted to women. This assertion finds support from, for example, an earlier study utilising extensive data from the UK Household Longitudinal Study from 2009 to 2016 (Jacob et al., 2021), where which switching from car commuting to active modes such as walking or cycling was associated with improvement in self-rated mental health among women, but not among men. Also, the study found that the beneficial association with perceived physical health was more pronounced in women than in men (Jacob et al., 2021).

4.2. Inconclusive findings for recovery from work

Our main analyses showed a weak positive between-individual association for increase in active commuting with recovery from work. However, considering that no within-individual associations were observed, the findings suggest that the between-individual part of the model was confounded by some unobserved factor(s) (e.g., personality, life situation, or other off-job activities). The existing literature underscores the complex interplay between physical and other leisure-time activities, job stress, and recovery (Sonnentag, 2018; Sonnentag and Zijlstra, 2006; van Hooff, 2015). For example, some previous research indicates that the beneficial effects of recovery-enhancing activities, including physical activities, are attenuated by high job stress (Sonnentag et al., 2017). However, we did not find evidence supporting interaction between change in active commute and job strain.

In general, active commuting as a recovery-enhancing activity appears to have received very little attention in research. We are aware of only two studies sharing somewhat similar objectives as our study and their results point to the same direction as ours. In a diary study on daily commute and recovery experiences, time spent commuting by walking or cycling was not associated with any of the examined recovery indicators, but time spent commuting by public transport was adversely associated with two recovery-related indicators, namely serenity after work and anxiety in evening (van Hooff, 2015). Accordingly, active commuting was not associated with recovery in a cross-sectional study examining the associations of physical and other off-job and workplace activities (Coffeng et al., 2015) Of the different types of physical activities, only stair climbing and non-commuting leisure-time physical activities were found to associate with better recovery (Coffeng et al., 2015).

There are some potential – although somewhat contradictory – explanations for the lack of association between increased active commute and improved recovery. First, the intensity of active commuting may be insufficient. In a mixed methods study (diary study and experimental design), only high levels of strenuous leisure-time physical activity were found to associate with beneficial effects on recovery – especially after stressful workdays (van Hooff et al., 2019). In another study among Finnish female early childhood education and care professionals, accelerometer-measured leisure-time physical activity was not associated with recovery, but the participants almost entirely lacked vigorous leisure-time physical activity (Karihtala et al., 2023). While the intensity of cycling commuting may be of moderate-to-vigorous (Ainsworth et al., 2011; Hendriksen et al., 2010), the intensity of walking is typically of light-to-moderate (Ainsworth et al., 2011; Audrey et al., 2014).

Second, although the amount of active commuting is likely to be relevant for overall health, relatively short active commutes may be more beneficial for recovery than very long ones requiring a lot of time and effort. It is possible that spending more time commuting leads to less time available for (other) favourable off-job activities and relaxation that could enhance recovery. For example, a large panel study from the UK (Clark et al., 2020) showed that shorter and walkable commutes were associated with higher job and leisure-time satisfaction particularly through increased leisure time. In fact, although active commuters in general appear to be less stressed (Denstadli et al., 2017; Handy and Thigpen, 2019) and more satisfied with their commute than passive commuters (De Vos et al., 2022; Handy and Thigpen, 2019; St-Louis et al., 2014; Willis et al., 2013), this difference may stem partly from their typically shorter commutes (Chatterjee et al., 2019; De Vos et al., 2022). In our study population, those who remained as entirely passive commuters had the longest one-way commutes (19 km on average) and those who sustained any level of active commuting had the shortest (5 km on average). On the other hand, compared to the latter group, among those who increased their active commuting at least 10 km/week commute lengths were nearly two-fold (9 km on average).

4.3. Evidence for beneficial effects of substituting passive commute modes use with active commuting

The findings of our secondary analyses, examining the associations between change in the net amount of active commuting and changes in the outcomes, complemented our main findings. Contrary to our main results, these analyses suggest that substituting passive commute modes use with active commutes can yield beneficial outcome for not only work ability but also for recovery from work. Importantly, the positive results remained significant even after adjusting for commute distance. This implies that the observed positive effects were not solely driven by the generally shorter commute distances among the active commuters or decreased commute lengths among those who increased their weekly active commutes. Consistent with existent literature reviewed in this study, it appears plausible that work ability – especially the psychological dimensions of it – and recovery from work are affected by not only changes in active commuting but also changes in passive commuting. Furthermore, women, who were overrepresented in this study, have been previously found to be particularly susceptible to the adverse psychological effects of long commutes – which are typically undertaken passively (Clark et al., 2020; Roberts et al., 2011).

4.4. Strengths of the study

The strengths of this study include the large number of participants and high response rates at baseline (73%) and at follow-up (62%). Additionally, the detailed survey questions on commute modes use, where distinctions were made between summer and winter, allowed us to capture a diverse range of commuting behaviour combinations and account for Nordic wintertime commuting.

Another notable strength in this study is the hybrid model approach that enabled us to examine simultaneously both within- and between-individual associations. Moreover, the within-individual part of the hybrid model in which each participant serves as their own control, provides stronger evidence for the causal inference compared to longitudinal designs with solely between-individual estimates (Firebaugh et al., 2013; Rohrer and Murayama, 2023). We were also able to adjust both parts of the model with several potential time-varying confounders including job strain which is likely to affect not only work ability (van den Berg et al., 2009) and recovery from work (Coffeng et al., 2015; Sonnentag, 2018; van Hooff, 2015) but also commuting behaviour.

The employed sex-stratified and sensitivity analyses allowed us to address some potential issues related to our study population and commute distance. Furthermore, our secondary analyses provided some additional evidence of the beneficial effect of substituting passive commute modes use with active commuting on both work ability and recovery from work. Given the established other types of benefits of replacing motorized commute modes with sustainable alternatives such as walking and cycling, these findings further underscore the co-benefits of active commuting for employee health, well-being, and environment.

4.5. Study limitations

The limitations of this study include our inability to control for leisure-time or occupational physical activity. Although weekly hours of overall physical activity were assessed at both time points, the measure does not disentangle between leisure-time and commuting physical activity. Our data also lacked information on, for example, respondents' subjective commute experiences, including commute stress and satisfaction, as well as other off-job activities. Future studies should aim to control for these.

Lacking information on commuting time restricted our possibilities to account for the average intensity difference between walking and cycling. Although our focus was on assessing changes in active commuting rather than the absolute level of active commuting, a participant switching from walking to bicycle or vice versa could introduce bias due to the concurrent change in intensity. However, while such a switch between walking and cycling may often be related to changes in commute length, we were able to somewhat mitigate this bias in our sensitivity analyses restricted to the participants with unchanged commute distance.

As this was an observational study, we cannot exclude reverse causation as employees who experience improvements in their work ability or recovery from work may be more inclined to participate more in active commuting. Our study period did also include the COVID-19 pandemic which may have affected commuting behaviour beyond the increase in remote working (this was considered in our exclusion criteria) as well as participants' perceptions of their work ability and recovery from work. Despite the good response rates, the possibility of some selection bias exists. As all the data were self-reported, information and common source biases may exist.

4.5.1. *Considerations specific to the study population*

In our study population, the average work ability was good (WAS = 8 at both time points). Of the participants, 43% (at T1) and 38% (at T2) reported having very good (WAS = 9) or excellent (WAS = 10) work ability. This may partly explain the lack of stronger associations between change in active commuting and change in work ability in this study. As suggested in a study by Phanprasit et al. (2022), the benefits of active commuting may be restricted to moderate-to-good work ability as employees with very good or excellent work ability may have less room for further improvement (Phanprasit et al., 2022).

Our study population also appeared to be more physically active than Finnish adults in general. While only 20% of our study participants employed by public sector reported insufficient level of overall physical activity (<14 MET-hours/week) (Leskinen et al., 2020), approximately 50% of the general Finnish working-age population – whether employed or not – do not meet the global physical activity recommendations including the muscle-strengthening component (Lahti and Borodulin, 2023; World Health Organization, 2020). On the other hand, more than 70% of the same study population reported participating in everyday exercise such as walking, domestic physical activities, and stair climbing for several hours per week. (Lahti and Borodulin, 2023). However, comparisons between studies are limited due to the likely higher levels of overall physical activity among fully employed populations (Wennman et al., 2019), such as ours, compared to general adult populations. Additionally, the varying instruments used to measure physical activity and differing definitions of sufficient physical activity levels further complicate these comparisons. In any case, it is possible that the benefits of active commuting on work ability could be greater in less physically active populations. To test this, we conducted a set of sensitivity analyses within a subsample of participants with low to moderate level of physical activity at baseline, but our results provided no evidence of a stronger association. Moreover, we did not find evidence of an association between an increase in active commuting and work ability in our subsample analyses of initially passive commuters. A large proportion of these participants sustained passive commuting: 48% reported being entirely passive commuters at baseline and only 15% of these changed their commuting behaviour towards more active. This may have resulted in too low statistical power to detect any associations. Some earlier studies from the UK (Clark et al., 2016; Jacob et al., 2021) have also observed that particularly car commuters are rather hesitant to switch to active commute modes use.

Overall, as our study population consisted of female-dominated public sector occupations, the generalizability to private sector, or male-dominated occupations may be limited. However, we did have about 3000 men in our sample allowing us to conduct separate analyses among men and women.

5. Conclusions

It may be possible to improve work ability by increasing active commuting. However, it appears that the weekly increase in walking or cycling to and from work needs to be tens of additional kilometres to achieve even a small beneficial effect. Our findings add to the existing evidence of employee health and wellbeing benefits of active commuting and may provide further reasons for promoting sustainable and active commute modes. While we observed a potential sex-specific beneficial effect on work ability among women, further research is needed to identify the most important and viable populations for targeted promotion of active commuting.

Ethics

The Finnish Public Sector study was approved by the Ethical Committee of the Helsinki and Uusimaa Hospital district (HUS/1210/2016). Informed consent was obtained from the participants.

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CRediT authorship contribution statement

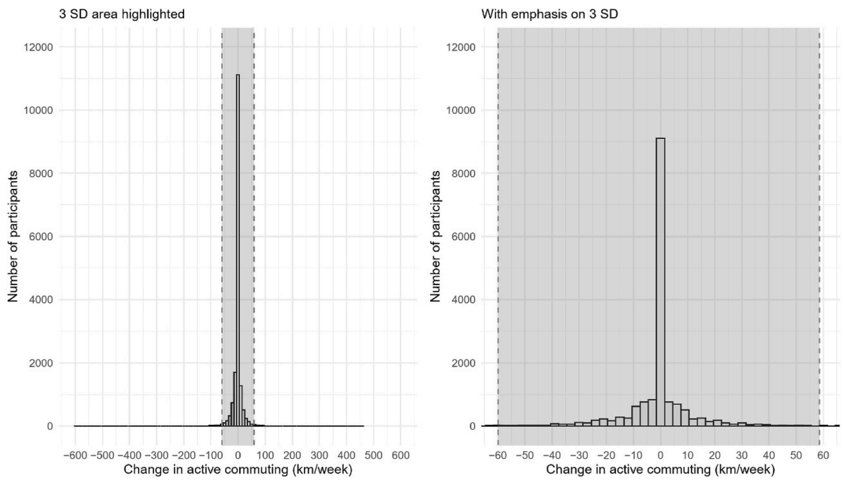
Essi Kalliolahti: Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Kia Gluschkoff:** Writing – review & editing, Visualization, Methodology, Formal analysis. **Eija Haukka:** Writing – review & editing. **Timo Lanki:** Writing –

review & editing. **Juuso J. Jussila:** Writing – review & editing. **Jaana I. Halonen:** Writing – review & editing. **Tuula Oksanen:** Writing – review & editing. **Jenni Ervasti:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Conceptualization.

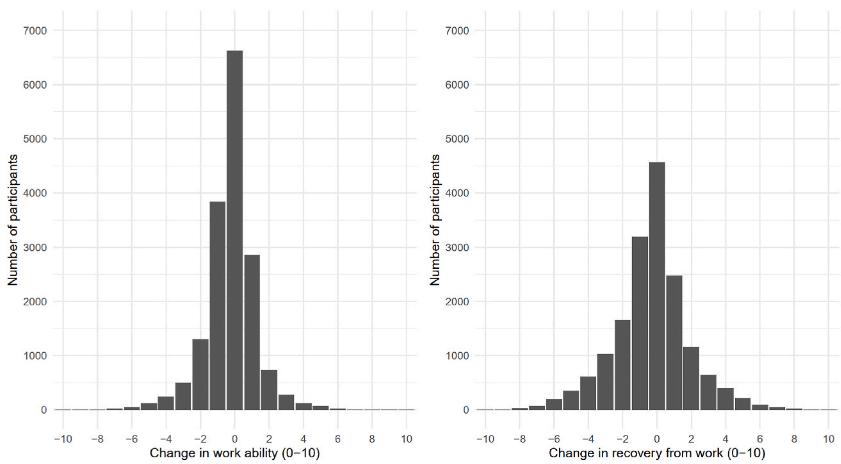
Declaration of competing interest

The study was funded by the Strategic Research Council of Finland (#335382; #336003; #336004) and the Finnish Work Environment Fund (#220245). The funders had no role in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

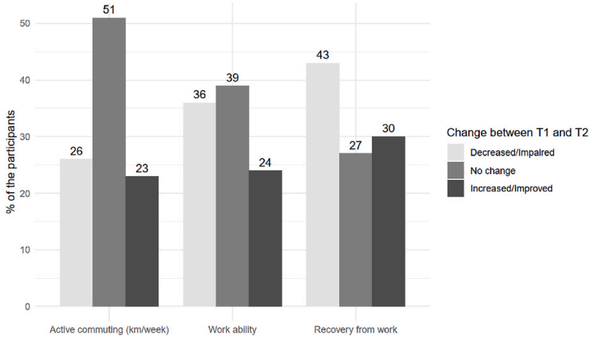
Appendix



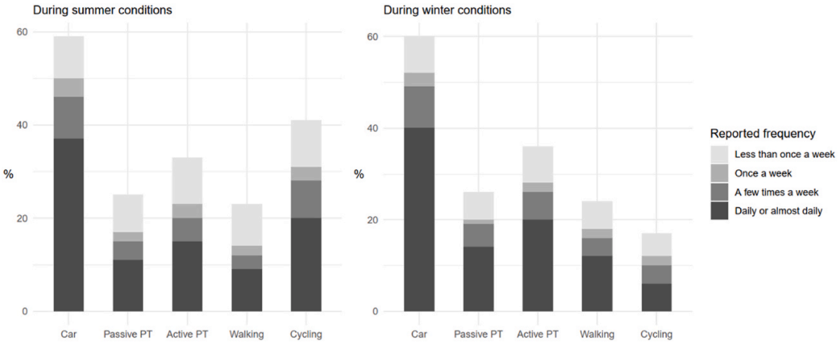
Appendix Fig. A1. Distribution of change in active commuting between T1 (2020) and T2 (2022) in the study population (n = 16,778). SD = 19.7.



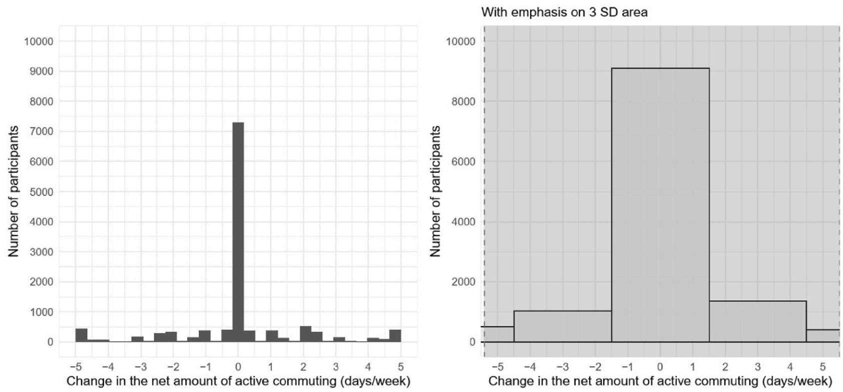
Appendix Fig. A2. Distributions of changes in work ability and recovery from work between T1 (2020) and T2 (2022) in the study population (n = 16,778).



Appendix Fig. A3. Proportions of participants (n = 16,778) with any changes in their active commuting (km/week), work ability, and recovery from work between T1 (2020) and T2 (2022).



Appendix Fig. A4. Commute mode shares by the reported frequencies in the study population (n = 16,778) at T1 (2020) during summer and winter conditions. The reported frequencies of using each commute mode are shown as stacked (non-cumulative) proportions (%) of the participants who had reported at least some use.



Appendix Fig. A5. Distribution of change in the net amount of active commutes between T1 (2020) and T2 (2022) in a subpopulation from which participants who had reported any commuting by public transport with 1 km or more walking or cycling are excluded (n = 12,388).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2024.101872.

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