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Original Article

The Effects of Single Long and Accumulated Short Bouts of Exercise on Cardiovascular Risks in Male Japanese Workers: A Randomized Controlled Study

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Abstract: The aim of this study was to determine whether accumulated short bouts of exercise can achieve the same cardiovascular benefits as a single long bout of exercise in sedentary male Japanese workers and to compare the programs' relative effects on oxidative stress. Twenty-three sedentary male workers were randomly assigned into 2 different exercise programs: a Long-bout group, which performed a single period of continuous exercise (Long-bout group: 30 min × 1) 3 d per week, and a Short-bouts group, which performed 3 short bouts of exercise (Short-bouts group: 10 min × 3) 3 d per week. Cardiovascular risk factors, including the plasma thiobarbituric acid-reactive substances (TBARS) level, were examined at baseline and after both 10 and 20 wk. In the Long-bout group, waist circumference and maximum oxygen uptake ($\dot{V}O_{2max}$) significantly improved after 20 wk. The Short-bouts group demonstrated significant increases in $\dot{V}O_{2max}$ after 10 weeks and in HDL-C after 20 wk. Plasma TBARS significantly decreased after 20 weeks in the Long-bout group and tended to decrease (but not significantly) in the Short-bouts group. These results indicate that accumulated short bouts of exercise are an effective option, especially for busy workers, for incorporating exercise into one's lifestyle.

Key words: Aerobic exercise, Lifestyle-related disease, Oxidative stress, Cardiorespiratory endurance, Busy workers, Accumulated short-bout exercise, Sedentary Japanese workers

Introduction

With the aging of the workforce, the incidence of cardiovascular risk factors such as dyslipidemia and hypertension has increased in Japan[1)]. One recommended approach to address these issues is an increase in physical activity[2)]. However, according to the Survey on State of Employees' Health 2007 by the Ministry of Health, Labour, and Welfare, Japan, 30.6% of Japanese employees report regular mild or moderate physical activity, including brisk walking, calisthenics, and jogging[3)]. This represented a slight increase compared with the previous survey (28.9% in 2002). However, adherence to an exercise program in Japanese employees is less than desirable[4)]. One reason for employees' low adherence to exercise programs is lack of available time[5)].

Many studies have shown that for improvements in physical fitness and body weight, exercise programs comprising an accumulation of several short sessions per day are as effective as those comprising longer continuous sessions[6–11)]. The Active Guide 2013, issued by the Ministry of Health, Labour, and Welfare, Japan, also emphasizes

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that the accumulation of physical activity throughout the week is important for health promotion[2]. An exercise program that includes short bouts can be performed more frequently, especially by employees with limited time available for daily exercise. In their review, Murphy *et al.* found that most studies reported no difference in the effect on cardiovascular fitness between accumulated and continuous patterns of exercise[12]. However, whether accumulated exercise is as effective as continuous exercise in terms of adiposity, the lipid profile, and glucose metabolism remains unclear.

Oxidative stress is associated with the pathogenesis and progression of such cardiovascular risk factors as adiposity, high blood pressure, dyslipidemia, and glucose intolerance and is detectable before the onset of clinically significant disease[13–16]. Continuous moderate-intensity exercise potently reduces CV risk factors and oxidative stress[17, 18]. However, there is no study reporting whether accumulated exercise has the same effect as continuous exercise on oxidative stress.

The aim of this study was to determine if several short bouts of exercise can achieve the same effects on cardiovascular risk factors in sedentary male Japanese workers as single long bouts of exercise during a period of 20 weeks and to compare the relative effects of these exercise programs on oxidative stress.

Methods

Subjects

This was a non-blinded randomized controlled study. Twenty-three sedentary male Japanese workers with a mean (± SD) age of 43.9 ± 11.6 years were recruited through the university newsletter. The inclusion criteria specified men who did not participate in any vigorous physical activity (reported exercising <20 $min \cdot d^{-1}$ on <3 $d \cdot wk^{-1}$ for the previous 6 months). We also included workers who had some cardiovascular risk factors (e.g., obesity, mild hypertension, controlled diabetes, and dyslipidemia) but not a history of cardiovascular disease or of musculoskeletal problems preventing the use of a cycle ergometer. All subjects had sedentary jobs. Medication levels were not modified during the study period. Workers were randomly assigned using random numbers generated by a personal computer to one of the following exercise programs: the Long-bout group, which performed a single period of continuous exercise for 30 min on 3 days per week, or the Short-bouts group, which performed 3 short bouts of exercise, 10 min each, on 3 days per week. A

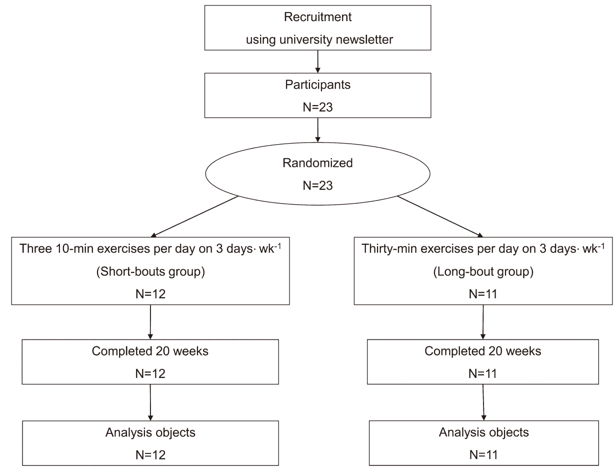

Fig. 1. Flowchart for participants.

flowchart depicting the participant selection is shown in Fig. 1. All subjects provided written informed consent to participate in the present study. This study was approved by the ethics committee of the University of Occupational and Environmental Health, Japan.

Clinical assessment

All subjects underwent complete clinical examination at baseline, after 10 weeks, and again after 20 weeks. Body weight and height were determined using a portable scale and body mass index (BMI) was calculated by dividing the weight (kg) by the square of the height (m^2). Waist circumference was measured using a standard protocol[19]. Resting blood pressure with the subject seated was measured 3 times between 8:00 AM and 10:00 AM using an automatic sphygmomanometer (BP-203RVIII; Nihon Colin, Tokyo, Japan). The mean of the 3 blood pressure readings was used for further analysis.

Blood samples were collected after nocturnal fasting for at least 12 h. Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), fasting plasma insulin (FPI), and fasting plasma glucose (FPG) were measured. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald formula (LDL-C=TC − HDL-C − 1/5 × TG). Insulin resistance was calculated using the homeostasis model assessment of insulin resistance (HOMA-IR) with the formula: HOMA-IR=FPI ($\mu U \cdot ml^{-1}$) × FPG ($mg \cdot dL^{-1}$) / 405. The plasma level of thiobarbituric acid-reactive substances (TBARS) was assayed using the fluorescence method, as previously described[20, 21]. The level of TBARS, which are byproducts of lipid peroxidation, is a biomarker of the systemic oxidative stress level and is correlated with cardiovascular disease and its risk factors[22].

Maximum oxygen uptake ($\dot{V}O_{2max}$) was estimated using a 3-stage graded submaximal test with a cycle ergometer (ML-1800, Fukuda Denshi, Tokyo, Japan)[23]. A 6-lead electrocardiogram was recorded and blood pressure was monitored every 2 min during the test. The workload was increased by 35, 40, or 50 W every 3 min depending on the subject's age and physical constitution. $\dot{V}O_{2max}$ can be used as an index for cardiorespiratory endurance.

Protocol

Both the Long-bout and Short-bouts exercise programs were 20 wk long and consisted of 30 min of cycle ergometer exercise per day on 3 days per week. An exercise intensity of 50% $\dot{V}O_{2max}$ was established for each subject based on the result of the $\dot{V}O_{2max}$ test. Exercise intensity could be calculated in watts, and the participants were instructed to practice exercising by themselves with the cycle ergometer at the proper intensity. Cycle ergometers were placed near their workplaces so that each participant could attain access to an ergometer within 5 min. $\dot{V}O_{2max}$ was reassessed during the tenth week, and the exercise intensity was adjusted according to the 10-wk $\dot{V}O_{2max}$ test for the remaining 10 wk. Subjects in the Short-bouts group were instructed to accumulate 30 min of cycle ergometer activity per day in 3 10-min sessions separated by intervals of ≥2 h on 3 d per week. Subjects in the Long-bout group were instructed to perform a single 30-min continuous bout of cycle ergometer activity 3 d per week. Both exercise programs were self-monitored, and the participants were encouraged to schedule their exercise times into their daily routines while at work. The subjects recorded the time of day for each exercise bout and agreed not to make changes to their diet.

Statistical analysis

Statistical calculations were performed with personal computer statistical software (JMP 9.0; SAS Institute, Inc., Cary, USA). Differences in mean values were assessed using unpaired and paired t-tests for comparisons of 2 variables after confirmation of the normality of each data distribution using the Shapiro-Wilk W-test. Some data that were not normally distributed were subjected to logarithmic conversion prior to analysis. Changes in the cardiovascular risk factors and oxidative stress data were assessed using multivariate analysis of variance (MANOVA) with 2 factors, time (baseline, 10 weeks, and 20 weeks) and pattern of exercise (Short-bouts vs. Long-bout). The level of statistical significance was set at $p<0.05$.

In addition, the effect size (ES) was calculated using G*Power 3, which is a power analysis program designed as a standalone application to handle several types of statistical tests[24]. The indices of ES were Cohen's d for the paired t-tests and f or f^2 for MANOVA[25]. According to standard practice, the thresholds for small, medium, and large effects were defined as d values below 0.20, 0.50, and 0.80; f values below 0.10, 0.25, and 0.40; and f^2 values below 0.02, 0.15, and 0.35, respectively[25].

Results

Characteristics of the subjects

No medical complications occurred during the study. As shown in Table 1, with the exception of FPG, there were no significant differences in age, blood pressure, heart rate, body weight, BMI, waist circumference, $\dot{V}O_{2max}$, lipid profile, FPI, HOMA-IR, or plasma TBARS between the groups at baseline. There were also no differences between the groups with respect to the subjects' smoking and drinking habits. Three subjects in the Short-bouts group and 2 subjects in the Long-bout group were taking antihypertensive medication, 1 in the Short-bouts group was using an oral anti-diabetes agent, and 1 in the Long-bout group was taking medication for hyperlipidemia (Table 1). An additional 2 subjects were taking medication for other diseases. Subjects did not alter their medications during the intervention. Thirteen of the subjects were researchers, and the others were clerical workers in the university; there was no significant difference in job type between the 2 groups (p=0.51). The percentages of the actual total exercise duration (of the 1,800 min prescribed) reported by subjects in the Long and Short-bouts groups over the entire 20 weeks were 68.9% (1,239 ± 670 min) and 55.5% (999 ± 528 min), respectively (p=0.35).

Group differences

In the Long-bout group, waist circumference and $\dot{V}O_{2max}$ significantly improved after 20 wk, whereas the DBP after 10 weeks showed a significant increase compared with the baseline value (Table 2). The Short-bouts group demonstrated significant increases in $\dot{V}O_{2max}$ after 10 weeks and in HDL-C after 20 weeks, whereas the DBP after both 10 and 20 wk and the SBP after 20 wk had significantly increased (Table 2). The $\dot{V}O_{2max}$ after 20 wk showed a trend toward an increase in the Short-bouts group, with a medium ES (d=0.55), but this change did not reach statistical significance (p=0.08). Physical fitness levels increased with both multiple short bouts

Table 1. Baseline characteristics

	Short-bouts, n=12, mean ± SD (range)		Long-bout , n=11, mean ± SD (range)		p^b
Age (yr)	43.3 ± 12.4	(27–63)	44.5 ± 11.1	(27–59)	0.822
SBP (mm Hg)	122.5 ± 11.2	(105.3–140.6)	118.6 ± 8.9	(104.3–131.7)	0.374
DBP (mm Hg)	77.5 ± 6.8	(67.0–89.7)	75.1 ± 6.1	(67.0–85.0)	0.370
PR (bpm)	76.8 ± 12.4	(60.3–115.7)	73.7 ± 12.4	(60.0–90)	0.567
BW (kg)	74.1 ± 8.5	(59.7–87.0)	73.3 ± 11.4	(57.5–89.7)	0.856
BMI ($kg·m^{-2}$)	26 ± 2.4	(22.7–32.0)	25.6 ± 3.9	(20.8–32.1)	0.760
Waist circumference (cm)	89.5 ± 5.1	(83.5–101.2)	89.9 ± 7.6	(79.8–99.4)	0.895
$\dot{V}O_{2max}$ ($mL·kg^{-1}·min^{-1}$)[a]	35.1 ± 4.5	(26.6–46.4)	38 ± 7.5	(29.8–53.3)	0.280
TC ($mg·dL^{-1}$)	212.8 ± 32.4	(169–281)	201.5 ± 20	(167–234)	0.331
HDL-C ($mg·dL^{-1}$) [a]	51.8 ± 13.9	(33–81)	47.5 ± 9.2	(38–62)	0.451
TG ($mg·dL^{-1}$) [a]	150.4 ± 82.5	(66–356)	143.1 ± 79.4	(74–348)	0.787
LDL-C ($mg·dL^{-1}$)	130.8 ± 29.5	(92.8–176.2)	125.3 ± 27.1	(71.4–159.2)	0.645
FPI ($\mu U·mL^{-1}$) [a]	8.9 ± 3.6	(3.4–16.4)	7.7 ± 3	(2.4–13.8)	0.449
FPG ($mg·dL^{-1}$) [a]	124.7 ± 46.1	(96–266)	100.5 ± 7.1	(91–112)	0.049
HOMA-IR [a]	2.64 ± 1.00	(0.81–4.41)	1.95 ± 0.9	(0.54–3.82)	0.127
TBARS ($\mu mol·L^{-1}$) [a]	0.28 ± 0.05	(0.20–0.36)	0.28 ± 0.05	(0.22–0.37)	0.999
Smoking					0.465
Current smoker	1		0		
Ex-smoker	5		4		
Non-smoker	6		7		
Alcohol consumption					0.901
Almost every day	9		8		
Occasional drinker	3		3		
Medication					–
Antihypertensive agent	3		2		
Oral anti-diabetes agent	1		0		
Lipid-lowering agent	0		1		
Type of a Job					0.509
Researcher	6		7		
Clerical worker	6		4		

Short-bouts = three 10-min exercises d^{-1} on 3 d $week^{-1}$; Long-bout = 30-min exercises d^{-1} on 3 d $weeks^{-1}$.
SBP: systolic blood pressure, DBP: diastolic blood pressure, PR: pulse rate, BW: body weight, BMI: body mass index, $\dot{V}O_{2max}$: maximum oxygen uptake, TC: total cholesterol, HDL-C: high-density lipoprotein cholesterol, TG: triglyceride, LDL-C: low-density lipoprotein cholesterol, FPI: fasting plasma insulin, FPG: fasting plasma glucose, HOMA-IR: Homeostasis model assessment of insulin resistance, TBARS: thiobarbituric acid reactive substances. a: for analyses these continuous values were log-transformed. b: p for unpaired t-test or χ^2 test.

(2.4 $ml·kg^{-1}·min^{-1}$, 7.0%) and a single long bout (2.7 $ml·kg^{-1}·min^{-1}$, 7.1%) of exercise. Plasma levels of TBARS significantly decreased after 20 wk in the Long-bout group (Table 2). A trend towards decreased plasma levels of TBARS with a medium ES (d=0.58) was observed after 20 wk in the Short-bouts group but did not reach statistical significance (p=0.07).

As shown in Table 2, comparison [p (time × group)] between the long and short bouts of exercise showed no significant difference in the effects of the interventions on the overall variables. Moreover, the ES (f^2) values for $\dot{V}O_{2max}$, TC, and HDL-C were also below the medium level (0.15). Waist circumference, HDL-C, $\dot{V}O_{2max}$, and TBARS significantly improved in all subjects over the 20 wk, whereas diastolic blood pressure significantly increased [p (time) in Table 2].

Discussion

This study highlights 2 major findings in sedentary male Japanese workers. First, the results of this study demonstrated no significant differences in cardiorespira-

Table 2. Changes in anthropometric measures, blood pressure, predicted maximum oxygen uptake, and glucose and lipid metabolism of subjects from pre- (baseline) to mid- (10 wk) and post- (20 wk) training for the long-bout and short-bouts groups

	Short-bouts (n=12)						Long-bout (n=11)						*Time*		*Time × Group*	
	10 wk-baseline	p^b	ES (*d*)	20 wk-baseline	p^b	ES (*d*)	10 wk-baseline	p^b	ES (*d*)	20 wk-baseline	p^b	ES (*d*)	p^c	ES (*f*)	p^c	ES (f^2)
Δ SBP (mm Hg)	2.6 ± 7.1	0.229	0.37	9.6 ± 10.5	0.009	0.91	1 ± 7.9	0.683	0.13	0.7 ± 11.3	0.843	0.06	0.109	0.50	0.183	0.39
Δ DBP (mm Hg)	3.2 ± 4.3	0.024	0.74	8.1 ± 7.4	0.023	1.09	2.1 ± 2.6	0.023	0.81	1.8 ± 6.2	0.368	0.29	0.004	0.87	0.111	0.44
Δ PR (bpm)	–3.5 ± 11.8	0.329	0.30	–5.7 ± 21	0.372	0.27	–0.8 ± 7.8	0.742	0.10	–1.4 ± 12.9	0.717	0.11	0.611	0.22	0.674	0.19
Δ BW (kg)	–0.15 ± 1.3	0.698	0.12	–0.48 ± 2.86	0.57	0.17	–0.62 ± 1.28	0.14	0.48	–0.49 ± 1.71	0.363	0.29	0.396	0.31	0.551	0.20
Δ BMI ($kg{\cdot}m^{-2}$)	–0.05 ± 0.47	0.719	0.11	–0.22 ± 1.03	0.471	0.21	–0.28 ± 0.49	0.088	0.57	–0.23 ± 0.71	0.301	0.32	0.297	0.36	0.336	0.43
Δ Waist (cm)	–0.66 ± 1.63	0.19	0.40	–1.31 ± 3.3	0.196	0.40	–1.41 ± 2.25	0.065	0.63	–2.19 ± 2.47	0.015	0.89	0.033	0.64	0.672	0.20
Δ Ln $\dot{V}O_{2max}$($mL{\cdot}kg^{-1}{\cdot}min^{-1}$)[a]	0.024 ± 0.036	0.042	0.67	0.065 ± 0.118	0.083	0.55	0.055 ± 0.072	0.03	0.76	0.073 ± 0.081	0.014	0.90	0.007	0.88	0.558	0.00
ΔTC ($mg{\cdot}dL^{-1}$)	–1.5 ± 19.6	0.796	0.08	2.9 ± 18.3	0.593	0.16	–0.3 ± 10.1	0.931	0.03	1.2 ± 16.7	0.819	0.07	0.786	0.16	0.942	0.08
Δ Ln HDL-C ($mg{\cdot}dL^{-1}$)[a]	0.013 ± 0.105	0.679	0.12	0.083 ± 0.118	0.034	0.70	–0.044 ± 0.103	0.192	0.43	0.036 ± 0.093	0.228	0.39	0.003	0.96	0.291	0.00
Δ Ln TG ($mg{\cdot}dL^{-1}$)[a]	–0.005 ± 0.267	0.952	0.02	–0.163 ± 0.421	0.208	0.39	–0.074 ± 0.437	0.583	0.17	–0.122 ± 0.238	0.119	0.51	0.209	0.44	0.424	0.16
ΔLDL-C ($mg{\cdot}dL^{-1}$)	–2.4 ± 21	0.698	0.11	4.1 ± 23	0.546	0.18	6 ± 15.6	0.229	0.38	3.3 ± 14.6	0.477	0.23	0.678	0.20	0.412	0.29
Δ Ln FPI ($\mu U{\cdot}mL^{-1}$)[a]	–0.079 ± 0.253	0.306	0.31	0.001 ± 0.377	0.995	0.00	0.082 ± 0.391	0.505	0.16	0.055 ± 0.381	0.643	0.01	0.926	0.09	0.502	0.18
Δ Ln FPG ($mg{\cdot}dL^{-1}$)[a]	–0.044 ± 0.086	0.106	0.51	–0.007 ± 0.065	0.729	0.11	0.003 ± 0.049	0.86	0.06	0.005 ± 0.069	0.831	0.07	0.416	0.33	0.365	0.31
Δ Ln HOMA-IR[a]	–0.122 ± 0.255	0.126	0.48	–0.006 ± 0.387	0.959	0.02	0.084 ± 0.411	0.513	0.20	0.059 ± 0.425	0.653	0.14	0.816	0.14	0.322	0.34
Δ Ln TBARS ($\mu mol{\cdot}L^{-1}$) [a]	–0.006 ± 0.09	0.82	0.07	–0.071 ± 0.123	0.071	0.58	–0.059 ± 0.111	0.112	0.53	–0.085 ± 0.124	0.047	0.69	0.011	0.71	0.208	0.30

Short-bouts = three 10-min exercises d^{-1} on 3 d $week^{-1}$; Long-bout = 30-min exercises d^{-1} on 3 d $weeks^{-1}$. SBP: systolic blood pressure, DBP: diastolic blood pressure, PR; pulse rate, BW: body weight, BMI: body mass index, $\dot{V}O_{2max}$: maximum oxygen uptake, TC: total cholesterol, HDL-C: high-density lipoprotein cholesterol, TG: triglyceride, LDL-C: low-density lipoprotein cholesterol, FPI: fasting plasma insulin, FPG: fasting plasma glucose, HOMA-IR: Homeostasis model assessment of insulin resistance, TBARS: thiobarbituric acid reactive substances, ES: effect size (these values represent as absolute values). The thresholds for small, medium, and large effects were defined as *d* values below 0.20, 0.50, and 0.80; *f* values below 0.10, 0.25, and 0.40; and f^2 values below 0.02, 0.15, and 0.35, respectively. a: for analyses there values were log-transformed. b: *p* for paired *t*-test, versus baseline. c: *p* for MANOVA.

tory fitness, anthropometry, or the lipid profile between accumulated short bouts of exercise and single long bouts of exercise even over a long-term intervention. Second, the subjects overall showed a significant reduction in oxidative stress during the exercise programs, and no significant difference in these effects was observed between the exercise programs. These findings suggest that accumulation of total exercise duration per week is more important than the length of each exercise session and thus provide an alternative for busy workers.

Effect on physical fitness

High levels of physical fitness have been shown to reduce the risks of cardiovascular disease, diabetes mellitus, and some types of cancer in male Japanese workers[26–28]. Therefore, it is important for occupational health to promote physical fitness among workers to prevent in-office deaths and decreased productivity due to these diseases[29–31]. The present study demonstrated that physical fitness levels, as indicated by $\dot{V}O_{2max}$, increased in response to both short bouts (2.4 $ml \cdot kg^{-1} \cdot min^{-1}$, 7.0%, p=0.08, d=0.55 [a medium ES]) and long bouts (2.7 $ml \cdot kg^{-1} \cdot min^{-1}$, 7.1%, p=0.01, d=0.90 [a large ES]) of exercise. In a long-term intervention study by Jakicic, et al., physical fitness levels in overweight women increased by 6.3% and 9.9% after 72 wk of short-bouts or long-bout exercise, respectively, with no difference between the exercise groups[7]. Recently, Osei-Tutu *et al.*, reported that physical fitness levels increased by 7.2% in the Short-bouts group and by 6.7% in the Long-bout group in studies conducted over 8 weeks in sedentary men[10]. The results of the present study investigating the improvements in physical fitness over 20 wk in sedentary male workers are consistent with those of these previous studies.

On the other hand, a previous study reported that physical fitness in sedentary healthy men who jogged for 30 min/d on 5 days per week for 8 wk increased by 7.6% in a Short-bouts group and 13.9% in a Long-bout group, a significantly greater increase in the Long-bout group[6]. Murphy *et al.*, have shown improvements in physical fitness in response to either 3 short bouts (14.2%) or 1 long bout (3.8%) of brisk walking for 10 weeks in sedentary women, but this increase was greater in the group walking for short bouts[8]. These differences may be due to the exercise intensities used in each study. For example, the exercise intensities (>70% maximum heart rate) in the studies cited above were higher than the intensity used in the current study (50% of maximal oxygen consumption, ≤70% maximum heart rate). Further study is needed to clarify the effects of the mode and intensity of exercise on physical fitness.

Effects on fat distribution, lipid profile, and other cardiovascular risk factors

The Long-bout group demonstrated a significant decrease in waist circumference after 20 wk compared with the baseline value, but the decrease in waist circumference in the Short-bouts group showed a small ES (d=0.40) and did not reach statistical significance. BMI was unaltered in both groups. The decreases in waist circumference in the Long-bout group could indicate a potential alteration in the distribution of body fat away from the waist, which may lower the risk of cardiovascular disease. An interventional study by Osei-Tutu *et al.*, also reported that only long-bout walking produced significant reductions in the percentage of body fat[10]. However, there are some reports that exercise patterns do not influence the magnitudes of anthropometric changes[7–9]. These inconsistencies may be attributed to population differences in parameters such as the pre-intervention waist circumference.

The Short-bouts group in the current study demonstrated a significant increase in the HDL-C level after 20 wk, but the HDL-C level in the Long-bout group showed a small ES (d=0.39) and was not significantly different. Increases in HDL-C may reduce cardiovascular risk. However, findings from other studies vary regarding the effects of brisk walking (whether accumulated through short bouts or through longer sessions) on serum lipid levels. While some studies report changes in response to both patterns of exercise[9], others do not[32]. These inconsistencies may also be attributed to population differences in parameters such as the pre-intervention lipid profile[12].

No changes in other cardiovascular risk factors (TC, TG, LDL-C, or glucose metabolism) were observed in the 2 exercise groups in this study. Eriksen and colleagues have reported that short bouts of exercise are preferable to a single continuous exercise period with regard to their effects on glucose metabolism[32], but the intensity of exercise in that study (60% to 65% of maximal oxygen consumption) was higher than that used in the current study, suggesting that this difference in exercise intensity might explain the inconsistencies.

Effect on oxidative stress

The current study showed almost identical reductions in plasma levels of TBARS between the exercise groups over the 20-wk study period, based on the findings of no significant difference in the effects of the interventions when the long and short bouts of exercise were compared and on significant improvements in plasma levels of TBARS in all subjects over the 20 wk. The plasma levels of TBARS after 20 wk tended to be lower in the short-bouts group; although this trend did not reach statistical significance (p=0.07), the ES was medium (d=0.58), suggesting possible practical implications. Despite other studies that have reported the efficacy of 1 continuous exercise period[33, 34], to our knowledge, no other studies have examined whether the total accumulated exercise duration could suppress oxidative stress. Oxidative stress is closely associated with the pathogenesis and the progression of cardiovascular risk factors[13–16]. Thus, from the perspective of occupational health for busy workers, it is highly significant that the total accumulated exercise duration may limit cardiovascular risk through the reduction of oxidative stress.

Strength and limitations

This study has several strengths. First, this was a randomized controlled study. Second, the subjects of this study were middle-aged male Japanese workers. There have been few studies that focused on the comparison between short and long bouts of exercise using data from Japanese workers. Third, the exercise programs used in this study were tailor-made exercise programs of moderate intensity, which was measured objectively by the cycle ergometer. However, this study also has several limitations. First, this study did not have a control group despite the random assignment of the interventional groups. The aim of this study was to compare the effects of short-bout and long-bout exercise on cardiovascular risk factors, and a single continuous exercise session lasting 30 min is generally recognized as a non-pharmacologic therapy for lifestyle-related diseases. Therefore, in this study, the Long-bout group was considered the control group. Second, in the Short-bouts group, a significant increase in blood pressure in comparison with baseline was observed after 20 wk. This interventional study began in June, and the laboratory follow-ups were held in September (after 10 wk) and December (after 20 wk). Blood pressure is known to vary with the time of year, and the odds ratio for a systolic blood pressure ≥ 120 mm Hg is 1.24 for winter versus summer months[35]. Such seasonal changes in blood pressure may explain the unexpected increase associated with short bouts of exercise. However, the blood pressure levels in the Long-bout group were unchanged, suggesting a suppressive effect of continuous exercise on the seasonal increase in blood pressure. Third, this study is limited by the relatively small sample size. A larger sample would be necessary to establish full equivalence between the effects of 3 short bouts of exercise and 1 longer bout of exercise[36, 37]. Moreover, all of the ES (f^2) values in Table 2 except those for $\dot{V}O_{2max}$, TC, and HDL-C were either large or medium. Therefore, based on the results of the current study, exercise in short bouts cannot be deemed as effective as long-bout exercise. Finally, the rates of adherence to the prescribed exercise programs were 60% to 70%, but there was no dropout. Low exercise compliance may explain the small effects of exercise on cardiovascular risk factors, including the smaller-than-expected improvements in lipid profiles and glucose metabolism. Moreover, the adherence rate in the Short-bouts group was unexpectedly lower than that in the Long-bout group, although the difference was not significant. Because the participants in this study included researchers from the university who make frequent business trips, it may have been difficult to practically implement the short-bouts exercise program using a fixed cycle ergometer. These results also imply that occupational practitioners should match the exercise program, either short or long bouts of exercise, to the participant's workstyle.

Conclusions

We have demonstrated in this study that it is the performance of an exercise program itself rather than the exact nature of the program that is effective for improving physical fitness, the lipid profile, and oxidative stress and that short-bout exercise protocols are an option, especially for busy workers, for incorporating exercise into one's lifestyle. A larger-scale randomized controlled test should be planned to determine the equivalence between the effects of 3 short bouts of exercise versus 1 longer bout of exercise.

References

1) Japan Industrial Safety & Health Association (2010) General Guidebook on Industrial Health. Japan Industrial Safety & Health Association, Tokyo.
2) Ministry of Health, Labour and Welfare. Active Guide 2013. http://www.mhlw.go.jp/stf/houdou/2r9852000002xple-att/2r9852000002xpqt.pdf. Accessed June 3, 2013 (in Japanese).
3) Ministry of Health, Labour and Welfare. The Survey on State of Employees' Health 2007. http://www.mhlw.go.jp/toukei/itiran/roudou/saigai/anzen/kenkou07/dl/kenkou07_0001.pdf. Accessed June 3, 2013 (in Japanese).
4) Japan Health Promotion & Fitness Foundation. Health

Japan 21 (2nd edition). http://www.mhlw.go.jp/bunya/kenkou/dl/kenkounippon21_01.pdf. Accessed June 3, 2013 (in Japanese).
5) Ishii K, Inoue S, Ohya Y, Odagiri Y, Takamiya T, Suijo K, Owen N, Shimomitsu T (2009) Sociodemographic variation in the perception of barriers to exercise among Japanese adults. J Epidemiol **19**, 161–8. [Medline] [CrossRef]
6) DeBusk RF, Stenestrand U, Sheehan M, Haskell WL (1990) Training effects of long versus short bouts of exercise in healthy subjects. Am J Cardiol **65**, 1010–3. [Medline] [CrossRef]
7) Jakicic JM, Winters C, Lang W, Wing RR (1999) Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. JAMA **282**, 1554–60. [Medline] [CrossRef]
8) Murphy MH, Hardman AE (1998) Training effects of short and long bouts of brisk walking in sedentary women. Med Sci Sports Exerc **30**, 152–7. [Medline] [CrossRef]
9) Murphy M, Nevill A, Neville C, Biddle S, Hardman A (2002) Accumulating brisk walking for fitness, cardiovascular risk, and psychological health. Med Sci Sports Exerc **34**, 1468–74. [Medline] [CrossRef]
10) Osei-Tutu KB, Campagna PD (2005) The effects of short- vs. long-bout exercise on mood, VO2max, and percent body fat. Prev Med **40**, 92–8. [Medline] [CrossRef]
11) Schmidt WD, Biwer CJ, Kalscheuer LK (2001) Effects of long versus short bout exercise on fitness and weight loss in overweight females. J Am Coll Nutr **20**, 494–501. [Medline] [CrossRef]
12) Murphy MH, Blair SN, Murtagh EM (2009) Accumulated versus continuous exercise for health benefit: a review of empirical studies. Sports Med **39**, 29–43. [Medline] [CrossRef]
13) Fukui T, Yamauchi K, Maruyama M, Yasuda T, Kohno M, Abe Y (2011) Significance of measuring oxidative stress in lifestyle-related diseases from the viewpoint of correlation between d-ROMs and BAP in Japanese subjects. Hypertens Res **34**, 1041–5. [Medline] [CrossRef]
14) Griendling KK, FitzGerald GA (2003) Oxidative stress and cardiovascular injury: Part II: animal and human studies. Circulation **108**, 2034–40. [Medline] [CrossRef]
15) Sakano N, Wang DH, Takahashi N, Wang B, Sauriasari R, Kanbara S, Sato Y, Takigawa T, Takaki J, Ogino K (2009) Oxidative stress biomarkers and lifestyles in Japanese healthy people. J Clin Biochem Nutr **44**, 185–95. [Medline] [CrossRef]
16) Cai H, Harrison DG (2000) Endothelial dysfunction in cardiovascular diseases: the role of oxidant stress. Circ Res **87**, 840–4. [Medline] [CrossRef]
17) Ohta M, Takigami C, Ikeda M (2007) Effect of lifestyle modification program implemented in the community on workers' job satisfaction. Ind Health **45**, 49–55. [Medline] [CrossRef]
18) Park JY, Ferrell RE, Park JJ, Hagberg JM, Phares DA, Jones JM, Brown MD (2005) NADPH oxidase p22phox gene variants are associated with systemic oxidative stress biomarker responses to exercise training. J Appl Physiol **99**, 1905–11. [Medline] [CrossRef]
19) Ministry of Health, Labour and Welfare. Standard Program for Health Checkups and Health Guidance. http://www.mhlw.go.jp/bunya/kenkou/seikatsu/pdf/02b_0015.pdf. Accessed June 3, 2013 (in Japanese).
20) Ohta M, Nanri H, Matsushima Y, Sato Y, Ikeda M (2005) Blood pressure-lowering effects of lifestyle modification: possible involvement of nitric oxide bioavailability. Hypertens Res **28**, 779–86. [Medline] [CrossRef]
21) Yagi K (1976) A simple fluorometric assay for lipoperoxide in blood plasma. Biochem Med **15**, 212–6. [Medline] [CrossRef]
22) Schisterman EF, Faraggi D, Browne R, Freudenheim J, Dorn J, Muti P, Armstrong D, Reiser B, Trevisan M (2001) TBARS and cardiovascular disease in a population-based sample. J Cardiovasc Risk **8**, 219–25. [Medline] [CrossRef]
23) Okazaki T, Himeno E, Nanri H, Ikeda M (2001) Effects of a community-based lifestyle-modification program on cardiovascular risk factors in middle-aged women. Hypertens Res **24**, 647–53. [Medline] [CrossRef]
24) Faul F, Erdfelder E, Lang AG, Buchner A (2007) G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods **39**, 175–91. [Medline] [CrossRef]
25) Cohen J (1992) A power primer. Psychol Bull **112**, 155–9. [Medline] [CrossRef]
26) Sawada SS, Muto T, Tanaka H, Lee IM, Paffenbarger RS Jr, Shindo M, Blair SN (2003) Cardiorespiratory fitness and cancer mortality in Japanese men: a prospective study. Med Sci Sports Exerc **35**, 1546–50. [Medline] [CrossRef]
27) Sawada SS, Lee IM, Muto T, Matuszaki K, Blair SN (2003) Cardiorespiratory fitness and the incidence of type 2 diabetes: prospective study of Japanese men. Diabetes Care **26**, 2918–22. [Medline] [CrossRef]
28) Sawada SS, Lee IM, Naito H, Noguchi J, Tsukamoto K, Muto T, Higaki Y, Tanaka H, Blair SN (2010) Long-term trends in cardiorespiratory fitness and the incidence of type 2 diabetes. Diabetes Care **33**, 1353–7. [Medline] [CrossRef]
29) Burton WN, Chen CY, Conti DJ, Schultz AB, Pransky G, Edington DW (2005) The association of health risks with on-the-job productivity. J Occup Environ Med **47**, 769–77. [Medline]
30) Pelletier B, Boles M, Lynch W (2004) Change in health risks and work productivity over time. J Occup Environ Med **46**, 746–54. [Medline] [CrossRef]
31) Tsai SP, Wendt JK, Ahmed FS, Donnelly RP, Strawmyer TR (2005) Illness absence patterns among employees in a petrochemical facility: impact of selected health risk factors. J Occup Environ Med **47**, 838–46. [Medline]
32) Eriksen L, Dahl-Petersen I, Haugaard SB, Dela F (2007) Comparison of the effect of multiple short-duration with single long-duration exercise sessions on glucose

homeostasis in type 2 diabetes mellitus. Diabetologia **50**, 2245–53. [Medline] [CrossRef]

33) Gomes VA, Casella-Filho A, Chagas AC, Tanus-Santos JE (2008) Enhanced concentrations of relevant markers of nitric oxide formation after exercise training in patients with metabolic syndrome. Nitric Oxide **19**, 345–50. [Medline] [CrossRef]

34) Nojima H, Watanabe H, Yamane K, Kitahara Y, Sekikawa K, Yamamoto H, Yokoyama A, Inamizu T, Asahara T, Kohno N (2008) Effect of aerobic exercise training on oxidative stress in patients with type 2 diabetes mellitus. Metabolism **57**, 170–6. [Medline] [CrossRef]

35) Thomas C, Wood GC, Langer RD, Stewart WF (2008) Elevated blood pressure in primary care varies in relation to circadian and seasonal changes. J Hum Hypertens **22**, 755–60. [Medline] [CrossRef]

36) Gøtzsche PC (2006) Lessons from and cautions about noninferiority and equivalence randomized trials. JAMA **295**, 1172–4. [Medline] [CrossRef]

37) Piaggio G, Elbourne DR, Altman DG, Pocock SJ, Evans SJ (2006) Reporting of noninferiority and equivalence randomized trials: an extension of the CONSORT statement. JAMA **295**, 1152–60. [Medline] [CrossRef]