Research Article

The Effects of Changes in Workplace Environment on Sedentary Behavior and Work Efficiency: A Natural Pre-Post Study

Jiameng Ma¹ , Dongmei Ma^{1,2} , Qiang Wang³, Hyunshik Kim^{1,4*}

¹ Faculty of Physical Education, Sendai University, Miyagi, Japan.

² Department of Medicine and Science in Sports and Exercise, Tohoku University Graduate School of Medicine, Sendai, Japan.

³ College of Sports Science, Shenyang Normal University, Shenyang, China.

⁴ Advanced Research Center for Human Sciences, Waseda University, Saitama, Japan.

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ABSTRACT

Objectives: The workplace environment has an influence on the physical well-being of workers and their productivity. This study examined how sedentary time and work efficiency changed before and after an intervention to improve the ergonomics of a workplace environment.

Methods: This study was designed as a natural pre-post study. Workers were evaluated 101 (77% men, mean [SD] age=44.6[9.8] years) after the intervention. The intervention included the addition of sit-stand desks, fitness rooms, and rest areas at the workplace. The effect of the intervention was assessed after a period of three months. Sedentary behavior and physical activities were evaluated using triaxial accelerometers, body fat percentage and fat-free mass were calculated from body composition, and work engagement and work performance were evaluated through questionnaires. T-tests were used to compare the differences.

Results: The percentage of time spent sitting decreased post-intervention (-1.7, 95% CI: -0.4, -3.1). Work performance compared to either three months pre-survey increased significantly post-intervention (Most workers assessment: 0.4, 95% CI: 0.8, 0.3; Self-rated performance the past year or two: 0.4, 95% CI: 0.6, 0.4; Self-rated performance the past 4 weeks: 0.3, 95% CI: 0.6, 0.3). Work engagement improved significantly in terms of vigor at work (0.8, 95% CI: 1.1, 0.5), dedication to work (0.8, 95% CI: 1.1, 0.7), and absorption in work (0.7, 95% CI: 1.1, 0.5).

Conclusions: Improving a workplace environment using existing facilities decreased sedentary time and enhanced work efficiency—these findings are useful for workplace health promotion and public health policies.

INTRODUCTION

Environmental changes can be introduced to promote health and ensure long-term and persistent changes in behavior. This further enables population-based promotion of healthy behavior. Adults spend a considerable time at work; hence, there are many intervention opportunities for health promotion in workplaces, and these may exert

a significant influence on changing their behavior. That is, workplaces are important spaces for health promotion [1].

Many people, especially those in developed countries, primarily sit while they work and thus tend to spend more than half of their working hours sitting down [2,3]. Considering that sedentary behavior (SB) has been identified as a risk factor—notably, epidemiological studies on the relationship between SB and disease have reported that SB increases risks of obesity [4], diabetes [5], and circulatory system diseases [6]—analyzing the relationship between SB in workers and health risks is important for future public health policies pertaining to the workplace. Responding to such findings, Australia has completed focused research on SB and published preventative health guidelines. These

*Correspondence: Hyunshik Kim, Faculty of Physical Education, Sendai University, 2-2-18 Funaokaminami, Shibata-machi, Miyagi-ken, Japan.

E-mail address: hs-kim@sendai-u.ac.jp

guidelines strongly advise people to decrease the time spent sitting while working, to avoid being overweight, and to address issues like obesity, type 2 diabetes, and coronary artery diseases, which have been exhibiting steep rising curves [7].

In Japan, an average worker spends eight to nine hours per day sitting at work. An international study that compared sedentary time on weekdays in adults in twenty countries [8] reported that Japanese adults spent a median of 420 minutes per day being sedentary—this rate is higher than that of any other country. The negative impact of long sedentary periods on both work and health indices has recently gained attention in Japan [9].

The workplace environment is associated not only with health but also with work performance, productivity, and motivation [10]. It has been observed that an active workplace environment leads to higher work engagement, better mental and physical health, and higher productivity [11]. Work performance and productivity are important predictors of work-related happiness and are also associated with missed workdays, burnout syndrome, and early retirement [12–14].

Studies have suggested that the Japanese work for long hours even though their productivity is low [15]. Moreover, a cross-sectional study on Japanese workers showed that people in their twenties and thirties who spent a lot of time sitting displayed low work efficiency; similarly, a significant correlation with low work engagement was seen in those in their forties and fifties [16]. Based on these findings, the Japanese Ministry of Health, Labor and Welfare established “work style reform” and, relatedly, the “Act on the Arrangement of Related Acts to Promote Work Style Reform,” in 2019 [17]. Additionally, the Ministry has stated that workplace environments should be improved to maintain and improve employee health and productivity. Interventional studies that directly improve workplace environment or use behavioral interventions to decrease SB at work are garnering interest in Japan [17].

Notably, the most commonly used environmental intervention is the introduction of sit-stand desks or workstations [18] where the user can easily transition between sitting and standing depending on his or her height and purpose [19]. In a six-week intervention study in which high desks were used at work, a significant increase was reported in moderate and high-intensity physical activity in the intervention group as compared to the control group [20]. Similarly, new ideas regarding the layout and design of workplaces have also led to improved decision-making to promote exercise and physical activity [21,22].

Meanwhile, another study reported that long working hours have a negative impact on psychological health and lead to reduced work efficiency [23]. As most companies in Japan have long working hours and the productivity of workers is low, creating a work environment that promotes psychological and physical health should be prioritized. However, few studies have investigated the influence of workplace environment interventions on SB and productivity. In response to this gap in knowledge, this study reviewed

the impact of an improved workplace environment on sedentary time and productivity.

MATERIALS AND METHODS

Study Design and Participants

This study was conducted at a branch of R company in Miyagi prefecture in northeast Japan. According to the National Health and Nutrition Survey (NHNS), 30% of the adult population from Miyagi prefecture are obese with body mass index (BMI) over 25. This region has the highest number of patients with metabolic syndrome in the past 8 years in Japan [24]. As part of an industry-university collaboration, the university-affiliated R company, which has participated in employee health promotion projects in the past, was selected as the company to be surveyed. We explained the purpose of this research project to 140 employees from the R company, all of whom consented to participate. From these employees, 127 full-time workers (i.e., workers who complete more than eight hours of work per day on weekdays) without disease and between the ages of 20–59 consented to participate. To evaluate physical activity and SB, triaxial accelerometers were used.

Demographic information and work performance data were collected through questionnaires. Evaluable data from accelerometers, body composition analyzers, and questionnaires were used for the study. Participants who disclosed their answers to others or dropped out were excluded. Finally, data from 110 (86.6%) participants before the intervention and 101 (79.5%) after the intervention were eligible for analysis. This study was designed as a natural pre-post study. The intervention took place over three months between June and September 2018, and the data for analysis were collected before and after the intervention. In addition, the study was conducted after obtaining approval from the institutional review board of Sendai University (Approval No. 27-6). The purpose, benefits, disadvantages, risks, and disclosure of data associated with the measurements and analyses were explained to the participants prior to obtaining their consent to participate.

Intervention

The specific interventions used for this project were automated sit-stand desks, stride markers, and the arrangement of fitness rooms and rest spaces. In particular, for the purpose of increasing work efficiency, subjects had free access to all these intervention items without any limits on usage time. Figure 1 present the environmental changes introduced along with the intended goals.

Measures and Outcome Criteria

The survey of demographic variables included questions on gender, age, and employment status. Surveys were conducted for two age brackets: twenty- to thirty-nine-year-olds and

Items	Goal	Explanation
<p>Automated sit-stand desks</p>	Decrease sedentary behavior and improve work efficiency	The height of automated sit-stand desks could be adjusted for different purposes. There were two elevated desks that could be used by up to eight people each and six elevated desks that could be used by one person. These desks were placed in open spaces for meetings or small group discussions in lieu of existing chairs and desks. Multiple sit-stand desks were also placed in open spaces and personal spaces for personal use.
<p>Stride markers</p>	Increase physical activity and improve health awareness	Stride markers were introduced so that employees could measure their stride length. The average stride length of people of different heights and genders were marked on hallway floors. Increasing stride length leads to increased energy consumption and awareness of the importance of walking.
<p>Fitness room</p>	Increase muscle strength; fatigue recovery	Smoking rooms were refitted as fitness rooms to encourage workers to exercise and relax after long sitting hours, thus helping them to increase muscle strength and promote psychological and physical rejuvenation. The fitness room offered facilities for stretching and simple muscle training. The room also had posters that taught simple shoulder and back stretching exercises and included pull-up bars and other exercise equipment.
<p>Spaces for rest</p>	Refresh the mind and increase work efficiency	Rocking chairs and bright colored chairs and sofas were placed in the cafeteria for this purpose. Workers could enjoy a cup of coffee or other drinks here.

Figure 1. Changes in environmental items, goals, and explanations.

forty- to fifty-nine-year-olds. Based on level of education, participants were placed into two groups: those with at least a four-year degree and those with at most a two-year degree. Meanwhile, based on occupation, participants were placed into two groups: sales/service workers and office workers.

Health indices were measured using a body composition analyzer (InBody470, Tokyo, Japan). Measurements included weight, BMI, body fat percentage, and fat-free mass. To evaluate SB and the amount of physical activity, a triaxial accelerometer (Active Style Pro HJA-750C, Omron Health Care Co., Ltd. Kyoto, Japan) was used. The participants were asked to wear an accelerometer on their waist for ten working days from the time that they woke up until they went to sleep, except when they were taking a shower or swimming. This device stores synthetic acceleration using a measurement range of ± 6 G and a resolution of 3 mG. Moreover, it is also capable of precisely measuring SB [25,26]. If the accelerometer value remained at 0 for twenty minutes or longer, then it was assumed that the participant was not wearing the accelerometer. In terms of physical activity, the triaxial accelerometer measured sedentary time (≤ 1.5 metabolic equivalents (METs)), light-intensity (1.6–2.9 METs), and moderate and vigorous physical activity (3 METs or above); these measures were evaluated every ten seconds. To measure SB and

physical activity per day, the data were extracted when the participants wore the accelerometer for six hundred minutes or more per day over a period of four days [27].

Next, we considered work-related outcomes. To measure work engagement, this study used the Japanese version of the Utrecht Work Engagement scale (UWES-J) [28]. The scale has three dimensions: vigor (characterized by high levels of energy and mental resilience while working), dedication (being strongly involved in one's work and experiencing a sense of significance and pride), and absorption (being fully concentrated and happily engrossed in one's work). The internal validity of the scale is sufficiently high ($\alpha = 0.92$) and the test–retest reliability with an interval of two months is 0.66 [28].

The simplified UWES-J has nine items, which are answered on a 7-point Likert scale. The total score (range 0–54) is divided by the number of items and the mean score per item is evaluated as the work engagement score [29]. To estimate work performance, the study used a part of the Health and Work Questionnaire, which is known to have good reliability [30]. Work performance was assessed on a scale of 1 (worst ever) to 10 (best possible) with the following question: “On a scale from 0 to 10 where 0 is the worst performance a person could have at your job and 10 is

the performance of the best worker, how would you rate the performance of most workers in a job similar to yours?” and “How would you rate your job performance in the past year or two?” and “How would you rate your overall job performance on the days that you worked in the past four weeks (twenty-eight days)?”

Statistical Analysis

A percentage of each category was calculated for demographic variables. The mean was calculated for health outcomes, sedentary periods, and physical activity time based on the accelerometer and work performance. The pre-intervention data and the post-intervention data were compared to determine the changes in outcome. Paired-sample t-tests were performed to determine significant changes in accelerometer data for physical activity and SB. These indicated a mean change in number of minutes and a mean change in the time spent during a working day compared to pre- and post-intervention to achieve health-related outcomes, sedentary time, physical activity, and work-related outcomes. A statistical significance level of $p < .05$ was used for all factors; SPSS 25 software was used for analyses.

RESULTS

The pre-intervention survey was conducted with 110 participants. After the intervention, two of the participants dropped out and seven were excluded because of errors in accelerometer data. Consequently, data from 101 participants were used for the post-intervention analysis (91.8 % of pre-intervention participants analyzed). The mean age of the participants was 43.0 ± 9.8 years in the pre-intervention group and 44.2 ± 9.9 years in the post-intervention group.

In the pre- and post-intervention data, 80.9 % and 77.2 % of the participants, respectively, were males, and 33.6 % and 29.7 %, respectively, were between 20 and 39 years of age. In terms of education, 62.7 % of the pre-intervention participants and 62.4 % of post-intervention participants

had four-year college degrees or higher. In terms of work profile, 48.2 % and 46.5 % of the participants in the pre- and post-interventions, respectively, were office workers (Table 1). Physical activity time, SB, health outcomes, and work-related outcomes were compared pre- and post-intervention to determine the differences. No clear differences were found in terms of light, moderate, and high-intensity physical activities, number of steps, and total sedentary time. From the accelerometer data, the percentage of sedentary time showed a significant decrease from 58.0 percent pre-intervention to 56.3 percent post-intervention ($p = 0.011$).

Regarding health-related outcomes, BMI, body fat percentage, and fat-free mass did not change significantly post-intervention; however, a significant decrease in body weight was noted post-intervention ($p = 0.039$).

With respect to work performance measures, higher scores (range 0-10) indicated improved self-perceived work performance. The mean scores for the following items increased significantly. The mean score for the item “I can work better than other people,” was 5.7 pre-intervention and 6.1 post-intervention ($p = 0.035$). The mean score for the item “evaluation of self as compared to one year ago” was 5.9 pre-intervention and 6.3 post-intervention ($p = 0.026$). The mean score for the item “evaluation of self as compared to four weeks ago” was 5.9 pre-intervention and 6.2 post-intervention ($p = 0.030$).

Work engagement scores also improved significantly. The mean score for the item “vigor at work” was 2.31 pre-intervention and 3.12 post-intervention ($p < 0.001$), whereas mean score for the item “dedication to work” was 3.26 pre-intervention and 4.11 post-intervention ($p < 0.001$). The mean score for the item “absorption in work” was 2.42 pre-intervention and 3.19 post-intervention ($p < 0.001$) (Table 2).

DISCUSSION

This study evaluated how changes in the workplace environment influenced the physical health and productivity of workers. This was the first study in Japan

Table 1. Characteristics of the participants.

	Pre-intervention (n=110)		Post-intervention (n=101)	
	N	(%)	N	(%)
Sex (%)				
Men	89	(80.9)	78	(77.2)
Women	21	(19.1)	23	(22.8)
Age (%)				
20-39 years	37	(33.6)	30	(29.7)
40-59 years	73	(66.4)	71	(70.3)
Education level (%)				
4 years of university or higher	69	(62.7)	63	(62.4)
2 years of college or less	41	(37.3)	38	(37.6)
Employment status (%)				
Office clerk	42	(41.6)	45	(40.9)
Sales (services)	59	(58.4)	65	(59.1)

Table 2. Differences in pre-intervention and post-intervention physical activity and sedentary, health, and work-related outcomes.

	Pre-intervention	Post-intervention	Mean Change (95% CI)	<i>t</i>	<i>P</i> -value
Physical activity and sedentary outcomes					
LPA, min/work day ^a	223.2 (61.8)	229.1 (56.6)	5.9 (-4.4, 16.0)	1.132	0.260
MVPA, min/work day ^b	85.2 (22.9)	87.8 (25.9)	2.6 (-6.6, 1.4)	-1.276	0.205
Steps, steps/workday	8616 (2725)	9076 (2956)	460 (-989, 69)	-1.724	0.088
Sedentary time, min/work day	416 (77)	408 (72)	-8.0 (-4.2, 19.3)	1.267	0.208
Wear time, min/work day	718 (118)	725 (85)	7.1 (-23.6, 9.4)	-0.857	0.939
Sedentary time of ratio, min/work day ^c	58.0 (6.5)	56.3 (7.6)	-1.7 (-0.4, -3.1)	2.601	0.011
Health outcomes					
Weight (kg)	67.3 (12.3)	67.0 (12.2)	-0.3 (0.0, 0.5)	2.092	0.039
BMI (kg/m ²)	23.4 (3.2)	23.3 (3.2)	-0.1 (-0.3, 0.3)	-0.622	0.837
Body fat percent (%)	23.4 (5.8)	23.5 (5.8)	0.2 (0.5, 0.3)	-0.622	0.535
Fat-free mass (kg)	48.7 (8.5)	48.8 (8.7)	0.1 (0.6, 0.4)	-2.449	0.762
Work-related outcomes					
Most workers assessment ^d	5.7 (1.5)	6.1 (1.5)	0.4 (0.8, 0.3)	-2.146	0.035
Self-rated performance the past year or two ^e	5.9 (1.4)	6.3 (1.4)	0.4 (0.6, 0.4)	-2.262	0.026
Self-rated performance the past 4 weeks ^f	5.9 (1.5)	6.2 (1.4)	0.3 (0.6, 0.3)	-2.210	0.030
Vigor ^g	2.3 (1.4)	3.1 (1.8)	0.8 (1.1, 0.5)	-5.447	<0.001
Dedication ^h	3.3 (1.4)	4.1 (1.6)	0.8 (1.1, 0.7)	-6.424	<0.001
Absorption ⁱ	2.4 (1.4)	3.2 (1.7)	0.7 (1.0, 0.5)	-6.604	<0.001

^aLight physical activity; ^bModerate-to-vigorous physical activity; ^cRatio of wear time in sedentary time; ^dWork-performance, self versus most workers;

^eWork-performance, my own job rating of the past year or two; ^fWork-performance, my own job rating of the past 4 weeks; ^gWork-engagement, vigor;

^hWork-engagement, dedication; ⁱWork-engagement, absorption.

that used this design and evaluated sedentary time and physical activity using accelerometers. We found that sedentary time during the workday decreased and job performance improved post-intervention as compared to pre-intervention.

There were 110 participants and 101 participants pre- and post-intervention, respectively. Those who did not meet the selection criteria were excluded. It was observed that the time spent on low-intensity activities was less than that spent on moderate and vigorous intensity activities as compared to data from other studies using the same accelerometers [20]. The average number of steps per day was between 8616 to 9076, thus satisfying the recommended daily average of 8000 steps as per the guidelines on physical activity [31]. The mean sedentary time on an average working day was between 416 to 408 minutes, which is slightly lower than what was reported in previous studies [9]. Compared to previous studies, the overall activity level of the participants in this study was higher and they spent less time sitting, indicating that they were relatively more active. This could also be attributed to the fact that 60 % of the study participants worked in the sales department, which would have increased physical activity while at work.

Regarding health-related outcomes, the mean BMI, body fat percentage, and muscle mass of the participants were within the standard ranges, indicating that they were relatively healthy. For the three items used to evaluate work performance, the mean scores for work performance

compared to other workers were 5.7 and 6.1, and the mean scores for work performance in comparison to one year and four weeks ago were 5.9 and 6.3 (higher scores indicate higher work efficiency). In a previous study of Canadians, the mean score for work performance evaluated using the same scale was 7.1 to 7.3 [32]. The mean score for work performance for participants in this study was lower, but it was not clear not be due to fact differences in objective productivity or cultural factors affecting self-reported score. In terms of work engagement, the mean scores pre- and post-intervention were 2.31 and 3.12 for vigor, 3.26 and 4.11 for dedication, and 2.42 and 3.19 for absorption. In a study that investigated work engagement in sixteen countries, the mean score in the US was 6.03 while in Japan it was 3.52. Japan's score was significantly lower than those of other countries. A possible reason for this could be a negative response due to cultural bias [33]. The scores clearly indicate that the work engagement of the participants was very low.

Upon comparing the pre- and post-intervention scores, it was observed that the percentage of total sitting time spent per day reduced significantly. Notably, sit-stand desks were used with the intent to decrease sedentary time. Although it was not possible to provide these desks for all participants, personal sit-stand desks for shared use and for meetings were made available. The shared desks were easily accessible compared to the desks used previously and were user-friendly, facilitated communication, and could be easily moved. These personal sit-stand desks were

placed in the open areas and personal spaces and could be used for various purposes. It is important to note here that an ecological model of sedentary behavior identified embarrassment as a relevant factor in sociocultural environments [34]. Specifically, embarrassment stemming from standing while others were sitting down was an obstacle in the usage of these desks. The availability of these desks in personal spaces could have addressed this and increased the time spent standing while at work.

Moreover, fitness rooms and stride marker were introduced to improve InBody-measured indices and to increase physical activity. Fitness rooms were in closed areas and the roads to health were made in open hallways for convenient access and use. These fitness rooms were converted from smoking rooms as part of implementing a smoke-free policy at the company; however, no clear effects of the intervention were observed. Although the fitness rooms were in easily accessible places to ensure that they adequately served the purpose, only body weight decreased post-intervention as compared to pre-intervention, with no changes in BMI, body fat percentage, muscle mass, or physical activity. Previous interventional studies that used sit-stand desks or educational intervention to decrease SB at work reported that the effects of environmental intervention in the workplace on body composition were limited, suggesting the need for approaches that also increase physical activity during time spent on leisure activities [35,36]. This type of approach may be effective in improving perception regarding health and may decrease sedentary time at work. Future research might focus on promoting active leisure activities and monitoring the long-term effects of such interventions.

Work performance and engagement were used as the criteria to evaluate work efficiency. Lower work engagement may lead to lower happiness and reduced performance [37]. Previous studies have suggested that efforts to improve work organization can have a positive impact on work-related outcomes, particularly on missed workdays [38]. Another study on improvement of workplace environments suggested that moving to new buildings, changing old stairs to glass-encased open staircases, and using sit-stand desks decreased sedentary time at work but did not lead to any significant changes in work performance [32]. For this study, spaces to rest were set up for participants to refresh themselves, improve their satisfaction with workplace environment, and increase productivity. Hanging chairs are visually refreshing due to their bright colors and can refresh the mind and body. Also, the sit-stand desks in the open spaces for meetings may have promoted communication between workers, thus serving as places that provided enjoyment and motivation for new tasks and improving work efficiency.

This study has a few limitations. First, initiatives were taken to improve the workplace environment to promote health and work efficiency, and these were freely available for everyone without limit on the number or frequency of use; actual usage was not tracked in this study. As a result,

although the correlation with the impact on the evaluated outcomes (sedentary time and work efficiency) could be explained to a certain extent, how each factor influenced different outcomes specifically could not be assessed. Second, since moderating variables, such as personal characteristics and leisure activities, were not considered in the analysis. Finally, since this study does not have a control group, on the contrary, the comparative investigation on the effect of intervention cannot be performed. Also, since the statistical analysis with t-test has a strong power of a test for the effect size. The results have to be interpreted cautiously. Despite these limitations, the study found that an improved workplace environment decreased the percentage of sedentary time, weight-loss and improved work efficiency. The study thus provides valuable research findings [38], especially considering the scarcity of studies that evaluate the influence of workplace interventions on work-related outcomes, such as productivity and performance. Also, the environmental interventions were implemented after three days of pre-intervention measurements. For most studies investigating improvement in workplace environments, large-scale improvements require a great deal of time, labor power, and costs and therefore are often difficult to implement. The interventions in this study did not require large-scale renovations or structural changes to the building and were easily implemented within the existing facilities, thus reducing the required time and costs. These relatively low-cost interventions were found to be helpful in decreasing sedentary time and improving work efficiency, indicating that readily achievable environmental improvements at work can lead to a positive change for workers. The findings of this study are expected to contribute to policies formulated for creating healthy working environments.

CONCLUSIONS

This study reviewed changes in SB and physical activity, measured with triaxial accelerometers, as well as other health- and work-related outcomes before and after workplace environment interventions. Notably, the percentage of sedentary time and weight-loss decreased while work engagement and performance improved post-intervention compared to pre-intervention. We hope that future studies will expand our knowledge of this phenomenon, such as by elucidating the effect size of individual interventions on physical and psychological factors, and that the findings will be used to introduce health-promotion policies at work.

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Conflicts of Interest

The authors declare no conflict of interest.

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