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Effect of Using a Sit-Stand Desk on Ratings of Discomfort, Fatigue, and Sleepiness across a Simulated Work Day in Overweight and Obese Adults

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Abstract

Background: Limited research examines the influence of sit-stand desks on ratings of discomfort, sleepiness, and fatigue. This study evaluated the time course of these outcomes over one day.

Methods: Adults (N=25) completed a randomized crossover study in a laboratory with two 8-hour workday conditions: 1) prolonged sitting (SIT) and 2) alternating sitting and standing every 30 minutes (SIT-STAND). Sleepiness was assessed hourly. Discomfort, physical fatigue, and mental fatigue were measured every other hour. Linear mixed models evaluated whether these measures differed across conditions and the workday. Effect sizes were calculated using Cohen's *d*.

Results: Participants were primarily white (84%) males (64%), with mean (SD) BMI of 31.9 (5.0) kg/m² and age 42 (12) years. SIT-STAND resulted in decreased odds of discomfort (OR=0.37 *p*=0.007) and lower overall discomfort (β =−0.19, *p*<0.001, *d*=0.42) vs. SIT. Discomfort during SIT-STAND was lower in the lower and upper back, but higher in the legs (all *p*<0.01, *d*=0.26–0.42). Sleepiness (β =−0.09, *p*=0.009, *d*=0.15) and physical fatigue (β =−0.34, *p*=0.002, *d*=0.34) were significantly lower in SIT-STAND. Mental fatigue was similar across conditions.

Conclusions: Sit-stand desks may reduce acute levels of sleepiness, physical fatigue, and both overall and back discomfort. However, levels of lower-extremity discomfort may be increased with acute exposure.

Keywords

Sedentary behavior; musculoskeletal health; physical activity; sitting/standing

INTRODUCTION

Sedentary behavior, defined as any waking behavior in a seated or reclined posture at 1.5 METs,¹ has been established as a risk factor for early mortality and other adverse health outcomes including cardiometabolic disease and musculoskeletal conditions.^{2,3} It is estimated that desk workers spend approximately 80% of their day sitting at work.⁴ Thus, replacing some of the time desk workers spend in sedentary behavior with more active behaviors could be an important strategy to improve health. Furthermore, since individuals who are either overweight or obese might be more susceptible to increased levels of discomfort,⁵ it is an important to develop interventions to improve discomfort resulting from prolonged sitting in this population.

Strategies to reduce workplace sedentary behavior and related discomfort and fatigue include walking or activity breaks and active workstations.^{6,7} Walking breaks (either indoor or outdoor) and activity breaks (e.g., resistance exercises or stretches) interrupt sitting time by performing specific activities away from the workstation, while active workstations use devices such as desk treadmills or under-desk cycles to interrupt sedentary behavior while working. All of these strategies provide reasonable approaches to increase activity and reduce sedentary behavior, however, they also present potential barriers that could limit participation. An environmental limitation to some of these strategies is the need for space to perform walking or activity breaks that are not disruptive to co-workers. Another environmental barrier could be unfavorable weather, which could hamper outdoor walking and activity breaks participation that cannot be performed inside the workspace. Other limitations may include real or perceived decreases in work productivity from having to leave the desk or to change clothes (e.g., shoes) to perform activities. Active workstations (treadmill desks and under-desk cycles) may address some of the barriers to activity breaks, but can be costly, noisy, or require significant space under and around a workstation.

Using sit-stand desks or attachments to replace sitting time with standing while allowing work to continue uninterrupted is another strategy to decrease sedentary time, and potentially, improve feelings of discomfort and fatigue. Though sit-stand workstations facilitate lower intensity activity breaks and can be costly, desktop versions can be economical and other barriers such as space, disruption to productivity and coworkers, and barriers due to wardrobe and weather are reduced as compared to other strategies. Several studies have demonstrated that using sit-stand desks can reduce total and prolonged bouts of sedentary time at work,^{8,9} but less is known about the effects of using a sit-stand desk on ratings of discomfort, fatigue and levels of sleepiness.

Physical discomfort, fatigue and sleepiness are factors that can impact quality of life and productivity at work.^{10,11} In the United States, total cost of physical discomfort, including loss of productivity, is estimated between \$560 to \$635 billion per year, which is higher than the annual cost of heart disease, cancer, or diabetes.¹² Physical discomfort, particularly lower back discomfort, is a major health problem globally that has a point prevalence of 9.4%. Low back pain also is the highest ranking cause of disability.¹³ Further, back discomfort is related to decreased quality of life and presenteeism (defined as loss of worker productivity due to illness or personal reasons).^{14,15} These are essential components of

worker productivity and satisfaction, which is important to both individual and employers. Preliminary experimental evidence suggests that sit-stand desks can reduce discomfort in working adults,^{16–18} but these studies measured discomfort retrospectively and averaged the outcomes for the entire day or week, rather than measurement in real-time and across the workday. Fatigue and sleepiness, which can be conceptually differentiated,¹⁹ are also potentially improved by using sit-stand desks; however, previous studies simply evaluated an overall fatigue score^{9,17,20} or had a limited 2.5 hour simulated work period.²¹

Therefore, we examined the acute (same day) effect of alternating between sitting and standing postures every 30 minutes in a simulated office setting and over a full workday on subjective levels of discomfort, physical fatigue, mental fatigue, and sleepiness. We hypothesized that using a sit-stand desk to change posture every 30 minutes would improve these ratings in working-aged adults when compared to prolonged sitting.

METHODS

Participants

Participants were recruited as part of a study designed to evaluate the influence of using a sit-stand desk on cardiovascular measures,²² with this study evaluating secondary outcomes of discomfort, fatigue, and sleepiness. These methods and primary results are reported elsewhere in greater detail.²² Briefly, overweight and obese (BMI 25.0 to <40.0 kg/m²) men and women (aged 20–65 years old) were recruited from the University of Pittsburgh, Oakland campus and surrounding community through posted flyers, flyers distributed via emails to university employees, and research registries. All participants were required to be inactive (<90 minutes of moderate-to-vigorous intensity exercise per week) and to not be taking any medications that could influence cardiometabolic responses (e.g., blood pressure or glucose-lowering medication). Participants also had to spend at least 20 hours/week performing desk-based work. Other exclusion criteria included a cardiovascular event in the past 6 months, atrial fibrillation, current enrollment in a weight loss program, current treatment for heart disease, cancer, end stage renal disease or any other serious condition, smoking on most days of the week, pregnant in the past 6 months or breastfeeding in the past 3 months, or any limitation to standing. These were all determined by self-report. Furthermore, participants needed to be able to complete 8 hours of their own work (job-related or school work) at a desk on two separate occasions during experimental visits in our laboratory.

Study Design and Protocol

This randomized crossover trial was conducted at the University of Pittsburgh Physical Activity and Weight Management Research Center from July to October 2016 and was approved by the University of Pittsburgh Institutional Review Board. All participants provided informed written consent prior to any data collection.

Individuals reported to the laboratory on two different occasions for simulated workdays where deskwork was completed in a continuous sitting condition (SIT) or alternating between standing and sitting every 30 minutes (SIT-STAND), in randomized order. All

conditions were directly observed by research staff for compliance to the protocol. Experimental conditions lasted approximately 10 hours and were completed at least 5 but no more than 14 days apart. During each condition (described below), participants had access to a computer with internet connection and a phone but performed personal, job-related desk-based work to increase generalizability of the results.

SIT: Participants were instructed to arrive between 7:00 and 7:30 am. Individuals were instructed to report following a 12-hour fast from food and beverages, except water, as well as a 24-hour abstention from alcohol, nicotine, and moderate-to-vigorous physical activity, but no other instructions were given to allow for normal day-to-day activities. Participant compliance with instructions was confirmed by self-report. After baseline testing and consuming a standardized breakfast (30% of daily caloric need; 55% carbohydrate, 35% fat, 10% protein), participants completed baseline questionnaires rating their sleepiness, physical discomfort, mental fatigue and physical fatigue. Participants then performed deskwork for 3 hours and 40 minutes in a seated posture. Restroom breaks were allowed ad libitum, but participants were otherwise required to remain seated. Compliance to posture and breaks was confirmed by direct observation from study staff. Following the morning work period, participants completed midday testing and consumed a standardized lunch (30% daily caloric need; 55% carbohydrate, 35% fat, 10% protein). Next, participants completed another 3 hour and 40 minute work period in a seated posture with an identical protocol to the morning session.

SIT-STAND: Participants followed the same protocol as the SIT condition with the exception that, during the work periods, they started deskwork in a standing posture and were instructed by the research staff to change posture every 30 minutes by adjusting the height of the Humanscale Float desk or QuickStand desk attachment (Humanscale, New York, NY) themselves. Direct observation by research staff ensured compliance to the protocol. The height of the desk was self-selected by the participant to be at a height that was most comfortable for the participant and with the top of the computer screen at roughly eye level. Participants were given no other instructions for standing and could shift their body weight from leg to leg or any other leg manipulation to mimic normal postural changes with standing. Like the SIT condition, participants could use the restroom when needed but were otherwise required to remain at the desk (standing or sitting).

Measurements

Demographic information was collected during the screening visit. Height and weight were assessed using a wall-mounted stadiometer and a digital scale, respectively, with shoes removed and in lightweight clothing. Both measures were recorded twice, averaged, and then used to calculate BMI (kg/m^2). Average sitting time was obtained from a single item on the Global Physical Activity Questionnaire (GPAQ),²³ which asked participants to report how much time they spend sitting on an average day.

Physical discomfort, physical fatigue, and mental fatigue were assessed at baseline and every 2 hours for a total of 6 measures. These were measured using the Physical Discomfort and Fatigue Questionnaire,²⁴ with modifications by Kar and Hedge,²⁵ which has been used in

adults to assess discomfort in office-specific tasks. This instrument uses 100mm visual analog scales that range from no discomfort/no fatigue to extreme discomfort/extreme fatigue to rate acute perceptions. Previous research has demonstrated the reliability of using 100mm visual analog scales to determine acute changes in pain.²⁶ Participants first reported on whether they had any presence of physical discomfort at the time of completing the questionnaire. If present, participants then rated discomfort on 100-point scales that ranged from no discomfort to extreme discomfort for 15 separate sites of the body. If not present, ratings of discomfort were scored as 0 for all sites. Physical and mental fatigues were assessed each by a single item, 100mm visual analog scale. Visual analog scales were measured by research staff using a ruler (in mm) and recorded as 0 to 100 points. Discomfort ratings were averaged across all sites and for specific regions as follows: 1) upper back, shoulders and neck [upper back], 2) lower back and hips [lower back], and 3) knees and lower legs [legs].

Sleepiness ratings were measured using the Karolinska Sleepiness Scale, a 9-point scale where participants rate their sleepiness over the previous 5 minutes.²⁷ This scale has been shown to be valid for assessing acute feelings of sleepiness in adult populations.²⁸ Response options range from “extremely alert” (1) to “very sleepy, great effort to keep awake, fighting sleep” (9) with higher scores indicating greater sleepiness. Ratings were obtained at baseline and every hour thereafter for a total of 8 measures.

STATISTICAL ANALYSIS

Data were analyzed using Stata 14 (Statacorp, College Station, Texas). Descriptive statistics summarized participant characteristics as means (SD) or n (%). Linear mixed models with random effects were used to evaluate the effects of time, condition (SIT-STAND vs SIT), and time x condition interactions on discomfort, fatigue and sleepiness. Since no interactions were statistically significant, only main effects of time and condition were retained in the models. All models were adjusted for order, age, and gender; differences at baseline were modeled separately as specified by Kenward and Roger for randomized crossover studies to limit potential bias.²⁹ Non-normal outcomes (discomfort, mental fatigue, physical fatigue, and sleepiness) were log-transformed prior to analysis due to right skewness of data. Odds ratios for the reporting any physical discomfort were calculated at each time point and overall. Cohen’s *d* was calculated to describe the magnitude of the condition effect by dividing the adjusted overall condition effect from the linear mixed model by the standard deviation at baseline. Interpretation of effect sizes were considered small (0.2), moderate (0.5), or large (0.8 or greater) effects.³⁰ Calculation of Cohen’s *d* was also performed to improve interpretability and comparison across multiple measures with different scales, most of which required log transformation.

RESULTS

Following screening of 158 people, 25 individuals were enrolled in the study and completed both experimental visits. The most frequent reasons for ineligibility were BMI being outside the required range (25.0 to <40.0 kg/m²; n=50) or weekly exercise 90 minutes per week (n=49). Sample characteristics of subjects completing the study protocol are presented in

Table 1. No differences were observed across conditions for the number of restroom breaks during experimental visits (SIT: 3.7 ± 1.3 ; SIT-STAND: 3.4 ± 1.7 , $p=0.142$).

Physical Discomfort

Figure 1-A displays the percentage of participants reporting musculoskeletal discomfort across the simulated workday by condition. The odds of having musculoskeletal discomfort averaged across the day were significantly lower in the SIT-STAND vs SIT condition (OR=0.37, $p=0.007$) but were not different over time (OR=1.17, $p=0.146$). Figure 1-B displays the quantitative ratings of discomfort (average of 15 sites across body) with ratings being significantly higher in the SIT vs SIT-STAND condition ($\beta=-0.19$ log-points, $p<0.001$, $d=0.42$) but with no significant effect for time ($\beta=0.03$ log-points, $p=0.062$). When examined in specific regions (Figure 2), ratings of discomfort for SIT-STAND vs SIT were significantly lower in the upper back region ($\beta=-0.28$ log-points, $p=0.001$, $d=0.27$) with no effect of time ($\beta=0.00$ log-points, $p=0.998$) and in the lower back region ($\beta=-0.38$ log-points, $p=0.001$, $d=0.42$) with no effect of time ($\beta=0.07$ log-points, $p=0.05$). However, discomfort in the legs was higher in the SIT-STAND vs SIT condition across the day ($\beta=0.19$ log-points, $p=0.001$, $d=0.26$) with no effect of time ($\beta=0.00$, $p=0.881$).

Physical and Mental Fatigue

For mental fatigue (Figure 3), participants reported similar levels over time ($\beta=0.05$ log-points, $p=0.111$) and by condition ($\beta=-0.02$ log-points, $p=0.832$, $d=0.02$). Physical fatigue (Figure 3) significantly increased over time ($\beta=0.12$ log-points, $p<0.001$) and was lower in the SIT-STAND vs. SIT condition ($\beta=-0.34$ log-points, $p=0.002$, $d=0.34$).

Daytime Sleepiness

Figure 4 displays the pattern of sleepiness throughout the day by condition. Sleepiness increased throughout the day for both conditions ($\beta=0.03$ log-points, $p<0.001$); however, this increase was attenuated in the SIT-STAND vs SIT condition ($\beta=-0.09$ log-points, $p=0.009$, $d=0.15$). Due to the condition effect largely occurring at only the last measurement of the day, a sensitivity analysis was performed removing the last time point to determine its influence over the results. The difference between conditions was slightly attenuated and became non-significant ($\beta=-0.07$ log-points, $p=0.08$).

DISCUSSION

Using a sit-stand desk to change posture every 30 minutes across a simulated work day was an effective strategy to reduce acute levels of overall discomfort, physical fatigue, and potentially sleepiness when compared to uninterrupted sitting in adults. Specifically for discomfort, individuals reported lower levels of total body discomfort when using the sit-stand desk, as compared to prolonged sitting, with the largest difference occurring later in the day. Furthermore, back discomfort, an established area of discomfort for individuals with desk jobs,³¹ was significantly improved when using the sit-stand desk as compared to prolonged sitting. Yet, reported discomfort in the lower legs was higher in the sit-stand vs. prolonged sitting condition. Sleepiness and physical fatigue increased significantly across the workday in both conditions, but increases were attenuated when using the sit-stand desk.

Mental fatigue did not differ between conditions. Taken together, these results support current recommendation to reduce sitting by 2–4 hours a day with frequent postural changes during an 8-hour workday³² to improve acute perceptions of discomfort, fatigue, and potentially sleepiness. Further, these data suggest standing is a sufficient replacement for sedentary behavior to realize these acute benefits. However, it should be noted that the effect sizes observed for all outcomes were “small” to “moderate”, so interpretation of outcomes should be done with caution. Moreover, it is unclear if these small to moderate benefits in subjective ratings (how a person is feeling) are clinically meaningful.

Our results are comparable to other studies that have demonstrated a beneficial effect of sit-stand desks on discomfort. In a laboratory-based randomized crossover trial, Thorp et al. demonstrated that a 5-day period using a sit-stand desk to change posture every 30 minutes compared to continuous sitting reduced recalled discomfort in the lower back but had no effect on the upper back or legs.¹⁷ Our intervention period (1 day vs 5 days) was shorter in length, but similarly changed posture every 30 minutes, and observed a reduction in lower back discomfort, similar to Thorp. Our results additionally indicated a decrease in upper back discomfort. The slight difference in results may stem from differences in measurement procedures and tools. Thorp et al. measured recalled fatigue and discomfort on Day 5 of the 5-day protocol, asking participants to rate average fatigue and discomfort over the previous week. Other intervention studies of greater length (e.g., 12-week) have demonstrated a similar beneficial effect of using sit-stand desks on discomfort, primarily in the lower back compared to prolonged sitting in a workplace setting.^{16,18} Our findings add to the literature that there is a potential beneficial effect of using a sit-stand desk on levels of discomfort, and specifically with our study, this effect is observed acutely over the course of a day. Daily adherence over time to alternating postures while performing desk work may be beneficial, but importantly, even one day adherence may be beneficial.

We also found that discomfort in the lower legs was higher in the SIT-STAND vs SIT condition. It is possible that our protocol of standing continuously for 30 minutes each hour over an 8-hour workday was too intense for our participants, who were inactive and not conditioned to using a sit-stand desk. This may have caused discomfort from overuse of the lower leg muscle groups. These findings might suggest that untrained individuals should begin to use a sit-stand desk in a more progressive manner, such as starting with 10–15 minutes per hour. This progressive approach would be consistent with recommendations for the adoption of other physical activity prescriptions. However, more research is needed to determine if this method would attenuate increases in lower leg discomfort that may occur with the use of a sit-stand desk.

Though increasing physical activity in the form of standing likely has a beneficial health effect, it is important to acknowledge the potential risk that could arise from prolonged standing, specifically in the occupational setting. Studies have demonstrated increased musculoskeletal discomfort resulting from occupations that require prolonged amounts of standing.^{33,34} However, the frequent posture changes (every 30 minutes) prescribed in the current study resulted in an amount and frequency of standing that was drastically less than that accumulated in studies linking increased discomfort to standing. Further research should specifically evaluate the influence sit-stand desks can have on lower leg discomfort.

Other studies have reported modest beneficial effects of using a sit-stand desk on fatigue, but these studies typically assessed fatigue with a limited frequency and comprehensiveness.^{9,17} Most relevant to our study is the previously mentioned study by Thorp et al., and their finding of the beneficial impact of using a sit-stand desk over a 5-day period vs continuous sitting on recalled fatigue. However, greater understanding of the impact of using a sit-stand desk on fatigue during the workday is important due to its potential to improve worker productivity.³⁵ Presenteeism of employees is vital for productivity at work,³⁶ and strategies that influence outcomes such as fatigue and sleepiness that directly influence presenteeism are needed. While we found an all-day reduction in physical fatigue while using a sit-stand desk, our results should be interpreted with caution because analysis of individual time points revealed that the only statistical difference between conditions occurred during the second hour of the 8-hour simulated workday. This may suggest that the benefits of a sit-stand desk reduce fatigue early in the workday, but have limited effect of fatigue and the workday progresses. The null finding for mental fatigue suggests that using a sit-stand desk does not either positively or negatively influence mental fatigue when compared to prolonged sitting.

Several mechanisms could have contributed to the findings of decreased back discomfort, physical fatigue, and sleepiness across the simulated workday in SIT-STAND vs SIT. Although we did not specifically investigate mechanisms, we hypothesize that prolonged sitting can lead to poor posture, tightening and deconditioning of musculature, and decreased blood flow.^{37–39} By using a sit-stand desk, our study employed frequent postural changes which would, for example, help to extend the hip flexors to reduce chronic anterior pelvic tilt due to tight hip flexors as well as improve posture throughout the spine.⁴⁰ Furthermore, allowing for variability in postural alignment allows for relaxation in spinal compression to reduce pain.⁴¹ Postural changes could also lead to muscle contraction, increased musculoskeletal blood pump, and increased blood flow/decreased blood pooling.⁴² Daytime sleepiness can be influenced by a compensatory insulin surge following a postprandial glucose spike that results in hypoglycemic symptoms such as drowsiness and the inability to concentrate.⁴³ Reducing the postprandial spike through increased muscle activation from standing could potentially be a mechanism for decreased daytime sleepiness.⁴⁴

Strengths of this study include the randomized crossover design, a simulated work day that increased external validity by allowing individuals to complete their own work, and repeated quantitative measurements that allowed for comprehensive analysis of study outcomes in real-time and over time. This study also tested a protocol (alternating sit/stand posture every 30 minutes) that is consistent with one current recommendation for desk workers to reduce workplace sitting.³² Lastly, the study did not exclude subjects based on the presence of pre-existing pain; thus, these results may be more generalizable to a typical office population. Limitations of the study include the acute, one-day timeframe which limits the extrapolation of the results to long-term outcomes, and a limited generalizability due to our eligibility criteria (elevated blood pressure, overweight or obese) which could have influenced results. Other factors that could limit external validity include the simulated office setting which may have limited extra movement or otherwise altered behavior. Participants were instructed to wear comfortable clothing and athletic shoes, which are not typical office attire, and this

could have potentially influenced ratings. Lastly, the current media attention on sit-stand desks and the potential benefits could have biased subjective ratings by participants towards a beneficial impact of the sit-stand desks.

In summary, using a sit-stand desk to interrupt prolonged sedentary behavior in an office setting during a simulated workday reduced discomfort, physical fatigue and potentially sleepiness. These novel findings add support to the current recommendations to reduce and interrupt prolonged sedentary behavior for desk workers. Importantly, these benefits were observable with a scalable, intermittent standing strategy, which does not remove the individual from the area immediately surrounding the work station. Future research studies should evaluate mechanisms and long-term benefits, such as sustained reductions in discomfort, fatigue, and sleepiness. Furthermore, research with this or a similar protocol should analyze the effects on worker productivity, quality of life, and health care expenditures as well as evaluating these outcomes in a field setting.

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Figure 1-

Presence and rating of overall physical discomfort across SIT-STAND versus SIT. (A) Overall effect of condition: $OR = 0.37$, $P = .01$; effect of time: $OR = 1.17$, $P = .15$. (B) Data reported are log-transformed. Overall effect of condition: $\beta = -0.19$, $P < .001$, $d = 0.42$; effect of time: $\beta = 0.03$, $P = .62$. * $P < .05$ for individual time points. ** $P < .01$ for individual time points.

Figure 2-

Rating of physical discomfort for upper back, lower back and legs across SIT-STAND versus SIT. (A) Data reported are log-transformed. Overall effect of condition: $\beta = -0.28$, $P = .001$, $d = 0.27$; effect of time: $\beta = 0.00$, $P < .99$. (B) Data reported are log-transformed. Overall effect of condition: $\beta = -0.38$, $P = .001$, $d = 0.42$; effect of time: $\beta = 0.07$, $P = .05$. (C) Data reported are log-transformed. Overall effect of condition: $\beta = 0.19$, $P = .001$, $d = 0.26$; effect of time: $\beta = 0.00$, $P = .88$. * $P < .05$ for individual time points. ** $P < .01$ for individual time points.

Figure 3-
Mental and physical fatigue across SIT-STAND versus SIT. (A) Data reported are log-transformed. Overall effect of condition: $\beta = -0.02$, $P = .83$, $d = 0.02$; effect of time: $\beta = 0.05$, $P = .11$. (B) Data reported are log-transformed. Overall effect of condition: $\beta = -0.34$, $P = .002$, $d = 0.34$; effect of time: $\beta = 0.12$, $P < .001$. ** $P < .01$ for individual time points.

Figure 4- Sleepiness across SIT-STAND versus SIT. Data reported are log-transformed. Overall effect of condition: $\beta = -0.09$, $P = .01$, $d = 0.15$; effect of time: $\beta = 0.03$, $P < .001$. ** $P < .01$ for individual time points.

Table 1.

Participant Characteristics (N=25)

	Mean $\pm$ SD or n (%)
Age (years)	42 (12)
Gender	
Male	16 (64)
Female	9 (36)
Race	
White	21 (84)
Black	2 (8)
Asian	2 (8)
Education	
High school graduate	5 (20)
College graduate	5 (20)
Post graduate degree	15 (60)
Occupational Status	
Full-time	17 (68)
Part-time	5 (20)
Student	3 (12)
Body Mass Index, kg/m²	31.9 $\pm$ 5.0
Sitting Time, hr/day	9.8 $\pm$ 3.7