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Original

Comparison of accelerometer-measured sedentary behavior, and light- and moderate-to-vigorous-intensity physical activity in white- and blue-collar workers in a Japanese manufacturing plant

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Abstract: Objective: The times spent in sedentary behavior (SB) and moderate-to-vigorous physical activity (MVPA) are independently associated with health outcomes; however, objective data on physical activity levels including SB among different occupations is limited. We compared accelerometer-measured times spent in SB, light-intensity physical activity (LPA), and MVPA, and the patterns associated with prolonged bouts of SB between white- and blue-collar workers. **Methods:** The study population consisted of 102 full-time plant workers (54 white-collar and 48 blue-collar) who wore a triaxial accelerometer during waking hours for 5 working days. Accelerometer-measured activity levels were categorized as SB (≤1.5 metabolic equivalents (METs)), LPA (1.6-2.9 METs), and MVPA (≥3.0 METs). A sedentary bout was defined as consecutive minutes during which the accelerometer registered less than ≤1.5 METs. Accelerometer variables were compared between white- and blue-collar workers through analysis of covariance. **Results:** During working hours, white-collar workers spent significantly more time in SB and less time in LPA than blue-collar workers (SB: 6.4 h vs. 4.8 h, 73% vs. 55% of total work time; LPA: 1.9 h vs. 3.5 h, 22% vs. 40% of total work time, $p<.001$), whereas the MVPA time was similar between the groups. White-collar workers spent significantly more SB time in prolonged sedentary bouts (≥30 min) compared to blue-collar workers. During leisure time, the SB, LPA, and MVPA times were similar between the groups. **Conclusions:** White-collar workers have significantly longer SB times than blue-collar workers during work hours, and do not compensate for their excess SB during work by reducing SB during leisure time.

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Introduction

On work days, full-time workers usually spend at least one-third of their day in the workplace[1]. Since moderate-to-vigorous physical activity (MVPA) is associated with positive health outcomes, the amount of time spent in MVPA during the work day is an important consideration for workers' health[2,3]. Moreover, research has shown that high levels of sedentary behavior (SB) are associated with chronic diseases and mortality, independent of MVPA[4,5], and that the patterns of SB (i.e. prolonged sedentary bouts and fewer breaks in SB) are also associated with deleterious cardio-metabolic health outcomes[6,7]. In addition, light-intensity physical activity (LPA) is beneficially as-

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sociated with 2 h plasma glucose levels in glucose tolerance tests, independent of MVPA[8]. Thus, information about the time spent at different levels of physical activity (i.e. SB, LPA, and MVPA), and the patterns of SB among workers will be useful for developing health promotion programs for the workplace.

Previous studies have objectively measured physical activity levels among office workers and reported that they spend longer time in SB with uninterrupted sitting during work hours; however, these studies focused solely on office workers[9-13]. It remains unclear whether there are any differences between white- and blue-collar jobs in terms of the total time spent in SB, LPA and MVPA, as well as the patterns of SB. To our knowledge, there is one study by Tigbe et al., which compared the levels of objectively measured daily activities, such as walking, standing, and sitting or lying down between postal office and postal delivery workers[14]. In that study, office staff spent 2.2 h more time in sedentary postures, and 1.7 h less time in walking than delivery staff on work days[14]. However, that study did not examine the workers' patterns of SB. Therefore, there is a lack of objectively measured, descriptive data on the duration and patterns of SB, LPA and MVPA between white- and blue-collar workers.

Here, we conducted a descriptive study to evaluate and compare accelerometer-determined SB, LPA, and MVPA levels between white- and blue-collar workers. Specifically, we examined differences between the groups in the times spent in SB, LPA, and MVPA during working and non-working hours throughout the day. Additionally, we compared their patterns of SB, including the frequency and duration of sedentary bouts.

Methods

Participants

The study participants comprised full-time employees aged 18 to 69 years at an electric machinery and apparatus manufacturing sales plant in Nagano Prefecture, Japan. The plant has six business departments: general affairs, accounting, sales, engineering, quality assurance, and production, with 152 employees in total. Two of these workers were on maternity leave, leaving 150 employees eligible for the study. There was no shift work at this plant; all employees began working at 8:25 AM and finished at 5:10 PM if overtime was not required. Two orientations explaining the study schedule and procedure were offered in July and September 2014. The data were collected from September 30 to October 6, 2014. The study protocol was approved by the Tokyo Medical University Ethics Committee prior to initiation of the study, and all participants provided written informed consent.

Occupational classifications

White- and blue-collar workers were classified using the International Standardized Classification of Occupations (ISCO-08). Prior to the study, we assigned the ten major group categories (Major Groups 0 to 9) in the ISCO-08 into white- and blue-collar occupations. White-collar occupations included managers, professionals, technicians, clerks, and sales workers, while blue-collar occupations included crafts, machine operators and assemblers, elementary occupations, agricultural and fishery workers, and armed forces. Thereafter, details of workers' tasks were assigned according to the ISCO-08 categories, and were directly inspected by the researcher through site visits accompanied by the plant manager over 3-4 h in July and September.

Measurement of SB, LPA, and MVPA

We measured SB, LPA, and MVPA times by using a triaxial accelerometer (Active style Pro HJA-350IT; Omron Healthcare, Kyoto, Japan). Participants were instructed to wear the accelerometer on their waists during waking hours for 5 consecutive work days, except during water activities, such as bathing or swimming, or during contact sports, for safety reasons. The accelerometer estimated the intensity of physical activity based on metabolic equivalents (METs). The algorithm for the prediction of METs was established by the Douglas bag method in a controlled laboratory setting[15,16]. Physical activity was classified into three intensity categories based on METs: SB (≤1.5 METs), LPA (1.6 - 2.9 METs), and MVPA (≥3.0 METs)[17-19]. The data were collected in 60-s epochs. If no acceleration signal was obtained for ≥60 consecutive minutes, the period was defined as "non-wear". Participant records were considered valid when the device was worn for at least 10 h/day. Valid records collected for ≥4 working days were included in the analyses. We calculated the mean total daily minutes of SB, LPA, and MVPA. A sedentary bout was defined as consecutive minutes during which the accelerometer registered less than ≤1.5 METs.

Covariates and sociodemographic variables

General demographic information (age, sex, weight, height, and educational attainment) and overtime hours were obtained using a self-reported questionnaire. Body mass index (BMI) was calculated as weight (kg)/height $(m)^2$.

Statistical analysis

Comparisons between white- and blue-collar workers were conducted using Student's t-test or the Mann-Whitney U test for continuous variables, and the Chi-squared test for categorical variables. For the analyses, daily accelerometer data was segmented as follows: 8:25 AM to 5:09 PM was considered working time, and 12:00 AM to 8:24 AM and 5:10 PM to 11:59 PM were defined as leisure time (i.e., non-working time). First, the mean

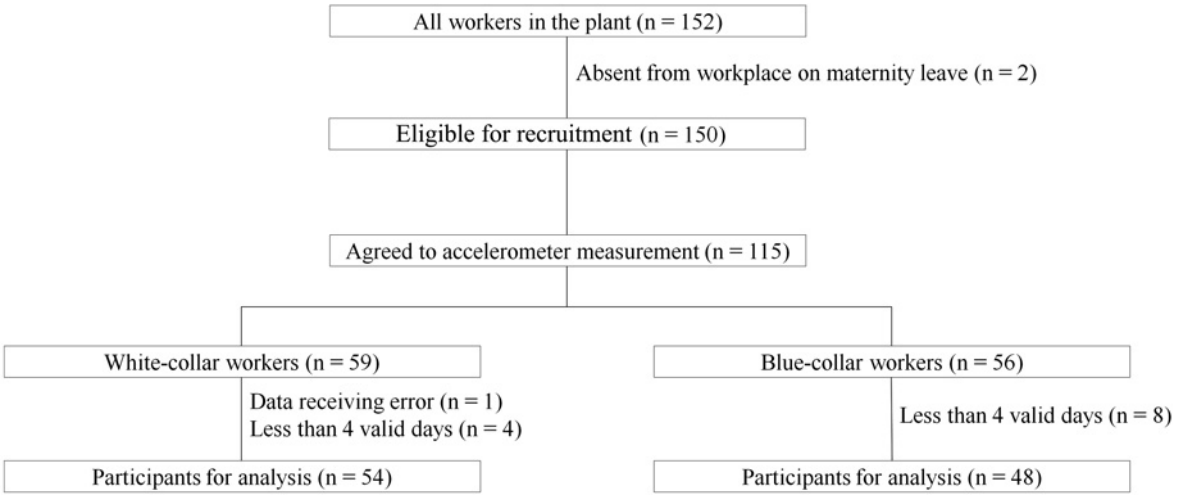

Fig. 1. Participant sampling flow chart.

Table 1. Participant characteristics

	White-collar (n = 54)	Blue-collar (n = 48)	*p*-value
Age (years)	46.5 (11.3)	43.4 (12.2)	0.18
Sex (male)	50 (92.6)	41 (85.4)	0.24
BMI (kg/m^2)	23.0 (3.4)	23.0 (2.3)	0.97
BMI category			0.80
<25 kg/m^2	43 (79.6)	40 (83.3)	
≥25 kg/m^2	11 (20.4)	8 (16.7)	
Educational attainment			<.001
High school or less	17 (31.5)	31 (64.6)	
Junior college	8 (14.8)	10 (20.8)	
University (4-year college or higher)	29 (53.7)	7 (14.6)	
Overwork time (h/month)	20.0 (22.2)	22.5 (25.5)	0.60
Accelerometer wearing time, min			
Whole day (0:00-23:59)	892 (99.5)	860 (109.4)	0.13
Working time (8:25-17:09)	524 (9.6)	524 (8.7)	0.66
Leisure time (0:00-8:24, 17:10-23:59)	368 (99.7)	336 (109.8)	0.12

Values are presented as the mean (SD) or number (%). BMI: body mass index. A whole day is from 12:00 AM to 11:59 PM; working time is from 8:25 AM to 5:09 PM; leisure time (non-working) is the sum of the periods from 12:00 AM to 8:24 AM and 5:10 PM to 11:59 PM.

times spent in SB, LPA, and MVPA were descriptively compared between white-collar and blue-collar workers before adjusting for covariates in each period (i.e., whole day, work time, and leisure time). Then, analysis of covariance was performed, adjusting for age, sex, accelerometer wear time (min/day), BMI, educational attainment, and overtime work (h/month). Sex, BMI (<25 vs. ≥25 kg/m^2), and educational attainment (≤high school vs. junior college vs. ≥university graduate) were treated as categorical variables. For all analyses, *p*-values <.05 were considered statistically significant. The statistical analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Tokyo, Japan).

Results

Participants

The participant flowchart is shown in Figure 1. Of 150 full-time employees, 115 workers (59 white- and 56 blue-collar) agreed to wear an accelerometer (response rate, 76.7%). One and four white-collar workers were excluded due to an error in downloading accelerometer data or for logging <4 valid days, respectively. Eight blue-collar workers were excluded for logging <4 valid days. The demographic characteristics of the study participants are presented in Table 1. Most study participants were male

Table 2. Differences in the times spent in SB, LPA, and MVPA between white- and blue-collar workers

	Model 1			Model 2		
	White-collar	Blue-collar	*p*-value	White-collar	Blue-collar	*p*-value
Whole day						
SB time (min)	619 (97.7)	489 (147.9)	<.001	614 (12.9)	499 (13.9)	<.001
LPA time (min)	225 (74.0)	326 (100.9)	<.001	217 (12.1)	331 (13.1)	<.001
MVPA time (min)	46 (21.9)	44 (20.0)	0.67	44 (2.9)	46 (3.2)	0.66
Working time						
SB time (min)	384 (61.6)	289 (89.6)	<.001	387 (10.4)	288 (11.2)	<.001
LPA time (min)	115 (52.2)	210 (84.3)	<.001	112 (9.5)	209 (10.3)	<.001
MVPA time (min)	24 (15.7)	25 (14.8)	0.78	24 (2.1)	25 (2.3)	0.71
Leisure time						
SB time (min)	235 (79.6)	200 (88.3)	0.04	227 (5.2)	211 (5.7)	0.04
LPA time (min)	110 (38.8)	116 (41.1)	0.48	105 (4.7)	121 (5.1)	0.03
MVPA time (min)	22 (12.5)	19 (10.9)	0.26	20 (1.5)	21 (1.7)	0.76

Values are presented as mean (SD) in Model 1, and adjusted mean (SE) in Model 2. Model 1: no adjustment. Model 2: adjusted for age, sex, accelerometer wear time, BMI category, educational attainment, and overtime work. A whole day is from 12:00 AM to 11:59 PM; working time is from 8:25 AM to 5:09 PM; leisure time (non-working) is the sum of the periods from 12:00 AM to 8:24 AM and 5:10 PM to 11:59 PM. BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate-to-vigorous physical activity.

(92.6% of white-collar workers; 85.4% of blue-collar workers). There were no significant differences between white- and blue-collar workers in terms of age, BMI, or hours of overtime work/month. White-collar workers had a higher level of education than blue-collar workers (p <.001). The accelerometer was worn for 4 valid days by 12 (22.2%) and 11 (22.9%) of white- and blue-collar workers, and for 5 valid days by 42 (77.8%) and 37 (77.1%) white- and blue-collar workers, respectively. There were no significant differences between white- and blue-collar workers in the mean daily duration of accelerometer wear (whole day: 892±99.5 vs. 860±109.4 min, p =.13; during work: 524±9.6 vs. 524±8.7 min, p =.66; and during leisure time: 368±99.7 vs. 336±109.8 min, p =.12).

Comparisons of SB, LPA, and MVPA times between white- and blue-collar workers

The times spent in each activity level are presented in Table 2, and unadjusted descriptive data are shown in Model 1, Table 2. During the whole day, white-collar workers spent more time in SB and less time in LPA than blue-collar workers (SB: 619±97.7 vs. 489±147.9 min, p <.001; LPA: 225±74.0 vs. 326±100.9 min, p <.001). The time spent in MVPA was similar between the groups (46±21.9 vs. 44±20.0 min, p =.67). During the work day, white-collar workers spent a significantly greater time in SB (approximately 100 min more) and significantly less time in LPA (approximately 100 min less) than blue-collar workers. However, the time spent in MVPA was similar between the groups (p =.78). The SB time in white-collar workers was also significantly longer than that of blue-collar workers during leisure time. Even after adjusting for age, sex, accelerometer wear time, BMI status, educational level, and overtime work, the between-group differences in SB and LPA time remained significant. However, the differences during leisure time were quite small compared to those measured during work and across the whole day (See Model 2, Table 2).

Proportions of SB, LPA, and MVPA times in white- and blue-collar workers

Figure 2 presents the percentages of accelerometer wear time spent in each PA level. White-collar workers spent a significantly higher proportion of their day in the sedentary state and spent a significantly lower proportion of their day in LPA than blue-collar workers (70% vs. 56%, p <.001; 25% vs. 39%, p <.001, respectively). Over the whole day, the time spent in MVPA was not significantly different between the groups (5% vs. 5%, p =.971) (Fig. 2A). Distinct differences were observed in the times spent in SB and LPA during the work day (73% vs. 55%, p <.001; 22% vs. 40%, p <.001, respectively), while there was no significant difference in the time spent in MVPA (5% vs 5%, p =.797) (Fig. 2B). There were slight differences in the times spent in SB and LPA during leisure time, but no significant difference in the time spent in MVPA (SB: 63% vs. 58%, p =.019; LPA: 31% vs. 36%, p =.014; and MVPA: 6% vs. 6%, p =.717, respectively) (Fig. 2C).

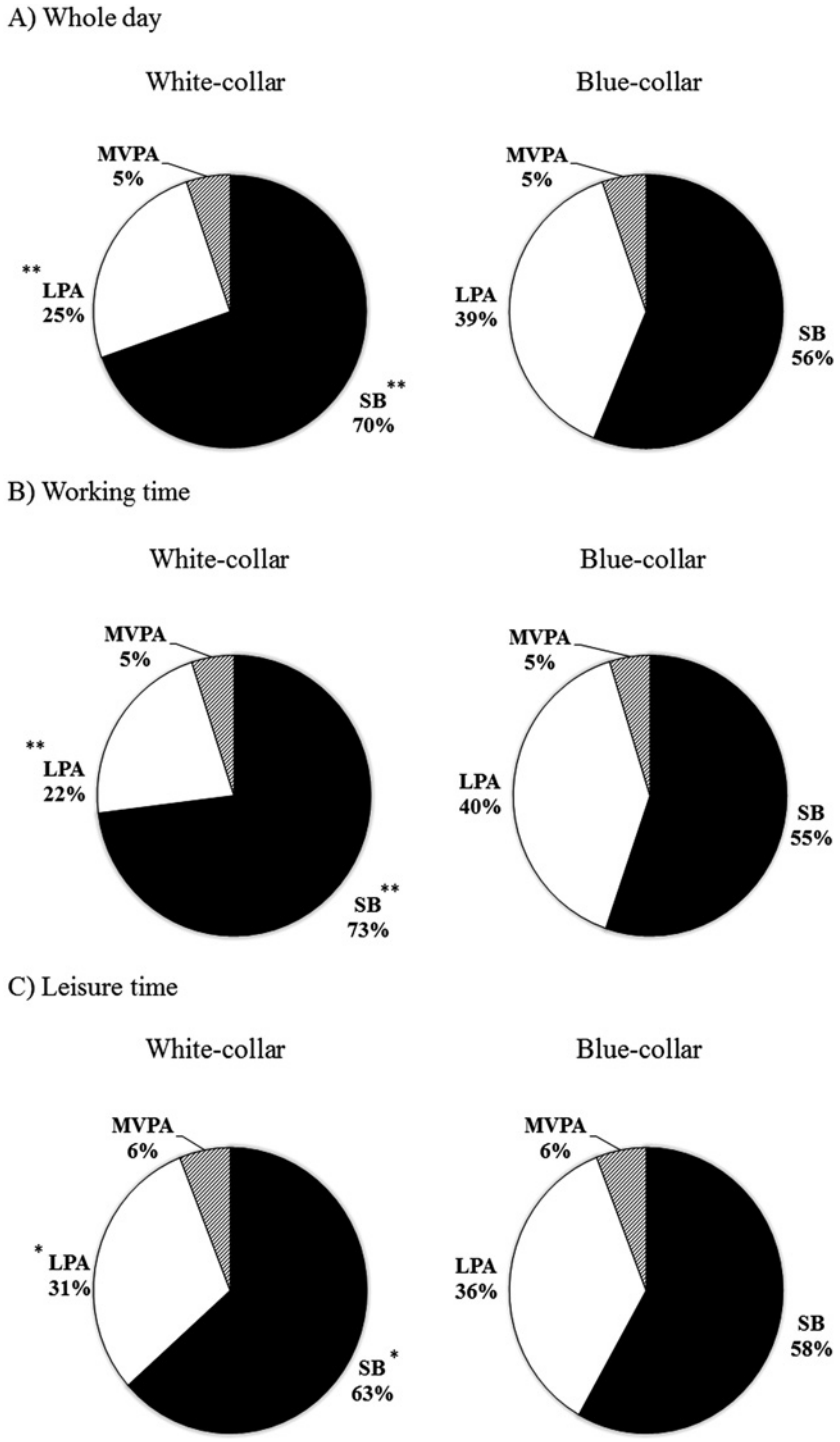

Fig. 2. Differences in the proportion of accelerometer-measured time spent in SB, LPA, and MVPA between white- and blue-collar workers. SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate-to-vigorous physical activity. *p*-values were obtained using Student's t-test (white- vs. blue-collar workers). **p*<.05, ***p*<.001.

Characteristics of sedentary bouts during work time

The median number of sedentary bouts during work was 39.1 (1st and 3rd quartiles: 33.4 - 47.5) in white-collar workers and 56.3 (47.6-64.4) in blue-collar workers (Table 3). Of all recorded sedentary bouts, the median percentages of prolonged sedentary bouts lasting ≥30 min were 8.8% (4.6-12.9%) for white-collar workers and 1.8% (0.7-2.9%) for blue-collar workers, representing

Table 3. Comparisons of sedentary bouts during work time between white- and blue-collar workers

Bout duration, min	No. of bouts/d			Percent of bouts †			Percent of sedentary time ‡		
	White-collar	Blue-collar	*p*-value	White-collar	Blue-collar	*p*-value	White-collar	Blue-collar	*p*-value
≥1	39.1 (33.4 to 47.5)	56.3 (47.6 to 64.4)	<.001	100	100		100	100	
≥5	17.2 (15.5 to 19.8)	15.6 (10.8 to 20.5)	0.14	45.3 (39.3 to 53.8)	28.6 (18.0 to 39.2)	<.001	89.3 (83.8 to 92.5)	73.7 (58.7 to 82.2)	<.001
≥10	11.2 (9.4 to 12.1)	7.5 (4.3 to 11.0)	<.001	28.7 (21.8 to 36.4)	13.0 (7.2 to 20.0)	<.001	78.6 (67.2 to 84.4)	54.0 (39.4 to 63.8)	<.001
≥20	5.6 (4.4 to 6.7)	2.1 (1.1 to 4.0)	<.001	14.6 (9.0 to 19.6)	4.0 (1.8 to 6.9)	<.001	57.5 (47.8 to 68.0)	29.8 (18.6 to 41.3)	<.001
≥30	3.5 (2.2 to 4.5)	1.1 (0.4 to 1.7)	<.001	8.8 (4.6 to 12.9)	1.8 (0.7 to 2.9)	<.001	42.3 (30.3 to 55.3)	20.2 (12.4 to 28.4)	<.001
≥40	2.1 (1.2 to 2.8)	0.7 (0.2 to 1.0)	<.001	4.8 (2.8 to 7.9)	1.2 (0.4 to 2.3)	<.001	31.6 (22.0 to 41.5)	14.5 (9.2 to 21.4)	<.001
≥50	1.2 (0.8 to 1.9)	0.4 (0.2 to 0.8)	<.001	3.1 (1.6 to 5.5)	0.7 (0.4 to 1.7)	<.001	21.8 (14.2 to 32.3)	12.5 (7.8 to 17.2)	<.001
≥60	0.6 (0.4 to 1.3)	0.2 (0.2 to 0.8)	<.001	1.5 (1.0 to 3.7)	0.4 (0.3 to 0.9)	<.001	13.9 (9.2 to 24.1)	8.7 (3.6 to 13.3)	<.001

Values are presented as the median (1st and 3rd quartiles). A sedentary bout was defined as consecutive minutes during which the accelerometer registered less than ≤1.5 METs.
† Percentage of sedentary bouts: number of sedentary bouts of n min/number of sedentary bouts of ≥1 min. ‡ Percentage of sedentary time: summed time of sedentary bouts of n min/summed time of all sedentary bouts ≥1 min. *p*-values were obtained by the Mann-Whitney U test (white- vs. blue-collar workers)

42.3% (30.3-55.3%) and 20.2% (12.4-28.4%) of the total sedentary time, respectively (Table 3).

Discussion

This study yielded four key implications for considering SB, LPA, and MVPA levels in different occupations. First, these findings demonstrate that white-collar workers spend significantly more time in SB and significantly less time in LPA than blue-collar workers during working hours and across the whole day. However, there was no significant difference between the groups in the time spent in MVPA. In other words, the difference in SB time was countered by differences in LPA during work time, rather than MVPA. Second, the times spent in SB, LPA, and MVPA during leisure time were similar between white- and blue-collar workers. Third, the most distinct differences in the proportions of time spent in SB and LPA were observed during working hours. Finally, a greater number of prolonged SB bouts (i.e., ≥30 min) were observed in white-collar workers during work time. Because occupational exposure to SB is associated with adverse health outcomes[4-7], these results have implications for developing worker health programs.

In this study, white-collar workers spent 73% of their work time in SB, compared to 55% for blue-collar workers; this was the period in which the difference in SB time (or LPA time) between white- and blue-collar workers was most pronounced. Other studies have reported similar findings on the proportion of SB in white-collar workers. Clemes et al. and Thorp et al. both used an Actigraph GT1M accelerometer and observed a large percentage of work time spent in sedentary activities (71% and 77%, respectively)[9,10]. Parry et al. used an Actical accelerometer and reported that 82% of work hours are spent in sedentary activities[11]. Although different devices and SB definitions were used in these studies, the proportion of time spent in SB by white-collar workers was similar between this study and these previous reports[9-11]. However, these previous studies did not include blue-collar workers; therefore, our study provides new and important information addressing differences in the proportion of SB between white- and blue-collar workers on work days.

During leisure time, the differences in the time spent in SB and LPA between white- and blue-collar workers were quite small, and the MVPA level was also similar. Tigbe et al. also reported no significant differences between physically active and inactive occupations in sedentary and standing times during non-work hours of working days, while times spent in sedentary, standing, and walking activities during work were all significantly different[14]. Furthermore, a study by Jans et al. using self-reported data from Dutch workers found that workers who sat for long periods during work did not compensate for their SB by sitting less during their leisure time[20].

These results support our findings that sedentary workers are not necessarily more active than non-desk-based workers during leisure time. Additionally, these findings suggest that both white- and blue-collar workers require more MVPA in their leisure time if workplace MVPA time is considered insufficient[21].

We found that during the whole day white-collar workers spent on average 2 h more time in SB than blue-collar workers (10 h vs. 8 h), similar to the values reported by Tigbe et al[14]. Healy et al. reported that a difference of 2.3 h in sedentary time is associated with clinically meaningful differences in triglyceride levels and insulin resistance[7]. Matthews et al. reported that just a 1-h increase in sedentary time causes a 12% increase in mortality risk (this increase was reduced to 5% after adjusting for MVPA time)[22]. Compared with adults who were sedentary for 6 h/day, those sedentary for 8 h/day (the amount of time blue-collar workers spent in SB in this study) had a 14% greater mortality risk. Furthermore, adults who were sedentary for 10 h/day (the amount of time white-collar workers spent in SB in this study) had a 29% greater mortality risk[22]. Our study confirmed that white-collar workers are significantly more exposed to prolonged sitting than blue-collar workers, suggesting that white-collar workers should be the predominant target group of initiatives to reduce occupational sitting. However, our results indicate that blue-collar workers also have moderate occupational sedentary exposure. Because the current guidelines regarding occupational sedentary activity predominantly target desk-based workers[23], our results suggest that blue-collar workers may not be sufficiently protected against occupational sedentary exposure.

A greater number of prolonged SB bouts were observed in white-collar workers during working hours. Thorp et al. reported that overweight/obese office workers who alternate sitting and standing every 30 min while remaining productive experience a significant reduction in fatigue levels and lower back discomfort, as well as modest beneficial effects on postprandial glucose[24,25]. Moreover, an experimental study by Dunstan et al. found that interrupting periods of sitting with even a short bout of LPA every 20 min lowers postprandial glucose and insulin levels[26]. Our results indicate that white-collar workers are more exposed to the risks of uninterrupted periods of sitting time than blue-collar workers, and that interventions are needed to prevent prolonged SB in white-collar workers. For example, a multi-component intervention combining individual, organizational, and environmental factors, including the use of sit-stand workstations, could mitigate prolonged SB[27].

This study has several strengths. First, we sampled participants across all business sectors within the studied plant, which enabled us to compare office and non-office workers. Previous studies have generally only focused on office workers[9-12]. Second, we measured SB, LPA, and MVPA levels with a validated accelerometer[15,16] rather than self-reporting. Measurement of LPA is difficult to capture through questionnaires, and recall bias may affect the accuracy of results due to the difficulty in recalling specific sitting times and durations for workers who frequently change their posture (i.e., sitting to standing, and vice versa). Third, all participants simultaneously wore accelerometers for exactly the same period of time. Since businesses may have different busy seasons, measurements of workplace SB, LPA, and MVPA may change throughout the year, even within the same business department. Finally, we classified each worker as either white- or blue-collar through direct observation in a systematic way.

Nevertheless, this study also has limitations. First, it was performed at a single plant with a relatively small sample size. Second, we designated the end of routine work at 5:09 PM, regardless of overtime hours. Although we confirmed that there were no differences between white- and blue-collar workers in the amount of overtime work per month, overtime periods could have increased the amount of SB time observed during leisure hours, especially among white-collar workers. Finally, we categorized SB, LPA, and MVPA by activity intensity measured with the accelerometer; however, the accelerometers used in this study could not measure posture. Therefore, quiet standing, which should be defined as non-SB, might have been counted as SB in this study. Quiet standing may be more frequent in blue-collar workers, therefore the SB time in blue-collar workers may be overestimated compared to that measured by using an inclinometer, which assesses both intensity and posture[18,28].

Conclusions

In the workplace, white-collar workers exhibited significantly more SB, including prolonged sedentary bouts, than blue-collar workers. Additionally, white-collar workers did not compensate for their excessive SB at work by reducing SB during their leisure time. Occupational health professionals or practitioners should be mindful that white-collar workers tend to spend more time in SB than blue-collar workers throughout a work day. Further studies are needed to evaluate the health impact of differences in SB time among occupations, and to determine the optimal length of SB time for prevention of chronic diseases among workers.

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