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## Patterns of Objectively-Assessed Sedentary Time and Physical Activity among Japanese Workers

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## ABSTRACT

**Objectives:** To examine patterns of sedentary behavior and physical activity, among Japanese workers with differing occupational-activity types.

**Methods:** Full-time workers aged 40-64 years (n = 345; 55% men) wore an accelerometer for 7 days and completed a socio-demographic and occupational activity-type survey. Mean overall sedentary time, prolonged bouts of sedentary time and light-and moderate-to vigorous-intensity of physical activity (LPA and MVPA) as a proportion of accelerometer wear time, and number of breaks per sedentary hour, were identified for four time periods: working hours; workdays; non-work hours; and, non-work days. These sedentary behavior and physical activity measures in the four time periods were examined among workers with four self-attributed occupational activity types (mainly sitting, standing, walking, physical labor), adjusting for sociodemographic attributes. Diurnal patterns of sedentary behavior, LPA and MVPA were examined.

**Results:** In working hours, those with a sitting job had significantly more total and prolonged sedentary time along with less LPA and MVPA, and less frequent breaks, compared to those with the three more-active job type. Similar differences by job type were found for the whole working day, but not for prolonged sedentary time and breaks. On non-working hours and days, differences in sedentary and physically- active patterns by job type were not apparent.

**Conclusions:** Occupational activity type is related to overall sedentary time and patterns on working days, but not to leisure-time sitting and activity patterns, which were similar across the sitting, standing, walking, and physical labor occupational-activity types.

## ARTICLE SUMMARY

### Strengths and limitations of this study

- This is the first study to report descriptive patterns of objectively measured workers' sedentary behavior comprehensively in non-Western countries, and their relationships with occupational activity types.
- This study was used population-recruited sample and accelerometer-assessed sedentary behavior and physical activity.
- Data were cross-sectional and therefore any causality cannot be inferred.
- Low response rate was not completely at random, which may have resulted in selection bias.

## INTRODUCTION

Sedentary behavior, defined as any waking behavior characterized by an energy expenditure  $\leq 1.5$  METs while in a sitting or reclining posture [1] has distinctive adverse effects on human health [2]. For example, excessive sedentary behavior increases the risk of all-cause mortality [3, 4] and risk of type 2 diabetes, cardiovascular disease, and some cancers [5], with some evidence of dose-response relationships [6]. There are benefits of more-frequent breaks from sedentary time on cardio-metabolic risk biomarkers [7]. Reducing prolonged sedentary behavior is an important public health issue.

Among the Japanese adult population, the worksite is a key setting in which to address sedentary behaviors, since approximately 60% of the total population are employed, and 60 % are full-time workers (>40 hours/week) [8]. Understanding patterns of sedentary behavior (e.g. overall daily time, prolonged time, breaks, diurnal patterns) on working days and non-working days can help to identify the most sedentary segments of the day and whether there is carry-over of those patterns that may influence workers' whole-of-day sedentary time and physical activity. Such insights can inform approaches to sedentary behavior as an emerging occupational-health risk.

Sedentary behavior patterns at work and potentially across the whole day may be influenced by the demands of work – in terms of having to be seated, standing, or physically active for job tasks [9]. Hence, it is important to examine in more depth the relationship between types of occupational activity requirements with overall patterns of physical activity and sedentary behavior, in order to provide evidence that can inform approaches to workplace health promotion through sedentary behavior reduction.

The majority of previous studies examining objectively-measured occupational sedentary patterns has only focused on office-based workers and primarily seated occupational groups [10-16]. Only one previous study conducted in Netherland has examined the pattern of sedentary behavior across different types of occupations including white-collar, office-based workers and blue-collar construction and factory workers [17]. However, there have been no detailed examinations of overall diurnal patterns and the variability between workdays and non-workdays. In addition, while a

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3 small number of studies have examined patterns of sedentary behavior among workers,  
4 based on different occupational categories [18] or on types of occupational activity [9,  
5 19], they have used self-report measures of total and/or domain-specific sedentary  
6 behavior. Objectively-measured patterns of occupational sedentary behavior have not  
7 been examined.  
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13 Previous studies on sedentary behaviors among workers have been conducted  
14 mainly in Western countries. One international-comparative study found that  
15 self-reported sitting time of working adult population in Japan was the longest among  
16 20 countries [20]. Although the Japanese working adult population seems to be at-risk  
17 population considered in this international context, patterns of sedentary behavior in  
18 Japanese workers have not been examined. Since working environments (e.g. social  
19 norms, working spaces and work time) are likely to be different in Japan and other Asian  
20 countries compared with Western countries, understanding the sedentary behavior  
21 patterns in the Japanese work environment context will be informative.  
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29 We examined accelerometer-derived patterns of sedentary behavior (overall  
30 sedentary time, sedentary time accumulated in prolonged bouts, breaks from sedentary  
31 time and diurnal patterns of sedentary time) and physical activity among Japanese  
32 workers, based on occupational-activity types. These behaviors were characterized for  
33 four time periods: during work and non-work hours, on work days and on work and  
34 non-work days.  
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## 40 **METHODS**

### 41 **Study design and procedure**

42 This was a cross-sectional observational study, as a part of a project to investigate the  
43 associations between built environment attributes and sedentary behavior among  
44 Japanese middle-aged adults. A mail survey was conducted in Matsuyama city in Ehime  
45 prefecture (428.9 km<sup>2</sup>; 516,000 people) from July to December 2013, and Koto Ward in  
46 Tokyo (40.2 km<sup>2</sup>; 484,000 people) from April 2014 to February 2015. The study was  
47 approved by the Institutional Ethics Committee of Waseda University (2012-269,  
48 2013-264).  
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3 The survey procedures were as follows: first, 3,000 potential participants aged  
4 40-64 were extracted randomly from each basic resident register stratified by gender  
5 and age (40-49 years/ 50-59 years/ 60-64 years) for Matsuyama city and Koto Ward.  
6 Second, invitation letters were mailed to the potential participants and asked to return  
7 an enclosed form to indicate their expression of interest to participate in the study.  
8 Non-respondents were mailed an additional request to join the study two weeks after  
9 the initial invitation letter was sent. Then, those who expressed interest were mailed the  
10 informed-consent form of this study, an accelerometer, an activity diary, and a  
11 questionnaire. Those who finally agreed to participate were asked to sign the consent  
12 form, wear the accelerometer and record the activity diary for 7 days, respond to the  
13 questionnaire, and then return all of these within two weeks. Non-respondents were  
14 sent a reminder notice up to three times, and those who completed survey were sent  
15 thank-you letter with a ¥1,000 book voucher card.

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26 In total, 864 (14.4% of the originally-approached sample) including 437 (14.6%)  
27 from Koto Ward and 427 (14.2%) from Matsuyama city agreed to participate: 778  
28 (13.0% of the originally-approached sample) completed the questionnaire and wore the  
29 accelerometer. Those who worked either full-time or part-time were included (n=633).  
30 Those who had missing or invalid data for occupational activity type (n=38) or  
31 insufficient accelerometer data (n=175) were excluded (numbers not mutually  
32 exclusive). The final study sample size was 443 (full-time workers: n=345; part-time  
33 workers: n= 98).

### 40 **Assessment of sedentary behavior and physical activity**

41 Participants were asked to wear a triaxial accelerometer, Active style Pro HJA-350IT  
42 (Omron Health Care Co., Ltd., Kyoto, Japan) on the left side of the waist for seven days.  
43 This accelerometer was reported to be valid and to accurately assess low intensity  
44 physical activity including sedentary behavior [21, 22]. A recent comparative study of  
45 three activity monitors showed that the Active style Pro HJA-350IT underestimated total  
46 sedentary time (-25.6 min/day) and the ActiGraph GT3X overestimated it (+63.7  
47 min/day), compared with the activePAL3 as the criterion [23]. Data were collected in  
48 one-minute epochs. In order to obtain the information of work day including work and  
49 non-work hours and non-work day, participants were also asked to record the time  
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3 when wearing and removing accelerometer as well as starting and finishing a job on 7  
4 days.  
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### 8 **Socio-demographic data and occupational activity type**

9 Age and gender were obtained from the basic resident register. Height, weight,  
10 educational level (university or further education; high school or less), marital status  
11 (currently married; single), employment status (full-time; part-time), occupation and  
12 main occupational activity type (sitting; standing; walking; physical labor) were  
13 obtained. Body mass index (BMI) was calculated from self-reported height and weight.  
14 Occupations were referenced to Japanese standard classification of occupations [24].  
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### 21 **Data management**

22 Accelerometer data were processed using Omron health management software BI-LINK  
23 for physical activity professional edition ver1.0 and custom software [23]. Valid data for  
24 a wear day was defined as  $\geq 10$  hours/day excluding  $\geq 60$  consecutive minutes of no  
25 activity (0.9 or less metabolic equivalents; METs) with allowance for up to 2 min of some  
26 limited movement ( $\leq 1.0$  METs) within these periods and  $\geq 75\%$  wear time of work hours  
27 for a work day [12]. Those who had four or more valid days of data including at least  
28 three work days and a non-work day were included in the analysis. The data were  
29 extracted according to the following four time periods: working-hours (from starting to  
30 finishing job on work day), non-working hours (from wearing accelerometer to starting  
31 job and from finishing job to taking off accelerometer on work day), working day (a sum  
32 of working and non-working hours), and for non-working days (from wearing to taking  
33 off accelerometer).  
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44 The five measures of sedentary behavior and physical activity were first extracted  
45 for each time segments: time spent in all sedentary behavior, prolonged sedentary bouts,  
46 number of breaks per sedentary hour, and light-intensity physical activity (LPA) and  
47 moderate-to vigorous-intensity physical activity (MVPA). Time spent in sedentary  
48 behavior, LPA, and MVPA were defined as all wear time for any activity with an  
49 accelerometer-estimated intensity of  $\leq 1.5$  METs, 1.6-2.9 METs, and 3.0 or more METs,  
50 respectively. Prolonged sedentary bouts were defined as a period of uninterrupted  
51 sedentary time lasting  $\geq 30$  minutes [1]. A break in sedentary time was defined as a  
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3 period of non-sedentary bout in between two sedentary bouts [1]. For each of the time  
4 segments, daily averages of all sedentary and physically-active measures were  
5 calculated over valid work and non-work days. Daily summaries of time spent in all  
6 sedentary behavior, prolonged sedentary bouts, LPA, and MVPA for each time segments  
7 were also calculated in terms of the percentage of these intensities in worn time (%  
8 wear time). Finally, daily average values including work and non-work days of five  
9 measures in a week were then computed by weighting for 5 work days and 2 non-work  
10 days.  
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### 16 17 18 **Statistical Analysis**

19 Full-time (n=345) and part-time (n=98) workers were separately analyzed.  
20 Comparisons of the sociodemographic characteristics and five sedentary behavior and  
21 physical activity measures among the four occupational-activity types were conducted  
22 using one-way ANOVA for continuous variables and chi-square test for category  
23 variables. Each of the five sedentary and physical activity measures were compared  
24 among four occupational activity types in 4 time periods (working hours, non-working  
25 hours, working days, non-working days) using Analysis of Covariance (ANCOVA) with  
26 Bonferroni post-hoc test, adjusting for sociodemographic variables. For these analyses,  
27 those who had missing data for socio-demographic variables were excluded among the  
28 full-time workers (n= 4). For part-time workers, only one person was engaged in  
29 physical labor tasks. Thus, statistical analyses were not conducted. For describing  
30 diurnal patterns, those who had  $\geq 6$  h of work time starting morning were included  
31 (n=403). Diurnal pattern of sedentary behavior, LPA and MVPA in each hour from  
32 06:00-06:59 to 22:00-22:59 for each occupational activity type on work day and  
33 non-work day were illustrated by line graphs. All statistical analyses were performed  
34 using STATA 13.0 (Stata Corp., College Station, TX, US) and IBM SPSS Statistics 22  
35 software (IBM Japan Inc., Tokyo, Japan). Significant levels were  $p < 0.05$ .  
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### 48 49 **RESULTS**

50 The characteristics of participants in full-time work are summarized in Table 1. The  
51 mean age and BMI were 50.3(SD 6.9) and 22.8 (3.2), respectively. About a half of them  
52 were men and lived in Koto Ward. The majority had completed university or higher  
53 education, were married, and worked in mainly-sitting type jobs. Those with job types  
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3 involving mainly sitting and physical labor were more likely to be men than those with  
4 other two occupational activity types. Those mainly sitting at work were also more  
5 likely to live in Koto Ward and completed university or further education than those in  
6 three other more active jobs. Mean wearing days and hours of accelerometer were 6.8  
7 (SD=0.9) days and 15.3 (SD=1.1) hours. There were no significant differences in wearing  
8 days and hours of accelerometer wear time among the four of occupational-activity  
9 types. Those with sitting jobs had proportionally more total and prolonged sedentary  
10 time and less MVPA time, compared with those with other three occupational-activity  
11 types ( $p<0.001$ ). Additionally, those with sitting jobs had less LPA time in proportion  
12 and frequent breaks than those with standing and walking job( $p<0.001$ ). There were no  
13 significant differences in any of the sedentary behavior and physical activity measures  
14 among those in three physically active job types. The findings remained unchanged after  
15 adjusting for sociodemographic attributes in the sensitivity analyses.  
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**Table 1. Socio-demographic characteristics for participants of full-time jobs**

	n (%)				
	All participants	Occupational activity type			
		Sitting	Standing	Walking	physical labor
<b>N</b>	345	239 (69.3)	47 (13.6)	48 (13.9)	11 (3.2)
<b>Age, mean(SD)#</b>	50.3(6.9)	50.1(7.0)	50.7(6.8)	50.5(6.7)	52.6(6.7)
<b>Women</b>	156 (45.2)	99 (41.4)	25 (53.2)	29 (60.4)	3 (27.3) *
<b>BMI, kg/m<sup>2</sup> a, mean (SD)#</b>	22.8 (3.2)	23.0(3.4)	21.9(2.4)	22.3(2.6)	25.5(4.2) **
<b>Residence area</b>					
Matsuyama city	170 (49.3)	98 (41.0)	37 (78.7)	26 (54.2)	9 (81.8) ***
Koto Ward	175 (50.7)	141 (59.0)	10 (21.3)	22 (45.8)	2 (18.2)
<b>Education<sup>a</sup></b>					
High school or less	109 (31.6)	59 (24.8)	23 (48.9)	21 (43.8)	6 (54.5) ***
Greater than high school	235 (68.1)	179 (75.2)	24 (51.1)	27 (56.3)	5 (45.5)
<b>Marital status<sup>b</sup></b>					
Single	85 (24.6)	60 (25.4)	11 (23.4)	12 (25.0)	2 (18.2)
Married	257 (74.5)	176 (74.6)	36 (76.6)	36 (75.0)	9 (81.8)
<b>Occupation<sup>c</sup></b>					
Professional and engineering	71 (20.6)	39 (16.5)	13 (28.3)	18 (37.5)	1 (10.0)
Administrative and managerial	59 (17.1)	56 (23.6)	0 (0)	2 (4.2)	1 (10.0)
Clerical	114 (33.0)	111 (46.8)	2 (4.3)	1 (2.1)	0 (0.0)
Sales	17 (4.9)	7 (3.0)	4 (8.7)	6 (12.5)	0 (0.0)
Service	34 (9.9)	9 (3.8)	17 (37)	8 (16.7)	0 (0.0)
Security	1 (0.3)	0 (0.0)	1 (2.2)	0 (0.0)	0 (0.0)
Agricultural, forestry and fishery	4 (1.2)	0 (0.0)	1 (2.2)	3 (6.3)	0 (0.0)
Transport and machine operation	9 (2.6)	1 (0.4)	0 (0.0)	4 (8.3)	4 (40.0)
Manufacturing process	14 (4.1)	4 (1.7)	5 (10.9)	1 (2.1)	4 (40.0)
Others	17 (4.9)	10 (4.2)	2 (4.3)	5 (10.4)	0 (0.0)
<b>Sedentary behavior and Physical activity measures per day , mean (SD)#</b>					
% of worn time spent					
All sedentary	57.5(12.7)	62.8(9.8)	43.4(10.3)	47.9(10.3)	43.9(9.7) ***
Prolonged sedentary bout	19.1(11.0)	22.5(11.5)	13.3(5.7)	14.4(7.4)	16.7(7.3) ***
LPA	34.8(11.0)	30.5(9.1)	46.9(8.8)	42.2(7.9)	44.4(8.8) ***
MVPA	7.7(4.5)	6.8(3.2)	9.7(6.6)	9.9(5.7)	11.6(3.7) **
Breaks per sedentary hour	9.4(3.1)	8.6(2.7)	12.1(3.0)	11.1(2.6)	10.1(2.5) ***

<sup>a</sup> 1 missing in sitting; <sup>b</sup> 3 missing in sitting; <sup>c</sup> 2 missing in sitting, 1 missing in standing and physical labor

# Asterisks indicate statistical significance of F value of one-way ANOVA

\*\*\* <.001, \*\* <.01, \* <.05

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3 The sedentary behavior and physical activity measures on work and non-work days  
4 and hours on all and occupational activity types of full-time workers are presented in  
5 Table2. Regarding working hours, those with jobs involving sitting had significantly  
6 more total and prolonged sedentary time along with less LPA and MVPA in proportion,  
7 and less frequent breaks compared with those with three other more active jobs. Similar  
8 results were found for the working days, except for the prolonged sedentary time and  
9 sedentary breaks variables; there were no significant differences between those in the  
10 job types involving sitting and those involving physical labor. The differences in  
11 sedentary time between the sitting jobs and the other jobs types on working time and  
12 working day were 17.7-26.4, and 28.5-42.0% of wear time, respectively. Among the  
13 three non-sitting job types, the order of most total and prolonged sedentary time along  
14 with less LPA and MVPA in proportion, and less frequent breaks on both working time  
15 and day were descriptively as follows: those with walking, standing and physical labor  
16 jobs. However, apparent patterns which reached statistical difference were only found in  
17 MVPA: the proportion of MVPA in those with job involving physical labor was  
18 significantly higher than those with other two less active jobs on only working hours. As  
19 a descriptive feature of non-work hours, the more active jobs in which workers were  
20 involved, the more total sedentary time along with less LPA in proportion was reported  
21 except those with mostly sitting jobs. In large part, the proportions of total sedentary  
22 time and LPA in those with sitting jobs were similar to those with the jobs involving  
23 physical labor. The differences reaching statistical significance were as follows: those  
24 with standing jobs had proportionally less total sedentary time and more LPA than did  
25 those with sitting jobs. There were no descriptive and statistical differences apparent  
26 between the four occupational activity types on non-working day.  
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**Table 2. Comparison of sedentary behavior and physical activity among four occupational activity types in full-time workers**

	Mean (SD)		Marginal mean (95% CI) <sup>a</sup>		
	All	Sitting	Standing	Walking	physical labor
<b>Wear time (h)</b>					
Work day <sup>a</sup>	15.6(1.8)	15.5 (15.3-15.8)	15.8 (15.2-16.3)	15.7 (15.2-16.2)	16.6 (15.6-17.7)
Work hours <sup>b</sup>	9.4(1.8)	9.3 (9.1-9.5)	9.7 (9.2-10.3)	9.7 (9.2-10.2)	9.8(8.8-10.9)
Non-work hours <sup>c</sup>	6.2(2.3)	6.3 (6.0-6.5)	6.0 (5.4-6.6)	6.0 (5.4-6.6)	6.8 (5.5-8.1)
Non-work day <sup>d</sup>	14.3(2.0)	14.4 (14.1-14.7)	14.3 (13.7-14.9)	13.9 (13.3-14.4)	14.4 (13.2-15.6)
<b>All sedentary (%wear time)</b>					
Work day	56.8(15.3)	63.2 (61.8-64.5)	40.6 (37.4-43.7)***	45.5 (42.5-48.5)***	36.8 (30.4-43.2)***
Work hours	58.6(21.9)	68.5 (66.7-70.3)	34.6 (30.4-38.7)***	40.0 (36.0-44.0)***	26.5 (18.1-34.9)***, †
Non-work hours	53.3(11.9)	54.0 (52.4-55.4)	49.8 (46.3-53.3)*	52.5 (49.2-55.9)	56.5 (49.4-63.6)
Non-work day	59.1(13.8)	59.8 (58.1-61.6)	56.3 (52.3-60.4)	58.2 (54.3-62.1)	60.3 (52.0-68.5)
<b>Prolonged sedentary bouts (% wear time)</b>					
Work day	18.2(12.5)	21.0 (19.5-22.4)	11.7 (8.4-15.0)***	12.4 (9.2-15.5)***	12.0 (5.3-18.7)
Work hours	18.6(18.2)	23.1 (21.1-25.2)	8.5 (3.8-13.2)***	9.0 (4.4-13.5)***	7.0 (-2.5-16.6)**
Non-work hours	16.7(11.1)	16.6 (15.2-18.0)	16.2 (13.0-19.5)	16.5 (13.4-19.7)	20.5 (13.9-27.0)
Non-work day	24.1(15.1)	24.8 (22.9-26.8)	22.3 (17.9-26.7)	23.1 (18.8-27.4)	24.1 (15.2-33.1)
<b>Breaks per sedentary hour</b>					
Work day	9.8(3.6)	8.8 (8.4-9.1)	12.7 (11.8-13.6)***	11.7 (10.8-12.6)***	10.9 (9.1-12.7)
Work hours	10.8(5.7)	8.8 (8.2-9.4)	16.2 (14.9-17.5)***	14.7 (13.4-16.0)***	13.3 (10.6-16.0)**
Non-work hours	10.0(3.7)	10.0 (9.5-10.5)	10.5 (9.4-11.6)	10.0 (8.9-11.0)	9.7 (7.4-11.9)
Non-work day	8.6(3.7)	8.6 (8.1-9.0)	8.9 (7.6-10.0)	8.7 (7.6-9.7)	8.8 (6.5-11.0)
<b>LPA (%wear time)</b>					
Work day	35.1(13.1)	30.3 (29.1-31.5)	48.1 (45.4-50.8)***	42.9 (40.3-45.6)***, †	48.2 (42.6-53.7)***
Work hours	34.6(17.7)	27.4 (25.9-29.0)	53.3 (49.7-56.9)***	47.1 (43.6-50.6)***	54.9 (47.6-62.1)***
Non-work hours	36.2(11.3)	35.3 (33.9-36.6)	40.4 (37.3-43.5)*	37.7 (34.7-40.7)	34.7 (28.4-41.0)
Non-work day	34.2(11.9)	33.7 (32.2-35.2)	35.6 (32.2-39.1)	35.3 (32.0-38.6)	34.6 (27.6-41.5)
<b>MVPA (%wear time)</b>					
Work day	8.2(5.4)	6.5 (5.9-7.2)	11.3 (9.9-12.8)***	11.5 (10.2-12.9)***	15.0 (12.1-17.9)***
Work hours	6.8(7.5)	4.1 (3.3-4.9)	12.2 (10.3-14.0)***	12.9 (11.1-14.6)***	18.6 (14.9-22.4)***, †, ‡
Non-work hours	10.5(6.8)	10.8 (10.0-11.6)	9.8 (8.0-11.6)	9.8 (8.0-11.6)	8.8 (5.1-12.5)
Non-work day	6.7(4.6)	6.5 (5.9-7.1)	8.0 (6.6-9.3)	6.5 (5.2-7.8)	5.2 (2.4-7.9)

<sup>a</sup> Marginal mean and 95% CI from ANCOVA adjusted for covariates including gender, age, BMI, residence area, educational attainment, marital status.

Asterisks indicate significant difference from the sitting: \*p < 0.05, \*\*p < 0.01, \*\*\* < .001

Dagger indicates significant difference from the standing: †p < 0.05

Double dagger indicates significant difference from the walking: ‡p < 0.05

Hourly patterns of sedentary behavior, LPA and MVPA on four occupational activity types are summarized in Figure 1 for full time workers. Overall, time and LPA showed an inverse pattern. On work days, a notable difference was observed in the pattern of sedentary behavior during work hours between those in the sitting jobs and the other three types, while all occupational activity types showed a similar pattern after work, with a linear increase in the sedentary fraction until 22:00-22:59. Those with jobs involving mainly standing, walking and physical labor constantly accounted for a larger fraction of LPA than that of sedentary behavior from 6:00-6:59 throughout almost of all working hours. On non-work days, sedentary behavior in all occupational activity types was mostly dominant from 7:00-7:59 to 18:00-18:59. However, the time differences between sedentary behavior and LPA in those with sitting jobs stayed more constant and larger than those in other more active job from 7:00-7:59 to 18:00-18:59. After 18:00-18:59 on non-work day, all types showed increase in sedentary time as the same with work days. All results of the part-time workers were presented in Table S1,2 and Figure S1.

INSERT FIGURE 1 ABOUT HERE

## DISCUSSION

This is the first study to examine accelerometer-measured patterns of sedentary behaviors and physical activity among Japanese workers in their work and non-work contexts, and to examine how these patterns differed by occupational activity type. Among full-time workers, sedentary time comprised more than half of the working day. Overall, those whose jobs involving mainly sitting, who accounted for 70% of this study sample, had higher amount of both total and prolonged sedentary time and less frequent breaks from sitting across the whole day, compared with those in more physically active job types. Previous studies in Western countries have examined the differences in objectively-measured total sedentary behavior only among 19 occupation groups or sectors [18] and self-reported leisure and domain-specific sedentary behaviors among occupational activity types [9, 19]. The present study extends these findings, for the first time in a non-Western country, by examining the differences in additional sedentary behavior measures such as prolonged sedentary behavior and breaks using objective measurements. The present findings suggest that further public health efforts focused on the worksite should be emphasized, especially for office-workers who are a majority of the working adult population in Japan and are an

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3 apparent at-risk subgroup due to high volumes of sitting, not only at work but also in  
4 non-work time.  
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8 Among those involving mainly sitting jobs of this study sample, 63% of working day  
9 (60% of non-work day) were sedentary. Some previous studies conducted in Australia  
10 and the UK found that sedentary behavior assessed by Actigraph were 68-70% of  
11 working day of office workers (60-63% of non-work day)[12, 14]. Our recent  
12 comparative study of activity devices found that total sedentary time assessed by the  
13 Active style Pro HJA-350IT were proportionally 11% less time spent in total sedentary  
14 behavior than Actigraph [23]. These findings suggest that Japanese office-workers may  
15 spend more time in sedentary behavior across whole day compared with those in  
16 Western countries, which is similar to the previous international-comparative study  
17 examining self-reported sitting time of working adult population [20]. As an at-risk  
18 population considered in the international context, promoting effective public health  
19 strategies to reduce sedentary behavior on the worksite may be a necessary effort in  
20 Japan.  
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30 We found significant differences in overall sedentary time and number of breaks  
31 from sedentary time in work hours across the occupational activity types that we  
32 examined, especially for working hours. Full-time workers with mainly sitting jobs spent  
33 most sedentary time and had less breaks from sedentary behavior than those with more  
34 active job types: these differences were approximately 20-30% in the proportion (2.5-4  
35 hours) and 5-7 times per sedentary hours. On the other hand, these patterns on  
36 non-working hours or days were relatively similar although workers with sitting and  
37 physical labor jobs somewhat spent more sedentary along with in less LPA than those  
38 with standing and walking jobs. These findings indicate that the occupational activity  
39 type, which is commonly determined by job requirements can have the greatest impact  
40 on overall sedentary time and patterns in workers' population. These findings are  
41 consistent with the only previous study from The Netherlands, which found all  
42 white-collar workers from financial service providers and research institutes had  
43 significantly greater occupational (30-35%) and total sitting time (10-15%) in  
44 proportion than all blue-color workers of construction company [17]. In addition, these  
45 findings supported those of previous studies using self-reported data in Australia,  
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3 France, and The Netherlands, which showed that workers with higher occupational  
4 sitting time did not sit less, rather sat more, on their leisure time [9, 18, 25]. Similar to  
5 studies conducted in Western countries, the present findings suggest that further  
6 promotion of worksite interventions to reduce office-workers' sedentary time along  
7 with increased sedentary breaks should be prioritized on working populations in not  
8 only Western countries but also in Japan.  
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15 Similar to the average patterns, the analysis of the accelerometer output by hour of  
16 the working day showed that the pattern of sedentary behavior, LPA and MVPA were  
17 highly dependent on occupational activity types during working hours (except for lunch  
18 time), whereas all were similar on the evening time after work. The descriptive features  
19 were observed on non-working day, especially during the daytime, across occupational  
20 activity types. Even though the average sedentary and activity patterns were not distinct  
21 among them, some dips in sedentary behavior along with increases in LPA were found  
22 in those with standing, walking, and physical labor job types, whereas the conditions in  
23 which sedentary behavior is the most dominant stayed constant throughout a day in  
24 those with sitting job types. The pattern of MVPA was stable and independent from  
25 those of sedentary behavior and LPA in all occupational activity types. The variations in  
26 pattern of sedentary behavior and LPA among occupational activity types could be  
27 partly attributed to differences in socio-demographic attributes (especially gender) and  
28 sample size. However, in a previous study from the UK examining the diurnal patterns of  
29 sedentary behavior and physical activity among office workers grouped into tertiles  
30 based on occupational sedentary time, the higher the tertile for occupational sedentary  
31 time in which office workers were categorized, the more pronounced and stable the  
32 difference between sedentary behavior and LPA (less crossing and reversing time points  
33 in a graph between them) became throughout a non-working day [14]. These results  
34 imply that routine diurnal occupational sedentary and LPA patterns, which were  
35 repeated 5 days a week, on working day may carry over their leisure-time behavioral  
36 patterns as a habit. Similarly, the previous study in French working adults using  
37 self-reported questionnaire found that occupational activity level workers involved as  
38 job were negatively associated with averaged time spent sedentary in leisure-time on  
39 both working and non-working day [19]. Future intervention studies are necessary to  
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clarify spreading effects whether promoting breaking behavior by LPA on working-hour this may transfer to leisure-time behavior and activity.

This is the first study to report descriptive patterns of objectively measured Japanese workers' sedentary behavior comprehensively, and their relationships with occupational activity types. Other strengths of this study were use of population-recruited sample and accelerometer -assessed sedentary behavior and physical activity. There are also some limitations in this study. First, data were cross-sectional and therefore any causality cannot be inferred. Second, the present samples were selected from only two cities in Japan although central and average-sized local cities were chosen. Thus, the results may differ in other cities and areas. Third, the response rate was relatively low.

## CONCLUSION

In summary, full-time workers involved in mostly sitting jobs had a higher volume of sedentary behavior with prolonged bouts on workdays, compared with other occupational-activity job types. The differences in sedentary patterns mainly occurred during work hours. There may be carry-over of sedentary and physical activity patterns in working time, which could influence leisure time and whole of day time spent sedentary, with potential for adverse health consequences. Therefore, intervention for to reduce workers' sedentary behaviors are needed, especially for those in office-based workplace where prolonged periods of sitting are required.

## AUTHORS' CONTRIBUTION

Kurita and Shibata conceived the study, analyzed the data, and drafted the manuscript. Koohsari and Owen assisted with analyzing data and drafting manuscript. Ishii and Oka were involved in the development and implementation of this study. All authors contributed to study design, interpretation of the results, and manuscript preparation. All authors have read and approved the final manuscript.

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#### 14 **CONFLICT OF INTEREST STATEMENT**

15 The authors declare no conflicts of interest.  
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#### 19 **DATA SHARING STATEMENT**

20 Requests for access to data should be addressed to the corresponding author.  
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#### 24 **REFERENCE**

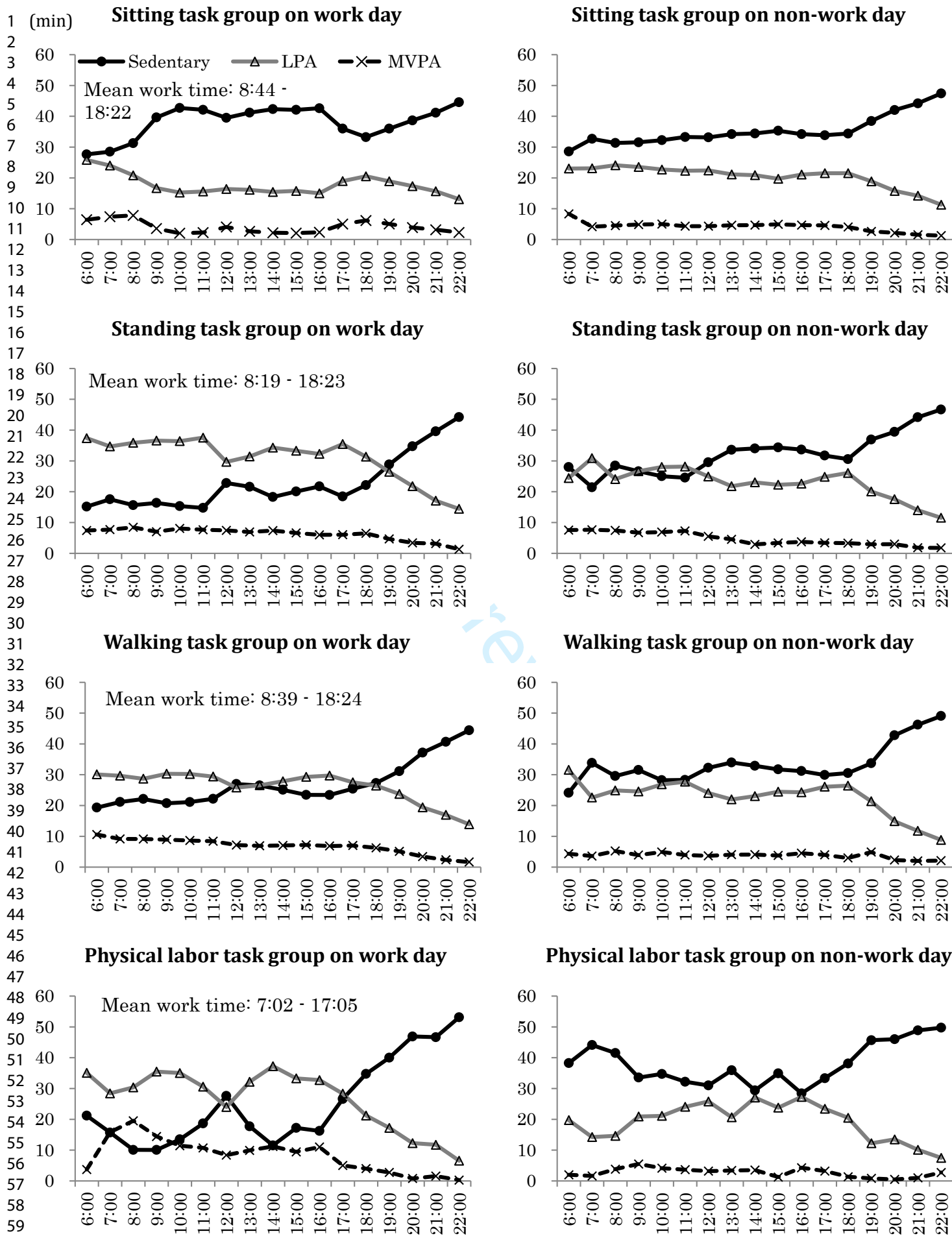
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3 **Figure1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types**  
4 **among full-time workers**  
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**Figure 1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types among full-time workers**

**Table S1. Socio-demographic characteristics for participants of part-time workers**

	n (%)				
	All participants	Occupational task group			
		Sitting	Standing	Walking	Physical labor
<b>n</b>	98	35 (35.7)	35 (35.7)	27 (27.6)	1 (1.0)
<b>Age, mean(SD)</b>	51.1(7.3)	50.4 (6.8)	52.7(8.0)	49.9(6.8)	54.0
<b>Women</b>	94 (95.9)	34 (97.1)	33 (94.3)	26 (96.3)	1 (100)
<b>BMI (kg/m<sup>2</sup>)<sup>a</sup>, mean(SD)</b>	21.1(2.2)	21.2 (2.3)	20.9(2.1)	21.3(2.2)	18.8
<b>Residence area</b>					
Matsuyama city	44 (44.9)	15 (42.9)	23 (65.7)	16 (59.3)	0 (0.0)
Koto Ward	54 (55.1)	20 (57.1)	12 (34.3)	11 (40.7)	1 (100)
<b>Education</b>					
High school or less	44 (44.9)	11 (31.4)	22 (62.9)	11 (40.7)	0 (0.0)
Greater than high school	54 (55.1)	24 (68.6)	13 (37.1)	16 (59.3)	1 (100)
<b>Marital status<sup>b</sup></b>					
Single	12 (12.2)	4 (11.4)	4 (11.4)	4 (15.4)	0 (0.0)
Married	85 (86.7)	31 (88.6)	31 (88.6)	22 (84.6)	1 (100.0)
<b>Occupation<sup>c</sup></b>					
Professional and engineering	17 (17.5)	6 (17.6)	4 (11.4)	7 (25.9)	0 (0.0)
Administrative and managerial	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Clerical	23 (23.7)	21 (61.8)	2 (5.7)	0 (0.0)	0 (0.0)
Sales	7 (7.2)	1 (2.9)	5 (14.3)	1 (3.7)	0 (0.0)
Service	33 (34)	3 (8.8)	18 (51.4)	11 (40.7)	1 (100)
Security	1 (1.0)	0 (0.0)	1 (2.9)	0 (0.0)	0 (0.0)
Agricultural, forestry and fishery	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Transport and machine operation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Manufacturing process	5 (5.2)	1 (2.9)	3 (8.6)	1 (3.7)	0 (0.0)
Others	10 (10.3)	1 (2.9)	2 (5.7)	7 (25.9)	0 (0.0)
<b>Sedentary behavior and Physical activity measures per day , mean (SD)</b>					
% of worn time spent	15.7(1.44)	15.7(1.4)	15.5(1.5)	16.1(1.5)	16.4
All sedentary	47.6(9.8)	53.9(7.7)	44.7(10.3)	43.6(7.7)	41.8
Prolonged sedentary bout	14.4(7.6)	15.1(8.0)	15.0(8.0)	12.7(6.4)	14.7
LPA	44.2(8.4)	39.2(6.9)	47.5(8.5)	46.3(7.2)	44.2
MVPA	8.1(3.9)	6.9(2.5)	15.6(3.4)	10.0(5.2)	14.0
Breaks per sedentary hour	10.8(2.3)	10.1(1.9)	11.1(2.7)	11.2(2.2)	10.2

a 1 missing in standing task group

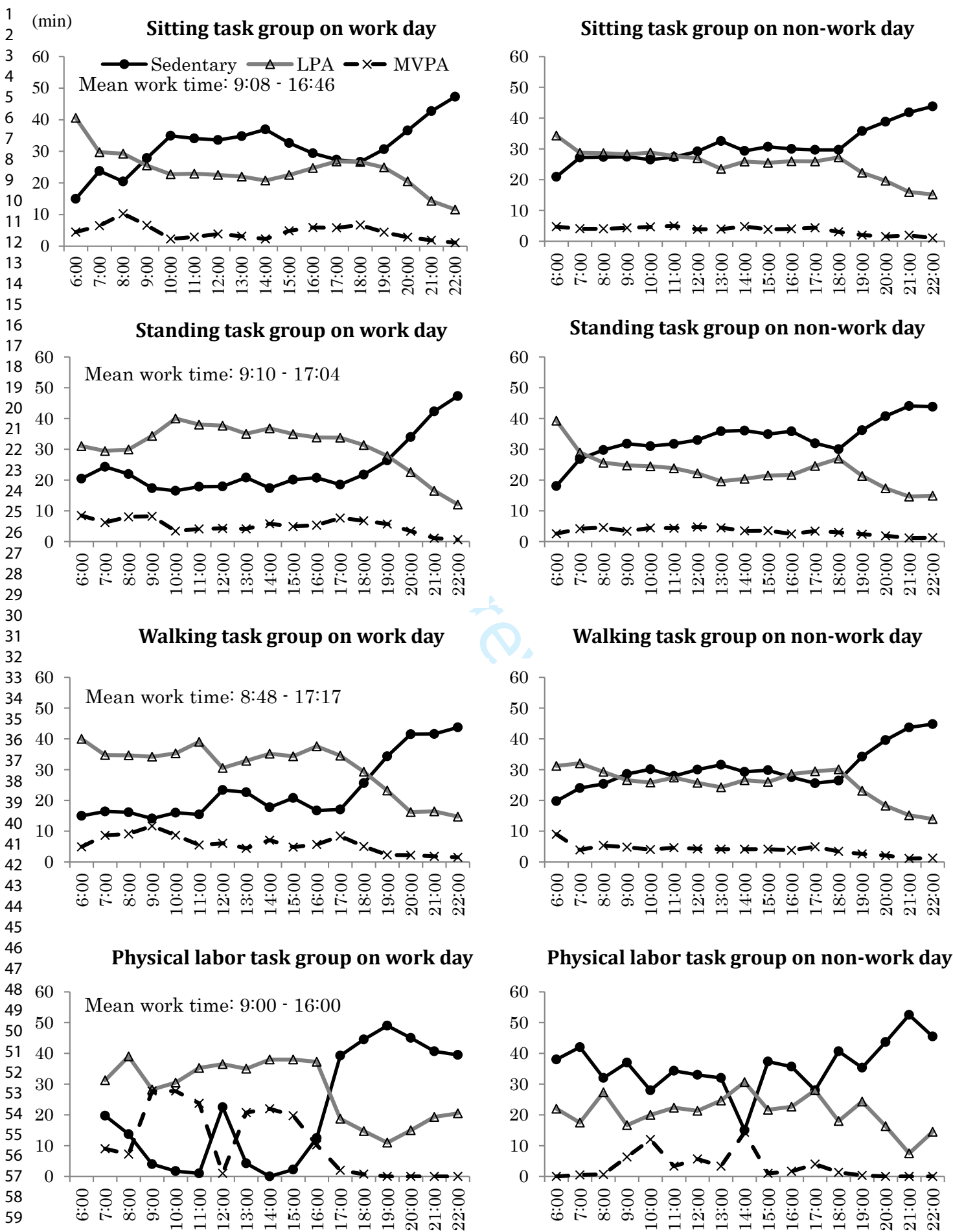
b 1 missing in walking task group

c 1 missing in sitting task group



**Table S2 Comparison of sedentary behavior and physical activity among four occupational activity types in part-time workers**

	Mean(SD)				
	All	Sitting	Standing	Walking	Physical labor
<b>Wear time (h)</b>					
Work day	16.0(1.6)	15.9(1.7)	15.8(1.6)	16.3(1.7)	16.6
Work hours	6.2(2.4)	6.4(2.2)	5.9(2.5)	6.5(2.5)	7.0
Non-work hours	9.7(3.0)	9.5(2.8)	9.8(2.8)	9.9(3.7)	9.6
Non-work day	15.1(1.6)	15.0(1.2)	14.7(1.9)	15.6(1.6)	15.8
<b>Sedentary (%wear time)</b>					
Work day	45.1(11.3)	54.2 (7.9)	40.1 (10.9)	40.3 (8.4)	35.0
Work hours	36.6(23.4)	59.9 (12.6)	24.4 (19.4)	23.4 (14.3)	8.5
Non-work hours	49.8(9.7)	50.2 (8.9)	49.5 (10.8)	49.7 (9.9)	54.5
Non-work day	53.9(12.7)	53.1 (12.0)	56.4 (14.6)	51.8 (11.2)	58.8
<b>Prolonged sedentary bouts of sedentary (%wear time)</b>					
Work day	12.2(7.1)	14.0 (8.1)	11.4 (6.6)	10.7 (6.3)	14.0
Work hours	6.8(11.3)	12.5 (14.4)	4.3 (9.5)	2.7 (3.9)	0.0
Non-work hours	15.8(9.1)	15.4 (9.0)	15.8 (8.7)	15.8 (9.8)	24.3
Non-work day	20.0(14.3)	18.0 (13.4)	24.0 (16.4)	17.5 (12.1)	16.7
<b>Breaks per sedentary hour</b>					
Work day	11.3(2.6)	10.3 (2.2)	12 (2.9)	11.7 (2.6)	10.5
Work hours	19.4(11.7)	11.6 (4.8)	24.3 (12.5)	23.1 (12.3)	26.0
Non-work hours	9.9(2.5)	9.7 (2.2)	10.2 (2.4)	9.9 (2.9)	8.8
Non-work day	9.5(3.7)	9.8 (3.6)	8.9 (4.4)	9.8 (3.1)	9.5
<b>LPA (%wear time)</b>					
Work day	46.0(10.0)	38.6 (7.5)	51.5 (9.1)	48.6 (8.2)	47.6
Work hours	53.0(19.4)	35.3 (11.7)	65.4 (16.3)	59.6 (14.3)	57.6
Non-work hours	41.7(9.0)	40.4 (8.3)	42.8 (9.9)	42.1 (8.9)	40.3
Non-work day	39.7(10.2)	41 (10.4)	37.5 (11.3)	41 (8.3)	35.5
<b>MVPA (%wear time)</b>					
Work day	8.8(4.6)	7.2 (2.8)	8.4 (3.8)	11.1 (6.1)	17.3
Work hours	10.4(11.1)	4.8 (3.2)	10.2 (7.2)	17 (16.3)	33.9
Non-work hours	8.4(4.2)	9.4 (4.4)	7.7 (4.3)	8.2 (3.8)	5.2
Non-work day	6.4(4.8)	5.9 (2.8)	6.2 (4.9)	7.2 (6.6)	5.7



**Figure S1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types among part-time workers**

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	page
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	16
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8
		(b) Describe any methods used to examine subgroups and interactions	8
		(c) Explain how missing data were addressed	8
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	N/A

Continued on next page

<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6 8-9
		(b) Give reasons for non-participation at each stage	8-9
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	6,8
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11- 12
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13- 16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16- 17

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Patterns of Objectively-Assessed Sedentary Time and Physical Activity among Japanese Workers: Cross-sectional study

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3 1 **Title:** Patterns of Objectively-Assessed Sedentary Time and Physical Activity among  
4 Japanese Workers: Cross-sectional study  
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21 **Word count:** 3596 words

23 **Key words:** descriptive epidemiology, occupational sitting, occupational activity  
24 patterns, Asia.  
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3 26 **ABSTRACT**

4 27 **Objectives:** To examine patterns of sedentary behavior and physical activity, among  
5  
6 28 Japanese workers with differing occupational-activity types.

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8 29 **Methods:** Full-time workers aged 40-64 years (n = 345; 55% men) wore an  
9  
10 30 accelerometer for 7 days and completed a socio-demographic and occupational  
11  
12 31 activity-type survey. Mean overall sedentary time, prolonged bouts of sedentary time  
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14 32 and light-and moderate-to vigorous-intensity of physical activity (LPA and MVPA) as a  
15  
16 33 proportion of accelerometer wear time, and number of breaks per sedentary hour, were  
17  
18 34 identified for four time periods: working hours; workdays; non-work hours; and,  
19  
20 35 non-work days. These sedentary behavior and physical activity measures in the four  
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22 36 time periods were examined among workers with four self-attributed occupational  
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24 37 activity types (mainly sitting, standing, walking, physical labor), adjusting for  
25  
26 38 sociodemographic attributes. Diurnal patterns of sedentary behavior, LPA and MVPA  
27  
28 39 were examined.

29  
30 40 **Results:** In working hours, those with a sitting job had significantly more total and  
31  
32 41 prolonged sedentary time along with less LPA and MVPA, and less frequent breaks,  
33  
34 42 compared to those with the three more-active job type. Similar differences by job type  
35  
36 43 were found for the whole working day, but not for prolonged sedentary time and breaks.  
37  
38 44 On non-working hours and days, differences in sedentary and physically- active patterns  
39  
40 45 by job type were not apparent.

41  
42 46 **Conclusions:** Occupational activity type is related to overall sedentary time and  
43  
44 47 patterns on working days, but not to leisure-time sitting and activity patterns, which  
45  
46 48 were similar across the sitting, standing, walking, and physical labor  
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48 49 occupational-activity types.  
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3 51 **ARTICLE SUMMARY**

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5 52 **Strengths and limitations of this study**

- 6  
7 53 ● This is the first study to report descriptive patterns of objectively measured  
8  
9 54 workers' sedentary behavior comprehensively in non-Western countries, and their  
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11 55 relationships with occupational activity types.  
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13 56 ● This study was used population-recruited sample and accelerometer-assessed  
14  
15 57 sedentary behavior and physical activity.  
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17 58 ● Examination of hourly patterns of sedentary behavior and physical activity was  
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19 59 novel.  
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21 60 ● Data were cross-sectional and therefore any causality cannot be inferred.  
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23 61 ● Low response rate was not completely at random, which may have resulted in  
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25 62 selection bias.  
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## 65 INTRODUCTION

66 Sedentary behavior, defined as any waking behavior characterized by an energy  
67 expenditure  $\leq 1.5$  METs while in a sitting or reclining posture [1] has distinctive adverse  
68 effects on human health [2]. For example, excessive sedentary behavior increases the  
69 risk of all-cause mortality [3, 4] and risk of type 2 diabetes, cardiovascular disease, and  
70 some cancers [5], with some evidence of dose-response relationships [6]. There are  
71 benefits of more-frequent breaks from sedentary time on cardio-metabolic risk  
72 biomarkers [7]. Reducing prolonged sedentary behavior is an important public health  
73 issue.

74 Among the Japanese adult population, the worksite is a key setting in which to  
75 address sedentary behaviors and, since approximately 60% of the total population are  
76 employed, and 60 % of those employed are full-time workers (>40 hours/week) [8].  
77 Understanding patterns of sedentary behavior (e.g. overall daily time, prolonged time,  
78 breaks, diurnal patterns) on working days and non-working days can help to identify the  
79 most sedentary segments of the day and whether there is carry-over of those patterns  
80 that may influence workers' whole-of-day sedentary time and physical activity. Such  
81 insights can inform approaches to sedentary behavior and as emerging  
82 occupational-health risks.

84 Sedentary behavior patterns at work and potentially across the whole day may be  
85 influenced by the demands of work – in terms of having to be seated, standing, or  
86 physically active for job tasks [9]. Hence, it is important to examine in more depth the  
87 relationship between types of occupational activity requirements with overall patterns  
88 of sedentary behavior, in order to provide evidence that can inform approaches to  
89 workplace health promotion through sedentary behavior reduction.

91 The majority of previous studies examining objectively-measured occupational  
92 sedentary patterns has only focused on office-based workers and primarily seated  
93 occupational groups [10-16]. One previous study conducted in Netherland has examined  
94 the pattern of sedentary behavior across different types of occupations including  
95 white-collar, office-based workers and blue-collar construction and factory workers [17].  
96 However, there have been no detailed examinations of overall diurnal patterns and the  
97 variability between workdays and non-workdays. Although another previous study

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3 98 conducted in Scotland has compared the pattern of total sedentary behavior between  
4 99 delivery and office staffs across workdays and non-workdays, further in-depth  
5 100 examinations of sedentary patterns in larger sample size and across various  
6 101 occupational types may more needed [18]. In addition, while a small number of studies  
7 102 have examined patterns of sedentary behavior among workers, based on different  
8 103 occupational categories [19] or on types of occupational activity [9, 20], they have used  
9 104 self-report measures of total and/or domain-specific sedentary behavior.  
10 105 Objectively-measured patterns of occupational sedentary behavior have not been  
11 106 examined.  
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19 108 Although there are distinct health consequences of sedentary behavior,  
20 109 light-intensity physical activity (LPA), and moderate-to-vigorous intensity physical  
21 110 activity (MVPA) [21,22], the time available for each of them in a day is finite. More time  
22 111 spent in sedentary behavior indicates less time spent in LPA, MVPA, or both, indicating  
23 112 that these behaviors are linked. Thus, it may be important to examine patterns of not  
24 113 only sedentary behavior, but also LPA and MVPA concurrently. A small number of  
25 114 previous studies has simultaneously examined sedentary and active behavior patterns  
26 115 during working and leisure-time [9, 12-15, 17, 18]. However, little is known about how  
27 116 different the patterns or relationships between sedentary behaviors and physical  
28 117 activities during working and leisure-time would be between those in types of  
29 118 occupations with different activity requirements.  
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39 120 Previous studies on sedentary behaviors among workers have been conducted  
40 121 mainly in Western countries. One international-comparative study found that  
41 122 self-reported sitting time of working adult population in Japan was the longest among  
42 123 20 countries [23]. Although the Japanese working adult population seems to be at-risk  
43 124 population considered in this international context, patterns of sedentary behavior in  
44 125 Japanese workers have not been examined. Since working environments (e.g. social  
45 126 norms, working spaces and work time) are likely to be different in Japan and other Asian  
46 127 countries compared with Western countries, understanding the sedentary behavior and  
47 128 physical activity patterns in the Japanese work environment context will be informative.  
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55 130 We examined accelerometer-derived patterns of sedentary behavior (total sedentary  
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3 131 time, sedentary time accumulated in prolonged bouts, sedentary breaks and diurnal  
4 132 patterns of sedentary time) and physical activity among Japanese workers, based on  
5 133 occupational-activity types. These behaviors were characterized for four time periods:  
6 134 during work and non-work hours, on work days and on work and non-work days.  
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## 11 136 **METHODS**

### 12 137 **Study design and procedure**

13 138 This was a cross-sectional observational study, as a part of a project to investigate the  
14 139 associations between built environment attributes and sedentary behavior among  
15 140 Japanese middle-aged adults. A mail survey was conducted in Matsuyama city in Ehime  
16 141 prefecture (428.9 km<sup>2</sup>; 516,000 people) from July to December 2013, and Koto Ward in  
17 142 Tokyo (40.2 km<sup>2</sup>; 484,000 people) from April 2014 to February 2015. The study was  
18 143 approved by the Institutional Ethics Committee of Waseda University (2012-269,  
19 144 2013-264).  
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27 146 The survey procedures were as follows: first, 3,000 potential participants aged  
28 147 40-64 were extracted randomly from each basic resident register stratified by gender  
29 148 and age (40-49 years/ 50-59 years/ 60-64 years) for Matsuyama city and Koto Ward.  
30 149 Second, invitation letters were mailed to the potential participants and asked to return  
31 150 an enclosed form to indicate their expression of interest to participate in the study.  
32 151 Non-respondents were mailed an additional request to join the study two weeks after  
33 152 the initial invitation letter was sent. Then, those who expressed interest were mailed the  
34 153 informed-consent form of this study, an accelerometer, an activity diary, and a  
35 154 questionnaire. Those who finally agreed to participate were asked to sign the consent  
36 155 form, wear the accelerometer and record the activity diary for 7 days, respond to the  
37 156 questionnaire, and then return all of these within two weeks. Participants were guided  
38 157 to wear the accelerometers during waking time (put it on straight after waking up) and  
39 158 to remove it during sleeping (take it off just before going to bed) and during  
40 159 water-based activities such as bathing or swimming. In addition, participants were  
41 160 asked to record for every day during the period of accelerometer wear, their time getting  
42 161 up, putting on the accelerometer, leaving home to travel to their workplace, starting  
43 162 their job, finishing their job, arriving at home, taking off the accelerometer, and going to  
44 163 bed. Non-respondents were sent a reminder notice up to three times, and those who  
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3 164 completed survey were sent thank-you letter with a ¥1,000 book voucher card.  
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6 166 In total, 864 (14.4% of the originally-approached sample) including 437 (14.6%)  
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8 167 from Koto Ward and 427 (14.2%) from Matsuyama city agreed to participate: 778  
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10 168 (13.0% of the originally-approached sample) completed the questionnaire and wore the  
11  
12 169 accelerometer. Those who worked either full-time or part-time were included (n=633).  
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14 170 Those who had missing or invalid data for occupational activity type (n=38) or  
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16 171 insufficient accelerometer data (n=175) were excluded (numbers not mutually  
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18 172 exclusive). The final study sample size was 443 (full-time workers: n=345; part-time  
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20 173 workers: n= 98).  
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### 21 175 **Assessment of sedentary behavior and physical activity**

22 176 Participants were asked to wear a triaxial accelerometer, Active style Pro HJA-350IT  
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24 177 (Omron Health Care Co., Ltd., Kyoto, Japan) on the left side of the waist for seven days.  
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26 178 This accelerometer device has been reported to be valid and to accurately assess not  
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28 179 only MVPA, but also low-intensity physical activity (including sedentary behavior), in  
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30 180 comparison to indirect calorimetry [24, 25]. A recent comparative study of three activity  
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32 181 monitors showed that the Active style Pro HJA-350IT underestimated total sedentary  
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34 182 time (-25.6 min/day) and the ActiGraph GT3X overestimated it (+63.7 min/day),  
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36 183 compared with the activePAL3 as the criterion [26]. Data were collected in one-minute  
37  
38 184 epochs. In order to obtain the information of work day including work and non-work  
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40 185 hours and non-work day, participants were also asked to record the time when wearing  
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42 186 and removing accelerometer as well as starting and finishing a job on 7 days.  
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### 42 188 **Socio-demographic data and occupational activity type**

43 189 Age and gender were obtained from the basic resident register. Height, weight,  
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45 190 educational level (university or further education; high school or less), marital status  
46  
47 191 (currently married; single), employment status (full-time; part-time), occupation  
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49 192 (professional and engineering; administrative and managerial; clerical; sales; service;  
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51 193 security; agricultural, forestry and fishery; transport and machine operation;  
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53 194 manufacturing process; others) were self-reported in questionnaire. Main occupational  
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55 195 activity type was also self-reported. Participants were asked to choose the occupational  
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57 196 activity type that most accurately described their work from the following 4 categories:  
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197 sitting, standing, walking, and physical labor. Body mass index (BMI) was calculated  
198 from self-reported height and weight. Occupations were referenced to Japanese  
199 standard classification of occupations [27].

## 201 **Data management**

202 Accelerometer data were processed using Omron health management software BI-LINK  
203 for physical activity professional edition ver1.0 and custom software [26]. Valid data for  
204 a wear day was defined as  $\geq 10$  hours/day excluding  $\geq 60$  consecutive minutes of no  
205 activity (0.9 or less metabolic equivalents; METs) with allowance for up to 2 min of some  
206 limited movement ( $\leq 1.0$  METs) within these periods and  $\geq 75\%$  wear time of work hours  
207 for a work day [12]. Those who had four or more valid days of data including at least  
208 three work days and a non-work day were included in the analysis. The data were  
209 extracted according to the following four time periods: working-hours (from starting to  
210 finishing job on work day), non-working hours (from wearing accelerometer to starting  
211 job and from finishing job to taking off accelerometer on work day), working day (a sum  
212 of working and non-working hours), and for non-working days (from wearing to taking  
213 off accelerometer). Work-hours were obtained from the activity diary.

214  
215 The five measures of sedentary behavior and physical activity were first extracted  
216 for each time segments: total sedentary time (min/day; % of wear time), sedentary time  
217 accumulated in prolonged sedentary bouts (% of wear time), number of sedentary  
218 breaks (times/sedentary hour), and LPA (% of wear time) and MVPA (% of wear time).  
219 Total sedentary time, LPA time, and MVPA time were defined as all wear time for any  
220 activity with an accelerometer-estimated intensity of  $\leq 1.5$  METs,  $1.5 <$  and  $< 3.0$  METs,  
221 and 3.0 or more METs, respectively. A sedentary bout was defined as a period of  
222 uninterrupted sedentary time [1]. Total sedentary time was calculated by a sum of  
223 uninterrupted sedentary time lasting  $\geq 1$  minutes. A prolonged sedentary bout was  
224 defined as a period of uninterrupted sedentary time lasting  $\geq 30$  minutes [1]. Sedentary  
225 time accumulated in prolonged bouts was calculated as the sum of prolonged sedentary  
226 bouts (% of wear time). A sedentary break was defined as a non-sedentary bout in  
227 between two sedentary bouts [1]. The number of sedentary breaks was calculated by  
228 the total number of sedentary breaks divided by time spent in all sedentary behavior.  
229 For each of the time segments, daily averages of all sedentary and physically-active

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3 230 measures were calculated over valid work and non-work days. Daily summaries of time  
4 231 spent in all sedentary behavior, prolonged sedentary bouts, LPA, and MVPA for each  
5 232 time segments were also calculated in terms of the percentage of these intensities in  
6 233 worn time (% wear time). Finally, daily average values including work and non-work  
7 234 days of five measures in a week were then computed by weighting for 5 work days and 2  
8 235 non-work days.  
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### 14 237 **Statistical Analysis**

15 238 Full-time (n=345) and part-time (n=98) workers were separately analyzed.  
16 239 Comparisons of the sociodemographic characteristics and five sedentary behavior and  
17 240 physical activity measures among four occupational activity types were conducted using  
18 241 one-way ANOVA for continuous variables and chi-square test for category variables.  
19 242 Each of the five sedentary and physical activity measures were compared among four  
20 243 occupational activity types in four time periods (working hours, non-working hours,  
21 244 working days, non-working days) using Analysis of Covariance (ANCOVA) with  
22 245 Bonferroni post-hoc test, adjusting for gender, age, residential area, educational level,  
23 246 marital status, and BMI. For these analyses, those who had missing data for these  
24 247 covariates were excluded among the full-time workers (n= 4). For part-time workers,  
25 248 only one person was engaged in physical labor tasks and thus their data were excluded  
26 249 from the analyses. For describing diurnal patterns, those who had  $\geq 6$  h of work time  
27 250 starting morning were included (n=403). Diurnal pattern of sedentary behavior, LPA  
28 251 and MVPA in each hour from 06:00-06:59 to 22:00-22:59 for each occupational activity  
29 252 type on work day and non-work day were illustrated by line graphs. All statistical  
30 253 analyses were performed using STATA 13.0 (Stata Corp., College Station, TX, US) and  
31 254 IBM SPSS Statistics 22 software (IBM Japan Inc., Tokyo, Japan). Significant levels were  $p$   
32 255  $< 0.05$ .  
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### 47 257 **RESULTS**

48 258 The characteristics of participants in full-time work are summarized in Table 1. The  
49 259 mean age and BMI were 50.3(SD 6.9) and 22.8 (3.2), respectively. About a half of them  
50 260 were men and lived in Koto Ward. The majority had completed university or higher  
51 261 education, were married, and worked in mainly-sitting type jobs. Those with sitting and  
52 262 physical labor jobs were more likely to be men than those with other two occupational  
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3 263 activity types. Those with sitting jobs were also more likely to live in Koto Ward and  
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5 264 completed university or further education than those in three other more active jobs.  
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266 **Table 1. Basic characteristics for participants of full-time jobs (N=345)**

	All participants	Occupational activity type				Group differences <sup>‡</sup>
		Sitting <sup>a</sup>	Standing <sup>b</sup>	Walking <sup>c</sup>	physical labor <sup>d</sup>	
<b>N</b>	345	239 (69.3)	47 (13.6)	48 (13.9)	11 (3.2)	
<b>Age, mean (SD)</b>	50.3(6.9)	50.1(7.0)	50.7(6.8)	50.5(6.7)	52.6(6.7)	
<b>Women, n (%)</b>	156 (45.2)	99 (41.4)	25 (53.2)	29 (60.4)	3 (27.3)	a,d<c
<b>BMI, kg/m<sup>2</sup>†, mean (SD)</b>	22.8 (3.2)	23.0(3.4)	21.9(2.4)	22.3(2.6)	25.5(4.2)	b,c<d
<b>Residence area, n (%)</b>						
Matsuyama city	170 (49.3)	98 (41.0)	37 (78.7)	26 (54.2)	9 (81.8)	a<b,d
Koto Ward	175 (50.7)	141 (59.0)	10 (21.3)	22 (45.8)	2 (18.2)	b<c
<b>Education<sup>a</sup>, n (%)</b>						
High school or less	109 (31.6)	59 (24.8)	23 (48.9)	21 (43.8)	6 (54.5)	a<b,c,d
Greater than high school	235 (68.1)	179 (75.2)	24 (51.1)	27 (56.3)	5 (45.5)	
<b>Marital status<sup>††</sup>, n (%)</b>						
Single	85 (24.6)	60 (25.4)	11 (23.4)	12 (25.0)	2 (18.2)	
Married	257 (74.5)	176 (74.6)	36 (76.6)	36 (75.0)	9 (81.8)	
<b>Occupation<sup>†††</sup>, n (%)</b>						
Professional and engineering	71 (20.6)	39 (16.5)	13 (28.3)	18 (37.5)	1 (10.0)	
Administrative and managerial	59 (17.1)	56 (23.6)	0 (0)	2 (4.2)	1 (10.0)	
Clerical	114 (33.0)	111 (46.8)	2 (4.3)	1 (2.1)	0 (0.0)	
Sales	17 (4.9)	7 (3.0)	4 (8.7)	6 (12.5)	0 (0.0)	
Service	34 (9.9)	9 (3.8)	17 (37)	8 (16.7)	0 (0.0)	
Security	1 (0.3)	0 (0.0)	1 (2.2)	0 (0.0)	0 (0.0)	
Agricultural, forestry and fishery	4 (1.2)	0 (0.0)	1 (2.2)	3 (6.3)	0 (0.0)	
Transport and machine operation	9 (2.6)	1 (0.4)	0 (0.0)	4 (8.3)	4 (40.0)	
Manufacturing process	14 (4.1)	4 (1.7)	5 (10.9)	1 (2.1)	4 (40.0)	
Others	17 (4.9)	10 (4.2)	2 (4.3)	5 (10.4)	0 (0.0)	

267 †:1 missing in sitting group; ††:3 missing in sitting group; †††: 2 missing in sitting group, 1  
 268 missing in both standing group and physical labor group

269 ‡: significant differences between 4 occupational activity types with one-way ANOVA for  
 270 continuous variables; chi-square test for category variables; a= sitting, b=standing,  
 271 c=walking; d=physical labor

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273 The sedentary behavior and physical activity measures in all days, work and  
 274 non-work contexts on all and occupational activity types of full-time workers are  
 275 presented in Table 2. In all days, mean wearing days and hours of accelerometer were  
 276 6.8 (SD: 0.9) days and 15.3 (SD: 1.1) hours. There were no significant differences in  
 277 wearing days and hours of accelerometer wear time among the four of



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3 278 occupational-activity types. In all days, those with sitting jobs had proportionally more  
4 279 total and prolonged sedentary time and less LPA and MVPA time in proportion,  
5 280 compared with those with other three occupational-activity types ( $p<0.001$ ).  
6 281 Additionally, those with sitting jobs had more frequent breaks than those with standing  
7 282 and walking jobs ( $p<0.001$ ). There were no significant differences in any of the  
8 283 sedentary behavior and physical activity measures among those in three physically  
9 284 active job types.

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11 285 Regarding working hours, those with sitting jobs had significantly more total and  
12 286 prolonged sedentary time along with less LPA and MVPA in proportion, and less  
13 287 frequent breaks compared with those with three other more active jobs ( $p<0.01$ ). The  
14 288 differences in sedentary time between the sitting jobs and the other jobs types on  
15 289 working hours were 17.7–26.4% of wear time. In addition, those with walking jobs had  
16 290 significantly more total sedentary time in proportion than those with physical labor jobs  
17 291 ( $p<0.05$ ). Also, those with physical labor jobs had significantly more MVPA time in  
18 292 proportion than those with standing and walking jobs ( $p<0.05$ ).

19 293 As a descriptive feature of non-work hours, the more active the jobs in which  
20 294 workers were involved, the more was their proportion of total sedentary time and the  
21 295 less their LPA, except for those with mostly sitting jobs. In large part, the proportions of  
22 296 total sedentary time and LPA in those with sitting jobs were similar to those with the  
23 297 jobs involving physical labor. The differences reaching statistical significance were as  
24 298 follow: those with standing jobs had proportionally less total sedentary time and more  
25 299 LPA than those with sitting jobs ( $p<0.05$ ).

26 300 Results similar to working hours were found for the total for working days, except  
27 301 for the prolonged sedentary time and sedentary breaks variables; there were no  
28 302 significant differences between those with sitting job and physical labor. The differences  
29 303 in sedentary time between the sitting jobs and the other jobs types on working days  
30 304 were 28.5–42.0% of wear time, respectively. In addition, those with standing job had  
31 305 significantly more LPA time in proportion than those with walking jobs ( $p<0.05$ ).

32 306 On non-work days, there were no significant differences apparent between the four  
33 307 occupational activity types.

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309 **Table2. Comparison of sedentary behavior and physical activity among four**  
 310 **occupational activity types in full-time workers**

	All Mean (SD)	Occupational activity type Marginal mean (95% CI) <sup>a</sup>				
		Sitting	Standing	Walking	Physical labor	
<b>Wear time (hours)</b>						
All day	15.3 (1.1)	15.2 (15.0-15.4)	15.3 (14.9-15.8)	15.2 (14.7-15.6)	16.0 (15.0-16.9)	
Work day <sup>a</sup>	15.6(1.8)	15.5 (15.3-15.8)	15.8 (15.2-16.3)	15.7 (15.2-16.2)	16.6 (15.6-17.7)	
Work hours <sup>b</sup>	9.4(1.8)	9.3 (9.1-9.5)	9.7 (9.2-10.3)	9.7 (9.2-10.2)	9.8(8.8-10.9)	
Non-work hours <sup>c</sup>	6.2(2.3)	6.3 (6.0-6.5)	6.0 (5.4-6.6)	6.0 (5.4-6.6)	6.8 (5.5-8.1)	
Non-work day <sup>d</sup>	14.3(2.0)	14.4 (14.1-14.7)	14.3 (13.7-14.9)	13.9 (13.3-14.4)	14.4 (13.2-15.6)	
<b>Total sedentary (%wear time)</b>						
All day	57.5(12.7)	62.2 (61.0-63.5)	45.1 (42.2-47.9)***	49.1 (46.4-51.9)***	43.5 (37.7-49.3)***	
Work day	56.8(15.3)	63.2 (61.8-64.5)	40.6 (37.4-43.7)***	45.5 (42.5-48.5)***	36.8 (30.4-43.2)***	
Work hours	58.6(21.9)	68.5 (66.7-70.3)	34.6 (30.4-38.7)***	40.0 (36.0-44.0)***	26.5 (18.1-34.9)***, ‡	
Non-work hours	53.3(11.9)	54.0 (52.4-55.4)	49.8 (46.3-53.3)*	52.5 (49.2-55.9)	56.5 (49.4-63.6)	
Non-work day	59.1(13.8)	59.8 (58.1-61.6)	56.3 (52.3-60.4)	58.2 (54.3-62.1)	60.3 (52.0-68.5)	
<b>Prolonged sedentary bouts (% wear time)</b>						
All day	19.1(11.0)	22.1(20.8-23.4)	14.8(11.8-17.7)***	15.4(12.6-18.3)***	15.5(9.4-21.5)	
Work day	18.2(12.5)	21.0 (19.5-22.4)	11.7 (8.4-15.0)***	12.4 (9.2-15.5)***	12.0 (5.3-18.7)	
Work hours	18.6(18.2)	23.1 (21.1-25.2)	8.5 (3.8-13.2)***	9.0 (4.4-13.5)***	7.0 (-2.5-16.6)**	
Non-work hours	16.7(11.1)	16.6 (15.2-18.0)	16.2 (13.0-19.5)	16.5 (13.4-19.7)	20.5 (13.9-27.0)	
Non-work day	24.1(15.1)	24.8 (22.9-26.8)	22.3 (17.9-26.7)	23.1 (18.8-27.4)	24.1 (15.2-33.1)	
<b>Breaks per sedentary hour</b>						
All day	9.4(3.1)	8.7 (8.4-9.1)	11.6 (10.8-12.4)***	10.8 (10.1-11.6)***	10.3 (8.7-11.9)	
Work day	9.8(3.6)	8.8 (8.4-9.1)	12.7 (11.8-13.6)***	11.7 (10.8-12.6)***	10.9 (9.1-12.7)	
Work hours	10.8(5.7)	8.8 (8.2-9.4)	16.2 (14.9-17.5)***	14.7 (13.4-16.0)***	13.3 (10.6-16.0)**	
Non-work hours	10.0(3.7)	10.0 (9.5-10.5)	10.5 (9.4-11.6)	10.0 (8.9-11.0)	9.7 (7.4-11.9)	
Non-work day	8.6(3.7)	8.6 (8.1-9.0)	8.9 (7.6-10.0)	8.7 (7.6-9.7)	8.8 (6.5-11.0)	
<b>LPA (%wear time)</b>						
All day	34.8(11.0)	31.3 (30.2-32.3)	44.5 (42.1-47.0)***	40.8 (38.4-43.1)***	44.3 (39.3-49.2)***	
Work day	35.1(13.1)	30.3 (29.1-31.5)	48.1 (45.4-50.8)***	42.9 (40.3-45.6)***, †	48.2 (42.6-53.7)***	
Work hours	34.6(17.7)	27.4 (25.9-29.0)	53.3 (49.7-56.9)***	47.1 (43.6-50.6)***	54.9 (47.6-62.1)***	
Non-work hours	36.2(11.3)	35.3 (33.9-36.6)	40.4 (37.3-43.5)*	37.7 (34.7-40.7)	34.7 (28.4-41.0)	
Non-work day	34.2(11.9)	33.7 (32.2-35.2)	35.6 (32.2-39.1)	35.3 (32.0-38.6)	34.6 (27.6-41.5)	
<b>MVPA (%wear time)</b>						
All day	7.7(4.5)	6.5 (6.0-7.1)	10.4 (9.1-11.6)***	10.1 (8.9-11.3)***	12.2 (9.7-14.7)***	
Work day	8.2(5.4)	6.5 (5.9-7.2)	11.3 (9.9-12.8)***	11.5 (10.2-12.9)***	15.0 (12.1-17.9)***	
Work hours	6.8(7.5)	4.1 (3.3-4.9)	12.2 (10.3-14.0)***	12.9 (11.1-14.6)***	18.6 (14.9-22.4)***, †, ‡	
Non-work hours	10.5(6.8)	10.8 (10.0-11.6)	9.8 (8.0-11.6)	9.8 (8.0-11.6)	8.8 (5.1-12.5)	
Non-work day	6.7(4.6)	6.5 (5.9-7.1)	8.0 (6.6-9.3)	6.5 (5.2-7.8)	5.2 (2.4-7.9)	

311 <sup>a</sup> Marginal mean and 95% CI from ANCOVA adjusted for covariates including gender, age, BMI,  
 312 residence area, educational level, marital status.

313 Asterisks indicate significant difference from the sitting: \*p < 0.05, \*\*p < 0.01, \*\*\* < .001

314 Dagger indicates significant difference from the standing: †p < 0.05

315 Double dagger indicates significant difference from the walking: ‡p < 0.05

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Hourly patterns of sedentary behavior, LPA and MVPA on four occupational activity types are summarized in Figure 1 for full time workers. Overall, sedentary time and LPA showed an inverse pattern. On work days, a notable difference was observed in the pattern of sedentary behavior during work hours between those with the sitting jobs and the other three types, while all occupational activity types showed a similar pattern after work, with a linear increase in the sedentary fraction until 22:00-22:59. Those with standing, walking and physical labor jobs constantly accounted for a larger fraction of LPA than that of sedentary behavior from 6:00-6:59 throughout almost of all working hours. On non-work days, sedentary behavior in all occupational activity types was mostly dominant from 7:00-7:59 to 18:00-18:59. However, the time differences between sedentary behavior and LPA in those with sitting jobs stayed more constant and larger than those in other more active jobs from 7:00-7:59 to 18:00-18:59. After 18:00-18:59 on non-work day, all types showed increase in sedentary time as the same with work days. All results of the part-time workers were presented in Table S1,2 and Figure S1.

INSERT FIGURE 1 ABOUT HERE

## DISCUSSION

This is the first study to examine accelerometer-measured patterns of sedentary behaviors and physical activity among Japanese workers in their work and non-work contexts, and to examine how these patterns differed by occupational activity type. Among full-time workers, sedentary time comprised more than half of the working day. Overall, those with sitting jobs, who accounted for 70% of this study sample, had higher amount of both total and prolonged sedentary time and less frequent breaks from sitting across the whole day, compared with those in more physically active job types. Previous studies in Western countries have examined the differences in objectively-measured total sedentary behavior among 2-19 occupation groups or sectors [18, 19] and self-reported leisure and domain-specific sedentary behaviors among occupational activity types [9, 20]. The present study extends these findings, for the first time in a non-Western country, by examining the differences in additional sedentary behavior measures such as prolonged sedentary behavior and breaks using objective measurements. The present findings suggest that further public health efforts focused on the worksite should be emphasized, especially for office-workers who are a majority of the working adult population in Japan and are an apparent at-risk subgroup due to high volumes of sitting, not only at work but also in non-work time.

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5 353 Among those with sitting jobs of this study sample, 63% of working day (60% of  
6 354 non-work day) were sedentary. Some previous studies conducted in Australia and the  
7 355 UK found that sedentary behavior assessed by Actigraph were 68-70% of working day  
8 356 of office workers (60-63% of non-work day)[12, 14]. Our recent comparative study of  
9 357 activity devices found that total sedentary time assessed by the Active style Pro  
10 358 HJA-350IT were proportionally 11% less time spent in total sedentary behavior than  
11 359 Actigraph [26]. These findings suggest that Japanese office-workers may spend more  
12 360 time in sedentary behavior across whole day compared with those in Western countries,  
13 361 which is similar to the previous international-comparative study examining  
14 362 self-reported sitting time of working adult population [23]. As an at-risk population  
15 363 considered in the international context, promoting effective public health strategies to  
16 364 reduce sedentary behavior on the worksite may be a necessary effort in Japan.  
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26 366 We found significant differences in overall sedentary time and number of breaks  
27 367 from sedentary time in work hours across the occupational activity types that we  
28 368 examined, especially for working hours. Full-time workers with sitting jobs spent most  
29 369 sedentary time and had less breaks from sedentary behavior than those with more  
30 370 active job types: these differences were approximately 20-30% in the proportion (2.5-4  
31 371 hours) and 5-7 times per sedentary hours. On the other hand, these patterns on  
32 372 non-working hours or days were relatively similar although workers with sitting and  
33 373 physical labor jobs somewhat spent more sedentary along with in less LPA than those  
34 374 with standing and walking jobs. These findings may indicate that the occupational  
35 375 activity type, which is commonly determined by job requirements can have the greatest  
36 376 impact on overall sedentary time and patterns in workers' population. These findings  
37 377 are consistent with the only previous study from The Netherlands, which found all  
38 378 white-collar workers from financial service providers and research institutes had  
39 379 significantly greater occupational (30-35%) and total sitting time (10-15%) in  
40 380 proportion than all blue-color workers of construction company [17]. In addition, these  
41 381 findings supported those of previous studies in Australia, France, Scotland, and the  
42 382 Netherlands, which showed that workers with higher occupational sitting time did not  
43 383 sit less, rather sat more, on their leisure time [9, 18, 19, 28]. Similar to studies  
44 384 conducted in Western countries, the present findings suggest that further promotion of  
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3 385 worksite interventions to reduce office-workers' sedentary time along with increased  
4 386 sedentary breaks should be prioritized on working populations in not only Western  
5 387 countries but also in Japan.  
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10 389 Similar to the average patterns, the analysis of the accelerometer output by hour of the  
11 390 working day showed that the pattern of sedentary behavior, LPA and MVPA were highly  
12 391 dependent on occupational activity types during working hours (except for lunch time),  
13 392 whereas all were similar on the evening time after work. The descriptive features were  
14 393 observed on non-working day, especially during the daytime, across occupational  
15 394 activity types. Even though the average sedentary and activity patterns were not distinct  
16 395 among them, some dips in sedentary behavior along with increases in LPA were found  
17 396 in those with standing, walking, and physical labor jobs, whereas the conditions in  
18 397 which sedentary behavior is the most dominant stayed constant throughout a day in  
19 398 those with sitting jobs on non-working day. The pattern of MVPA was stable and  
20 399 independent from those of sedentary behavior and LPA in all occupational activity types.  
21 400 The variations in pattern of sedentary behavior and LPA among occupational activity  
22 401 types could be partly attributed to differences in socio-demographic attributes  
23 402 (especially gender) and sample size. However, in a previous study from the UK  
24 403 examining the diurnal patterns of sedentary behavior and physical activity among office  
25 404 workers grouped into tertiles based on occupational sedentary time, the higher the  
26 405 tertile for occupational sedentary time in which office workers were categorized, the  
27 406 more pronounced and stable the difference between sedentary behavior and LPA (less  
28 407 crossing and reversing time points in a graph between them) became throughout a  
29 408 non-working day [14]. These results imply that routine diurnal occupational sedentary  
30 409 and LPA patterns, which were repeated 5 days a week, on working day may carry over  
31 410 their leisure-time behavioral patterns as a habit. Similarly, the previous study in French  
32 411 working adults using a self-report questionnaire found that the occupational activity  
33 412 levels involved in jobs were negatively associated with leisure time spent sedentary, on  
34 413 both working and non-working days [20]. Future intervention studies could help to  
35 414 clarify whether promoting breaks from sedentary time by more LPA during working  
36 415 hours may influence leisure-time sedentary behavior and physical activity. The hourly  
37 416 patterns for LPA and MVPA would also be useful to consider in relation to the timing of  
38 417 workplace physical activity interventions, which is fruitful as a future research topic.  
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4 419 This is the first study to report descriptive patterns of objectively measured Japanese  
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6 420 workers' sedentary behavior comprehensively, and their relationships with  
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8 421 occupational activity types. Other strengths of this study were use of  
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10 422 population-recruited sample and accelerometer -assessed sedentary behavior and  
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12 423 physical activity. There are also some limitations in this study. First, data were  
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14 424 cross-sectional and therefore any causality cannot be inferred. Second, the present  
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16 425 samples were selected from only two cities in Japan although central and average-sized  
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18 426 local cities were chosen. Thus, the results may differ in other cities and areas. Third, the  
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20 427 response rate was relatively low. Our middle-aged participants were recruited initially  
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22 428 by random sampling, which may have introduced some sampling bias; only 10 were  
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24 429 recruited whose jobs involved physical labor. Therefore, the findings may not be  
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26 430 generalizable to the broader middle-aged worker population, in particular to those  
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28 431 whose jobs involve physical labor. Fourth, accelerometers were unable to accurately  
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30 432 differentiate sitting and very-static standing postures, and they cannot detect some  
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32 433 types of physical activity such as cycling and water activity.

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### 435 **CONCLUSION**

436 In summary, full-time workers involved in mostly sitting jobs had a higher volume of  
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438 sedentary behavior with prolonged bouts on workdays, compared with other  
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440 occupational-activity job types. The differences in sedentary patterns mainly occurred  
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442 during work hours. There may be carry-over of sedentary and physical activity patterns  
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444 in working time, which could influence leisure time and whole of day time spent  
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446 sedentary, with potential for adverse health consequences. Therefore, intervention for  
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448 to reduce workers' sedentary behaviors are needed, especially for those in office-based  
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450 workplace where prolonged periods of sitting are required.

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### 452 **AUTHORS' CONTRIBUTION**

453 Kurita and Shibata conceived the study, analyzed the data, and drafted the  
454  
455 manuscript. Koohsari and Owen assisted with analyzing data and drafting manuscript.  
456  
457 Ishii and Oka were involved in the development and implementation of this study. All  
458  
459 authors contributed to study design, interpretation of the results, and manuscript  
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461 preparation. All authors have read and approved the final manuscript.

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**CONFLICT OF INTEREST STATEMENT**

The authors declare no conflicts of interest.

**DATA SHARING STATEMENT**

Requests for access to data should be addressed to the corresponding author.

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**Figure1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types among full-time workers**

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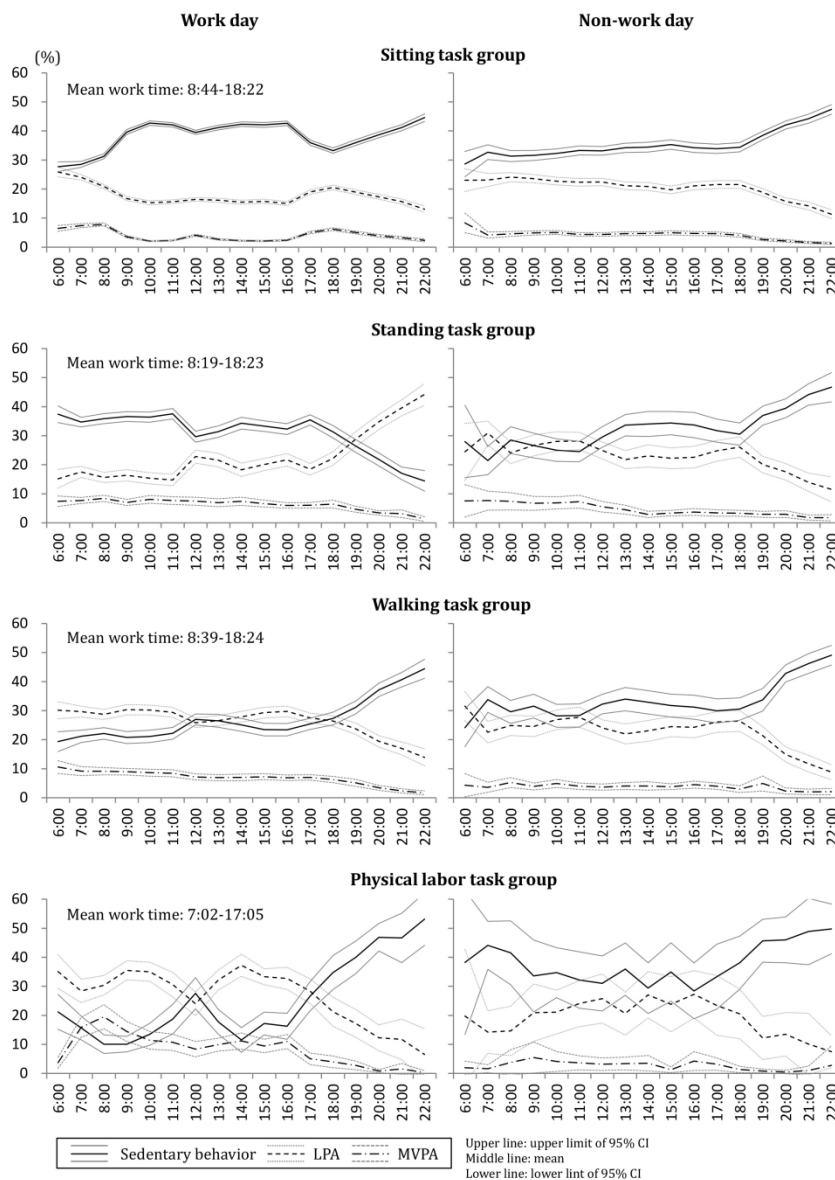


Figure 1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types among full-time workers

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**Table S1. Basic characteristics for participants of part-time workers**

	All participants	Occupational task group		
		Sitting	Standing	Walking
<b>n</b>	98	35 (35.7)	35 (35.7)	27 (27.6)
<b>Age, mean(SD)</b>	51.1(7.3)	50.4 (6.8)	52.7(8.0)	49.9(6.8)
<b>Women, n (%)</b>	94 (95.9)	34 (97.1)	33 (94.3)	26 (96.3)
<b>BMI (kg/m<sup>2</sup>)<sup>a</sup>, mean(SD)</b>	21.1(2.2)	21.2 (2.3)	20.9(2.1)	21.3(2.2)
<b>Residence area, n (%)</b>				
Matsuyama city	44 (44.9)	15 (42.9)	23 (65.7)	16 (59.3)
Koto Ward	54 (55.1)	20 (57.1)	12 (34.3)	11 (40.7)
<b>Education, n (%)</b>				
High school or less	44 (44.9)	11 (31.4)	22 (62.9)	11 (40.7)
Greater than high school	54 (55.1)	24 (68.6)	13 (37.1)	16 (59.3)
<b>Marital status<sup>b</sup>, n (%)</b>				
Single	12 (12.2)	4 (11.4)	4 (11.4)	4 (15.4)
Married	85 (86.7)	31 (88.6)	31 (88.6)	22 (84.6)
<b>Occupation<sup>c</sup>, n (%)</b>				
Professional and engineering	17 (17.5)	6 (17.6)	4 (11.4)	7 (25.9)
Administrative and managerial	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Clerical	23 (23.7)	21 (61.8)	2 (5.7)	0 (0.0)
Sales	7 (7.2)	1 (2.9)	5 (14.3)	1 (3.7)
Service	33 (34)	3 (8.8)	18 (51.4)	11 (40.7)
Security	1 (1.0)	0 (0.0)	1 (2.9)	0 (0.0)
Agricultural, forestry and fishery	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Transport and machine operation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Manufacturing process	5 (5.2)	1 (2.9)	3 (8.6)	1 (3.7)
Others	10 (10.3)	1 (2.9)	2 (5.7)	7 (25.9)

a 1 missing in standing task group

b 1 missing in walking task group

c 1 missing in sitting task group

**Table S2 Comparison of sedentary behavior and physical activity among three occupational activity types in part-time workers**

	All	Occupational activity types		
		Sitting	Standing	Walking
Mean (SD)				
<b>Wear time (hours)</b>				
All days	15.7(1.44)	15.7(1.4)	15.5(1.5)	16.1(1.5)
Work day	16.0(1.6)	15.9(1.7)	15.8(1.6)	16.3(1.7)
Work hours	6.2(2.4)	6.4(2.2)	5.9(2.5)	6.5(2.5)
Non-work hours	9.7(3.0)	9.5(2.8)	9.8(2.8)	9.9(3.7)
Non-work day	15.1(1.6)	15.0(1.2)	14.7(1.9)	15.6(1.6)
<b>Total sedentary (%wear time)</b>				
All days	47.6(9.8)	53.9(7.7)	44.7(10.3)	43.6(7.7)
Work day	45.1(11.3)	54.2 (7.9)	40.1 (10.9)	40.3 (8.4)
Work hours	36.6(23.4)	59.9 (12.6)	24.4 (19.4)	23.4 (14.3)
Non-work hours	49.8(9.7)	50.2 (8.9)	49.5 (10.8)	49.7 (9.9)
Non-work day	53.9(12.7)	53.1 (12.0)	56.4 (14.6)	51.8 (11.2)
<b>Prolonged sedentary bouts (%wear time)</b>				
All days	14.4(7.6)	15.1(8.0)	15.0(8.0)	12.7(6.4)
Work day	12.2(7.1)	14.0 (8.1)	11.4 (6.6)	10.7 (6.3)
Work hours	6.8(11.3)	12.5 (14.4)	4.3 (9.5)	2.7 (3.9)
Non-work hours	15.8(9.1)	15.4 (9.0)	15.8 (8.7)	15.8 (9.8)
Non-work day	20.0(14.3)	18.0 (13.4)	24.0 (16.4)	17.5 (12.1)
<b>Breaks per sedentary hour</b>				
All days	10.8(2.3)	10.1(1.9)	11.1(2.7)	11.2(2.2)
Work day	11.3(2.6)	10.3 (2.2)	12 (2.9)	11.7 (2.6)
Work hours	19.4(11.7)	11.6 (4.8)	24.3 (12.5)	23.1 (12.3)
Non-work hours	9.9(2.5)	9.7 (2.2)	10.2 (2.4)	9.9 (2.9)
Non-work day	9.5(3.7)	9.8 (3.6)	8.9 (4.4)	9.8 (3.1)
<b>LPA (%wear time)</b>				
All days	44.2(8.4)	39.2(6.9)	47.5(8.5)	46.3(7.2)
Work day	46.0(10.0)	38.6 (7.5)	51.5 (9.1)	48.6 (8.2)
Work hours	53.0(19.4)	35.3 (11.7)	65.4 (16.3)	59.6 (14.3)
Non-work hours	41.7(9.0)	40.4 (8.3)	42.8 (9.9)	42.1 (8.9)
Non-work day	39.7(10.2)	41 (10.4)	37.5 (11.3)	41 (8.3)
<b>MVPA (%wear time)</b>				
All days	8.1(3.9)	6.9(2.5)	15.6(3.4)	10.0(5.2)
Work day	8.8(4.6)	7.2 (2.8)	8.4 (3.8)	11.1 (6.1)
Work hours	10.4(11.1)	4.8 (3.2)	10.2 (7.2)	17 (16.3)
Non-work hours	8.4(4.2)	9.4 (4.4)	7.7 (4.3)	8.2 (3.8)
Non-work day	6.4(4.8)	5.9 (2.8)	6.2 (4.9)	7.2 (6.6)

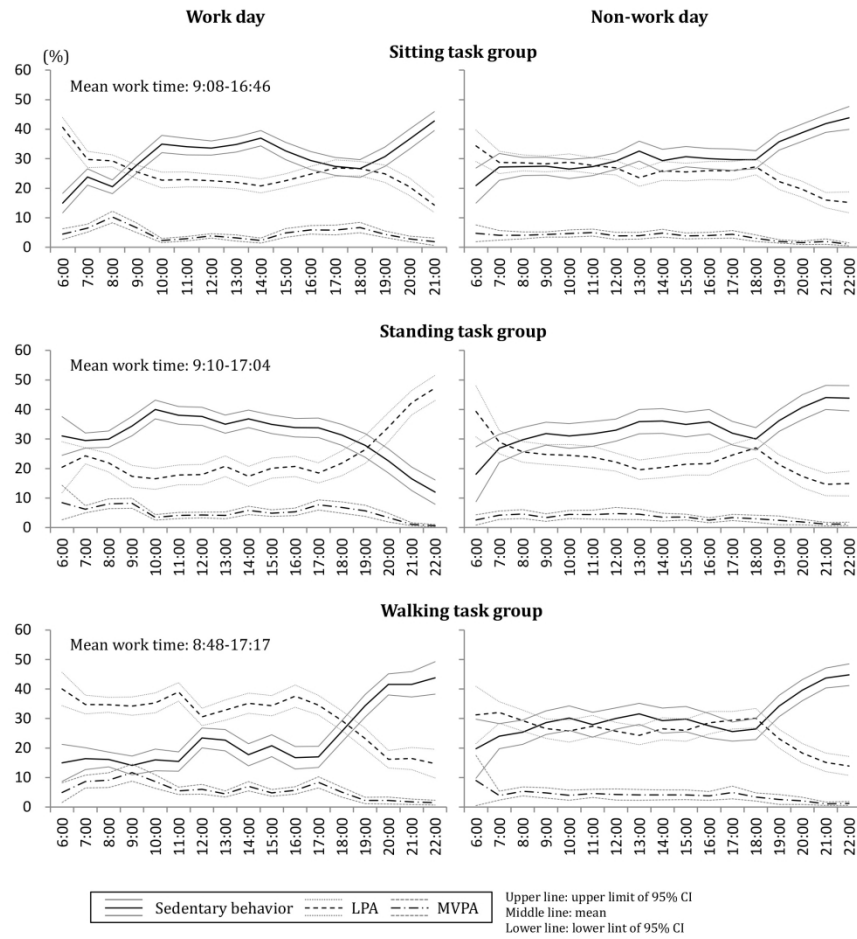


Figure S1. Hourly pattern of sedentary behavior, LPA and MVPA of three task types among part-time workers

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## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	page
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	16-18
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9
		(b) Describe any methods used to examine subgroups and interactions	9
		(c) Explain how missing data were addressed	9
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	N/A

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<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7 8-9
		(b) Give reasons for non-participation at each stage	8-9
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	7,9
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11- 13
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	14- 16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).



# BMJ Open

## Patterns of objectively-assessed sedentary time and physical activity among Japanese workers: a cross-sectional observational study

Journal:	<i>BMJ Open</i>
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<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology, Sports and exercise medicine
Keywords:	descriptive epidemiology, occupational sitting, occupational activity patterns, Asia

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4 1 **Title:** Patterns of objectively-assessed sedentary time and physical activity among  
5 2 Japanese workers: a cross-sectional observational study  
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8 4 **Authors:** Satoshi Kurita<sup>1</sup>, Ai Shibata<sup>2</sup>, Kaori Ishii<sup>3</sup>, Mohammad Javad Koohsari<sup>3,4,5</sup>, Neville  
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21 **Word count:** 4057 words

23 **Key words:** descriptive epidemiology, occupational sitting, occupational activity patterns,  
24 Asia.  
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1  
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4 26 **ABSTRACT**

5 27 **Objectives:** To examine patterns of sedentary behavior and physical activity, among  
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7 28 Japanese workers with differing occupational-activity types.

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9 29 **Design:** A cross-sectional observational study in 2013-2015.

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11 30 **Setting:** Two local communities in Japan

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13 31 **Participants:** Full-time workers aged 40-64 years (n = 345; 55% men) and who lived in  
14 32 two cities.

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16 33 **Main outcome measures:** From accelerometer data for 7 days, mean overall sedentary  
17 34 time, prolonged bouts of sedentary time and light-and moderate-to vigorous-intensity of  
18 35 physical activity (LPA and MVPA) as a proportion of accelerometer wear time, and number  
19 36 of breaks per sedentary hour, were identified for four time periods: working hours;  
20 37 workdays; non-work hours; and, non-work days. These sedentary behavior and physical  
21 38 activity measures in the four time periods were examined among workers with four self-  
22 39 attributed occupational activity types (mainly sitting, standing, walking, physical labor),  
23 40 adjusting for sociodemographic attributes. Diurnal patterns of sedentary behavior, LPA and  
24 41 MVPA were examined.

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26 42 **Results:** In working hours, those with a sitting job had significantly more total and  
27 43 prolonged sedentary time (total:  $p < 0.001$ ; prolonged:  $p < 0.01$ ) along with less LPA  
28 44 ( $p < 0.001$ ) and MVPA ( $p < 0.001$ ), and less frequent breaks ( $p < 0.01$ ), compared to those with  
29 45 the three more-active job type. Similar differences by job type were found for the whole  
30 46 working day, but not for prolonged sedentary time and breaks. On non-working hours and  
31 47 days, differences in sedentary and physically- active patterns by job type were not  
32 48 apparent.

33 49 **Conclusions:** Occupational activity type is related to overall sedentary time and patterns  
34 50 on working days, but not to leisure-time sitting and activity patterns, which were similar  
35 51 across the sitting, standing, walking, and physical labor occupational-activity types.

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2  
3 53 **ARTICLE SUMMARY**

4  
5 54 **Strengths and limitations of this study**

- 6  
7 55 ● This is the first study to comprehensively report descriptive patterns of workers'  
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9 56 objectively-measured sedentary behavior in a non-Western country, and relationships  
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11 57 with occupational activity types.  
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13 58 ● This study used a population-recruited sample and objectively (accelerometer)-  
14  
15 59 assessed sedentary and physically-active time  
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17 60 ● Distinct examination of work and leisure-time patterns of sedentary and physically-  
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19 61 active time was novel.  
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21 62 ● Since the study design was cross-sectional, causality cannot be inferred.  
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23 63 ● The response rate was low and not completely random, which may have resulted in  
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25 64 some selection bias.  
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## 67 INTRODUCTION

68 Sedentary behavior, defined as any waking behavior characterized by an energy  
69 expenditure  $\leq 1.5$  METs while in a sitting or reclining posture [1] has distinctive adverse  
70 effects on human health [2]. For example, excessive sedentary behavior increases the risk  
71 of all-cause mortality [3, 4] and risk of type 2 diabetes, cardiovascular disease, and some  
72 cancers [5], with some evidence of dose-response relationships [6]. There are benefits of  
73 more-frequent breaks from sedentary time on cardio-metabolic risk biomarkers [7].

74 Reducing prolonged sedentary behavior is an important public health issue.

75 Among the Japanese adult population, the worksite is a key setting in which to address  
76 sedentary behaviors and, since approximately 60% of the total population are employed,  
77 and 60 % of those employed are full-time workers (>40 hours/week) [8]. Understanding  
78 patterns of sedentary behavior (e.g. overall daily time, prolonged time, breaks, diurnal  
79 patterns) on working days and non-working days can help to identify the most sedentary  
80 segments of the day and whether there is carry-over of those patterns that may influence  
81 workers' whole-of-day sedentary time and physical activity. Such insights can inform  
82 approaches to sedentary behavior and as emerging occupational-health risks.

83  
84 Sedentary behavior patterns at work and potentially across the whole day may be  
85 influenced by the demands of work – in terms of having to be seated, standing, or  
86 physically active for job tasks [9]. Hence, it is important to examine in more depth the  
87 relationship between types of occupational activity requirements with overall patterns of  
88 sedentary behavior, in order to provide evidence that can inform approaches to workplace  
89 health promotion through sedentary behavior reduction.

90  
91 The majority of previous studies examining objectively-measured occupational  
92 sedentary patterns has only focused on office-based workers and primarily seated  
93 occupational groups [10-16]. One previous study conducted in Netherland has examined  
94 the pattern of sedentary behavior across different types of occupations including white-  
95 collar, office-based workers and blue-collar construction and factory workers [17].  
96 However, there have been no detailed examinations of overall diurnal patterns and the  
97 variability between workdays and non-workdays. Although another previous study

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4 98 conducted in Scotland has compared the pattern of total sedentary behavior between  
5 99 delivery and office staffs across workdays and non-workdays, further in-depth  
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7 100 examinations of sedentary patterns in larger sample size and across various occupational  
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9 101 types may more needed [18]. In addition, while a small number of studies have examined  
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11 102 patterns of sedentary behavior among workers, based on different occupational categories  
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13 103 [19] or on types of occupational activity [9, 20], they have used self-report measures of  
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15 104 total and/or domain-specific sedentary behavior. Objectively-measured patterns of  
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17 105 occupational sedentary behavior have not been examined.  
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19 107 Although there are distinct health consequences of sedentary behavior, light-intensity  
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21 108 physical activity (LPA), and moderate-to-vigorous intensity physical activity (MVPA)  
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23 109 [21,22], the time available for each of them in a day is finite. More time spent in sedentary  
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25 110 behavior indicates less time spent in LPA, MVPA, or both, indicating that these behaviors  
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27 111 are linked. Thus, it may be important to examine patterns of not only sedentary behavior,  
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29 112 but also LPA and MVPA concurrently. A small number of previous studies has  
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31 113 simultaneously examined sedentary and active behavior patterns during working and  
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33 114 leisure-time [9, 12-15, 17, 18]. However, little is known about how different the patterns or  
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35 115 relationships between sedentary behaviors and physical activities during working and  
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37 116 leisure-time would be between those in types of occupations with different activity  
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39 117 requirements.  
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41 119 Previous studies on sedentary behaviors among workers have been conducted mainly  
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43 120 in Western countries. One international-comparative study found that self-reported sitting  
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45 121 time of working adult population in Japan was the longest among 20 countries [23].  
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47 122 Although the Japanese working adult population seems to be at-risk population considered  
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49 123 in this international context, patterns of sedentary behavior in Japanese workers have not  
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51 124 been examined. Since working environments (e.g. social norms, working spaces and work  
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53 125 time) are likely to be different in Japan and other Asian countries compared with Western  
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55 126 countries, understanding the sedentary behavior and physical activity patterns in the  
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57 127 Japanese work environment context will be informative.  
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4 129 We examined accelerometer-derived patterns of sedentary behavior (total sedentary  
5 130 time, sedentary time accumulated in prolonged bouts, sedentary breaks and diurnal  
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7 131 patterns of sedentary time) and physical activity among Japanese workers, based on  
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9 132 occupational-activity types. These behaviors were characterized for four time periods:  
10 133 during work and non-work hours, on work days and on work and non-work days.  
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## 13 135 **METHODS**

### 14 136 **Study design and procedure**

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16 137 This was a cross-sectional observational study, as a part of a project to investigate the  
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18 138 associations between built environment attributes and sedentary behavior among  
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20 139 Japanese middle-aged adults. A mail survey was conducted in Matsuyama city in Ehime  
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22 140 prefecture (428.9 km<sup>2</sup>; 516,000 people) from July to December 2013, and Koto Ward in  
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24 141 Tokyo (40.2 km<sup>2</sup>; 484,000 people) from April 2014 to February 2015. The study was  
25  
26 142 approved by the Institutional Ethics Committee of Waseda University (2012-269, 2013-  
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28 143 264).  
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30 144

31 145 The survey procedures were as follows: first, 3,000 potential participants aged 40-64  
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33 146 were extracted randomly from each basic resident register stratified by gender and age  
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35 147 (40-49 years/ 50-59 years/ 60-64 years) for Matsuyama city and Koto Ward. Second,  
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37 148 invitation letters were mailed to the potential participants and asked to return an enclosed  
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39 149 form to indicate their expression of interest to participate in the study. Non-respondents  
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41 150 were mailed an additional request to join the study two weeks after the initial invitation  
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43 151 letter was sent. Then, those who expressed interest were mailed the informed-consent  
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45 152 form of this study, an accelerometer, an activity diary, and a questionnaire. Those who  
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47 153 finally agreed to participate were asked to sign the consent form, wear the accelerometer  
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49 154 and record the activity diary for 7 days, respond to the questionnaire, and then return all of  
50  
51 155 these within two weeks. Participants were guided to wear the accelerometers during  
52  
53 156 waking time (put it on straight after waking up) and to remove it during sleeping (take it  
54  
55 157 off just before going to bed) and during water-based activities such as bathing or  
56  
57 158 swimming. In addition, participants were asked to record for every day during the period  
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59 159 of accelerometer wear, their time getting up, putting on the accelerometer, leaving home to  
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4 160 travel to their workplace, starting their job, finishing their job, arriving at home, taking off  
5 161 the accelerometer, and going to bed. Non-respondents were sent a reminder notice up to  
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7 162 three times, and those who completed survey were sent thank-you letter with a ¥1,000  
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9 163 book voucher card.

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12 165 In total, 864 (14.4% of the originally-approached sample) including 437 (14.6%) from  
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14 166 Koto Ward and 427 (14.2%) from Matsuyama city agreed to participate: 778 (13.0% of the  
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16 167 originally-approached sample) completed the questionnaire and wore the accelerometer.  
17 168 Those who worked either full-time or part-time were included (n=633). Those who had  
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19 169 missing or invalid data for occupational activity type (n=38) or insufficient accelerometer  
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21 170 data (n=175) were excluded (numbers not mutually exclusive). The final study sample size  
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23 171 was 443 (full-time workers: n=345; part-time workers: n= 98).

### 24 172 25 26 173 **Assessment of sedentary behavior and physical activity**

27 174 Participants were asked to wear a triaxial accelerometer, Active style Pro HJA-350IT  
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29 175 (Omron Health Care Co., Ltd., Kyoto, Japan) on the left side of the waist for seven days. This  
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31 176 accelerometer device has been reported to be valid and to accurately assess not only MVPA,  
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33 177 but also low-intensity physical activity (including sedentary behavior), in comparison to  
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35 178 indirect calorimetry [24, 25]. A recent comparative study of three activity monitors showed  
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37 179 that the Active style Pro HJA-350IT underestimated total sedentary time (-25.6 min/day)  
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39 180 and the ActiGraph GT3X overestimated it (+63.7 min/day), compared with the activePAL3  
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41 181 as the criterion [26]. Data were collected in one-minute epochs. In order to obtain the  
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43 182 information of work day including work and non-work hours and non-work day,  
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45 183 participants were also asked to record the time when wearing and removing accelerometer  
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47 184 as well as starting and finishing a job on 7 days.

### 48 185 49 186 **Socio-demographic data and occupational activity type**

50 187 Age and gender were obtained from the basic resident register. Height, weight, educational  
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52 188 level (university or further education; high school or less), marital status (currently  
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54 189 married; single), employment status (full-time; part-time), occupation (professional and  
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56 190 engineering; administrative and managerial; clerical; sales; service; security; agricultural,



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4 191 forestry and fishery; transport and machine operation; manufacturing process; others)  
5 192 were self-reported in questionnaire. Main occupational activity type was also self-reported.  
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7 193 Participants were asked to choose the occupational activity type that most accurately  
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9 194 described their work from the following 4 categories: sitting, standing, walking, and  
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11 195 physical labor. Body mass index (BMI) was calculated from self-reported height and  
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13 196 weight. Occupations were referenced to Japanese standard classification of occupations  
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15 197 [27].  
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### 17 199 **Data management**

19 200 Accelerometer data were processed using Omron health management software BI-LINK for  
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21 201 physical activity professional edition ver1.0 and custom software [26]. Valid data for a  
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23 202 wear day was defined as  $\geq 10$  hours/day excluding  $\geq 60$  consecutive minutes of no activity  
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25 203 (0.9 or less metabolic equivalents; METs) with allowance for up to 2 min of some limited  
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27 204 movement ( $\leq 1.0$  METs) within these periods and  $\geq 75\%$  wear time of work hours for a  
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29 205 work day [12]. Those who had four or more valid days of data including at least three work  
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31 206 days and a non-work day were included in the analysis. The data were extracted according  
32  
33 207 to the following four time periods: working-hours (from starting to finishing job on work  
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35 208 day), non-working hours (from wearing accelerometer to starting job and from finishing  
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37 209 job to taking off accelerometer on work day), working day (a sum of working and non-  
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39 210 working hours), and for non-working days (from wearing to taking off accelerometer).  
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41 211 Work-hours were obtained from the activity diary.  
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44 213 The five measures of sedentary behavior and physical activity were first extracted for  
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46 214 each time segments: total sedentary time (min/day; % of wear time), sedentary time  
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48 215 accumulated in prolonged sedentary bouts (% of wear time), number of sedentary breaks  
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50 216 (times/sedentary hour), and LPA (% of wear time) and MVPA (% of wear time). Total  
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52 217 sedentary time, LPA time, and MVPA time were defined as all wear time for any activity  
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54 218 with an accelerometer-estimated intensity of  $\leq 1.5$  METs,  $1.5 <$  and  $< 3.0$  METs, and 3.0 or  
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56 219 more METs, respectively. A sedentary bout was defined as a period of uninterrupted  
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58 220 sedentary time [1]. Total sedentary time was calculated by a sum of uninterrupted  
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60 221 sedentary time lasting  $\geq 1$  minutes. A prolonged sedentary bout was defined as a period of

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4 222 uninterrupted sedentary time lasting  $\geq 30$  minutes [1]. Sedentary time accumulated in  
5 223 prolonged bouts was calculated as the sum of prolonged sedentary bouts (% of wear time).  
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7 224 A sedentary break was defined as a non-sedentary bout in between two sedentary bouts  
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9 225 [1]. The number of sedentary breaks was calculated by the total number of sedentary  
10 226 breaks divided by time spent in all sedentary behavior. For each of the time segments, daily  
11 227 averages of all sedentary and physically-active measures were calculated over valid work  
12 228 and non-work days. Daily summaries of time spent in all sedentary behavior, prolonged  
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14 229 sedentary bouts, LPA, and MVPA for each time segments were also calculated in terms of  
15 230 the percentage of these intensities in worn time (% wear time). Finally, daily average  
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17 231 values including work and non-work days of five measures in a week were then computed  
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19 232 by weighting for 5 work days and 2 non-work days.  
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#### 24 234 **Statistical analysis**

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26 235 Full-time (n=345) and part-time (n=98) workers were separately analyzed. Comparisons of  
27 236 the sociodemographic characteristics and five sedentary behavior and physical activity  
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29 237 measures among four occupational activity types were conducted using one-way ANOVA  
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31 238 for continuous variables and chi-square test for category variables. Each of the five  
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33 239 sedentary and physical activity measures were compared among four occupational activity  
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35 240 types in four time periods (working hours, non-working hours, working days, non-working  
36 241 days) using Analysis of Covariance (ANCOVA) with Bonferroni post-hoc test, adjusting for  
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38 242 gender, age, residential area, educational level, marital status, and BMI. For these analyses,  
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40 243 those who had missing data for these covariates were excluded among the full-time  
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42 244 workers (n= 4). For part-time workers, only one person was engaged in physical labor  
43 245 tasks and thus their data were excluded from the analyses. For describing diurnal patterns,  
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45 246 those who had  $\geq 6$  h of work time starting morning were included (n=403). Diurnal pattern  
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47 247 of sedentary behavior, LPA and MVPA in each hour from 06:00-06:59 to 22:00-22:59 for  
48  
49 248 each occupational activity type on work day and non-work day were illustrated by line  
50 249 graphs. All statistical analyses were performed using STATA 13.0 (Stata Corp., College  
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52 250 Station, TX, US) and IBM SPSS Statistics 22 software (IBM Japan Inc., Tokyo, Japan).  
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54 251 Significant levels were  $p < 0.05$ .  
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4 253 **Patients and public involvement**

5 254 Patients or public were not involved in this study.  
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9 256 **RESULTS**

10 257 The characteristics of participants in full-time work are summarized in Table 1. The mean  
11 258 age and BMI were 50.3(SD 6.9) and 22.8 (3.2), respectively. About a half of them were men  
12 259 and lived in Koto Ward. The majority had completed university or higher education, were  
13 260 married, and worked in mainly-sitting type jobs. Those with sitting and physical labor jobs  
14 261 were more likely to be men than those with other two occupational activity types. Those  
15 262 with sitting jobs were also more likely to live in Koto Ward and completed university or  
16 263 further education than those in three other more active jobs.  
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265 **Table 1. Basic characteristics for participants of full-time jobs (N=345)**

	All participants	Occupational activity type				Group differences <sup>‡</sup>
		Sitting <sup>a</sup>	Standing <sup>b</sup>	Walking <sup>c</sup>	physical labor <sup>d</sup>	
<b>N</b>	345	239 (69.3)	47 (13.6)	48 (13.9)	11 (3.2)	
<b>Age, mean (SD)</b>	50.3(6.9)	50.1(7.0)	50.7(6.8)	50.5(6.7)	52.6(6.7)	
<b>Women, n (%)</b>	156 (45.2)	99 (41.4)	25 (53.2)	29 (60.4)	3 (27.3)	a,d<c
<b>BMI, kg/m<sup>2</sup>†, mean (SD)</b>	22.8 (3.2)	23.0(3.4)	21.9(2.4)	22.3(2.6)	25.5(4.2)	b,c<d
<b>Residence area, n (%)</b>						
Matsuyama city	170 (49.3)	98 (41.0)	37 (78.7)	26 (54.2)	9 (81.8)	a< b,d
Koto Ward	175 (50.7)	141 (59.0)	10 (21.3)	22 (45.8)	2 (18.2)	b<c
<b>Education<sup>a</sup>, n (%)</b>						
High school or less	109 (31.6)	59 (24.8)	23 (48.9)	21 (43.8)	6 (54.5)	a<b,c,d
Greater than high school	235 (68.1)	179 (75.2)	24 (51.1)	27 (56.3)	5 (45.5)	
<b>Marital status<sup>††</sup>, n (%)</b>						
Single	85 (24.6)	60 (25.4)	11 (23.4)	12 (25.0)	2 (18.2)	
Married	257 (74.5)	176 (74.6)	36 (76.6)	36 (75.0)	9 (81.8)	
<b>Occupation<sup>†††</sup>, n (%)</b>						
Professional and engineering	71 (20.6)	39 (16.5)	13 (28.3)	18 (37.5)	1 (10.0)	
Administrative and managerial	59 (17.1)	56 (23.6)	0 (0)	2 (4.2)	1 (10.0)	
Clerical	114 (33.0)	111 (46.8)	2 (4.3)	1 (2.1)	0 (0.0)	
Sales	17 (4.9)	7 (3.0)	4 (8.7)	6 (12.5)	0 (0.0)	
Service	34 (9.9)	9 (3.8)	17 (37)	8 (16.7)	0 (0.0)	
Security	1 (0.3)	0 (0.0)	1 (2.2)	0 (0.0)	0 (0.0)	
Agricultural, forestry and fishery	4 (1.2)	0 (0.0)	1 (2.2)	3 (6.3)	0 (0.0)	
Transport and machine operation	9 (2.6)	1 (0.4)	0 (0.0)	4 (8.3)	4 (40.0)	
Manufacturing process	14 (4.1)	4 (1.7)	5 (10.9)	1 (2.1)	4 (40.0)	
Others	17 (4.9)	10 (4.2)	2 (4.3)	5 (10.4)	0 (0.0)	

266 †:1 missing in sitting group; ††:3 missing in sitting group; †††: 2 missing in sitting group, 1  
 267 missing in both standing group and physical labor group

268 ‡: significant differences between 4 occupational activity types with one-way ANOVA for  
 269 continuous variables; chi-square test for category variables; a= sitting, b=standing,  
 270 c=walking; d=physical labor

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272 The sedentary behavior and physical activity measures in all days, work and non-work  
 273 contexts on all and occupational activity types of full-time workers are presented in Table  
 274 2. In all days, mean wearing days and hours of accelerometer were 6.8 (SD: 0.9) days and

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4 275 15.3 (SD: 1.1) hours. There were no significant differences in wearing days and hours of  
5 276 accelerometer wear time among the four of occupational-activity types. In all days, those  
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7 277 with sitting jobs had proportionally more total and prolonged sedentary time and less LPA  
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9 278 and MVPA time in proportion, compared with those with other three occupational-activity  
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11 279 types ( $p<0.001$ ). Additionally, those with sitting jobs had more frequent breaks than those  
12  
13 280 with standing and walking jobs ( $p<0.001$ ). There were no significant differences in any of  
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15 281 the sedentary behavior and physical activity measures among those in three physically  
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17 282 active job types.

18 283       Regarding working hours, those with sitting jobs had significantly more total and  
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20 284 prolonged sedentary time along with less LPA and MVPA in proportion, and less frequent  
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22 285 breaks compared with those with three other more active jobs ( $p<0.01$ ). The differences in  
23  
24 286 sedentary time between the sitting jobs and the other jobs types on working hours were  
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26 287 17.7–26.4% of wear time. In addition, those with walking jobs had significantly more total  
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28 288 sedentary time in proportion than those with physical labor jobs ( $p<0.05$ ). Also, those with  
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30 289 physical labor jobs had significantly more MVPA time in proportion than those with  
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32 290 standing and walking jobs ( $p<0.05$ ).

33 291       As a descriptive feature of non-work hours, the more active the jobs in which workers  
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35 292 were involved, the more was their proportion of total sedentary time and the less their  
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37 293 LPA, except for those with mostly sitting jobs. In large part, the proportions of total  
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39 294 sedentary time and LPA in those with sitting jobs were similar to those with the jobs  
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41 295 involving physical labor. The differences reaching statistical significance were as follow:  
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43 296 those with standing jobs had proportionally less total sedentary time and more LPA than  
44  
45 297 those with sitting jobs ( $p<0.05$ ).

46 298       Results similar to working hours were found for the total for working days, except for  
47  
48 299 the prolonged sedentary time and sedentary breaks variables; there were no significant  
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50 300 differences between those with sitting job and physical labor. The differences in sedentary  
51  
52 301 time between the sitting jobs and the other jobs types on working days were 28.5–42.0% of  
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54 302 wear time, respectively. In addition, those with standing job had significantly more LPA  
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56 303 time in proportion than those with walking jobs ( $p<0.05$ ).

57 304       On non-work days, there were no significant differences apparent between the four  
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59 305 occupational activity types.

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For peer review only

307 **Table 2. Comparison of sedentary behavior and physical activity among four**  
 308 **occupational activity types in full-time workers**

	All	Occupational activity type			
		Marginal mean (95% CI) <sup>a</sup>			
	Mean (SD)	Sitting	Standing	Walking	Physical labor
<b>Wear time (hours)</b>					
All day	15.3 (1.1)	15.2 (15.0-15.4)	15.3 (14.9-15.8)	15.2 (14.7-15.6)	16.0 (15.0-16.9)
Work day <sup>a</sup>	15.6(1.8)	15.5 (15.3-15.8)	15.8 (15.2-16.3)	15.7 (15.2-16.2)	16.6 (15.6-17.7)
Work hours <sup>b</sup>	9.4(1.8)	9.3 (9.1-9.5)	9.7 (9.2-10.3)	9.7 (9.2-10.2)	9.8(8.8-10.9)
Non-work hours <sup>c</sup>	6.2(2.3)	6.3 (6.0-6.5)	6.0 (5.4-6.6)	6.0 (5.4-6.6)	6.8 (5.5-8.1)
Non-work day <sup>d</sup>	14.3(2.0)	14.4 (14.1-14.7)	14.3 (13.7-14.9)	13.9 (13.3-14.4)	14.4 (13.2-15.6)
<b>Total sedentary (%wear time)</b>					
All day	57.5(12.7)	62.2 (61.0-63.5)	45.1 (42.2-47.9)***	49.1 (46.4-51.9)***	43.5 (37.7-49.3)***
Work day	56.8(15.3)	63.2 (61.8-64.5)	40.6 (37.4-43.7)***	45.5 (42.5-48.5)***	36.8 (30.4-43.2)***
Work hours	58.6(21.9)	68.5 (66.7-70.3)	34.6 (30.4-38.7)***	40.0 (36.0-44.0)***	26.5 (18.1-34.9)***, ‡
Non-work hours	53.3(11.9)	54.0 (52.4-55.4)	49.8 (46.3-53.3)*	52.5 (49.2-55.9)	56.5 (49.4-63.6)
Non-work day	59.1(13.8)	59.8 (58.1-61.6)	56.3 (52.3-60.4)	58.2 (54.3-62.1)	60.3 (52.0-68.5)
<b>Prolonged sedentary bouts (% wear time)</b>					
All day	19.1(11.0)	22.1(20.8-23.4)	14.8(11.8-17.7)***	15.4(12.6-18.3)***	15.5(9.4-21.5)
Work day	18.2(12.5)	21.0 (19.5-22.4)	11.7 (8.4-15.0)***	12.4 (9.2-15.5)***	12.0 (5.3-18.7)
Work hours	18.6(18.2)	23.1 (21.1-25.2)	8.5 (3.8-13.2)***	9.0 (4.4-13.5)***	7.0 (-2.5-16.6)**
Non-work hours	16.7(11.1)	16.6 (15.2-18.0)	16.2 (13.0-19.5)	16.5 (13.4-19.7)	20.5 (13.9-27.0)
Non-work day	24.1(15.1)	24.8 (22.9-26.8)	22.3 (17.9-26.7)	23.1 (18.8-27.4)	24.1 (15.2-33.1)
<b>Breaks per sedentary hour</b>					
All day	9.4(3.1)	8.7 (8.4-9.1)	11.6 (10.8-12.4)***	10.8 (10.1-11.6)***	10.3 (8.7-11.9)
Work day	9.8(3.6)	8.8 (8.4-9.1)	12.7 (11.8-13.6)***	11.7 (10.8-12.6)***	10.9 (9.1-12.7)
Work hours	10.8(5.7)	8.8 (8.2-9.4)	16.2 (14.9-17.5)***	14.7 (13.4-16.0)***	13.3 (10.6-16.0)**
Non-work hours	10.0(3.7)	10.0 (9.5-10.5)	10.5 (9.4-11.6)	10.0 (8.9-11.0)	9.7 (7.4-11.9)
Non-work day	8.6(3.7)	8.6 (8.1-9.0)	8.9 (7.6-10.0)	8.7 (7.6-9.7)	8.8 (6.5-11.0)
<b>LPA (%wear time)</b>					
All day	34.8(11.0)	31.3 (30.2-32.3)	44.5 (42.1-47.0)***	40.8 (38.4-43.1)***	44.3 (39.3-49.2)***
Work day	35.1(13.1)	30.3 (29.1-31.5)	48.1 (45.4-50.8)***	42.9 (40.3-45.6)***, †	48.2 (42.6-53.7)***
Work hours	34.6(17.7)	27.4 (25.9-29.0)	53.3 (49.7-56.9)***	47.1 (43.6-50.6)***	54.9 (47.6-62.1)***
Non-work hours	36.2(11.3)	35.3 (33.9-36.6)	40.4 (37.3-43.5)*	37.7 (34.7-40.7)	34.7 (28.4-41.0)
Non-work day	34.2(11.9)	33.7 (32.2-35.2)	35.6 (32.2-39.1)	35.3 (32.0-38.6)	34.6 (27.6-41.5)
<b>MVPA (%wear time)</b>					
All day	7.7(4.5)	6.5 (6.0-7.1)	10.4 (9.1-11.6)***	10.1 (8.9-11.3)***	12.2 (9.7-14.7)***
Work day	8.2(5.4)	6.5 (5.9-7.2)	11.3 (9.9-12.8)***	11.5 (10.2-12.9)***	15.0 (12.1-17.9)***
Work hours	6.8(7.5)	4.1 (3.3-4.9)	12.2 (10.3-14.0)***	12.9 (11.1-14.6)***	18.6 (14.9-22.4)***, †, ‡
Non-work hours	10.5(6.8)	10.8 (10.0-11.6)	9.8 (8.0-11.6)	9.8 (8.0-11.6)	8.8 (5.1-12.5)
Non-work day	6.7(4.6)	6.5 (5.9-7.1)	8.0 (6.6-9.3)	6.5 (5.2-7.8)	5.2 (2.4-7.9)

309 <sup>a</sup> Marginal mean and 95% CI from ANCOVA adjusted for covariates including gender, age, BMI,  
 310 residence area, educational level, marital status.

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311 Asterisks indicate significant difference from the sitting: \*p < 0.05, \*\*p < 0.01, \*\*\* <.001  
312 Dagger indicates significant difference from the standing: †p < 0.05  
313 Double dagger indicates significant difference from the walking: ‡p < 0.05

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4 315 Hourly patterns of sedentary behavior, LPA and MVPA on four occupational activity  
5 316 types are summarized in Figure 1 for full time workers. Overall, sedentary time and LPA  
6 317 showed an inverse pattern. On work days, a notable difference was observed in the pattern  
7 318 of sedentary behavior during work hours between those with the sitting jobs and the other  
8 319 three types, while all occupational activity types showed a similar pattern after work, with  
9 320 a linear increase in the sedentary fraction until 22:00-22:59. Those with standing, walking  
10 321 and physical labor jobs constantly accounted for a larger fraction of LPA than that of  
11 322 sedentary behavior from 6:00-6:59 throughout almost of all working hours. On non-work  
12 323 days, sedentary behavior in all occupational activity types was mostly dominant from 7:00-  
13 324 7:59 to 18:00-18:59. However, the time differences between sedentary behavior and LPA in  
14 325 those with sitting jobs stayed more constant and larger than those in other more active  
15 326 jobs from 7:00-7:59 to 18:00-18:59. After 18:00-18:59 on non-work day, all types showed  
16 327 increase in sedentary time as the same with work days. All results of the part-time workers  
17 328 were presented in Table S1,2 and Figure S1.  
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26 330 INSERT FIGURE 1 ABOUT HERE  
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## 29 332 **DISCUSSION**

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31 333 This is the first study to examine accelerometer-measured patterns of sedentary behaviors  
32 334 and physical activity among Japanese workers in their work and non-work contexts, and to  
33 335 examine how these patterns differed by occupational activity type. Among full-time  
34 336 workers, sedentary time comprised more than half of the working day. Overall, those with  
35 337 sitting jobs, who accounted for 70% of this study sample, had higher amount of both total  
36 338 and prolonged sedentary time and less frequent breaks from sitting across the whole day,  
37 339 compared with those in more physically active job types. Previous studies in Western  
38 340 countries have examined the differences in objectively-measured total sedentary behavior  
39 341 among 2-19 occupation groups or sectors [18, 19] and self-reported leisure and domain-  
40 342 specific sedentary behaviors among occupational activity types [9, 20]. The present study  
41 343 extends these findings, for the first time in a non-Western country, by examining the  
42 344 differences in additional sedentary behavior measures such as prolonged sedentary  
43 345 behavior and breaks using objective measurements. The present findings suggest that  
44 346 further public health efforts focused on the worksite should be emphasized, especially for  
45 347 office-workers who are a majority of the working adult population in Japan and are an  
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4 348 apparent at-risk subgroup due to high volumes of sitting, not only at work but also in non-  
5 349 work time.  
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9 351 Among those with sitting jobs of this study sample, 63% of working day (60% of non-  
10 352 work day) were sedentary. Some previous studies conducted in Australia and the UK found  
11 353 that sedentary behavior assessed by Actigraph were 68-70% of working day of office  
12 354 workers (60-63% of non-work day)[12, 14]. Our recent comparative study of activity  
13 355 devices found that total sedentary time assessed by the Active style Pro HJA-350IT were  
14 356 proportionally 11% less time spent in total sedentary behavior than Actigraph [26]. These  
15 357 findings suggest that Japanese office-workers may spend more time in sedentary behavior  
16 358 across whole day compared with those in Western countries, which is similar to the  
17 359 previous international-comparative study examining self-reported sitting time of working  
18 360 adult population [23]. As an at-risk population considered in the international context,  
19 361 promoting effective public health strategies to reduce sedentary behavior on the worksite  
20 362 may be a necessary effort in Japan.  
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31 364 We found significant differences in overall sedentary time and number of breaks from  
32 365 sedentary time in work hours across the occupational activity types that we examined,  
33 366 especially for working hours. Full-time workers with sitting jobs spent most sedentary time  
34 367 and had less breaks from sedentary behavior than those with more active job types: these  
35 368 differences were approximately 20-30% in the proportion (2.5-4 hours) and 5-7 times per  
36 369 sedentary hours. On the other hand, these patterns on non-working hours or days were  
37 370 relatively similar although workers with sitting and physical labor jobs somewhat spent  
38 371 more sedentary along with in less LPA than those with standing and walking jobs. These  
39 372 findings may indicate that the occupational activity type, which is commonly determined  
40 373 by job requirements can have the greatest impact on overall sedentary time and patterns in  
41 374 workers' population. These findings are consistent with the only previous study from the  
42 375 Netherlands, which found all white-collar workers from financial service providers and  
43 376 research institutes had significantly greater occupational (30-35%) and total sitting time  
44 377 (10-15%) in proportion than all blue-color workers of construction company [17]. In  
45 378 addition, these findings supported those of previous studies in Australia, France, Scotland,  
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4 379 and the Netherlands, which showed that workers with higher occupational sitting time did  
5 380 not sit less, rather sat more, on their leisure time [9, 18, 19, 28]. Similar to studies  
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7 381 conducted in Western countries, the present findings suggest that further promotion of  
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9 382 worksite interventions to reduce office-workers' sedentary time along with increased  
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11 383 sedentary breaks should be prioritized on working populations in not only Western  
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13 384 countries but also in Japan.  
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15 386 Similar to the average patterns, the analysis of the accelerometer output by hour of the  
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17 387 working day showed that the pattern of sedentary behavior, LPA and MVPA were highly  
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19 388 dependent on occupational activity types during working hours (except for lunch time),  
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21 389 whereas all were similar on the evening time after work. The descriptive features were  
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23 390 observed on non-working day, especially during the daytime, across occupational activity  
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25 391 types. Even though the average sedentary and activity patterns were not distinct among  
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27 392 them, some dips in sedentary behavior along with increases in LPA were found in those with  
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29 393 standing, walking, and physical labor jobs, whereas the conditions in which sedentary  
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31 394 behavior is the most dominant stayed constant throughout a day in those with sitting jobs  
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33 395 on non-working day. The pattern of MVPA was stable and independent from those of  
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35 396 sedentary behavior and LPA in all occupational activity types. The variations in pattern of  
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37 397 sedentary behavior and LPA among occupational activity types could be partly attributed to  
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39 398 differences in socio-demographic attributes (especially gender) and sample size. However,  
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41 400 in a previous study from the UK examining the diurnal patterns of sedentary behavior and  
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43 401 physical activity among office workers grouped into tertiles based on occupational sedentary  
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45 402 time, the higher the tertile for occupational sedentary time in which office workers were  
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47 403 categorized, the more pronounced and stable the difference between sedentary behavior  
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49 404 and LPA (less crossing and reversing time points in a graph between them) became  
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51 405 throughout a non-working day [14]. These results imply that routine diurnal occupational  
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53 406 sedentary and LPA patterns, which were repeated 5 days a week, on working day may carry  
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55 407 over their leisure-time behavioral patterns as a habit. Similarly, the previous study in French  
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57 408 working adults using a self-report questionnaire found that the occupational activity levels  
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59 409 involved in jobs were negatively associated with leisure time spent sedentary, on both  
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61 409 working and non-working days [20]. Future intervention studies could help to clarify

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4 410 whether promoting breaks from sedentary time by more LPA during working hours may  
5 411 influence leisure-time sedentary behavior and physical activity. The hourly patterns for LPA  
6 412 and MVPA would also be useful to consider in relation to the timing of workplace physical  
7 413 activity interventions, which is fruitful as a future research topic.  
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12 415 This is the first study to report descriptive patterns of objectively measured Japanese  
13 416 workers' sedentary behavior comprehensively, and their relationships with occupational  
14 417 activity types. Other strengths of this study were use of population-recruited sample and  
15 418 accelerometer -assessed sedentary behavior and physical activity. There are also some  
16 419 limitations in this study. First, data were cross-sectional and therefore any causality cannot  
17 420 be inferred. Second, the present samples were selected from only two cities in Japan  
18 421 although central and average-sized local cities were chosen. Thus, the results may differ in  
19 422 other cities and areas. Third, the response rate was relatively low. Our middle-aged  
20 423 participants were recruited initially by random sampling, which may have introduced some  
21 424 sampling bias; only 10 were recruited whose jobs involved physical labor. Therefore, the  
22 425 findings may not be generalizable to the broader middle-aged worker population, in  
23 426 particular to those whose jobs involve physical labor. In other words, the relatively small  
24 427 sample size for those with physical-labor job types limits our capacity to generalize from  
25 428 those findings. Finally, accelerometers were unable to accurately differentiate sitting and  
26 429 very-static standing postures, and they cannot detect some types of physical activity such  
27 430 as cycling and water activity.  
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## 40 431 41 432 **CONCLUSION**

42 433 In summary, full-time workers involved in mostly sitting jobs had a higher volume of  
43 434 sedentary behavior with prolonged bouts on workdays, compared with other occupational-  
44 435 activity job types. The differences in sedentary patterns mainly occurred during work  
45 436 hours. There may be carry-over of sedentary and physical activity patterns in working time,  
46 437 which could influence leisure time and whole of day time spent sedentary, with potential  
47 438 for adverse health consequences. Therefore, intervention for to reduce workers' sedentary  
48 439 behaviors are needed, especially for those in office-based workplace where prolonged  
49 440 periods of sitting are required.  
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4 4415 442 **AUTHORS' CONTRIBUTION**

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7 443 Kurita and Shibata conceived the study, analyzed the data, and drafted the manuscript.  
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9 444 Koohsari and Owen assisted with analyzing data and drafting the manuscript. Ishii and Oka  
10  
11 445 were involved in the development and implementation of this study. All authors  
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13 446 contributed to the study design, interpretation of the results, and manuscript preparation.  
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15 447 All authors have read and approved the final manuscript.  
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17 448

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26  
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32  
33 457 (S1511017).  
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36 459 **CONFLICT OF INTEREST STATEMENT**

37 460 The authors declare no conflicts of interest.  
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40 462 **DATA SHARING STATEMENT**

41 463 Requests for access to data should be addressed to the corresponding author.  
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543 **Figure1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types**  
544 **among full-time workers**

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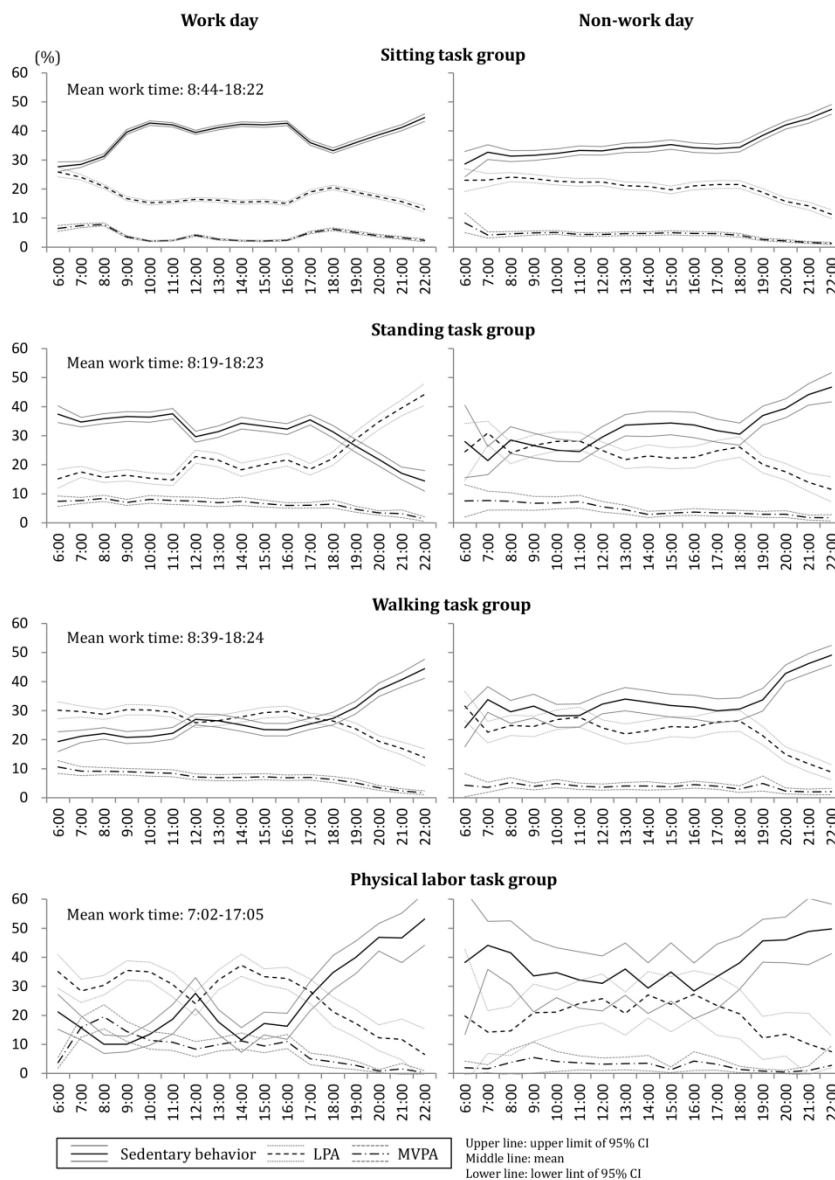


Figure 1. Hourly pattern of sedentary behavior, LPA and MVPA of four task types among full-time workers

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**Table S1. Basic characteristics for participants of part-time workers**

	All participants	Occupational task group		
		Sitting	Standing	Walking
<b>n</b>	98	35 (35.7)	35 (35.7)	27 (27.6)
<b>Age, mean(SD)</b>	51.1(7.3)	50.4 (6.8)	52.7(8.0)	49.9(6.8)
<b>Women, n (%)</b>	94 (95.9)	34 (97.1)	33 (94.3)	26 (96.3)
<b>BMI (kg/m<sup>2</sup>)<sup>a</sup>, mean(SD)</b>	21.1(2.2)	21.2 (2.3)	20.9(2.1)	21.3(2.2)
<b>Residence area, n (%)</b>				
Matsuyama city	44 (44.9)	15 (42.9)	23 (65.7)	16 (59.3)
Koto Ward	54 (55.1)	20 (57.1)	12 (34.3)	11 (40.7)
<b>Education, n (%)</b>				
High school or less	44 (44.9)	11 (31.4)	22 (62.9)	11 (40.7)
Greater than high school	54 (55.1)	24 (68.6)	13 (37.1)	16 (59.3)
<b>Marital status<sup>b</sup>, n (%)</b>				
Single	12 (12.2)	4 (11.4)	4 (11.4)	4 (15.4)
Married	85 (86.7)	31 (88.6)	31 (88.6)	22 (84.6)
<b>Occupation<sup>c</sup>, n (%)</b>				
Professional and engineering	17 (17.5)	6 (17.6)	4 (11.4)	7 (25.9)
Administrative and managerial	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Clerical	23 (23.7)	21 (61.8)	2 (5.7)	0 (0.0)
Sales	7 (7.2)	1 (2.9)	5 (14.3)	1 (3.7)
Service	33 (34)	3 (8.8)	18 (51.4)	11 (40.7)
Security	1 (1.0)	0 (0.0)	1 (2.9)	0 (0.0)
Agricultural, forestry and fishery	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Transport and machine operation	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Manufacturing process	5 (5.2)	1 (2.9)	3 (8.6)	1 (3.7)
Others	10 (10.3)	1 (2.9)	2 (5.7)	7 (25.9)

a 1 missing in standing task group

b 1 missing in walking task group

c 1 missing in sitting task group

**Table S2 Comparison of sedentary behavior and physical activity among three occupational activity types in part-time workers**

	All	Occupational activity types		
		Sitting	Standing	Walking
Mean (SD)				
<b>Wear time (hours)</b>				
All days	15.7(1.44)	15.7(1.4)	15.5(1.5)	16.1(1.5)
Work day	16.0(1.6)	15.9(1.7)	15.8(1.6)	16.3(1.7)
Work hours	6.2(2.4)	6.4(2.2)	5.9(2.5)	6.5(2.5)
Non-work hours	9.7(3.0)	9.5(2.8)	9.8(2.8)	9.9(3.7)
Non-work day	15.1(1.6)	15.0(1.2)	14.7(1.9)	15.6(1.6)
<b>Total sedentary (%wear time)</b>				
All days	47.6(9.8)	53.9(7.7)	44.7(10.3)	43.6(7.7)
Work day	45.1(11.3)	54.2 (7.9)	40.1 (10.9)	40.3 (8.4)
Work hours	36.6(23.4)	59.9 (12.6)	24.4 (19.4)	23.4 (14.3)
Non-work hours	49.8(9.7)	50.2 (8.9)	49.5 (10.8)	49.7 (9.9)
Non-work day	53.9(12.7)	53.1 (12.0)	56.4 (14.6)	51.8 (11.2)
<b>Prolonged sedentary bouts (%wear time)</b>				
All days	14.4(7.6)	15.1(8.0)	15.0(8.0)	12.7(6.4)
Work day	12.2(7.1)	14.0 (8.1)	11.4 (6.6)	10.7 (6.3)
Work hours	6.8(11.3)	12.5 (14.4)	4.3 (9.5)	2.7 (3.9)
Non-work hours	15.8(9.1)	15.4 (9.0)	15.8 (8.7)	15.8 (9.8)
Non-work day	20.0(14.3)	18.0 (13.4)	24.0 (16.4)	17.5 (12.1)
<b>Breaks per sedentary hour</b>				
All days	10.8(2.3)	10.1(1.9)	11.1(2.7)	11.2(2.2)
Work day	11.3(2.6)	10.3 (2.2)	12 (2.9)	11.7 (2.6)
Work hours	19.4(11.7)	11.6 (4.8)	24.3 (12.5)	23.1 (12.3)
Non-work hours	9.9(2.5)	9.7 (2.2)	10.2 (2.4)	9.9 (2.9)
Non-work day	9.5(3.7)	9.8 (3.6)	8.9 (4.4)	9.8 (3.1)
<b>LPA (%wear time)</b>				
All days	44.2(8.4)	39.2(6.9)	47.5(8.5)	46.3(7.2)
Work day	46.0(10.0)	38.6 (7.5)	51.5 (9.1)	48.6 (8.2)
Work hours	53.0(19.4)	35.3 (11.7)	65.4 (16.3)	59.6 (14.3)
Non-work hours	41.7(9.0)	40.4 (8.3)	42.8 (9.9)	42.1 (8.9)
Non-work day	39.7(10.2)	41 (10.4)	37.5 (11.3)	41 (8.3)
<b>MVPA (%wear time)</b>				
All days	8.1(3.9)	6.9(2.5)	15.6(3.4)	10.0(5.2)
Work day	8.8(4.6)	7.2 (2.8)	8.4 (3.8)	11.1 (6.1)
Work hours	10.4(11.1)	4.8 (3.2)	10.2 (7.2)	17 (16.3)
Non-work hours	8.4(4.2)	9.4 (4.4)	7.7 (4.3)	8.2 (3.8)
Non-work day	6.4(4.8)	5.9 (2.8)	6.2 (4.9)	7.2 (6.6)

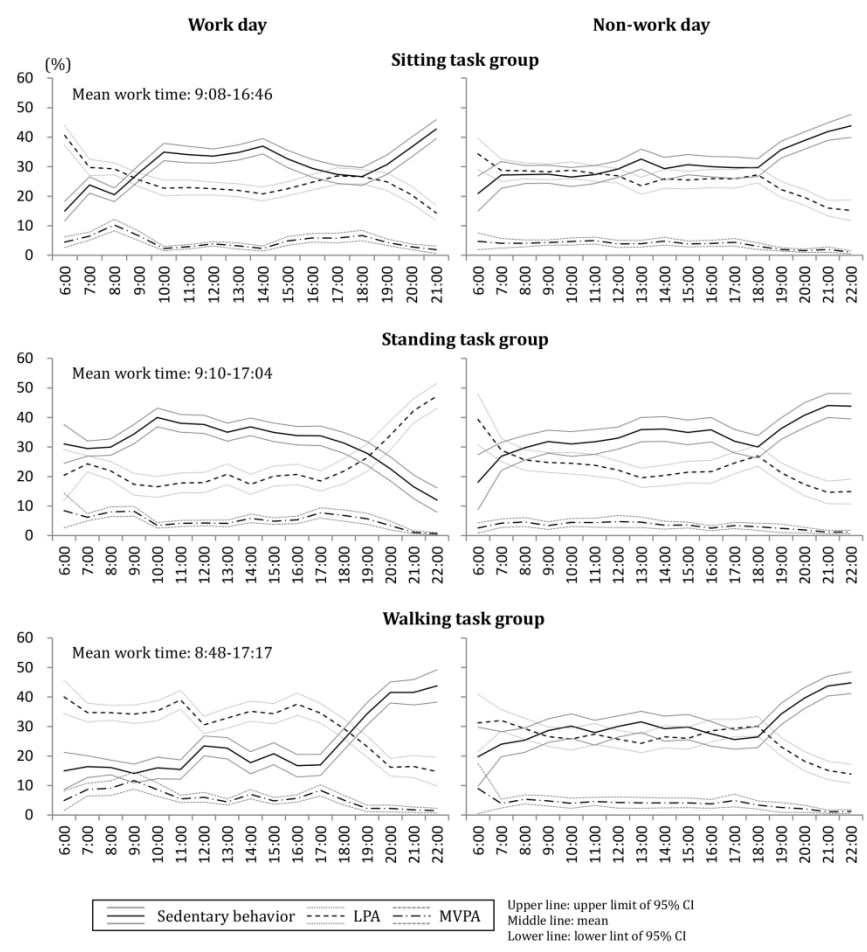


Figure S1. Hourly pattern of sedentary behavior, LPA and MVPA of three task types among part-time workers

183x255mm (300 x 300 DPI)

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	page
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	16-18
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9
		(b) Describe any methods used to examine subgroups and interactions	9
		(c) Explain how missing data were addressed	9
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	
<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy			
	(e) Describe any sensitivity analyses	N/A	

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<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7 8-9
		(b) Give reasons for non-participation at each stage	8-9
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	7,9
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11- 13
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	14- 16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).