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Association of the usage of height-adjustable desks with physical activity and sitting behavior in employees

Takashi Jindo[1), Mitsuru Makishima[2), Naruki Kitano[1),
Kyosuke Wakaba[1), and Yuko Kai[1)

SUMMARY

Installation of height-adjustable desks (HAD) are recommended to reduce sitting behaviors in the workplace. However, it is still unclear whether standing desk work using the HAD could decrease sitting time and increase physical activity (PA) during in-office working hours. This study aims to investigate the association of the usage of HADs with objectively measured sitting behaviors, or PA, among Japanese employees.

This study was conducted in Tokyo in November 2018 at a single office of an office furniture manufacturing and sales company. Participants included 90 employees that completed a self-reported questionnaire survey and wore a tri-axial accelerometer to measure PA and sitting time (ST). In the target office, electric HADs were installed on hot-desking spaces, and fixed seats which were available for all employees. Participants were divided into two groups of users or non-users of HADs based on their responses to the questionnaire. Independent t-tests were applied to examine the differences in ST and PA between HAD users and non-users for participants stratified by job type (sales work or other office work).

Among the office workers, users showed less ST and greater PA (ST: 377.4 ± 51.7, PA: 142.6 ± 51.7 min/8.67-hours) than non-users during working hours (ST: 412.0 ± 42.6, PA: 108.0 ± 42.6 min/8.67-hours), and greater non-locomotive activities (99.7 ± 45.1 min/8.67-hours) than non-users (67.1 ± 29.1 min/8.67-hours). HAD users showed fewer bouts of prolonged ST (consecutive ST for 30 minutes or longer) than non-users (1.2 ± 0.8 vs. 1.8 ± 0.6 time/8.67-hours). There were no significant differences observed between the two sales groups.

These results suggest that working in a standing position using an HAD effectively improves ST in office workers. On the other hand, using an HAD might enhance non-locomotive activities, such as standing or posture adjustments at or around the desk, but it may not enhance locomotive activities.

Key words: sit-stand desk, office environment, occupational health, locomotive activities.

Introduction

Previous studies have reported that too much sitting is associated with deterioration of physical and mental health[6,11,16)], and office workers are known to sit for more than half of their working hours[10,14)]. Therefore, improving sitting behaviors is an important issue for modern company management. As a strategy to improve sitting time (ST) at workplace, the installation of height-adjustable desks (HADs) in offices is recommended[2)]. Previous systematic review of workplace intervention strategies reported that HAD installation effectively reduced ST by around 73 minutes per 8-hour workday, and that the effectiveness of an HAD intervention on ST was greater than other educational or behavioral interventions[3)].

Limiting ST at an office by using an HAD results in an increase in time spent standing, which is considered

1) Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Tokyo, Japan.
2) Workstyle Research Laboratory, Okamura Corporation, Tokyo, Japan.

to be non-locomotive physical activity (PA). Moreover, by standing more often in an office environment, employees may increase their walking activity in the office, which is also considered locomotive PA. A previous study[12] investigated the differences in self-reported duration of walking at work between three groups of monthly, weekly, and daily HAD users, and reported that daily HAD users seemed to have longer walking time (3.2 hours/week) than monthly or weekly users (2.2 to 2.3 hours/week). However, a systematic review of seven studies (one subjective and six objective activity measurement) reported that there was no significant effect of the installation of an HAD on walking time in office workers. The contradicting results of these previous studies suggest that further research on the effects of the installation of HADs on ST and PA is needed. Since locomotive activities have larger health impacts and may relate to the increased likelihood of communication between employees at workplaces than just standing, investigating whether HADs play a role in additional walking is helpful in the understanding and creation of workplace.

Most of the above sited studies were conducted in western countries. There are currently no reports on this issue with Japanese workers, who show the longest ST in the world[1]. Additionally, environment, culture, workplace atmosphere, and workstyle in Japan are different from those in their Western counterparts. Therefore, it is unclear whether standing desk work using an HAD could decrease ST and increase PA during working hours in Japanese office workers. Accordingly, the purpose of this study was to examine the differences in objectively measured ST and PA of the HAD usage of Japanese employees.

Methods

A. Participants and ethical procedure

Participants recruited for this study were employees working at the Okamura Corporation in Tokyo, which is one of the leading office furniture manufacture and sales companies in Japan. One hundred thirty-one participants out of 150 employees in a single office responded to the self-reported questionnaire and accelerometer measurements disseminated in November of 2018.

To ensure ethicality, the company researchers and the office superior explained the aim and procedure of the study to the participants using printed material given to employees. Participants were asked to read the instruction of the study, which explained the usage of personal information, how to leave the study, and that the results of the investigation would never affect company performance appraisal. Every participant provided a signed letter of informed consent. This study was approved by the Ethical Committee of Meiji Yasuda Life Foundation of Health and Welfare (Approval number: 29001).

B. Measures

1. Usage of height-adjustable desk

Electric HADs were installed on hot-desking spaces (so-called "free-address" desks) and fixed seats at the target office. Every employee in this office was permitted to use the HADs during working hours. Since all employees of the target office had transferred from other offices in January of 2018, they had access to available HADs for around 10 months.

Usage of the HADs during working hours was assessed using the following question: "On average, how long do you usually perform standing desk work using an HAD during working hours?" The participants selected their potential response from the following options: 0 min/day (never use an HAD in standing position), shorter than 10 min/day, 10 to 30 min/day, 30 to 60 min/day, and longer than 60 min/day (whereby participants were required to write their actual duration). Based on the response, participants were divided into following two groups: non-users (0 min) and users (comprised "shorter than 10 min" or longer use). Since participants who used HADs were required to respond to this question, the 21 participants who did not respond to the question were presumed to have never used an HAD, and were subsequently coded as non-users.

2. Physical activity and sedentary behavior

PA and ST were measured using a tri-axial accelerometer, a device with a high accuracy (r = 0.88) for estimating total energy expenditure (Active Style Pro HJA-750C; Omron Healthcare Co. Ltd., Kyoto, Japan). Using correlation analysis, total energy expenditure was measured using the doubly labeled water method in the free-living condition[7]. This method can accurately classify (95.5–100% accuracy for correct discrimination) the type of PA as either locomotive (various speed walking/jogging) or non-locomotive activities (household activities such as laundry, dishwashing, moving small load, and vacuuming) using its algorism[8,9]. The output data of the device is measured in Metabolic Equivalents (METs) per minute, and each MET value has label of locomotive or non-locomotive activity. Since this study was conducted at an office environment, general walking was defined as the locomotive activity, and possible other body movements at work (e.g. standing work, sit-stand movements, and moving small loads) were defined as non-locomotive activities.

Participants were instructed to wear the tri-axial accelerometer for a period of 2 weeks on their waist during all waking hours, except while swimming or bathing. Non-wear time was defined as an interval of at least 20 consecutive minutes of no detectable intensity of the accelerometer, and a valid day was defined as a day that the participants had 10 hours or more wear-time per day[5]. The data from participants who had four or more valid days per work week were treated as valid data[15]. Of the valid data, activity recorded during the standard working hours (8:40-17:20) in the company on weekdays were used. Variables of the ST (≦ 1.5 METs) and PA (≧ 1.6 METs) were included in the analysis, and these variables converted into units of min/8.67-hours per workday using the following formula; min/8.67-hours = observed duration / wearing time * standard working hours (8.67-hours). Total PA was analyzed separately by locomotive and non-locomotive activities. Moreover, bouts of prolonged ST, which was defined as consecutive ST for 30 minutes or longer, were included in the analysis.

3. Demographic variables

Age, gender, body mass index (BMI), body pain, and job type (sales, sales support, design, research, and office clerk) were investigated as demographic variables. Body pain was evaluated using a 10-point Likert scale for each the neck, shoulder, back, and knee. BMI was calculated using self-reported height and weight of each participant. Type of desk ownership (hot-desking or fixed-seat) was documented for analysis.

C. Statistical analysis

Participants with missing questionnaire data (n = 24) or who did not have valid accelerometer data (n = 17) were excluded from the analysis. Thus, data of 90 participants were used in the final analysis.

Statistical analysis was stratified by participant job type (sales or other office work), because work style or working activity is different among job types. The results of descriptive statistics were shown using mean ± standard deviation for the proportional and interval variables, and with numbers and percentages for nominal variables. Independent t-test, chi-square test, and Fisher's Exact Test were adopted to compare the differences in PA, ST, and demographic variables between the two groups of HAD usage (non-users vs. users). IBM SPSS Statistics 24 for windows was used for the analysis, and the level of statistical significance was set at $P < 0.05$.

Results

Table 1 presents participant demographics, job type, and desk type in each HAD usage group of office workers and sales workers. In the office worker group, a significant difference was found in desk type between the HAD user groups, in that HAD user desk types were evenly mixed (hot-desking versus fixed-seat), but most non-users (95%) owned hot-desks. No significant difference was found between sales workers and groups of usage, and every worker in each usage group used hot-desking.

Table 2 showed the differences in PA and ST between the groups of HAD usage within job type. It

Table 1. Participants' characteristics by height-adjustable desk usages.

Variables	Office workers			Sales workers		
	Non-users (n = 20)	Users (n = 19)	*P*-value	Non-users (n = 14)	Users (n = 37)	*P*-value
Age, mean ± SD	40.3 ± 10.6	40.8 ± 13.2	0.899	44.7 ± 11.4	42.3 ± 11.1	0.498
Gender, n (%)						
Male	11 (55.0)	9 (47.4)	0.752	13 (92.9)	35 (94.6)	1.000
Female	9 (45.0)	10 (52.6)		1 (7.1)	2 (5.4)	
Body mass index, mean ± SD	22.7 ± 4.1	22.2 ± 3.6	0.741	22.4 ± 1.7	23.3 ± 2.7	0.271
Body pain, mean ± SD						
Neck and shoulder	4.8 ± 2.9	4.5 ± 2.7	0.805	3.4 ± 2.5	3.8 ± 2.7	0.569
Back	3.6 ± 3.0	4.1 ± 2.3	0.605	2.8 ± 2.4	3.5 ± 2.5	0.350
Knee	1.7 ± 2.7	1.0 ± 1.6	0.367	2.1 ± 2.0	2.5 ± 2.7	0.653
Job type						
Sales	NA			14 (100.0)	37 (100.0)	–
Sales support	8 (40.0)	3 (15.8)	0.002	NA		
Design	0 (0.0)	9 (47.4)				
Research	6 (30.0)	6 (31.6)				
Office clerk	6 (30.0)	1 (5.3)				
Desk ownership, n (%)						
Fixed-seat	1 (5.0)	10 (52.6)	0.001	0 (0.0)	0 (0.0)	–
Hot-desking	19 (95.0)	9 (47.4)		14 (100.0)	37 (100.0)	
Duration of standing desk work by using HAD, n (%)						
Shorter than 10 min/day	NA	6 (31.6)	–	NA	11 (29.7)	–
10 to 30 min/day		2 (10.5)			18 (48.6)	
30 to 60 min/day		5 (26.3)			5 (13.5)	
Longer than 60 min/day		6 (31.6)			3 (8.1)	

SD; standard deviation, NA; not applicable, HAD; height-adjustable desk.

Table 2. Differences in PA and ST between the usages of height-adjustable desk.

Variables	Office workers			Sales workers		
	Non-users (n = 20)	Users (n = 19)	*P*-value	Non-users (n = 14)	Users (n = 37)	*P*-value
Sitting time, min/8.67-hours	412.0 ± 42.6	377.4 ± 51.7	0.028	347.0 ± 42.3	346.2 ± 35.6	0.943
Physical activity, min/8.67-hours	108.0 ± 42.6	142.6 ± 51.7	0.028	173.0 ± 42.3	173.8 ± 35.6	0.943
Locomotive physical activity, min/8.67-hours	41.0 ± 17.9	42.9 ± 21.3	0.759	81.6 ± 29.8	77.4 ± 18.8	0.551
Non-locomotive physical activity, min/8.67-hours	67.1 ± 29.1	99.7 ± 45.1	0.010	91.4 ± 28.2	96.4 ± 29.2	0.581
Frequency of prolonged sitting time, time/8.67-hours	1.8 ± 0.6	1.2 ± 0.8	0.008	1.1 ± 0.6	1.2 ± 0.7	0.721

Prolonged sitting time was defined as sitting time consecutive for 30 minutes or longer.

was found that office workers had significantly different ST and PA time between the users and non-users, with the exception of locomotive PA during working hours. Specifically, the ST in non-users (412.0 ± 42.6 min/8.67-hours) was significantly longer than that of users (377.4 ± 51.7 min/8.67-hours). PA in total and non-locomotive activities were significantly different between the groups of HAD usage, in that users showed greater total PA (142.6 ± 51.7 min/8.67-hours) and non-locomotive PA (99.7 ± 45.1 min/8.67-hours) than non-users (PA: 108.0 ± 42.6, non-locomotive PA: 67.1 ± 29.1 min/8.67-hours). Users showed significantly smaller bouts of prolonged ST (1.2 ± 0.8 time/8.67-hours) than non-users (1.8 ± 0.6 time/8.67-hours). No significant difference was found between sales workers and the usage groups in either variable.

Discussion

This is the first study to examine the difference in objectively measured ST and PA through the use of HADs in Japanese employees. The results of this study indicate that the office workers using HADs showed less ST as well as less prolonged ST during working-hours. In addition, greater non-locomotive PA were found in HAD users over locomotive PA in office workers. Since previous studies only provide data from Western countries, the knowledge gained from the scope of this study was beneficial for Japanese companies.

Differences in ST and PA between the groups of non-users and users in office workers was 34.6 min/working hours in this study. This difference was accounted for by the difference in non-locomotive activity between the groups. These findings suggested that HAD users changed their position from sitting to standing more frequently than non-users during working hours. These changes in ST and non-locomotive PA, however, did not have a significant effect on locomotive PA during working hours. It was speculated that if standing posture increased in response to HAD usage, locomotive PA, such as walking in the office, would increase. This is because it is easier for a worker to move out of a standing position rather than a seated position in order to communicate with coworkers around the office.

The findings of this study suggest that introduction of HADs to offices is not enough to promote locomotive PA during working hours. Therefore, other strategies to increase locomotive activities at work appear to be necessary. For example, providing information about the benefits of enhanced PA over the replacement of ST to standing work, setting step count goal during working hours, and arranging the layout of HADs to create walkable offices may be effective.

Moreover, the frequency of prolonged ST was fewer in the HAD user group than in the non-users. This finding seemed to be important effect of using HADs, because prolonged ST for 30 minutes or longer is a reported risk factor for future health deterioration[4]. These results support prior knowledge from a systematic review[13], and suggested that introducing of HADs to offices promotes future well-being by reducing prolonged ST.

On the other hand, PA and ST showed no difference in sales workers between HAD usage. The reason for this might be that the duration of standing desk work was shorter than that of office workers, and that they might be active both inside and outside the office regardless of HAD usage. It is suggested that HAD usability is different for every job type, and we should consider how we can utilize HAD in a practical setting by taking into account the appropriate postures (i.e. sitting, standing, or walking) for various job tasks.

This study has several limitations. First, the assessments of HAD usage were conducted using self-reported questionnaire, which was not examined for its reliability and validity. Therefore, it is not clear whether the self-reported data of HAD usage was exact. In this study, however, the data of HAD usage was only used to divide the participants into users and non-users based on the duration of HAD usage. With this in mind, a potential error of group classification appears small. Second, multivariate analysis was not used to examine the difference in ST or PA between the groups of HAD usage due to a small sample size. Thus, demographic variables and other confounders should be included in analysis for adjustment. There were, however, no significant differences in demographic variables and the two groups of HAD usage in this study. The results of this study seemed to exhibit the relationships between HAD usage and ST or PA during working hours. Third, since this study was conducted at a single office of a single company, one should be careful not to generalize the findings in this study.

Conclusions

Overall, standing desk work using HADs correlated with less ST, greater PA, and fewer prolonged ST during working hours in office workers. Using HADs in offices would increase the PA of non-locomotive activities, such as standing desk work or sit-stand movements, but it would not increase locomotive activities.

Conflicts of interest statement

The authors declare that there are no conflicts of interest.

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Acute effects of light-intensity, slow-tempo aerobic dance exercise on mood and executive function in older adults

Kazuki Hyodo[1), Takashi Jindo[1), Kazuya Suwabe[2,3), Hideaki Soya[2,3), and Toshiya Nagamatsu[1,4)

SUMMARY

Although a growing number of studies have reported the positive effects of acute aerobic exercise on mood and executive function in older adults, little is known about the effect of aerobic dance exercise (ADE) on executive function. In the present study, we aimed to compare the acute effects of light-intensity, slow-tempo ADE and light-intensity cycling exercise (CE) on mood and executive function in older adults. Twenty-one older adults performed each type of exercise for 10 minutes on separate days. The intensity of the CE was set at 60% of the ventilatory threshold. Before and after the exercise, mood (i.e., vitality, stability, pleasure, and arousal) and executive function were assessed by using the Two-Dimensional Mood Scale and the Stroop task, respectively. The heart rates and ratings of perceived exertion during exercise indicated that the intensities of both types of exercise were within the light-intensity range. Vitality and pleasure levels were increased following ADE, but no such changes were observed following CE. Although no differences in stability levels were observed following either type of exercise, we observed a significant interaction between time and exercise group, suggesting that there could be differences between the acute effects of ADE and CE. Unlike other psychological levels, the arousal level was increased to the same extent following both types of exercise. Stroop interference time, an indicator of executive function, was shortened to the same extent after both types of exercise. These findings suggest that ADE may represent an effective exercise modality for enhancing mood and executive function in older adults.

Key words: older adults, aerobic dance exercise, cycling exercise, Two-Dimensional Mood Scale, Stroop task.

Introduction

Research has thoroughly demonstrated that cognitive function decreases with age. Executive function—which refers to prefrontal cortex-related, higher-order cognitive processes including inhibitory control, working memory, and cognitive flexibility[22)—is particularly vulnerable to aging[2). Since executive function is associated with instrumental activities of daily living in older adults[3), attenuating age-related decreases in executive function may aid in maintaining the quality of life in older adults.

Previous studies have reported that regular physical exercise exerts beneficial effects on cognitive function, especially executive function[5,14). In addition to the well-known chronic effects of exercise, accumulating evidence suggests that an acute bout of exercise can exert instantaneous positive effects on executive function[4,8,11,12,21). Furthermore, some meta-analyses have reported an inverted U-shaped relationship

1) Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Tokyo, Japan.
2) Laboratory of Exercise Biochemistry and Neuroendocrinology, University of Tsukuba, Ibaraki, Japan.
3) Sports Neuroscience Division, Advanced Research Initiative for Human High Performance (ARIHHP), Faculty of Health and Sport Sciences, University of Tsukuba, Ibaraki, Japan.
4) Yamano College of Aesthetics, Tokyo, Japan.

between exercise intensity and acute effects on cognitive function: i.e., moderate-intensity exercise appears to exert greater effects on cognitive function than light- or high-intensity exercise[15,20].

While such evidence suggests that moderate-intensity exercise exerts the greatest effects on executive function, light-intensity exercise may be safer and more feasible for older adults. In our recent study, 10 minutes of light-intensity cycling exercise (CE) improved inhibitory control and memory function in young adults[1,26]. Moreover, these improvements were associated with changes in psychological arousal levels due to exercise, suggesting that light-intensity aerobic exercise can effectively improve executive function by enhancing mood.

Many previous studies have examined the effects of aerobic exercise modalities such as CE and treadmill running[15,17,21]. However, in the present study, we focused on aerobic dance exercise (ADE), a music-based group activity enjoyable for people of all ages. Previous studies have revealed that participation in an ADE class instantly improves mood by, for example, increasing vigor and decreasing anger and depression[16,18,19,24]. However, only one previous study has examined the acute effect of ADE on executive function[13], and none has examined this effect in relation to that of typical aerobic exercise modalities such as walking or cycling. Therefore, in the present study, we aimed to determine whether acute ADE enhances mood and executive function in older adults more strongly than acute CE.

Methods

A. Participants

Thirty-one older adults (ages: 65 to 74 years) were initially recruited through advertisements in local magazines. After additional screening measures, one participant was excluded due to use of beta-adrenergic blockers, one was excluded due to smoking status, and two were excluded due to possible depression (> 7 scores on the Geriatric Depression Scale). Another six participants were excluded from analysis due to technical difficulties during CE or ADE (n = 2) or for falling asleep during the cognitive tasks (n = 4). Thus, we analyzed data from a total of 21 participants. Their baseline characteristics are shown in Table 1.

The inclusion criteria were as follows: (a) right-handedness, (b) normal or corrected-to-normal vision based on verbal reports, (c) no neuropsychiatric conditions, neurological diseases, or infarcts (e.g., multiple sclerosis, Alzheimer's disease, or stroke), and (d) no physical disabilities that could have been exacerbated by exercise.

Written informed consent was obtained from all participants prior to the experiment. This study was approved by the Ethics Committee of Meiji Yasuda Life Foundation of Health and Welfare (Approval number: 28003).

Table 1. Participant characteristics.

	Male (n = 10)		Female (n = 11)	
	Mean	SD	Mean	SD
Age (y)	70	2.4	69	3
Height (cm)	166	5.8	155	5.8
Weight (kg)	63	8.1	52	5.7
Education (y)	14	2.1	13	1.6
GDS (score)	0.9	0.99	1.5	1.2
VT (ml/kg/min)	13	3	13	2.6
Workload at 60% VT (W)	36	10	27	12

GDS; Geriatric Depression Scale, SD; standard deviation, VT; ventilatory threshold.

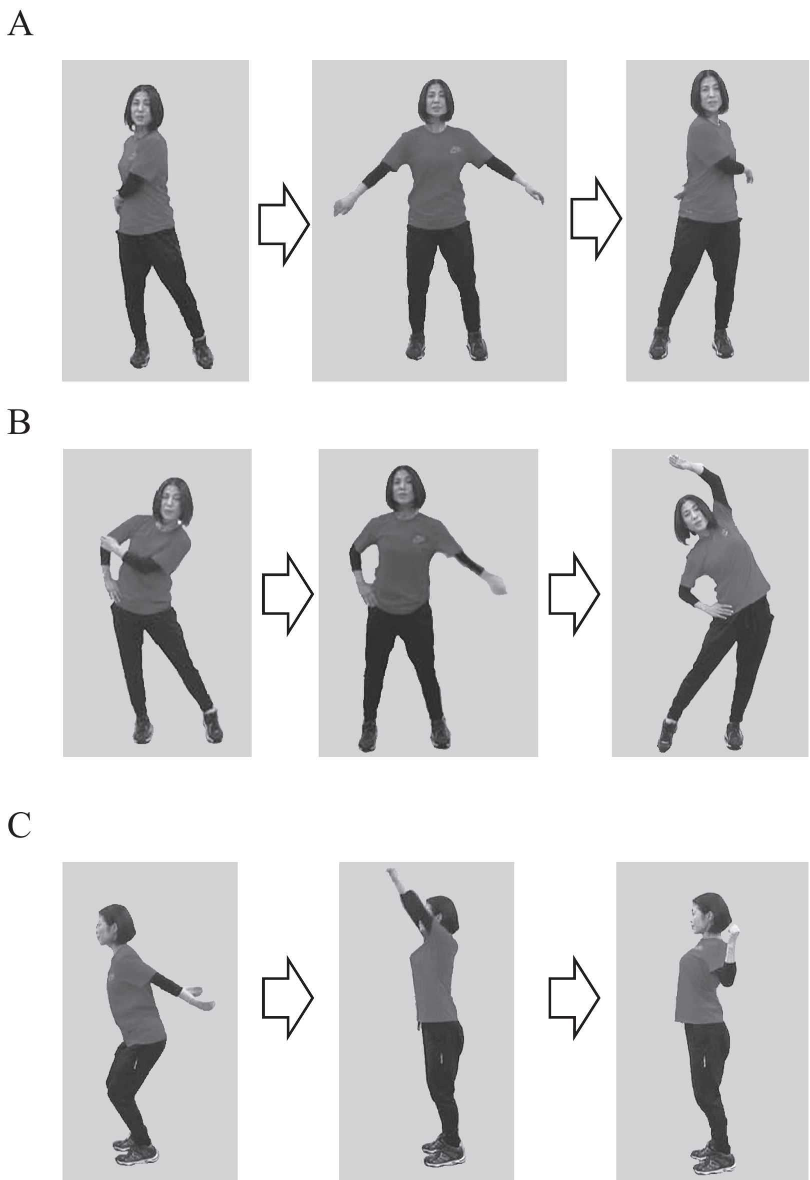

Figure 1. Illustration of the three basic components of the slow aerobic dance exercise routine.
(A) twisting the upper body, (B) swinging the arms from side to side while bending the body to each side, and (C) swinging the arms back and forth while pulling the elbows back.

B. Experimental procedure

Participants were asked to visit the laboratory used for this study three times on separate days. At the first visit, participants performed a graded exercise test on an upright cycle ergometer (Corival cpet, Lode, Netherlands) to assess their ventilatory threshold (VT). To familiarize themselves with the Stroop task, which was later used to assess executive function, the participants performed it twice. They also practiced the Slow Aerobic Dance once.

At the second and third visits, participants performed either 10 minutes of CE using an upright cycle ergometer or light-intensity, slow-tempo ADE. The participants performed the Stroop task before and 5 minutes after the CE or ADE. Mood was assessed using the Two-Dimensional Mood Scale (TDMS)[25] before the pre-exercise Stroop task session and immediately after the exercise. Heart rate (HR) was measured during both exercise sessions, and ratings of perceived exertion (RPE) were obtained at the end of each session. The order of exercise testing was counter-balanced across participants.

C. Graded exercise test

The participants exercised at 5 W for 3 min to warm up. After the warm-up, the exercise load was gradually increased by 1 W every 6 s. HR and RPE data were recorded every 1 and 2 min, respectively. The exercise test was stopped when the participant reached an RPE of 17 (very hard). The pedaling rate was kept at 55 rpm. Ventilation parameters including oxygen intake and carbon dioxide output were measured breath-by-breath using a respiratory gas analyzer (Aeromonitor AE300S, Minato Medical Science, Japan). VT was determined via the V-slope method using the same respiratory gas analyzer, as described by Itoh et al.[10]

D. Exercise intervention

The ADE intervention used in the present study ("Slow Aerobic Dance Exercise") consisted mainly of dynamic upper-body stretching (e.g., trunk rotation) performed to slow-tempo music. In our preliminary study, we observed that complex movements were difficult for older adults to perform, because most of them had no experience with ADE[9]. Therefore, in the present study, participants were required to perform three simple movements repeatedly: (a) twisting the upper body, (b) swinging the arms from side to side while bending the body to each side, and (c) swinging the arms back and forth while pulling the elbows back (Figure 1). They routinely executed each movement for approximately 3 min and 20 s while watching a tutorial video. Original music with a tempo of 90 bpm was used for the intervention[28].

In the CE condition, the participants performed CE at an intensity of 60% of the VT on an upright cycle ergometer (Corival cpet). Pedaling rates were displayed to the participants on a screen, and the participants were asked to maintain their pedaling rates at 55-60 rpm. During CE, participants listened to the same music used in the ADE condition.

E. Mood

The TDMS consists of eight mood-expressing words related to both pleasure and arousal states (i.e., energetic, lively, lethargic, listless, relaxed, calm, irritated, and nervous). Participants reported how they were feeling at the time by responding to each item using a six-point rating scale ranging from 0 (not at all) to 5 (extremely). Vitality, stability, pleasure, and arousal levels were determined by calculating scores for each item.

F. Executive function

Executive function was assessed using a computer-based color-word matching Stroop task[30]. Two rows of letters were presented on a computer screen. The participants were required to determine whether the color of the letters in the top row corresponded to the color name printed in the bottom row and to press the appropriate buttons with their forefingers to provide "yes" or "no" responses as quickly and accurately as possible. The task consisted of 30 neutral and 30 incongruent trials presented in a random order. For neutral trials, the letter sequence "XXXX" was displayed in the top row in red, green, blue, or yellow, and the word "RED", "GREEN", "BLUE", or "YELLOW" was displayed in the bottom row in black. For incongruent trials, the top row contained the word "RED", "GREEN", "BLUE", or "YELLOW" displayed in an incongruent color (e.g., "RED" in green). All word stimuli were displayed in Japanese. To achieve sequential visual attention, the top row appeared 350 ms earlier than the bottom row. The protocol contained equal numbers of trials in which "yes" was the correct answer and trials in which "no" was the correct answer. The trials were separated by inter-stimulus intervals during which a fixation cross was presented for 9-12 s to avoid prediction of the timing of the subsequent trial. Each stimulus remained on the screen for 3 s. The accuracy rate and correct reaction time were measured. Stroop interference time (i.e., the difference in correct reaction time between incongruent and neutral trials) was used as an index of executive function, as in previous studies[1,8,23,29].

G. Statistical analyses

TDMS scores and Stroop interference times were analyzed using two-way, repeated-measures analysis of variance (ANOVA) with condition (CE/ADE) and time (pre/post) as factors. When significant main effects or interactions were observed, we performed *post hoc* analyses with Bonferroni corrections. All statistical analyses were conducted using R version 3.5.1 (R Core Team 2018). Statistical significance was defined as $P < 0.05$ for all analyses.

Results

A. Exercise intensity

The average HR values during CE and ADE were 90.1 ± 12.0 bpm and 88.5 ± 13.1 bpm, respectively. The RPE values after CE and ADE were 11.3 ± 1.2 points and 11.0 ± 1.3 points, respectively. There were no significant differences in HR or RPE between the two exercise conditions.

B. Mood

Figure 2 shows the effects of exercise on TDMS scores. We observed significant interaction effects between time and condition for vitality ($F(1, 20) = 4.69$, $P = 0.043$), stability ($F(1, 20) = 7.32$, $P = 0.014$), and pleasure ($F(1, 20) = 9.74$, $P = 0.005$) levels. *Post hoc* analyses revealed that ADE significantly increased vitality ($t(20) = 3.69$, $P < 0.001$) and pleasure ($t(20) = 2.89$, $P = 0.007$) levels relative to pre-exercise levels. However, no such changes were observed following CE. Thus, vitality and pleasure levels were significantly higher following the ADE condition than following the CE condition (vitality: $t(20) = 2.24$, $P = 0.030$; pleasure: $t(20) = 2.30$, $P = 0.027$). We observed a significant main effect of time ($F(1, 20) = 8.44$, $P = 0.009$) on arousal levels. However, there were no

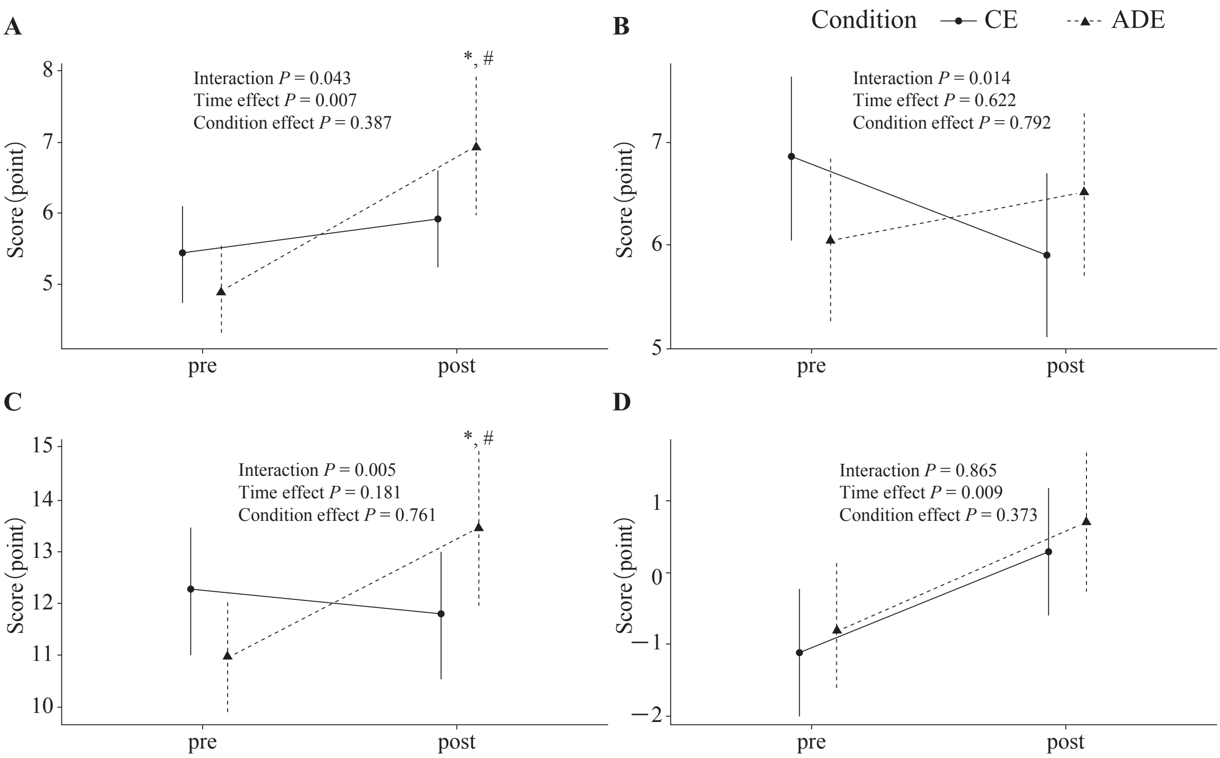

Figure 2. Changes in TDMS scores for vitality levels (A), stability levels (B), pleasure levels (C), and arousal levels (D). Error bars indicate standard errors. The P values shown are the results of two-way ANOVA with time and condition as factors. ADE; aerobic dance exercise, ANOVA; analysis of variance, CE; cycling exercise, TDMS; Two-Dimensional Mood Scale. * $P < 0.01$ vs. pre, #: $P < 0.05$ vs. CE.

Table 2. Behavioral data for the Stroop task.

	CE				ADE			
	Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CR (%)								
Neutral	99.4	1.7	98.7	2.0	98.6	2.0	99.7	1.0
Incongruent	95.6	4.9	98.3	2.3	98.3	2.0	98.9	1.9
RT (ms)								
Neutral	816.6	138.9	781.9	135.9	803.0	152.7	774.2	150.1
Incongruent	1037.9	226.1	978.3	206.0	1039.9	233.9	973.0	205.5
SIT (ms)	221.4	116.4	196.3	92.6	236.9	113.2	198.8	97.3

ADE; aerobic dance exercise, CE; cycling exercise, CR; correct rate, RT; reaction time, SD; standard deviation, SIT; Stroop interference time.

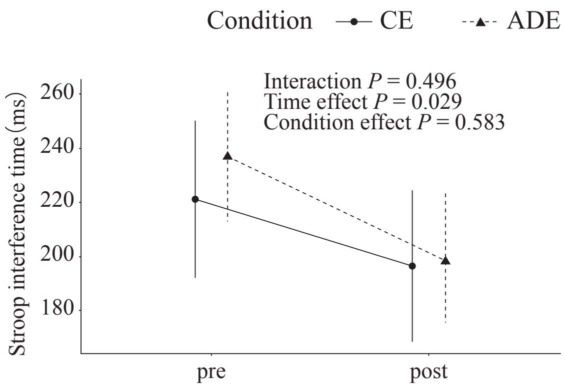

Figure 3. Changes in Stroop interference time.
Error bars indicate standard errors. The P values shown are the results of two-way ANOVA with time and condition as factors. ADE; aerobic dance exercise, ANOVA; analysis of variance, CE; cycling exercise.

significant interactions or main effects of condition. *Post hoc* analysis revealed that post-exercise arousal levels were higher than pre-exercise levels ($t(20) = 3.0$, $P < 0.007$).

C. Executive function

Table 2 shows the correct reaction times and accuracy rates for the neutral and incongruent trials in each exercise condition. Stroop interference time was calculated to examine the acute effect of exercise on executive function. Two-way ANOVA revealed a significant main effect of time for Stroop interference time ($F(1, 20) = 5.56$, $P = 0.029$). *Post hoc* analysis revealed that post-exercise Stroop interference times were significantly shorter than pre-exercise Stroop interference times ($t(20) = 2.36$, $P = 0.028$) (Figure 3). However, there were no significant interactions or main effects of condition.

Discussion

In the present study, we aimed to clarify the differences in the acute effects of light-intensity ADE and light-intensity CE on mood and executive function in older adults. Based on changes in HR and RPE, we confirmed that each condition consisted of comparable, very light- to light-intensity exercise, in accordance with the American College of Sports Medicine guidelines[7]. However, ADE significantly increased psychological vitality and pleasure levels, whereas CE did not. We observed no significant differences in arousal levels following the two exercise conditions. Stroop task performances showed similar improvements in executive function in both conditions. Indeed, our findings indicated that ADE exerted greater effects on mood than CE did and that both had comparable effects on executive function. Taken together, these findings highlight the potential of ADE as an effective exercise modality for enhancing mood and executive function in older adults.

The observed increases in vitality and pleasure levels following ADE are consistent with the findings of previous studies that have reported that ADE enhances vigor (equivalent to vitality) and decreases tension and fatigue as assessed using the Profile of Mood States in young and older adults[16,19,24]. However, participants in these previous studies performed ADE for more than 30 minutes in a group setting, and the authors did not compare the effects of ADE and other aerobic exercise modalities. In the present study, we demonstrated that 10 minutes of light-intensity ADE can enhance mood in older adults and that greater effects can be achieved by ADE than by CE at comparable intensities and durations. However, we observed no significant differences between the two exercise conditions in their effects on arousal levels. A previous study reported that exercise-induced arousal levels were associated with exercise intensity[6]. Therefore, exercise intensity may exert a greater impact on arousal levels than exercise modality.

Contrary to our expectations, we observed no significant differences in the effects of ADE and CE on Stroop interference time, a measure of executive function. The improvements in Stroop task performance after acute aerobic exercises found in this study are consistent with those of our previous studies that demonstrated that 10 minutes of light- or moderate-intensity CE reduces Stroop interference time in both young and older adults[1,8,29]. Arousal theory posits that appropriate levels of exercise-induced physiological arousal exert beneficial effects on cognitive function[27]. Thus, the lack of a difference in exercise-induced psychological arousal levels between the two conditions may explain the similarities in the Stroop task performance between them.

The present study has some notable limitations. First, because we did not include a resting control condition, decreases in reaction time might have been influenced by habituation. However, previous studies have reported no significant differences in Stroop task performance prior to and following the resting condition[1,8,29], suggesting that the decreases in Stroop interference time observed in this study reflect the acute effects of exercise. Second, participants performed ADE while watching a tutorial video in which the instructor also performed the movements, whereas no videos were utilized in the CE condition. Thus, visual stimulation might have exerted effects on mood and executive function in the ADE condition.

In summary, our experiments with older adults showed that a single session of light-intensity, slow-tempo ADE exerts positive effects on mood that are greater than those of light-intensity CE and positive effects on executive function that are similar to those of light-intensity CE. Long-term interventional studies are required to more fully elucidate the effect of ADE on executive function in this population.

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【Report】

Reduction in anxiety-like behavior in environmental enrichment

Mizuki Sudo[1)] and Soichi Ando[2)]

Key words: enriched environment, wheel running activity, locomotor activity, anxiety.

Introduction

Environmental enrichment (EE) involves housing conditions that facilitate enhanced sensory, cognitive, and motor stimulation[9)]. Previous studies have suggested that EE can enhance exploration, social interaction, and physical exercise in animals, leading to improvements in cognitive function, depression, and anxiety-like behavior[1-13)]. Based on these findings, it is widely accepted that EE conditions have neuroprotective effects on a range of brain functions.

The beneficial effects of EE on anxiety-like behavior is thought to be due to increases in locomotor activity. However, given that EE usually involves wheel running, it is still unclear whether reduction in anxiety-like behavior in EE is ascribed to increases in wheel running activity and/or locomotor activity except for wheel running.

The present study examined the effects of wheel running activity and locomotor activity in the absence of wheel running on anxiety-like behavior. Wheel running activity and locomotor activity of each rat was recorded using a recently developed device. The purpose of the present study was to determine the factors that reduce anxiety-like behavior in EE.

Materials and Methods

A. Experimental animals and environmental housing conditions

All animal care and protocols were approved by the Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare Animal Care and Use Committee (Approval number: 2014002). Male Wistar rats (4 weeks of age; Japan SLC, Shizuoka, Japan) were housed in a temperature-controlled room (22 ± 2 ºC) with a 12 : 12-h light-dark cycle, and received standard rat chow and water *ad libitum*. The present EE consisted of running wheel, slope, tunnel, and small hut. Rats were divided into four different housing groups (standard environment: SE, only running wheel group: EE-W, EE without running wheel (only slope, tunnel, and hut) group: EE-S, and EE, n = 7-8, each). In the SE group, rats were housed in groups of 2 rats per cage in standard laboratory cages (length × width × height: 60 × 40 × 25 cm). In the EE group, rats were housed in groups of 2 per cage in large cages (60 × 40 × 40 cm).

B. Measurement of locomotive activity

Locomotor activity was continuously recorded using three-axis accelerometers (Nano-Tag: 15 × 14.2 × 7.1 mm, 2.5g, Kissei Comtec Co. Ltd., Nagano, Japan). The accelerometers were subcutaneously

1) Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Tokyo, Japan.
2) Department of Mechanical Engineering and Intelligent Systems, Control Systems Program, University of Electro-Communications, Tokyo, Japan.

implanted in the back under anesthesia. The accelerometer counted locomotor activities above the threshold that was determined based on the preliminary experiments. In this study, we determined movements during feeding behavior as the threshold. This allowed to detect all kinds of movements in the cage as locomotor activity.

C. Anxiety-like behavior measurement

After exposure to each environment for 6 weeks, the animals were submitted to the light-dark exploration test to assess anxiety-like behavior.

D. Statistics

All experimental data are expressed as mean ± standard deviation. Comparisons were performed using one-way analysis of variance followed by Bonferroni multiple comparisons. The level of significance was set at $P < 0.05$.

Results

A. Locomotor activity

Locomotor activity was higher during the dark period in the EE group (28260 ± 12705 frequency/day) compared with SE (19757 ± 9964, $P = 0.02$) and EE-S (15703 ± 6510, $P < 0.001$) groups. Locomotor activity was higher during the dark period in the EE-W (23182 ± 9730) group compared with EE-S group ($P = 0.02$).

B. Light-dark exploration test

The light-dark exploration test indicated that time spent in the light compartment was significantly longer in the EE-W group (145 ± 65 sec, $P = 0.05$), EE-S group (163 ± 63 sec, $P = 0.01$), and the EE (156 ± 24 sec, $P = 0.01$) groups as compared with the SE group (68 ± 30 sec).

Discussion

As predicted, anxiety-like behavior reduced in the EE group as compared with the SE group. Anxiety-like behavior also reduced in the EE-W group. This indicates that wheel running activity contributed to reduce anxiety-like behavior. Locomotor activity reduced in the EE-S group as compared with other EE groups (EE-W and EE), which suggests that wheel running plays a key role in increase in locomotor activity in the EE condition. Nevertheless, anxiety-like behavior reduced in the EE-S group as compared with the SE group. Locomotor activity was comparable between SE and EE-S groups. Hence, these results suggest that reduction in anxiety-like behavior in the EE-S group is not primarily due to locomotor activity, but to enriched environment *per se*. Collectively, the present study suggests that both wheel running activity and locomotor activity in the EE condition reduce anxiety-like behavior. Locomotor activity in the SE may be less effective to reduce anxiety-like behavior as compared with the EE condition despite same amount of locomotor activity.

In conclusion, both wheel running activity and locomotor activity without wheel running reduce anxiety-like behavior in the EE. The EE seems to be helpful to reduce anxiety-like behavior.

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海外研修レポート

7th International Society for Physical Activity and Health（ISPAH）Congress に参加して

神藤隆志[1)]

■はじめに

2018年10月15～17日にイギリス・ロンドンで開催された身体活動と健康の国際会議（International Society for Physical Activity and Health（ISPAH）Congress）に参加し，研究成果を発表した。本レポートでは学会参加によって得られた成果等について報告する。

■大会概要

7th ISPAH Congress は，すべての人々の一生涯における身体活動の促進を目標とする国際団体であり，２年に１度国際会議を開催している。今大会の会場は，ロンドン・ヒースロー空港から電車で約１時間のロンドン市街地にある Queen Elizabeth Center Ⅱであった。

大会はオープニングセレモニーから始まり，基調講演，シンポジウム，口頭発表，ePoster（モニターを使用したポスター）発表が合わせて69セッション行われた。すべてのセッションが身体活動や健康に関連するものであり，身体活動の促進介入や測定評価手法，関連要因などの興味深いテーマを扱うセッションが数多く開かれていた。

会場入り口

■大会の雰囲気

身体活動研究のさきがけとなったバス運転手と乗務員の心血管疾患発症リスクを比較した研究は，ロンドンのバス乗務員を対象に1953年に行われた。今大会はこの研究が行

学会会場（Queen Elizabeth Center Ⅱ）


会場近くを走るロンドンの赤いバス

1）公益財団法人 明治安田厚生事業団体力医学研究所　Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Tokyo, Japan.

われてから65年という切りのいい数字で記念大会的な雰囲気があった。身体活動促進を効率的に行っていくためには研究者のみならず多職種，多業種の連携が必要であることから，今大会には，WHO（世界保健機関）や Public Health England（英国公衆衛生庁），Sport England（スポーツイングランド，日本でのスポーツ庁）などの関連する組織の代表者らも参加していた。

職域の身体活動に関するシンポジウムの様子

■研究発表

今大会にエントリーした発表は「Self-efficacy scale for breaking up prolonged sitting for office workers: development and validity」で，ePoster 発表に割り当てられた。本研究は，勤労者における座りすぎ解消に対する認識を評価する心理尺度を開発したものである。座りすぎの健康悪影響の多くはオフィスワーカーに生じており，作成した心理尺度を活用して効果的な介入手法を見いだすことが今後の課題である。今大会では，職域における研究が多く発表されていたため，それらの研究を参考に勤労者の座りすぎや身体不活動を解消する方法について更に検討を深めていきたいと思う。

■おわりに

今大会への参加を通して，座りすぎや身体不活動を改善していくためには研究と現場をつなぐ社会実装の取り組みが必須であることを改めて認識した。また，身体活動研究はバス乗務員を対象とした職域から始まったにもかかわらず，現在では余暇の身体活動が着目されがちであるという発表もあり，仕事に関連する身体活動が心身の健康に与える影響をより深く理解することの重要性を感じた。職域の状況は各国で非常に異なるため，我が国独自の知見を見いだせるよう引き続き研究に取り組んでいきたいと思う。

なお次回の ISPAH Congress はカナダのバンクーバーにて2020年10月28～31日に開催予定である。

次回大会の告知