Changes in workers' sedentary and physically active behaviors in response to the COVID-19 pandemic and their relationships with fatigue: A longitudinal online study

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Abstract

Background: Sedentary behaviors and physical activity are likely to be affected by the outbreak of COVID-19, and sedentary lifestyles can increase subjective fatigue. The social isolation imposed by COVID-19 may also have adverse effects on fatigue.

Objective: This study has two aims: to examine the changes in sedentary behaviors and physical activity of company employees in response to COVID-19 in Japan and to examine relationships between these sedentary behaviors and physical activity changes with changes in fatigue.

Methods: Data from a nationwide prospective online survey conducted in 2019 and 2020 were used. On February 22, 2019, an e-mail with a link to participate in the study was sent to 45,659 workers (aged 20 to 59 years) randomly selected from the database of approximately one million individuals. A total of 2,466 and 1,318 company workers answered the baseline and follow up surveys, respectively. Surveys captured fatigue, sedentary behaviors, and physical activity. We used paired t-tests to compare the behaviors and total fatigue and subscales of fatigue before and after the initial outbreak of COVID-19 (July 2020). We used multivariable linear regression models to estimate associations of changes in sedentary behaviors and physical activities with changes in fatigue.

Results: There were significant increases in several domain-specific sedentary behaviors among workers after the COVID-19 epidemic. Participants reported significantly lower amounts of several physical activities after the epidemic. The average subjective fatigue score before and after COVID-19 was 31.2 ± 9.4 versus 31.9 ± 9.1 (P=.002), respectively. Increases in public transportation sitting during workdays, other leisure sitting time during workdays, total sitting time during non-workdays, and other leisure sitting time were associated with an increase in the motivation subscale of fatigue (b=0.29, 95% CI 0.00, 0.57, P=.048; b=0.40, 95% CI 0.18, 0.62, P <.001; b=0.05, 95% CI 0.00, 0.10, P=.04; and b=0.26, 95% CI 0.07, 0.45, P=.007, respectively). Increases in work-related sitting time during workdays, total sitting time during workdays, and total work-related sitting time were significantly associated with an increase in the physical activity subscale of fatigue (b=0.06, 95% CI 0.00, 0.12, P=.03; b=0.05, 95% CI 0.01, 0.09, P=.02; and b=0.07, 95% CI 0.00, 0.14, P=.04, respectively). Each motivation and physical activity subscale of fatigue increased by 0.06 for each one-hour increase in total sitting time between baseline and follow up (b=0.06, 95% CI 0.00, 0.11, P=.045 and b=0.06, 95% CI 0.01, 0.10, P=.009, respectively).

Conclusions: Our longitudinal findings add to the accumulating evidence demonstrating potential adverse consequences of

COVID-19 on sedentary behaviors, physical activity, and fatigue among workers in Japan. This study highlights the importance of reducing sedentary behaviors to improve workers' fatigue. Our findings provide unique insights into how future epidemics may affect active behaviors and fatigue. Clinical Trial: N/A

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Abstract

Background. Sedentary behaviors and physical activity are likely to be affected by the outbreak of COVID-19, and sedentary lifestyles can increase subjective fatigue. The non-pharmaceutical policies imposed by COVID-19 may also have adverse effects on fatigue.

Objective. This study has two aims: to examine the changes in sedentary behaviors and physical activity of company workers in response to COVID-19 in Japan and to examine relationships between these sedentary behaviors and physical activity changes with changes in fatigue.

Methods. Data from a nationwide prospective online survey conducted in 2019 and 2020 were used. On February 22, 2019, an e-mail with a link to participate in the study was sent to 45,659 workers (aged 20 to 59 years) randomly selected from the database of approximately one million individuals. A total of 2,466 and 1,318 participants, who self-reported their occupation as company workers, answered the baseline and follow up surveys, respectively. Surveys captured fatigue and workday and daily domain-specific and total sedentary behaviors and physical activity. We used multivariable linear regression models to estimate associations of changes in sedentary behaviors and physical activities with changes in fatigue.

Results. Increases in public transportation sitting during workdays, other leisure sitting time during workdays, and other leisure sitting time were associated with an increase in the motivation subscale of fatigue (*b*=0.29, 95% CI 0.00, 0.57, *P*=.048; *b*=0.40, 95% CI 0.18, 0.62, *P* <.001; *b*=0.05, 95% CI 0.00, 0.10, *P*=.04; and *b*=0.26, 95% CI 0.07, 0.45, *P*=.007, respectively). Increases in work-related sitting time during workdays, total sitting time during workdays, and total work-related sitting time were significantly associated with an increase in the physical activity subscale of fatigue (*b*=0.06, 95% CI 0.00, 0.12, *P*=.03; *b*=0.05, 95% CI 0.01, 0.09, *P*=.02; and *b*=0.07, 95% CI 0.00, 0.14, *P*=.04, respectively). Each motivation and physical activity subscale of fatigue increased by 0.06 for each one-hour increase in total sitting time between baseline and follow up (*b*=0.06, 95% CI 0.00, 0.11, *P*=.045 and *b*=0.06, 95% CI 0.01, 0.10, *P*=.009, respectively).

Conclusions. Our findings demonstrated that sedentary and active behaviors among company workers in Japan were negatively affected during the outbreak of COVID-19. Increases in several domain-specific sedentary behaviors also contributed to unfavourable changes in workers' fatigue. Social distancing and teleworking amid a pandemic may contribute to the sedentary lifestyle of company workers. Public health interventions are needed to mitigate the negative effects of the COVID-19 or future pandemics on sedentary and active behaviors and fatigue among company workers.

Key words: COVID-19; physical inactivity; sitting time; mental health; Japan; prospective design

Introduction

Sedentary lifestyles can increase the risk of many chronic diseases [1] and increase subjective fatigue in working adults [2, 3]. Subjective fatigue refers to “an overwhelming sense of tiredness, lack of energy, or feeling of exhaustion” (Karlsen et al., 1999). Subjective fatigue has several adverse effects on health and well-being, productivity, and safety among workers [4-6]. For example, a population-based study conducted in Germany found that chronic fatigue was negatively associated with quality of life [7].

While the exact causes of fatigue in workplaces have not yet been fully investigated [8], promoting physical activity and interrupting sedentary time may mitigate subjective fatigue at work [9]. For example, a randomised trial study found that breaking prolonged sitting time with walking breaks was associated with lower fatigue level among a sample of overweight/obese adults [10]. Longer sitting time was also found to be associated with more fatigue in a sample of Swedish adults [11]. Nevertheless, this evidence is mainly based on cross-sectional studies and conducted among high-risk groups such as overweight/obese individuals. Further research is warranted to assess whether longitudinal changes in sedentary and active behaviors may influence general workers’ fatigue.

The World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic on March 11, 2020 [12]. Since then, several social distancing policies, such as school and university closures, recommendations for working from home, and bans on large gatherings, have been implemented by governments and local authorities to slow the spread of COVID-19. In Japan, a state of emergency was declared on April 7, 2020, by the government to contain the spread of COVID-19 [13]. Under this state of emergency, prefectural governors were allowed to request residents to restrict their unnecessary trips and stay at home as much as possible and ask public places such as cinemas and museums to limit their operations. However, in contrast with several other countries, no penalty or legal force under Japanese law exists for those people or companies who disobeyed the lockdown request. Nevertheless, sedentary behaviors and physical activity are likely to be affected by these social distancing policies. A worldwide study of the effects of COVID-19 on physical activity found a rapid decrease in step counts, an indicator of physical activity, across multiple countries [14]. The non-pharmaceutical policies resulting from public health measures in place to reduce person-to-person transmission of COVID-19 may also have adverse effects on people's fatigue. For instance, a study conducted in Poland reported a high level of everyday fatigue (i.e., measured through items capturing physical, mental, and social fatigue) during the COVID-19 home quarantine compared to before the quarantine [15]. Since it is currently unknown how long the COVID-19 pandemic will last, workers may need to follow workplace social distancing policies for an unpredictable duration. Even after this pandemic ends, it is likely that workers will continue to be sedentary due to advancements in workplace technology. Given the links between fatigue and active lifestyle, further research is needed to shed light on how COVID-19 has influenced the sedentary behaviors and physical activities of different population groups, especially company workers who are already exposed to a sedentary lifestyle.

To our knowledge, no study has examined longitudinal changes in sedentary behaviors and physical

activity among company workers during the COVID-19 and their effects on fatigue. Therefore, the current study has two aims, specifically, to examine the changes in sedentary behaviors and physical activity of company workers during the COVID-19 outbreak in Japan and to examine the relationships between these changes in sedentary behaviors and physical activity and fatigue.

Methods

Data source and participants

Our study included data from a nationwide prospective online survey conducted in 2019 and 2020. The participants were recruited from the registered individuals of a Japanese internet research service company (MyVoice Communication, Inc. Tokyo, Japan). Approximately one million individuals across Japan voluntarily participated in this company's database and registered their sociodemographic information. The eligibility criteria for study participation were based on having the same number of each sex (female, male) and each age group (workers in their 20s, 30s, 40s, and 50s) and being a company worker. Given our research budget, we aimed to recruit a total of 3,200 workers (aged 20 to 59 years): 1,600 participants from each sex and 800 participants from each age group. On February 22, 2019, an e-mail with a link to participate in the study was sent to 45,659 individuals (the company sent e-mails until the planned sample size was reached) randomly selected from the database by sex and age strata. Of these, 2,921 individuals were eligible to participate in the follow up study on July 8, 2020 (279 responders had resigned from the company's database), and 1,709 completed the follow up survey (53.4% of the baseline participants). Only participants who self-reported their occupation as company workers were included in this study (2,466 and 1,318 participants at baseline and follow up, respectively). The follow-up timeframe had not been originally intended, and it was in response to the COVID-19. A cash reward valued at 140 and 120 yen was offered as an incentive to participate in the first and second surveys, respectively. All participants signed an online informed consent form. The internet research service company removed

participant names, addresses, personal health numbers, contact information, and any other details that might be used to identify individuals from prior to transferring data to researchers. The Institutional Ethics Committee of Waseda University approved this study (2020-135).

Measures

Fatigue. The Japanese version of the Checklist Individual Strength (CIS20-R) questionnaire was used to assess perceived fatigue during the past two weeks [16, 17]. The CIS20-R is a multidimensional 20-item questionnaire that measures four aspects of fatigue, including subjective fatigue, concentration, motivation, and physical activity as well as total fatigue [16]. This questionnaire has high internal reliability (Cronbach's alpha=0.90 for total fatigue and ranges from 0.83 to 0.92 for its subscales) [16], and the questionnaire is valid in the working population [17, 18]. Participants scored each item on a 7-point Likert scale ranging from 1 (exactly) to 7 (not at all). The scoring protocol for the CIS20-R has been described in detail elsewhere [18]. In brief, higher scores indicate a higher degree of fatigue, more concentration problems, reduced motivation, and less physical activity. Total fatigue was calculated from the sum of the four aspects of fatigue. We estimated absolute changes in total fatigue (total CIS20-R score) and subscales of fatigue before and during the COVID-19 pandemic by subtracting baseline values from follow up values.

Sedentary behaviors and physical activity. Domain-specific sedentary behaviors were assessed using a Japanese 6-item self-reported questionnaire with a 1-week recall period [19]. Participants were asked to report their daily average sedentary behaviors over the past seven days separately for workdays (or weekdays for unemployed individuals) and non-workdays (weekends) across the following six domains: driving or riding by car; using public transport; at work; watching television, videos, and DVDs; using a computer, cell phone, or tablet PC outside of working hours; and in leisure time (excluding watching television, videos, and DVDs). Participants reported average time

(hours and minutes) spent in each of these categories per day. The reliability and validity of this questionnaire have been reported elsewhere [19]. Average daily values of total sedentary time and each domain's sedentary time were calculated with weighting for the number of workdays and non-workdays. Average workday value of total sedentary time was also calculated by summing all six domains for workdays. Domain-specific physical activity was measured using the Global Physical Activity Questionnaire (GPAQ) [20]. The method of cleaning and scoring GPAQ data has been described in detail elsewhere [21]. Briefly, this questionnaire consists of 16 questions that assess self-reported domain-specific physical activity (during work, transport, and leisure) and sitting time in a typical week. It has acceptable reliability and validity in Japanese adults [22]. Average daily hours of work-related vigorous physical activity, work-related moderate physical activity, transport-related physical activity, leisure vigorous physical activity, leisure moderate physical activity, and total physical activity were calculated. We estimated absolute changes in sedentary behaviors and physical activity before and during COVID-19 by subtracting baseline values from follow up values.

Sociodemographics. Participants self-reported their baseline age, sex (female or male), marital status (single or couple), highest education (tertiary, below tertiary, or other), and gross annual individual income (<¥4,000,000 or ≥ ¥4,000,000).

Statistical Analysis

Descriptive statistics, including means (±standard deviation) and frequencies, were calculated for the baseline sociodemographic variables. Paired t-tests were used to compare the domain-specific sedentary and physically active behaviors and total fatigue and subscales of fatigue before and during the COVID-19 outbreak. A separate multivariable linear regression model estimated the associations between changes in sedentary behaviors and physical activities and the changes in each fatigue subscale at the individual level. The regression models were adjusted for the sociodemographic

variables (age, sex, marital status, highest education, and gross annual household income). The regression models were also adjusted for baseline fatigue to account for the potential effect of baseline values on change scores. Normality assumptions were checked by the QQ plots of the residuals. For all point estimates (*b* = unstandardized regression coefficients), 95% confidence intervals (CIs) were estimated. A complete-case analysis was chosen because the proportion of missing data for our variables of interest was low (5%)[23]. We found no significant differences in any measured characteristics between those individuals with missing data and those with complete data. Our analysis excluded those who were unable to engage in physical activity due to health issues. Analyses were conducted using Stata 15.0 (Stata Corp, College Station, Texas), and the level of significance was set at $P < .05$.

Results

Sample characteristics

Table 1 shows the baseline sample characteristics (n=2,466). The participants had an average age of 40 years, and the majority were male , single , had a high tertiary educational attainment , and had an annual gross household income lower than ¥4,000,000 per year . The majority of the participants had sedentary occupations (i.e., office-based workers) (73%) and about 27% had active occupations (e.g., manual labour). There were no participants who became unemployed by the follow-up survey. The participants reported the total number of weekly days they worked from home before and during the COVID-19 pandemic declaration. The average days of working from home was 0.2 and 1 day per week before and during the COVID-19, respectively.

Table 1. Baseline characteristics of study participants, Japan (N=2,466), February 2019.

Characteristic	Value
Age in years, mean (SD)	39.6 (10.7)
Sex, n (%)	
Female	1212 (49.1)

Male	1254 (50.9)
Marital status, n (%)	
Single	1392 (56.4)
Couple	1074 (43.6)
Highest education, n (%)	
Tertiary	1989 (80.7)
Below tertiary	477 (19.3)
Gross annual individual income, n (%)	
<¥4,000,000	1381 (56.0)
≥ ¥4,000,000	1085 (44.0)

Changes in sedentary behaviors, physical activity, and fatigue

Mean hours per day of sedentary behaviors and physical activity before and during the COVID-19 pandemic are shown in Tables 2 and 3. These comparisons were restricted to only participants who answered both surveys. There were several significant differences between workers' domain-specific sedentary behaviors between the two periods: participants spent more sedentary time in "work-related sitting time during workday", "TV viewing time during workday", "PC use sitting time during workday", "total sitting time during workday", "work-related sitting time", "PC use sitting time", and "total sitting time" during the COVID-19 pandemic (Table 2). Participants also reported significantly lower amounts of several domain-specific physical activities during the outbreak of COVID-19: the mean values of vigorous leisure physical activity and total physical activity were significantly lower during the outbreak of COVID-19 (Table 3).

At baseline, the Cronbach's alpha for internal consistency was 0.87, 0.75, 0.56, and 0.28 for the subjective fatigue, concentration, motivation, and physical activity items, respectively. These estimates were 0.86, 0.78, 0.59, and 0.33 for the follow up items, respectively. Despite a small difference in mean values between subjective fatigue before and during the outbreak of COVID-19, this difference was nevertheless statistically significant (higher scores refer to a higher degree of fatigue). No significant difference was observed for the means of the three subscales of

concentration, motivation, and physical activity, and total fatigue (total CIS20-R score) before and during COVID-19 (Table 4)

Table 2. Workers' domain-specific sedentary behaviors before (February 2019) and during the outbreak of COVID-19 (July 2020), Japan (n = 1,086).

	Mean (S.D.)		*p*-value	Differences
	Before	During		*Mean (S.D.)*
Car sitting time during workday (hours/day)	0.45 (0.86)	0.45 (0.87)	.80	0.01 (0.85)
Public transportation sitting during workday (hours/day)	0.46 (0.72)	0.49 (0.79)	.15	0.03 (0.72)
Work-related sitting time during workday (hours/day)	**5.18 (3.26)**	**5.69 (3.30)**	**<.001***	**0.50 (2.93)**
TV viewing time during workday (hours/day)	**1.56 (1.36)**	**1.65 (1.36)**	**.03***	**0.09 (1.27)**
PC use sitting time during workday (hours/day)	**1.36 (1.27)**	**1.47 (1.27)**	**.01***	**0.11 (1.40)**
Other leisure sitting time during workday (hours/day)	0.52 (0.69)	0.54 (0.73)	.53	0.02 (0.92)
Total sitting time during workday (hours/day)	**9.53 (3.96)**	**10.29 (3.99)**	**<.001***	**0.75 (3.95)**
Car sitting time (hours/day)	0.50 (0.78)	0.50 (0.76)	.90	-0.00 (0.72)
Public transportation sitting (hours/day)	0.39 (0.58)	0.39 (0.61)	.80	0.00 (0.57)
Work-related sitting time (hours/day)	**3.91 (2.49)**	**4.22 (2.52)**	**<.001***	**0.31 (2.32)**
TV viewing time (hours/day)	1.89 (1.54)	1.97 (1.56)	.06	0.08 (1.45)

PC use sitting time (hours/day)	**1.61 (1.41)**	**1.76 (1.45)**	**<.001***	**0.14 (1.47)**
Other leisure sitting time (hours/day)	0.67 (0.83)	0.69 (0.88)	.48	0.02 (1.09)
Total sitting time (hours/day)	**8.96 (3.53)**	**9.53 (3.59)**	**<.001***	**0.56 (3.67)**

* Statistically significant based on paired-sample t-tests

Table 3. Workers' domain-specific physical activity before (February 2019) and during the outbreak of COVID-19 (July 2020), Japan (n = 1,315).

	Mean (S.D.)		*p*-value	Differences
	Before	During		*Mean (S.D.)*
Work-related vigorous physical activity (hours/day)	0.21 (1.03)	0.19 (0.84)	.40	-0.02 (1.06)
Work-related moderate physical activity (hours/day)	0.43 (1.32)	0.39 (1.17)	.24	-0.05 (1.43)
Transport-related physical activity (hours/day)	0.48 (0.72)	0.44 (0.73)	.10	-0.04 (0.83)

Leisure vigorous physical activity (hours/day)	**0.25 (0.72)**	**0.20 (0.53)**	**.01***	**-0.05 (0.64)**
Leisure moderate physical activity (hours/day)	0.37 (0.83)	0.33 (0.72)	.07	-0.04 (0.80)
Total physical activity (hours/day)	**1.75 (2.79)**	**1.55 (2.31)**	**.01***	**-0.20 (2.61)**

* Statistically significant based on paired-sample t-tests

Table 4. Workers' total fatigue (total CIS20-R score) and subscales of fatigue before (February 2019) and during the outbreak of COVID-19 (July 2020), Japan (n = 1,318).

	Mean (S.D.)		*p*-value
	Before	During	
Subjective fatigue	**31.2 (9.4)**	**31.9 (9.1)**	**.002***
Concentration	20.1 (4.4)	20.3 (4.4)	.24
Motivation	17.4 (4.2)	17.3 (4.2)	.33
Physical activity	12.3 (3.0)	12.2 (3.0)	.45

Total fatigue (total CIS20-R score)	81.0 (16.9)	81.6 (16.6)	.10

* Statistically significant based on paired-sample t-test
Higher scores refer to a higher degree of fatigue, more concentration problems, reduced motivation, less physical activity, and higher total fatigue (total CIS20-R score).

Associations of changes in sedentary behaviors and physical activity with fatigue

Table 5 shows the associations of the changes in workers' total fatigue (total CIS20-R score) and subscales of fatigue with those in workers' domain-specific sedentary behaviors. Increases in public transportation sitting during workdays, other leisure sitting times during workdays, and other leisure sitting times were significantly associated with an increase in the motivation subscale of fatigue. Increases in work-related sitting time during workdays, total sitting time during workdays, and work-related sitting time were significantly associated with an increase in the physical activity subscale of fatigue. Each motivation and physical activity subscale of fatigue score increased by 0.03 for a half-hour increase in total sitting time between baseline and follow up (*b/2*=0.03, 95% CI 0.00, 0.05 and 0.01, 0.05, respectively). None of the changes in domain-specific physical activity were significantly associated with workers' total fatigue (total CIS20-R score) or fatigue subscale scores (Table 6).

Table 5. Results of multivariable linear regression models assessing associations between absolute changes in workers' domain-specific sedentary behaviors and changes in workers' total fa
score) and subscales of fatigue, Japan (n = 1,086).

	Subjective fatigue	Concentration	Motivation	Physical activity	Total f
	b (95%CI)	*b (95%CI)*	*b (95%CI)*	*b (95%CI)*	
Car sitting time during workday (hours/day)	-0.05 (-0.55, 0.45)	-0.04 (-0.30, 0.22)	-0.01 (-0.25, 0.24)	0.03 (-0.16, 0.22)	-0.
Public transportation sitting during workday (hours/day)	-0.23 (-0.82, 0.36)	-0.08 (-0.38, 0.23)	**0.29 (0.00, 0.57)***	0.04 (-0.19, 0.26)	0.
Work-related sitting time during workday (hours/day)	0.02 (-0.13, 0.16)	0.07 (-0.01, 0.14)	0.02 (-0.05, 0.10)	**0.06 (0.00, 0.12)***	0.
TV viewing time during workday (hours/day)	0.07 (-0.27, 0.40)	0.06 (-0.11, 0.23)	-0.02 (-0.18, 0.14)	0.04 (-0.09, 0.17)	0.
PC use sitting time during workday (hours/day)	0.05 (-0.25, 0.35)	-0.13 (-0.28, 0.03)	-0.02 (-0.16, 0.13)	0.03 (-0.09, 0.14)	-0.
Other leisure sitting time during workday (hours/day)	0.30 (-0.17, 0.76)	0.02 (-0.22, 0.26)	**0.40 (0.18, 0.62)***	0.12 (-0.06, 0.29)	0.
Total sitting time during workday (hours/day)	0.03 (-0.08, 0.14)	0.02 (-0.03, 0.08)	0.04 (-0.01, 0.09)	**0.05 (0.01, 0.09)***	0.
Car sitting time (hours/day)	0.23 (-0.36, 0.82)	0.07 (-0.24, 0.37)	0.09 (-0.20, 0.37)	0.10 (-0.13, 0.32)	0.
Public transportation sitting (hours/day)	-0.27 (-1.01, 0.47)	-0.13 (-0.51, 0.26)	0.31 (-0.05, 0.67)	0.05 (-0.23, 0.33)	-0.
Work-related sitting time (hours/day)	-0.02 (-0.21, 0.16)	0.07 (-0.02, 0.17)	0.03 (-0.06, 0.12)	**0.07 (0.00, 0.14)***	0.
TV viewing time (hours/day)	0.11 (-0.19, 0.40)	0.11 (-0.04, 0.26)	0.03 (-0.11, 0.17)	0.07 (-0.04, 0.18)	0.
PC use sitting time (hours/day)	-0.02 (-0.31, 0.27)	-0.11 (-0.26, 0.04)	0.03 (-0.11, 0.17)	0.04 (-0.07, 0.15)	-0.
Other leisure sitting time (hours/day)	0.23 (-0.16, 0.62)	0.02 (-0.18, 0.22)	**0.26 (0.07, 0.45)***	0.09 (-0.06, 0.24)	0.

	b (95%CI)	*b (95%CI)*	*b (95%CI)*	*b (95%CI)*	
Work-related vigorous physical activity (hours/day)	-0.23 (-0.59, 0.14)	-0.02 (-0.21, 0.17)	-0.08 (-0.26, 0.10)	0.01 (-0.13, 0.15)	-0.
Work-related moderate physical activity (hours/day)	-0.10 (-0.37, 0.17)	-0.07 (-0.21, 0.07)	-0.03 (-0.16, 0.10)	0.05 (-0.05, 0.15)	-0.
Transport-related physical activity (hours/day)	-0.06 (-0.52, 0.40)	-0.02 (-0.26, 0.22)	0.21 (-0.02, 0.43)	0.11 (-0.06, 0.28)	0.
Leisure vigorous physical activity (hours/day)	-0.26 (-0.86, 0.33)	-0.17 (-0.48, 0.15)	0.16 (-0.14, 0.45)	-0.11 (-0.33, 0.12)	-0.
Leisure moderate physical activity (hours/day)	-0.30 (-0.78, 0.18)	-0.16 (-0.41, 0.09)	0.13 (-0.11, 0.37)	-0.04 (-0.22, 0.14)	-0.
Total physical activity (hours/day)	-0.12 (-0.27, 0.03)	-0.05 (-0.13, 0.02)	0.02 (-0.05, 0.09)	0.02 (-0.04, 0.07)	-0.

Note: *b* = unstandardized regression coefficients; CI = confidence interval. All models adjusted for age, sex, marital status, highest education, gross annual household income, and baseline fa

Discussion

Principal Findings

This study is one of the first attempts to empirically examine the longitudinal changes in workers' domain-specific sedentary behaviors, physical activity, and fatigue during the outbreak of COVID-19. It also investigated the associations of the changes in workers' sedentary behaviors and physical activity with changes in their fatigue. Compared with before the COVID-19 pandemic, we found that workers spent more time (varied by 5-45 minutes per day) engaged in several domain-specific sedentary behaviors including work-related sitting, TV viewing time during workdays, and PC use sitting time and total sitting time during the COVID-19 pandemic. They also reported less time engaged in leisure vigorous physical activity and total physical activity during the outbreak of COVID-19. Several cross-sectional and longitudinal studies conducted among other population groups echoed similar patterns in how COVID-19 unfavorably affected people's active movement behaviors [24-29]. For example, a national study conducted in Canada found that children and youth reported higher sedentary behaviors and lower physical activity during the outbreak of COVID-19, and less than 5% and 1% of them, respectively, met the combined 24-hour movement behavior goals for physical activity, sedentary behavior, and sleep [24]. Another study conducted in China found that adults' average steps per day and average moderate- or vigorous-intensity exercise significantly decreased during the semi-lockdown period of the COVID-19 pandemic [27]. Moreover, a study conducted among hypertensive older adults found that there was an increase in accelerometer-based sedentary behavior and a decrease in physical activity during the COVID-19 pandemic [28]. Our longitudinal findings are the first to confirm that COVID-19-related social distancing policies negatively affect sedentary and active

behaviors among company workers, a population already at risk for being physically inactive [30, 31].

Our findings also identified changes in sedentary behaviors and physical activity for each domain during the outbreak of COVID-19. Influenced by the government's self-isolation advice [32], leisure vigorous physical activity significantly decreased during the outbreak of COVID-19. The pre-COVID-19 level of leisure vigorous physical activity was only 15 minutes per day in our sample, which became 12 minutes per day during the COVID-19 pandemic. Since only a few people engaged in this activity even in non-COVID-19 times, this pandemic has almost obliterated the vigorous physical activity in the leisure time in Japanese workers population. We also found that participants reported more work-related sitting time during the outbreak of COVID-19. Company workers usually are sitting during their work, and some of that additional sitting was due to an increase in the use of a computer for all work-related meetings during the COVID-19 pandemic. Several companies in Japan have introduced and supported some level of teleworking amid the outbreak of COVID-19. While teleworking may lead to less time traveling for work, it is also likely that teleworking limits the opportunities for employees to accumulate transport-related physical activity and intensifies workers' sedentary activities, especially during a pandemic. Further studies are needed to investigate the influence of teleworking on workers' sedentary behaviors and physical activity. We also found that participants spent more sitting time on watching TV or using PC. One reason for these increases is that people were more likely to avoid going outside following the Japan government's advice to minimize nonessential trips and reduce train operating hours in some areas. Staying at home limits

people's ability to engage in physical activity and socialize with their friends and family and increase screen sitting time. Future studies can identify home-based interventions to improve people's active behaviours during a pandemic.

We found that increases in several domain-specific sedentary behaviors were associated with unfavourable changes in motivation and physical activity subscales of fatigue. Several previous studies have shown adverse effects of too much sitting on fatigue [3, 10, 11]. While yet to be tested in other populations, public health strategies to reduce sedentary behaviors in company workers could have positive effects on worker fatigue. Reducing sedentary behavior has been highlighted as a more feasible strategy during the COVID-19 pandemic than achieving optimal exercise levels [33]. However, teleworking from home, a new norm resulting from COVID-19-related social distancing policies, may impose a new challenge to reducing occupational sitting time in workers [34]. Future research is needed to identify how teleworking may influence sedentary behaviors and how to develop new policies to reduce workers' sitting time in the new era of teleworking from home. Furthermore, we found a significant increase in subjective fatigue among workers during the outbreak of COVID-19. Although the exact reasons for increased subjective fatigue in workers during the COVID-19 pandemic remain to be elucidated, the burden of this pandemic on people's mental health may be involved [35]. Several studies have provided preliminary evidence on the harmful effects of the COVID-19 pandemic on mental health [36-38]. For instance, a national study conducted in the U.S. found that the prevalence of depression symptoms was more than three times higher during the outbreak of COVID-19 than before the outbreak [36]. Another study conducted in the Republic of Ireland found that

approximately 30% of their participants were screened positive for generalized anxiety disorder or depression during the first week of the COVID-19 lockdown [38]. A sedentary lifestyle, intensified by social distancing policies, may also play a role in the observed increase in worker fatigue since the onset of the COVID-19 pandemic.

Limitations and Strengths

This study has some limitations. Our self-reported measures of sedentary behaviors and physical activity may be subject to memory and recall bias [39]. While this is a national study of participants recruited from throughout Japan, we are unable to confirm the generalizability of the data from our sample to all company workers. Data on employment status, including full-time or part-time, were also unavailable. The physical activity subscale of fatigue had a low internal reliability at both baseline and follow up. Since subjective fatigue may also lead to less physical activity and more sedentary behaviors, the direction of the observed associations remains inconclusive. Our study has several unique strengths, including the use of national data, the focus on the less-studied population group of company workers, and the examination of domain-specific sedentary behaviors and physical activity at different intensities.

Conclusions

Following the outbreak of COVID-19, there have been many concerns regarding its effects on people's physical inactivity and chronic diseases [40-42]. Our findings demonstrated that sedentary and active behaviors among company workers in Japan were negatively affected during the outbreak of COVID-19. Increases in several domain-specific sedentary behaviors also contributed to unfavourable changes in

workers' fatigue. Social distancing and teleworking amid a pandemic may contribute to the sedentary lifestyle of company workers. Public health interventions are needed to mitigate the negative effects of the COVID-19 or future pandemics on sedentary and active behaviors and fatigue among company workers. More evidence is needed to identify the magnitude of changes in sedentary and active behaviors in workers during the outbreak of COVID-19 and how these changes may influence workers' health and well-being.

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Authors' Contributions

M.J.K. and K.O. conceived the idea, analyzed the data and drafted the paper. T.N. assisted with the statistical analysis. T.N., G.L.M., A.S., and K.I. contributed to the writing and assisted with the interpretation. All authors reviewed and approved the final manuscript.

Conflicts of Interest

None declared.

References

1. Dempsey PC, Matthews CE, Dashti SG, Doherty AR, Bergouignan A, van

Roekel EH, et al. Sedentary behavior and chronic disease: mechanisms and future directions. J Phys Act Health. 2020;17(1):52-61.

2. de Vries JD, Claessens BJ, van Hooff ML, Geurts SA, van den Bossche SN, Kompier MA. Disentangling longitudinal relations between physical activity, work-related fatigue, and task demands. Int Arch Occup Environ Health. 2016;89(1):89-101.

3. Thorp AA, Kingwell BA, Owen N, Dunstan DW. Breaking up workplace sitting time with intermittent standing bouts improves fatigue and musculoskeletal discomfort in overweight/obese office workers. Occup Environ Med. 2014;71(11):765-71.

4. Saremi M, Fallah MR. Subjective fatigue and medical errors among nurses in an educational hospital. Iran Occup Health. 2013;10(4):1-8.

5. Sadeghniiat-Haghighi K, Yazdi Z. Fatigue management in the workplace. Ind Psychiatry J. 2015;24(1):12.

6. Connolly D, Fitzpatrick C, O'Toole L, Doran M, O'Shea F. Impact of fatigue in rheumatic diseases in the work environment: a qualitative study. Int J Environ Res. 2015;12(11):13807-22.

7. Martin A, Chalder T, Rief W, Braehler E. The relationship between chronic fatigue and somatization syndrome: a general population survey. Journal of psychosomatic research. 2007;63(2):147-56.

8. Williamson A, Friswell R. Fatigue in the workplace: causes and countermeasures. Fatigue. 2013;1(1-2):81-98.

9. Lerman SE, Eskin E, Flower DJ, George EC, Gerson B, Hartenbaum N, et al. Fatigue risk management in the workplace. J Occup Environ Med. 2012;54(2):231-58.

10. Wennberg P, Boraxbekk C-J, Wheeler M, Howard B, Dempsey PC, Lambert G, et al. Acute effects of breaking up prolonged sitting on fatigue and cognition: a pilot study. BMJ Open. 2016;6(2).

11. Engberg I, Segerstedt J, Waller G, Wennberg P, Eliasson M. Fatigue in the general population-associations to age, sex, socioeconomic status, physical activity, sitting time and self-rated health: the northern Sweden MONICA study 2014. BMC Public Health. 2017;17(1):654.

12. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19-11 March 2020. 2020. URL: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 [accessed 2021-3-7]

13. The Prime Minister of Japan and His Cabinet. Declaration of a state of emergency in response to the novel coronavirus disease. 2020. URL:

https://japan.kantei.go.jp/ongoingtopics/_00020.html [accessed 2021-3-7]

14. Tison GH, Avram R, Kuhar P, Abreau S, Marcus GM, Pletcher MJ, et al. Worldwide effect of COVID-19 on physical activity: a descriptive study. Ann Intern Med. 2020.

15. Bartoszek A, Walkowiak D, Bartoszek A, Kardas G. Mental well-being (depression, loneliness, insomnia, daily life fatigue) during COVID-19 related home-confinement—a study from Poland. Int J Environ Res. 2020;17(20):7417.

16. Vercoulen JH, Swanink CM, Fennis JF, Galama JM, van der Meer JW, Bleijenberg G. Dimensional assessment of chronic fatigue syndrome. J Psychosom Res. 1994;38(5):383-92.

17. Aratake Y, Tanaka K, Wada K, Watanabe M, Katoh N, Sakata Y, et al. Development of Japanese version of the checklist individual strength questionnaire in a working population. J Occup Health. 2007;49(6):453-60.

18. Beurskens AJ, Bültmann U, Kant I, Vercoulen JH, Bleijenberg G, Swaen GM. Fatigue among working people: validity of a questionnaire measure. Occup Environ Med. 2000;57(5):353-7.

19. Ishii K, Shibata A, Kurita S, Yano S, Inoue S, Sugiyama T, et al. Validity and reliability of Japanese-language self-reported measures for assessing adults domain-specific sedentary time. J Epidemiol. 2017:JE20170002.

20. Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). J Public Health. 2006;14(2):66-70.

21. World Health Organization. Global physical activity questionnaire (GPAQ) analysis guide. Geneva; 2012. URL: https://www.who.int/ncds/surveillance/steps/resources/GPAQ_Analysis_Guide.pdf [accessed 2021-3-7]

22. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. J Phys Act Health. 2009;6(6):790-804.

23. Jakobsen JC, Gluud C, Wetterslev J, Winkel P. When and how should multiple imputation be used for handling missing data in randomised clinical trials–a practical guide with flowcharts. BMC Med Res Methodol. 2017;17(1):162.

24. Moore SA, Faulkner G, Rhodes RE, Brussoni M, Chulak-Bozzer T, Ferguson LJ, et al. Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey. Int J Behav Nutr Phys Act. 2020;17(1):1-11.

25. López-Bueno R, Calatayud J, Andersen LL, Balsalobre-Fernández C, Casaña J,

Casajús JA, et al. Immediate impact of the COVID-19 confinement on physical activity levels in Spanish adults. Sustainability. 2020;12(14):5708.

26. Wang Y, Zhang Y, Bennell K, White DK, Wei J, Wu Z, et al. Physical distancing measures and walking activity in middle-aged and older residents in Changsha, China, during the COVID-19 epidemic period: longitudinal observational study. J Med Internet Res. 2020;22(10):e21632.

27. He M, Xian Y, Lv X, He J, Ren Y. Changes in body weight, physical activity, and lifestyle during the semi-lockdown period after the outbreak of COVID-19 in China: an online survey. Disaster Med Public Health Prep. 2020:1-6.

28. Browne RA, Macêdo GA, Cabral LL, Oliveira GT, Vivas A, Fontes EB, et al. Initial impact of the COVID-19 pandemic on physical activity and sedentary behavior in hypertensive older adults: an accelerometer-based analysis. Exp Gerontol. 2020:111121.

29. Hu Z, Lin X, Kaminga AC, Xu H. Impact of the COVID-19 epidemic on lifestyle behaviors and their association with subjective well-being among the general population in mainland China: cross-sectional study. J Med Internet Res. 2020;22(8):e21176.

30. Parry S, Straker L. The contribution of office work to sedentary behaviour associated risk. BMC Public Health. 2013;13(1):1-10.

31. Waters CN, Ling EP, Chu AH, Ng SH, Chia A, Lim YW, et al. Assessing and understanding sedentary behaviour in office-based working adults: a mixed-method approach. BMC Public Health. 2016;16(1):360.

32. Japanese Ministry of Health Labour and Welfare. Prevention measures against coronavirus disease 2019 (COVID-19). 2020. URL: https://www.mhlw.go.jp/content/10900000/000607599.pdf [accessed 2021-3-7]
33. Zieff G, Bates LC, Kerr ZY, Moore JB, Hanson ED, Battaglini C, et al. Targeting sedentary behavior as a feasible health strategy during COVID-19. Transl Behav Med. 2020.

34. Chtourou H, Trabelsi K, H'mida C, Boukhris O, Glenn JM, Brach M, et al. Staying physically active during the quarantine and self-isolation period for controlling and mitigating the COVID-19 pandemic: a systematic overview of the literature. Frontiers in Psychology. 2020;11.

35. Salari N, Hosseinian-Far A, Jalali R, Vaisi-Raygani A, Rasoulpoor S, Mohammadi M, et al. Prevalence of stress, anxiety, depression among the general population during the COVID-19 pandemic: a systematic review and meta-analysis. Glob Health. 2020;16(1):1-11.

36. Ettman CK, Abdalla SM, Cohen GH, Sampson L, Vivier PM, Galea S. Prevalence of depression symptoms in US adults before and during the COVID-19

pandemic. JAMA Netw Open. 2020;3(9):e2019686-e.

37. De Boni RB, Balanzá-Martínez V, Mota JC, Cardoso TDA, Ballester P, Atienza-Carbonell B, et al. Depression, anxiety, and lifestyle among essential workers: a web surveyfrom Brazil and Spain during the COVID-19 pandemic. J Med Internet Res. 2020;22(10):e22835.

38. Hyland P, Shevlin M, McBride O, Murphy J, Karatzias T, Bentall RP, et al. Anxiety and depression in the Republic of Ireland during the COVID-19 pandemic. Acta Psychiatr Scand. 2020;142(3):249-56.

39. Ainsworth BE, Caspersen CJ, Matthews CE, Mâsse LC, Baranowski T, Zhu W. Recommendations to improve the accuracy of estimates of physical activity derived from self report. J Phys Act Health. 2012;9(s1):S76-S84.

40. Smirmaul BPC, Arena R. The urgent need to sit less and move more during the COVID-19 pandemic. J Cardiopulm Rehabil Prev. 2020;40(5):287-9.

41. Peçanha T, Goessler KF, Roschel H, Gualano B. Social isolation during the COVID-19 pandemic can increase physical inactivity and the global burden of cardiovascular disease. Am J Physiol Heart Circ. 2020;318(6):H1441-H6.

42. Pinto AJ, Dunstan DW, Owen N, Bonfá E, Gualano B. Combating physical inactivity during the COVID-19 pandemic. Nat Rev Rheumatol. 2020:1-2.