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Changes in active commuting and changes in health: Within- and between-individual analyses among 16 881 Finnish public sector employees

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A R T I C L E I N F O

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A B S T R A C T

Background: Active commuting, such as walking or cycling to work, can be beneficial for health. However, because within-individual studies on the association between change in active commuting and change in health are scarce, the previous results may have been biased due to unmeasured confounding. Additionally, prior studies have often lacked information about commuting distance.

Methods: We used two waves (2020, T1 and 2022, T2) of self-report data from the Finnish Public Sector study (N = 16,881; 80% female) to examine the within- and between associations (in a hybrid model) between active commuting and health. Exposure was measured by actively commuted kilometers per week, that is, by multiplying the number of walking or cycling days per week with the daily commuting distance. The primary outcome, self-rated health, was measured at T1 and T2. The secondary outcomes, psychological distress, and sleep problems were measured only at T2 and were therefore analyzed only in a between-individual design.

Results: After adjustment for potential time-varying confounders such as socioeconomic factors, body mass index, and health behaviors, an increase equivalent to 10 additional active commuting kilometers per week was associated with a small improvement in self-rated health (within-individual unstandardized beta = 0.01, 95% CI 0.01–0.02; between-individual unstandardized beta = 0.03, 95% CI 0.02–0.04). No associations were observed between changes in active commuting and psychological distress or sleep problems.

Conclusions: An increase in active commuting may promote self-rated health. However, increase of tens of additional kilometers in commuting every day may be required to produce even a small effect on health.

1. Introduction

Insufficient physical activity is a major risk factor for several non-communicable diseases (Dinu et al., 2019; Guthold et al., 2018; Katzmarzyk et al., 2022; Lee et al., 2012) and mortality worldwide (Katzmarzyk et al., 2022; Lee et al., 2012; Physical Activity Guidelines Advisory Committee, 2018). Based on the recent global estimates, 28% of adults do not meet the physical activity recommendations (Bull et al., 2020; Guthold et al., 2018). Moreover, the number of individuals with insufficient activity level is increasing – particularly in high-income countries (Guthold et al., 2018). Active commuting, such as walking or cycling to work, can be a convenient way to fit more physical activity into daily routines of working-age people as commuting is the most common reason for travel among adults (Jacob et al., 2021; Mueller et al., 2015; Page and Nilsson, 2016; Rojas-Rueda et al., 2016; World Health Organization, 2016).

Existing literature has indicated several beneficial effects of active commuting on health. Two recent meta-analyses of prospective studies found that active commuting decreased the risk of all-cause (Dinu et al., 2019; Dutheil et al., 2020) and cardiovascular mortality (Dutheil et al., 2020) and cardiovascular disease incidence (Dinu et al., 2019). Those who engaged in active commuting had a 30% lower risk of diabetes and,

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among cycling commuters, a significant risk reduction was observed for cancer mortality (Dinu et al., 2019). Furthermore, a systematic review on randomized controlled trials showed that active commuting improved physical fitness and had positive effects on risk factors associated with physical inactivity, such as body weight, body mass index, fat mass, cholesterol, and blood pressure (Schäfer et al., 2020). In contrast, evidence regarding mental health outcomes, such as psychological distress, is still scarce. The findings from a limited number of studies have been contradictory and mostly based on cross-sectional study designs (Liu et al., 2022; Marques et al., 2023). In addition, research specifically addressing the effects of active commuting on sleep problems is limited although there exists evidence (Huang et al., 2023) that physical activity in general is effective for improving sleep.

Despite strong evidence (Dinu et al., 2019; Dutheil et al., 2020; Schäfer et al., 2020) on the physical health benefits of active commuting, few studies have examined whether changes in commuting are associated with changes in health (Jacob et al., 2021; Knott et al., 2018; Schäfer et al., 2020). Most observational studies have used between-individual designs comparing active and less active commuters. This design does not consider possible unmeasured time-invariant confounders, such as personality or genetics potentially leading to biased results. A within-individual analysis adjusts these time-invariant characteristics, as each individual acts as their own control (Allison, 2005; Firebaugh et al., 2013; Gunasekara et al., 2014). Thus, a within-individual estimation can provide more insight into possible causal processes when both predictors and outcomes vary over time (Firebaugh et al., 2013). Moreover, while previous randomized controlled trials (Schäfer et al., 2020) have shown that active commuting can have health benefits, information about commuting distance has rarely been included.

As our primary aim, we examined whether an increase in active commuting was associated with improved perceptions of health using both within- and between-individual study designs including individuals with varying degrees of baseline commuting activity. As a secondary aim, we examined whether an increase in active commuting was associated with less psychological distress and sleep problems measured only at follow-up with a between-individual study design.

2. Methods

2.1. Study population

This study was nested within the ongoing Finnish Public Sector (FPS) study, comprising employees of 11 cities in Finland (Ervasti et al., 2022). Four out of eleven FPS organizations agreed to include measures of commuting mode and distance in 2020 (T1, $N = 43{,}281$, response rate 73%), and 2022 (T2, $N = 38{,}312$, 62%) into the questionnaire sent to their employees. The FPS study was approved by the Ethical Committee of the Helsinki and Uusimaa Hospital district (HUS/1210/2016). Informed consent was obtained from the participants.

We excluded those who did not have data on both timepoints, those with missing or implausible data about the daily commuting (e.g., individuals with a commuting distance of 0 km, with a walking commute of >40 km, or with a cycling commuting of >200 km), those with missing data on primary outcome variable, as well as those who reported working remotely in 2020 or 2022. The decision to exclude respondents with implausible commuting distances was made considering the self-reported nature of the data, acknowledging the potential for errors or mistakes. In deciding the cut-off for implausible commute distance values, we aimed to err on the side of caution to ensure data accuracy and reliability. The final sample consisted of 16,881 participants. Fig. 1 shows the flow chart of participant selection.

2.2. Exposure: active commuting

Participants were asked to assess how often they used various commuting modes. The options were walking, cycling, public transport with ≥1 km walking or cycling, public transport with <1 km walking or cycling, and private car use (as a passenger or driver). Participants provided responses on a scale ranging from “daily or almost daily” to “never” separately for summer and winter conditions. Additionally, participants reported their one-way commuting distance in kilometers.

Active commuting was defined as weekly workdays of walking or cycling to the workplace. “Daily or almost daily” was converted to 5 days, “a few times per week” to 3 days, “once per week” to 1 day, “less than once per week” to 0.5 day, and “never” to 0. First, we calculated the average active commuting days for both summer and winter conditions.

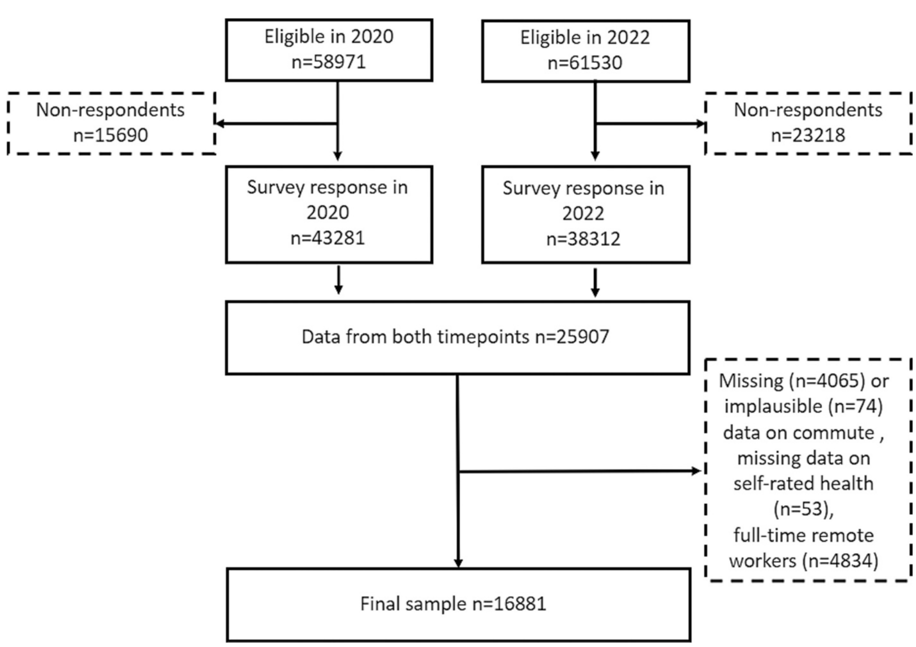

Fig. 1. Flow chart of the study participants. Final sample size is for the primary outcome. For the secondary outcomes, the final sample size was 16,934. Finnish Public Sector study.

We added up the days for both weather conditions and then divided it by two to represent the average weekly days of active commuting for the calendar year. Then, we calculated weekly active commuting kilometers by multiplying the number of weekly active commuting days with the round-trip distance of the daily commuting. To ease the interpretation, we further divided the kilometers by 10 to represent a change of 10 km per week in active commuting. This meant that a one-unit change in the active commuting represented a 10 km increase in active commuting.

2.3. Primary outcome: self-rated health

Self-rated health was measured by a validated single-item question: “How do you rate your health?” The response options were 1 = poor, 2 = fairly poor, 3 = average, 4 = fairly good, 5 = good (Robine et al., 2003). This single-item question of self-rated health is a widely used measure, which has been shown to be a robust predictor for many health-related outcomes (Berglund et al., 2016; Cullati et al., 2020).

2.4. Secondary outcomes: psychological distress and sleep problems

Psychological distress and sleep problems were measured only at T2. Psychological distress, comprising symptoms of depression and anxiety was measured using the Patient Health Questionnaire-4, the reliability and validity of which has been observed to be good (Kroenke et al., 2009; Löwe et al., 2010). Participants were asked to report the frequency of experiencing specific problems using the stem question: “How often have you been bothered by the following problems?” The items for depression included 1) feeling down, depressed, or hopeless, and 2) experiencing little interest or pleasure in doing things. Correspondingly, for anxiety, the items included 1) feeling nervous, anxious, or on edge, and 2) having difficulty stopping or controlling worrying. Response options for all items were 1 = not at all, 2 = on several days, 3 = more than half the days, 4 = nearly every. To determine the presence of depression or anxiety, a sum of the questions was calculated, with a sum of $\geq$3 on either depression or anxiety or both indicating case of psychological distress (Löwe et al., 2010).

Sleep problems were assessed using a validated one-item measure of the Patient Health Questionnaire-9 (Lequerica et al., 2022; MacGregor et al., 2012; Schulte et al., 2021) with the same stem question and same response options (1 = not at all, 2 = on several days, 3 = more than half the days, 4 = nearly every) that evaluated difficulty falling asleep, staying asleep, or experiencing excessive sleep. Sleep problems were considered present if the response was $\geq$2 (Lequerica et al., 2022).

2.5. Covariates

A range of factors hypothesized to potentially confound the relationship between active commuting and health were selected based on the previous literature (Donnelly and Schoenbachler, 2021; Hellgren et al., 2021; Hirdes and Forbes, 1993; Robards et al., 2012; Virtanen et al., 2005; Waenerlund et al., 2011).The covariates included both time-invariant variables (used only in the between-individual analysis) and time-varying variables (used in the within- and between-individual analysis). Age (at T1) and sex were considered as time-invariant covariates. Time-varying covariates included marital status (single, married, cohabiting, divorced, or widowed), occupational level (high, intermediate, low), job contract (temporary vs. permanent), employment type (part-time vs. full-time), and lifestyle factors (body mass index, smoking, and alcohol use). Occupational level was categorized into three groups based on the 2001 International Standard Classification of Occupations (International Labour Organization, 2023) codes: high (managers and senior specialists, such as physicians and teachers), intermediate (specialists, office workers, customer service, and health and social care workers), and low (manual workers, including construction and cleaning services workers, and practical nurses). Body mass index was calculated using self-reported height and weight and expressed as kg/m^2. Smoking status was dichotomized as current smoker vs. non-smoker (including ex- and never-smokers). Alcohol use was assessed by questions regarding weekly consumption and quantified as weekly grams of pure alcohol, with 100 g used as the unit in the analysis.

2.6. Statistical analyses

For the primary outcome variable of self-rated health (modeled as a continuous variable), we used a hybrid model. In the hybrid model, the between-subject part of the association is obtained using the individual mean over time, whereas the within-subject part is obtained using the deviation score, that is, the difference between the observations and the individual mean (Twisk and de Vente, 2019).

In practice, the within- and between individual associations of active commuting were disaggregated by including both individual deviations from an individual-mean value of active commuting and the individual-mean values of active commuting to a regression model. First, we ran an unadjusted model (model 1) using active commuting as the exposure variable and self-rated health as an outcome. Second, age and sex were added as time-invariant covariates (model 2). Third, marital status, occupational level, job contract type, employment type, body mass index, smoking status, and alcohol use were included as additional time-varying covariates (model 3). We also tested for potential interactions related to sex or age.

As sensitivity analyses, we 1) modeled self-rated health also as a categorical ordinal variable, 2) adjusted the models for whether the commute distance remained unchanged (yes/no), thereby eliminating the potential effects of a change in commuting distance on health, and 3) examined if the results were driven by initially inactive commuters by testing for an interaction term “T1 inactivity x active commuting”. The distance of the commute was deemed unchanged if the variance between T1 and T2 was within 10%, or if the time points differed by no more than 1 km for commutes with a one-way distance of 10 km or less.

As we only had a T2 measure for the secondary outcomes of psychological distress and sleep problems, they were analyzed using a between-individual model. Log-binomial regression models were employed for these binary outcomes, using change from T1 to T2 in active commuting as predictors. The modeling process followed similar steps as the models for self-rated health, starting from an unadjusted model and progressively incorporating adjustments.

We conducted the analyses using R version 4.2.2, (R Core Team, 2021) except for the ordered logistic analysis for self-rated health as a categorical ordinal variable, for which we utilized Stata 17 (StataCorp., 2021), because no R package was available for this type of analysis using the hybrid approach.

3. Results

Of the employees, 80% (n = 13,465) were women and their mean age at the baseline was 46.5 years (SD 10.2). The mean of weekly active commuting kilometers was 13.0 at T1 and 12.3 at T2. Both the level of active commuting and self-rated health decreased from T1 to T2. Depending on the time point, 50–51% were married and 46–47% had a high occupational level. The proportion of permanent job contracts decreased, and that of temporary job contract increased by 14% (from 13% to 27%). Part-time employment was also more common at T2. The mean body mass index was 26.6–26.9 suggesting higher than a healthy ($\leq$ 25) weight. A total of 12% were current smokers. Alcohol use decreased from T1 to T2 (from 42.1 to 38.2 g/week) (Table 1). Supplementary Fig. 1 shows the proportion of missing values in each variable.

3.1. Changes in active commuting and changes in self-rated health

3.1.1. Main analysis

Fig. 2 shows the raw associations between change in active

Table 1
Descriptive statistics of the study population at T1 (2020) and T2 (2022). Finnish public sector workers ($N = 16{,}881$).

Variable	T1 (2020)	T2 (2022)	p[a]
Active commuting (km/week)	13.0 (24.2)	12.3 (23.7)	0.001
Self-rated health (mean, SD) [b]	4.1 (0.9)	4.0 (0.9)	<0.001
Psychological distress (yes), (n, %) [c]		2185 (13)	
Sleep problems (yes), (n, %) [c]		2588 (15)	
Marital status (n, %)			0.015
Single	3027 (18)	2850 (17)	
Married	8363 (50)	8495 (51)	
Cohabiting	3292 (20)	3206 (19)	
Divorced	1955 (12)	2046 (12)	
Widowed	165 (1.0)	197 (1.2)	
Occupational level (n, %)			0.074
High	7072 (46)	7181 (47)	
Intermediate	4816 (31)	4615 (30)	
Low	3567 (23)	3475 (23)	
Job contract (n, %)			<0.001
Permanent	14,695 (87)	12,233 (73)	
Temporary	2186 (13)	4581 (27)	
Employment type (n, %)			0.002
Full-time	16,177 (96)	16,042 (95)	
Part-time	660 (3.9)	775 (4.6)	
Body mass index (mean, SD) [b]	26.6 (5.0)	26.9 (5.01)	<0.001
Smoking (yes), (n, %)	2007 (12)	1938 (12)	0.300
Alcohol use (gr/week), (mean, SD) [b]	42.1 (74.3)	38.18 (68.4)	<0.001

[a] *P*-value for change between T1 and T2 from a *t*-test (continuous variables) or chi squared test (categorical variables).
[b] SD, standard deviation.
[c] Assessed only at T2.

commuting and change in self-rated health (Panel A) and the regression estimates from within- and between-individual models (Panels B and C). In the unadjusted within-individual model, an increase equivalent to 10 additional active commuting kilometers per week was associated with a small improvement in self-rated health (unstandardized B = 0.01, 95% CI 0.01–0.02). A similar association was observed in the between-individual model (B = 0.05, 95% CI 0.04–0.05). The inclusion of age and sex as time-invariant covariates did not change these findings. Additional adjustments for time-varying covariates had no effect on the within-individual model results but led to a small attenuation of the between-individual effect (B = 0.03, 95% CI 0.02–0.04) in the fully adjusted model. There was no evidence for an interaction between active commuting and age or sex (all *p*-values for interaction $p > 0.05$). All covariates were associated with self-rated health in the between-individual analysis (see Table 2 for all regression estimates).

3.1.2. Sensitivity analyses

As a sensitivity analysis, we repeated the main analysis by using ordered logistic within- and between-individual regression models. The results were similar in regard to the magnitude of the association: in the fully adjusted model, compared to self-rated health status less than good, an increase equivalent to 10 additional active commuting kilometers per week was associated with higher odds of good self-rated health in the within-individual (odds ratio OR = 1.04, 95% CI 1.02–1.07) and the between-individual model (OR = 1.16, 95% CI 1.12–1.19).

Further, when we adjusted for whether the commute distance had remained unchanged (yes/no) the results were similar to those observed in the main analysis (B = 0.01, 95% CI 0.00–0.02 for the fully adjusted within-individual model; and B = 0.03, 95% CI 0.02–0.03 for the between-individual model).

Finally, we observed a significant interaction between T1 inactivity and active commuting ($p = 0.030$). To interpret the interaction, we stratified the sample into those inactive vs. active at T1 and rerun the models in the stratified samples. Among those who were inactive at T1, there was no within-individual association (B = -0.00, 95% CI -0.02-0.01) but only a between-individual association (B = 0.03, 95% CI 0.00–0.06) between active commuting and self-rated health. For those who were active at T1, the results corresponded those observed in the main analysis (B = 0.01, 95% CI 0.01–0.02 for the fully adjusted within-individual model; and B = 0.02, 95% CI 0.01–0.03 for the between-individual model).

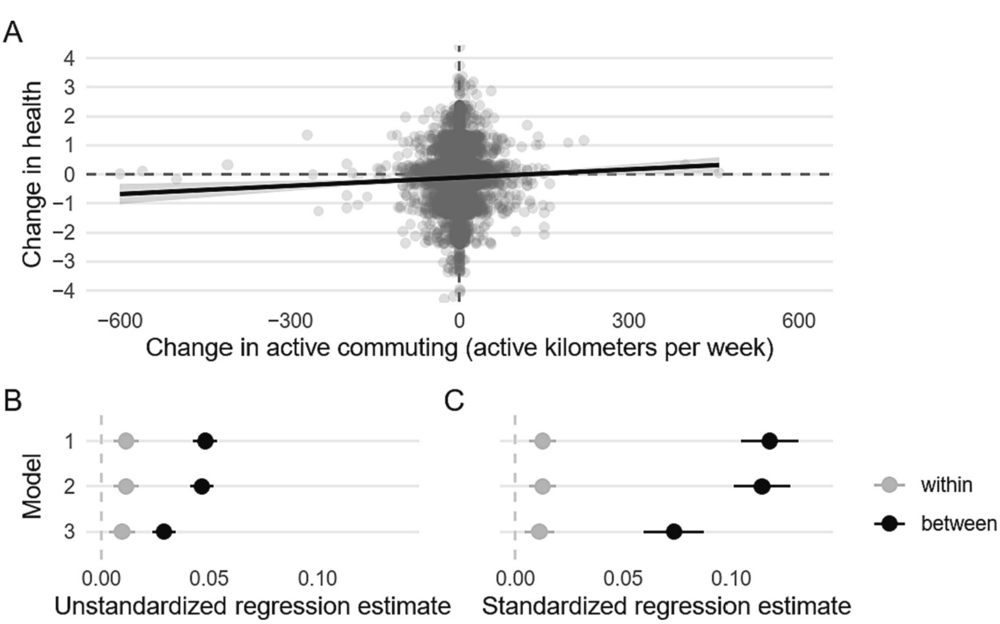

Fig. 2. Change in active commuting and change in self-rated health among Finnish public sector workers. Panel A: Change in self-rated health by one unit change in active commuting kilometers per week. Individual observations are shown with jittered grey dots and a black linear regression line is fitted to the data. Panels B and C: Unstandardized (B) and standardized (C) regression estimates with 95% confidence intervals from within- and between-individual analysis on changes in self-rated health. Model 1: Change in active commuting as the predictor (10 km per week as the unit). Model 2: Model 1 + age at T1 and sex (as time-invariant covariates). Model 3: Model 2 + marital status, occupational level, job contract type, employment type, body mass index, smoking status, and alcohol use (as time-varying covariates).

Table 2
Change in active commuting as predictor of change in self-rated health. The results from a within- and between-individual analysis. Finnish Public Sector study 2020–2022.

		Change in self-rated health					
		Model 1[a] (*N* = 16,881)		Model 2[b] (N = 16,881)		Model 3[c] (*N* = 13,875)	
Type	Predictor	B	95% CI	B	95% CI	B	95% CI
Within	Active commuting	0.01	0.01–0.02	0.01	0.01–0.02	0.01	0.00–0.02
	Marital status (married)					−0.06	−0.13-0.02
	Marital status (cohabiting)					−0.03	−0.09 − 0.03
	Marital status (divorced)					-0.03	−0.10-0.04
	Marital status (widowed)					−0.12	−0.33-0.10
	Occupational level (intermediate)					0.03	−0.05-0.10
	Occupational level (low)					−0.11	−0.22-0.00
	Job contract (temporary)					−0.03	−0.05-0.00
	Employment type (part time)					−0.06	−0.12-0.00
	Body mass index					−0.05	−0.06-0.04
	Smoking (yes)					−0.05	−0.11 − 0.01
	Alcohol use (100 g/week)					0.01	-0.01-0.03
Between	Active commuting	0.05	0.04–0.05	0.05	0.04–0.05	0.03	0.02–0.04
	Age at T1			0.02	−0.02-0.01	−0.02	−0.02-0.01
	Sex (men)			0.01	−0.02-0.04	0.05	0.02–0.08
	Marital status (married)					0.15	0.11–0.19
	Marital status (cohabiting)					0.05	0.00–0.09
	Marital status (divorced)					0.09	0.04–0.14
	Marital status (widowed)					0.20	0.07–0.33
	Occupational level (intermediate)					−0.18	−0.21-0.15
	Occupational level (low)					−0.10	−0.13-0.07
	Job contract (temporary)					0.09	0.05–0.13
	Employment type (part time)					−0.44	−0.51-0.37
	Body mass index					−0.04	−0.04-0.04
	Smoking (yes)					−0.14	−0.19-0.10
	Alcohol use (100 g/week)					−0.05	−0.07-0.03

[a] Model 1: Change in active commuting as the predictor, Pseudo-R^2 (fixed effects) =0.01; pseudo-R^2 (total) = 0.63.
[b] Model 2: Model 1 + age at T1 and sex (in between individual analysis), Pseudo-R^2 (fixed effects) =0.04; pseudo-R^2 (total) = 0.63.
[c] Model 3: Model 2 + marital status, occupational level, job contract type, employment type, body mass index, smoking status, and alcohol use. Pseudo-R^2 (fixed effects) = 0.13; pseudo-R^2 (total) = 0.64. B: Unstandardized beta, CI: Confidence interval.

3.2. Association of active commuting with psychological distress and sleep problems

Fig. 3 shows the association of change in active commuting with psychological distress and sleep problems. We could not demonstrate any association between change in active commuting and psychological distress or sleep problems (Supplementary tables 1–2 for all estimates).

4. Discussion

4.1. Main findings

We examined the effect of change in active commuting on change in self-rated health among Finnish public sector employees. After adjustment for age at T1, sex (as time-invariant covariates) and marital status, occupational level, job contract type, employment type, body mass index, smoking and alcohol consumption (as time-varying covariates), an increase equivalent to 10 additional active commuting kilometers per week was associated with a small (B from 0.01 to 0.03) improvement in self-rated health both in the within- and between-individual models. This translates to increasing the daily active commuting distance by 7–20 km to achieve a 0.1-point change in self-rated health on a scale from 1 to 5. As secondary outcomes, we analyzed changes in active commuting in relation to psychological distress and sleep problems but found no evidence of an association.

The results of the within- and between-analysis showed less similarity in the unadjusted model and increased similarity in the fully adjusted model. This suggest that confounding variables may have contributed to the initial differences. The results of the main analysis were similar when we adjusted the models for whether the commute distance had remained the same between T1 and T2. This suggests that the results of the main analysis were not driven by a change in commuting distance (or change in the place of work) but rather by changes in the actual commuting activity. When we considered only those who were inactive at T1, no association between change in active commuting and improvement of self-rated health was observed in the within-individual analysis. The mean increase in weekly active commuting for the initially inactive was only a few kilometers, which likely explains why increase in activity was not associated with better health among the initially inactive participants. The results of the main analysis were, therefore, driven mainly by initially active participants.

The lack of stronger association between active commuting and improved health may be partly explained by ceiling effect, as the employed study population may be healthier than the overall population due to the healthy worker effect. Reverse causation may also have contributed to the results, as those who are healthier may also be more active commuters, and those who rate their health as suboptimal, choose passive commuting. Also, the amount of active commuting among the

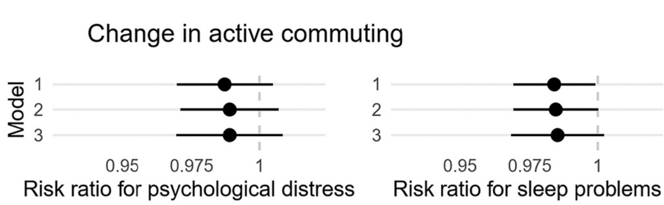

Fig. 3. The association of change in active commuting with psychological distress and sleep problems among Finnish public sector workers. Risk ratios and 95% confidence intervals from log-binomial regression analysis on the risk of psychological distress and sleep problems. Model 1: change in active commuting as the predictor (increase of 10 km per week as the unit). Model 2: Model 1 + age a T1 and sex. Model 3: Model 2 + marital status, occupational level, job contract type, employment type, body mass index, smoking status, and alcohol use.

study employees was quite high compared to the general commuting activity in Finland. In 2021, Finns made 11% of their commuting by bicycle and 8% by walking (Data.Traficom, 2023). In our sample, 28% of the employees cycled or walked to the work daily or almost daily during summertime, and 17% during wintertime. Moreover, the change in the active commuting may have been too small to be able to influence health as both the level of self-rated health and active commuting decreased from T1 to T2. The time between the study waves includes the COVID-19 pandemic which might have had an impact on participants' perceptions regarding their health, and at the same time decreased the level of active commuting. This decline in health noted in our data is supported by the statistics of the Organization for Economic Co-operation and Development (OECD stat, 2023), and a systematic review (Ahmed et al., 2023) comparing mental health outcomes before versus during the COVID-19 pandemic.

Comparing our results to the previous research is complicated because of the differences in study designs as well as definitions of the exposure and outcome variables. Overall, we identified only two previous studies from the UK utilizing within-individual analysis and focusing on the effects of change in active commuting on changes in physical or mental health. Jacob et al. (Jacob et al., 2021) used a nationally representative sample of UK households and seven waves of data from 2009 to 2016 with over 31,000 individuals. In line with our observations, the study reported that switching from car to active commuting was associated with improved self-rated physical health. Switching from active commuting to car use, in turn, reduced physical health and health satisfaction. They also observed that changing into active commuting resulted improvements in mental health, but, conversely, change from active commuting to car use declined mental health. An earlier study using data on approximately 18,000 adult commuters in the British Household Panel Survey showed that after accounting for changes in individual-level socioeconomic characteristics and potential confounding factors related to health, residence, and work, switching into active commuting was associated with an improvement in psychological well-being compared to individuals who always commuted by car or public transport (Martin et al., 2015).

We were not able to use within-individual analysis to assess associations between change in active commuting with changes in psychological distress or sleep problems, as these secondary outcomes were measured at one time point only. Based on the between-individual analysis, change in active commuting was not associated with these mental health indicators. In general, the evidence of the relationships between active commuting and mental health is scarce and contradictory (Avila-Palencia et al., 2018; Herman and Larouche, 2021; Knott et al., 2018; Martin et al., 2014; Zijlema et al., 2018). In a recent systematic review, (Marques et al., 2020) of the seven included studies, only two presented significant association of active commuting with depressive symptoms. We are not aware about previous studies focusing specifically on beneficial effects of active commuting on sleep problems.

4.2. Strengths and limitations

Our study has several strengths. We had a large, representative sample of almost 17,000 Finnish public sector employees across various occupations. We utilized methodologically appropriate within-individual approach to control for the omitted variable bias in longitudinal studies. The advantage of the within-individual analysis is that it considers time-invariant differences of the individuals by design when both predictor and outcome vary over time. The method controls for all stable individual characteristics, whether measured or not, and thereby makes it less likely that a real difference that probably exists between the active commuting and health will stay undetected. The approach uses participants as their own control and thereby can provide estimates closer to causal inference (Allison, 2005; Firebaugh et al., 2013; Gunasekara et al., 2014). Furthermore, we enhanced the depth of our analysis by comparing and contrasting the within-individual findings with those from a between-individual analysis. These parallel results not only validate our findings but also illustrate how the between-individual estimates approximate within-individual estimates as we account for potential confounding factors. Although the observed effects were small and fairly large change in commuting activity was needed for a small change in health, the results revealed possible causal evidence that a change in active commuting could promote health.

Our exposure measure considered both cycling and walking, commuting distance, and frequency, and covered both summer and winter conditions. Response rates were high at both time points ranging from 62% to 73%. We were also able to consider several possible confounders in the analysis. We excluded those with missing data on (primary) health outcome and the number of missing responses was low in the secondary outcomes, as well as in the other variables.

Some limitations should also be noted. The study participants represented only public sector employees of which 80% were women, corresponding to the Finnish public sector workers in general, restricting the generalizability of the results. We used self-reported data and information bias may be present. We were not able to control for leisure-time or work-related physical activity and, although we included commuting distance in the analysis, we lack information on commuting time. We did not separate between walking or cycling. In most cases the intensity of walking is less energy-intensive per unit of time than cycling (Ainsworth et al., 2011) and therefore for some participants the change in the "dose" of active commuting may be biased. This should be considered in future studies. Social desirability bias could also be present as the respondents may have tended to answer the questions in a favorable manner, causing possible over- or underreporting.

5. Conclusions

We have demonstrated that an increase in active commuting may promote self-rated health. However, a notable increase of tens of additional kilometers in walking or cycling to work every day may be required to produce even a small improvement in health.

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Declaration of Competing Interest

The authors declare that there are no conflicts of interests.

Data availability

Anonymized data are available upon reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2023.107744.

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