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Lifestyle-Based Physical Activity Intervention for One Year Improves Metabolic Syndrome in Overweight Male Employees

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Regular physical activity is associated with improvements of metabolic syndrome (MetS) risk factors. Furthermore, recent physical activity guidelines for health promotion recommend that moderate to vigorous physical activity should be performed in bouts lasting ≥ 10 min. Brisk walking is a popular and readily attainable form of moderate intensity physical activity and is suitable for the majority of individuals. However, it is unclear whether brisk walking lasting ≥ 10 min is associated with improvement in MetS. This study aimed to determine the effects of a 1-year lifestyle-based physical activity intervention with brisk walking of ≥ 10 min using a pedometer on the improvement in MetS. Three hundred and seventy-six overweight male employees with ≥ 1 MetS component(s) participated in this intervention study from 2008 to 2009 (age, 30-62 years; body mass index, 23.0-45.5 kg/m^2). Overall, 316 participants (84%) completed the 1-year intervention. MetS was defined according to the Japanese criteria at baseline and after 1 year. Brisk walking lasting ≥ 10 min was significantly associated with the decrease in waist circumference (β = −1.479) and triglyceride (β = −31.260), and the increase in high-density lipoprotein cholesterol (β = 2.117). The brisk walking step counts were also significantly associated with higher odds for an improvement in MetS (OR, 1.48; 95% CI, 1.05-2.09) and abdominal obesity (OR, 1.45; 95% CI, 1.12-1.87). In conclusion, the lifestyle-based intervention with brisk walking of ≥ 10 min is an effective strategy to improve MetS in overweight male employees.

Keywords: brisk walking; intervention; metabolic syndrome; pedometer; steps
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Metabolic syndrome (MetS) is a cluster of risk factors including abdominal obesity, hypertension, hyperglycemia, and dyslipidemia that predispose individuals to develop cardiovascular disease (Reaven 1988). Individuals with MetS are also at increased risk of developing type 2 diabetes (Laaksonen et al. 2002) and atherosclerotic cardiovascular disease, resulting in a greater cardiovascular disease mortality rate compared with individuals without MetS (Lakka et al. 2002; Hu et al. 2004).

Several recent studies have shown that moderate to vigorous physical activity is associated with improvements in obesity-related cardiovascular and metabolic abnormalities, and all-cause mortality (Byberg et al. 2001; Zhu et al. 2004; Brien et al. 2006; Lakka and Laaksonen 2007; Yang et al. 2008; Kim et al. 2011). However, despite the well-documented health benefits of physical activity, the majority of people in Japan remain physically inactive; only about 30% of Japanese adults achieve the recommended level of physical activity, particularly among the working population (Shibata et al. 2009). The working age population has mentioned lack of time and overtime working as the main reasons for not participating in leisure-time physical activity (Trost et al. 2002). Therefore, accessible and cost-effective lifestyle-based interventions capable of increasing physical activity are needed.

Brisk walking is a popular and readily attainable form of moderate intensity physical activity, suitable for the majority of individuals. Pedometers are small, inexpensive devices that are widely used in lifestyle-based physical activity interventions. Their immediate feedback on the number of steps taken has proven to be a motivating tool for increasing physical activity. Indeed, pedometers have been used in lifestyle-based physical activity interventions to motivate individuals to increase walking (Bravata et al. 2007). Several pedometer-based interventions have resulted in significant improvements in weight or body

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mass index (BMI), waist circumference (WC), and other risk factors for diabetes and cardiovascular disease (Gray et al. 2009; Pal et al. 2009; Freak-Poli et al. 2011). Furthermore, the earlier studies demonstrated that even short bouts of brisk walking of 10 minutes (min) accumulated throughout the day are at least as effective as one continuous bout (30 min) of a similar level of activity in improving cardiovascular risk, lipid profiles, fasting plasma insulin and cardiorespiratory fitness (Donnelly et al. 2000; Moreau et al. 2001; Murphy et al. 2002). Consequently, recent guidelines, based on this evidence, recommend that moderate to vigorous physical activity should be performed in bouts lasting 10 min (Haskell et al. 2007; World Health Organization 2012). However, most of the previous pedometer-based intervention studies only examined the total step count, without taking into account bouts of activity (Gray et al. 2009; Pal et al. 2009; Freak-Poli et al. 2011).

In this study, we examined the effects of a 1-year lifestyle-based physical activity program using a pedometer on MetS and its components in overweight Japanese male employees. We also examined the association of bouts of brisk walking of ≥ 10 min with changes in MetS and its components.

Methods

Participants and study design

This lifestyle-based physical activity intervention study was carried out at 12 workplaces around Japan that belonged to a large private pharmaceutical company between 2008 and 2009. Six hundred and fifty-five middle-aged male Japanese sedentary employees were initially enrolled in this study. The mean working time was approximately 45 hours per week, and 85% of the participants reported overtime working at least once a week. Subjects aged < 30 years of age (n = 10), with normal weight (BMI of < 23.0 kg/m^2, n = 92), or without MetS components (n = 133) were excluded from this analysis. Therefore, 376 men who were overweight or obese based on Japanese criteria for obesity (Kanazawa et al. 2002) (age, 30-62 years; BMI, 23.0-45.5 kg/m^2) with ≥ 1 MetS components were included in this analysis.

The lifestyle-based intervention was evaluated using pre-post study design, with data collected at baseline and after 1 year. All measurements were carried out by the trained staff at baseline and 1 year. This study conformed to the principles of the Helsinki Declaration and was approved by the ethics committees at the Institute of Health and Sport Sciences and the Institute of Clinical Medicine, University of Tsukuba. All of the participants provided written informed consent.

Intervention program

All subjects participated in the lifestyle-based physical activity intervention program managed using a pedometer alone (HJ-730IT, Omron Healthcare Co., Ltd., Kyoto, Japan). Subjects were instructed to increase their steps count to 3,000 steps/day on ≥ 5 days/week, of which ≥ 2,000 steps/day were to be fulfilled by brisk walking in daily life. All subjects received a 90-min lecture on the health benefits of physical activity and using a pedometer from a professional Health Fitness Programmer before starting the intervention. Participants were able to view the number of steps and the number of bouts of ≥ 10 min performed each day. Every month, we provided the subjects with feedback reports summarizing their adherence to the target physical activity level using e-mail.

Anthropometric variables

Body weight was measured to the nearest 0.1 kg using a digital scale (TBF-551, Omron Healthcare Co., Ltd., Kyoto, Japan). Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. BMI was calculated as body weight/height^2 (kg/m^2).

Physical activity

Daily physical activity was measured using the pedometer for 7 days at baseline (Clemes et al. 2008), and every day during the intervention. We also determined the mean numbers of total steps and brisk walking steps per day during the intervention as follow-up data (Kang et al. 2009). The duration of time spent walking each day and duration of time spent in brisk walking per day were also determined. In this study, brisk walking was defined as steps satisfying the following conditions: (1) walking at a pace equivalent to ≥ 4 metabolic equivalents (METs), (2) walking for ≥ 10 min continuously, and (3) taking a rest for < 1 min was allowed during each 10-min session of continuous walking.

MetS components

WC was measured three times to the nearest 0.1 cm at the umbilical level using a calibrated measuring tape. Blood pressure was measured using a sphygmomanometer (SM-100; Omron Healthcare Co., Ltd.) with subjects in a seated position after a 10-min rest. Approximately 10 mL of blood was drawn from each subject after an overnight fast of ≥ 12 h. Fresh samples were used for the enzymatic analysis of triglycerides, and fasting plasma glucose was determined using the glucose oxidase method. Serum high-density lipoprotein cholesterol was measured by heparin-manganese precipitation.

MetS was defined according to the Japanese criteria (The Examination Committee of Criteria for 'Metabolic Syndrome' in Japan 2005) as WC ≥ 85 cm for men plus at least two of the following components: (1) dyslipidemia (triglyceride ≥ 150 mg/dL and/or high-density lipoprotein cholesterol level < 40 mg/dL), (2) hypertension (systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg), or (3) hyperglycemia (fasting glucose ≥ 110 mg/dL).

Health questionnaire

The participants answered a general health questionnaire focusing on healthy eating behaviors, alcohol consumption, and smoking status. Healthy eating behaviors were evaluated by summing the score of eating behaviors each subject reported at baseline and follow-up in terms of the following: avoiding salty foods (Li et al. 2010), eating breakfast almost daily (van der Heijden et al. 2007), eating fast (Otsuka et al. 2006), and not eating until full (Maruyama et al. 2008). Smoking status was classified as never or current smoking. In addition, we investigated the alcohol consumption (never, 1-2 days per week, 3-5 days per week, or on most days of the week).

Statistical analyses

Values are expressed as means ± standard deviation (S.D.) or percentages. Values of $P < 0.05$ were considered statistically significant. All data were analyzed using R version 2.10.1 (R Development Core Team: R 2009). Paired t tests were used to compare differences in quantitative variables between before and after the intervention. Changes in the prevalence of MetS and its components were analyzed using McNemar's test. In addition, we also carried out the sensitivity analyses of the whole to examine the impact of the drop out. Differences in subject characteristics and MetS risk factors between subjects with or without improvements in MetS were tested using unpaired t tests. Multiple regression analysis was used to examine the associations between total and brisk walking step counts with changes in MetS components over 1 year. Age, smoking, changes in healthy eating behaviors, alcohol consumption, and baseline total or brisk walking step counts were included as covariates in these models. Differences in daily steps and brisk walking steps were compared between subjects with or without improvements in MetS were tested by two-way repeated-measures analysis of variance with a group × time interaction term. Logistic regression analysis was used to predict improvements in MetS based on the level of physical activity during the intervention, separately for the total step and brisk walking step counts. Age, smoking, changes in healthy eating behaviors, alcohol consumption, baseline BMI, and baseline total or brisk walking step counts were included in the logistic regression models as covariates.

Results

Overall, 316 participants (84%) completed the physical activity program and health examination. No differences in baseline measurement were observed between those who returned and those who did not return, except for the number of participants with hypertension (Table 1, $P < 0.05$). Table 1 summarizes their baseline characteristics and the changes at 1 year. BMI, WC, SBP, TG, and fasting plasma glucose were significantly lower at 1 year than at baseline (Table 1). HDL-C was significantly higher at 1 year than at baseline. The prevalence of MetS and its components decreased significantly after the intervention (all, $P < 0.05$). The mean daily step and brisk walking step counts increased significantly from baseline to the end of the intervention (all, $P < 0.001$).

We determined the characteristics of subjects who dropped out and who completed intervention. At baseline, age, brisk walking steps, WC, TG, HDL-C, and fasting glucose were not significantly different between these two groups of subjects (all, $P > 0.1$). However, baseline SBP, DBP, and total step counts were significantly higher in individuals who dropped out compared with those who completed the study (total step count: 7,121.2 ± 2,780.4 vs 6,320.4 ± 2,479.6 steps/day, $P < 0.05$). We also conducted a sensitivity analysis of all subjects, including those who dropped out. In this analysis, 144/376 (38.3%) and 84/376 (22.3%) of subjects at baseline and at the follow-up had MetS. However, these results did not significantly influence our overall results.

Table 1. Characteristics of the study subjects.

	Total subjects (n = 376)	Subjects who completed the 1-year intervention (n = 316)		
	Baseline	Baseline	Follow-up	P value
Age (years)	46.7 (6.8)	46.8 (6.8)	-	
BMI (kg/m^2)	27.2 (3.1)	27.1 (3.0)	26.2 (3.2)	< 0.001
Metabolic syndrome components				
Waist circumference (cm)	91.2 (6.9)	90.8 (7.1)	89.6 (8.0)	< 0.001
SBP (mmHg)	133.8 (19.2)	135.5 (15.3)	130.7 (14.1)	< 0.001
DBP (mmHg)	81.1 (13.4)	81.8 (11.7)	81.2 (11.1)	0.344
TG (mg/dL)	200.1 (280.0)	201.5 (296.8)	166.2 (136.5)	0.007
HDL-C (mg/dL)	54.2 (12.7)	54.6 (12.7)	56.7 (13.5)	< 0.001
Fasting glucose (mg/dL)	105.9 (29.2)	105.6 (29.3)	102.8 (24.8)	0.007
Number (%) of subject with				
Metabolic syndrome	144 (38.3)	126 (39.9)	66 (20.9)	< 0.001
Abdominal obesity	322 (85.6)	259 (82.0)	211 (66.8)	< 0.001
Hypertension	240 (64.0)	228 (72.2)*	167 (52.8)	< 0.001
Hyperglycemia	84 (22.3)	66 (20.9)	50 (15.8)	< 0.001
Dyslipidemia	198 (52.7)	164 (51.9)	106 (33.5)	< 0.001
Physical activity				
Total steps (steps/day)	6,448.1 (2,543.1)	6,562.9 (2,492.7)	8,044.3 (2,525.4)†	< 0.001
Brisk walking steps (steps/day)	958.1 (1,407.9)	950.0 (1,379.4)	1,520.2 (1,691.5)†	< 0.001

Values are means (S.D.) or percentages. †Mean value per day in the 1-year intervention. *Significant difference between total subjects and those who completed intervention at baseline by unpaired t-tests ($P < 0.05$). P value indicates differences in baseline and follow-up, in the completed subjects. BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HDL-C, high density lipoprotein cholesterol.

Table 2. The associations between total and brisk walking steps, and change in the MetS components.

$n = 316$	β-coefficients (95% CI)	
	Total steps (steps/day)	Brisk walking steps (steps/day)†
Δ WC (cm)	−0.732 (−1.087 to −0.377)*	−1.479 (−2.002 to −0.957)*
Δ SBP (mmHg)	0.348 (−2.464 to 3.159)	−0.736 (−2.150 to 0.677)
Δ DBP (mmHg)	0.639 (−1.463 to 2.741)	−0.535 (−1.592 to 0.523)
Δ TG (mg/dL)	15.409 (−29.108 to 59.998)	−31.260 (−53.456 to − 9.064)*
Δ HDL-C (mg/dL)	−0.834 (−2.333 to 0.664)	2.117 (1.387 to 2.846)*
Δ Fasting glucose (mg/dL)	0.534 (−2.964 to 4.031)	−0.562 (−2.325 to 1.201)

Adjusted for age, smoking, change in healthy eating behaviors, alcohol consumption, baseline total or brisk walking step counts. The dependent variable is the change in MetS components between baseline and follow-up. Total and brisk walking counts were included in units of 1000 steps/day in 1-year intervention. †Brisk walking was defined as continuous walking for ≥ 10 min at a pace equivalent to ≥ 4 METs. *$P < 0.05$. WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HDL-C, high density lipoprotein cholesterol.

Table 3. Baseline and follow-up characteristics of subjects with and without improvements in MetS.

	Baseline			Follow-up		
	Without improvements in MetS ($n = 66$)	With improvements in MetS ($n = 60$)	P value	Without improvements in MetS ($n = 66$)	With improvements in MetS ($n = 60$)	P value
WC (cm)	94.8 (6.7)	91.2 (5.1)	0.001	95.1 (7.4)	88.6 (6.3)*	< 0.001
SBP (mmHg)	142.5 (13.7)	139.7 (10.5)	0.191	138.8 (13.0)*	129.5 (13.7)*	< 0.001
DBP (mmHg)	86.4 (11.2)	83.0 (9.9)	0.081	88.3 (11.1)	78.5 (9.7)*	< 0.001
TG (mg/dL)	322.6 (587.6)	221.7 (146.8)	0.198	267.1 (211.5)	145.5 (83.6)*	< 0.001
HDL-C (mg/dL)	48.0 (9.5)	53.1 (12.3)	0.009	48.4 (10.1)	56.7 (11.9)*	< 0.001
Fasting glucose (mg/dL)	128.3 (49.8)	107.3 (26.7)	0.004	121.4 (39.2)	103.4 (26.6)*	0.004

Values are means (S.D.). WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HDL-C, high density lipoprotein cholesterol. *$P < 0.05$ versus baseline (paired t-test). This analysis only includes subjects with MetS at baseline.

Table 2 shows the associations between the total step count/brisk walking step count per day with changes in MetS components over 1 year. The total step count was significantly associated with the change in WC ($\beta = -0.732$; $P < 0.05$) after adjusting for age, smoking, changes in healthy eating behaviors, alcohol consumption, and brisk walking step count. In comparison, the brisk walking step count was significantly associated with changes in WC ($\beta = -1.479$; $P < 0.05$), TG ($\beta = -31.260$; $P < 0.05$), and HDL-C ($\beta = 2.117$; $P < 0.05$) after adjusting for age, smoking, changes in healthy eating behaviors, alcohol consumption, and total step count.

We also determined the association between bouts of brisk walking of ≥ 10 min and improvements in MetS within those who had MetS at baseline. At baseline, there were no significant differences in age, total step count, smoking status, or healthy eating behaviors between subjects with or without improvements in MetS (all, $P > 0.05$). However, at baseline, WC and fasting plasma glucose were significantly higher (both, $P < 0.05$) and HDL-C was significantly lower ($P = 0.009$) in subjects without improvements in MetS compared with subjects with improvements in MetS (Table 3). The changes in MetS components are summarized in Table 3.

Table 4 shows the comparison of total and brisk walking step counts between subjects with and without improvements in MetS. The total daily step count increased significantly during the intervention compared with that at baseline in subjects with and without improvements in MetS (Table 4, time effect, $P < 0.001$; group effect, $P = 0.278$; time × group effect, $P = 0.412$). Meanwhile, the brisk walking step count tended to be higher in subjects with improvements in MetS during the intervention compared with subjects without improvements (Table 4; time effect, $P < 0.001$; group effect, $P = 0.084$; time × group effect, $P = 0.009$).

Table 5 shows the results of logistic regression analyses for improvements in MetS and its components according to total and brisk walking step counts. The total step count was not significantly associated with improvements

Table 4. Comparison of total and brisk walking steps between subjects with or without improvements in MetS.

		Without improvements in MetS (n = 66)	With improvements in MetS (n = 60)	Time effect	Group effect	Time × group effect
Total steps (steps/day)	Baseline	6,415.6 (2,354.6)	6,684.9 (2,358.4)	< 0.001	0.278	0.412
	Follow-up	7,829.5 (2,478.8)	8,419.6 (2,676.0)			
Brisk walking steps (steps/day) †	Baseline	829.8 (1,295.8)	894.0 (1,302.7)	< 0.001	0.084	0.009
	Follow-up	1,247.1 (1,523.8)	1,998.7 (1,832.7)			

Values are means (S.D.). Mean steps of total and brisk walking per day in 1-year. †Brisk walking was defined as continuous walking for ≥ 10 min at a pace equivalent to ≥ 4 METs. This analysis only includes subjects with MetS at baseline.

Table 5. Logistic regression analysis for improvements in MetS and its components according to total step and brisk walking step counts†.

Outcome	Total step count OR (95% CI)	*P*-value	Brisk walking step count† OR (95% CI)	*P*-value
Metabolic syndrome (n = 126)	1.09 (0.88-1.35)	0.452	1.48 (1.05-2.09)	0.025
Abdominal obesity (n = 259)	1.12 (0.96-1.30)	0.147	1.45 (1.12-1.87)	0.005
Hypertension (n = 228)	0.95 (0.83-1.09)	0.497	1.05 (0.85-1.31)	0.641
Hyperglycemia (n = 66)	1.08 (0.82-1.42)	0.591	0.91 (0.57-1.50)	0.732
Dyslipidemia (n = 164)	1.01 (0.87-1.18)	0.864	1.18 (0.91-1.53)	0.213

Adjusted for age, smoking, changes in healthy eating behaviors, alcohol consumption, baseline total or brisk walking step counts, and baseline body mass index. Total and brisk walking step counts were included in units of 1000 steps/day in 1 year. †Brisk walking was defined as continuous walking for ≥ 10 min at a pace equivalent to ≥ 4 METs. OR, odds ratio; CI, confidence interval. This analysis only includes subjects with MetS or its components at baseline.

in MetS or its components after adjusting for age, smoking, changes in healthy eating behaviors, alcohol consumption, brisk walking step count, and baseline BMI (Table 5, all $P > 0.05$). By contrast, the brisk walking step count was significantly associated with higher odds for an improvement in MetS (OR, 1.48; 95% CI, 1.05-2.09, $P = 0.025$), abdominal obesity (OR, 1.45; 95% CI, 1.12-1.87, $P = 0.005$) after adjusting for age, smoking, changes in healthy eating behaviors, alcohol consumption, total step count, and baseline BMI.

Discussion

Our results suggest that a 1-year lifestyle-based physical activity intervention is associated with MetS improvements in overweight male employees with ≥ 1 MetS component. Our results also indicate that bouts of ≥ 10 min walking may improve MetS.

In this 1-year lifestyle-base intervention using a pedometer, we found significant improvements in WC, SBP, TG, HDL-C, and fasting glucose. Indeed, several recent studies have shown that pedometer-based physical activity interventions can achieve significant improvements in weight or BMI, risk factors for diabetes and cardiovascular disease (Gray et al. 2009; Pal et al. 2009; Freak-Poli et al. 2011). A systematic review of pedometer-based interventions revealed significant mean changes in SBP and DBP of −3.8 and −0.3 mmHg, respectively, despite different study designs and durations (Bravata et al. 2007). Another recent study reported that over a 4-month pedometer-based intervention was associated with a 1.6 cm reduction in WC (Freak-Poli et al. 2011). In the present study, we found that the change in DBP was not significant, which is different from the results of earlier studies (Bravata et al. 2007; Freak-Poli et al. 2011). The difference could be due to that participants in the present study had relatively good DBP at baseline. However, the authors of the earlier studies argued that the individual components should be addressed without considering whether the diagnostic criteria for MetS were met. To the best of our knowledge, the present study was the first study to investigate the effects of a lifestyle-based physical activity intervention using pedometers on the prevalence of MetS.

In the present study, 126/316 (39.9%) and 66/316 (20.9%) subjects had MetS at baseline and at follow-up, respectively. Recently, Ilanne-Parikka et al. (2010) reported that leisure-time physical activity was associated with a reduced prevalence MetS in adult men and women by ~30%, although direct comparison between these studies is limited by differences in study design and subjects enrolled. When considering the cost-effectiveness of an intervention, lifestyle-based interventions using a pedometer, such as the present study, have much potential because they are relatively easy to implement in a large population of subjects characterized by a high prevalence of MetS.

Intensive interventions, such as organized exercise in combination with a low-calorie diet, generally result in marked weight loss and can dramatically improve MetS over a short time (Nakata et al. 2009). Conversely, lifestyle-based interventions using a pedometer confer much smaller effects compared with organized exercise interventions (Gray et al. 2009; Pal et al. 2009; Freak-Poli et al. 2011). Nevertheless, the results of the present study indicate that a lifestyle-based physical activity intervention using pedometer can significantly reduce the prevalence of MetS. The difference in effectiveness between this study and the previous studies may be due to the different durations of intervention.

Most pedometer-based intervention studies involved relatively few repeated measurements, which were generally done at baseline and at follow-up. In several longitudinal studies (Yang et al. 2008; Aadahl et al. 2009), the prevalence of MetS was lower among individuals who maintained their physical activity level throughout the study compared with those who were persistently inactive or whose activity decreased during the study. Similarly, in the present study, the subjects who experienced improvements in MetS maintained an increased level of physical activity for 1 year, including walking for ≥ 10 min. Therefore, we believe our findings provide compelling support to the concept that long-term promotion of physical activity is beneficial in terms of improving MetS in overweight, middle-aged employees.

We also found that regular brisk walking for ≥ 10 min was associated with marked improvements in MetS, whereas the total step count was not. One explanation for these results was that we advised the participants to walk continuously for ≥ 10 min. This was reflected by the finding that the increase in total step count mainly consisted of continuous steps for ≥ 10 min. Another factor is that the pedometers used in our study were programmed to display bouts of brisk walking of ≥ 10 min, as well as the total number of steps per day. This visual information may provide effective feedback and motivation to promote physical activity. Moderate to vigorous intensity physical activity lasting ≥ 10 min is considered to have the greatest health-promoting benefits of all levels of physical activity (Haskell et al. 2007). Moreover, another study showed that regular bouts of physical activity of ≥ 10 min may be more effective than non-bouts for preventing overweight and obesity (Strath et al. 2008). We also found significant differences in WC, fasting plasma glucose, and HDL-C between subjects with and without improvements in MetS, at baseline (Table 3). However, our findings were not changed after adjusting for baseline BMI (Table 5). Therefore, the results of the present and other studies indicate that longer intensive sessions of physical activity may confer several advantages on improving MetS. However, because we focused on the total step count and brisk walking of ≥ 10 min, we could not determine the effects of brisk walking bouts of < 10 min. Therefore, the effect of brisk walking bouts of < 10 min on improving MetS may need to be confirmed in further studies.

Strengths and limitations

The main strength of the present study is that daily physical activity was objectively measured using a pedometer. These devices allow objective measurement of the timing, frequency, intensity, and duration of physical activity. However, pedometers are not sensitive to all activities, including biking, standing, and upper-body movement, which may influence our findings. In the present study, 16% of the participants were lost to follow-up; however, sensitivity analyses confirmed that loss to follow-up did not significantly influence our results. Another limitation is the lack of a control group. Therefore, we cannot definitively conclude that the present findings were solely due to physical activity intervention. Despite these limitations, our findings are important from a public health perspective, particularly in terms of designing interventions aimed at promoting physical activity and treating MetS among overweight, male employees.

Conclusion

In conclusion, the results of this study suggest that a 1-year lifestyle-based physical activity intervention using a pedometer may be an effective strategy to improve MetS among overweight, Japanese male employees with ≥ 1 MetS component. Our results also indicate that bouts of brisk walking of ≥ 10 min may have several advantages in terms of the degree of improvements in MetS. Interventions, in which participants are provided with a pedometer alone, are relatively inexpensive and can be carried out in a lifestyle-based setting to improve MetS.

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Conflict of Interest

The authors declare no competing interest.

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