Jurnal Sains Kesihatan Malaysia **17**(1) 2019: 21-29
DOI : http://dx.doi.org./10.17576/JSKM-2019-1701-04

Artikel Asli/*Original Article*

A 10-Week Pedometer-Based Walking Program Induced Weight Loss and Improved Metabolic Health in Community-Dwelling Adults

(Penurunan Berat Badan dan Peningkatan Kesihatan Metabolik Melalui Program Berjalan Berasaskan Pedometer Selama 10 Minggu)

ROSELINA MOKHTAR, HAZARIAH ABD HALIM, MOHD HANIF ZAILANI, AFENDI ISA & NOR FARAH MOHAMAD FAUZI

ABSTRACT

Walking 10,000 steps daily is associated with beneficial health outcomes. Recent systematic reviews have suggested that pedometers may be an effective motivational tool to promote walking. The aim of this study was to study the effectiveness of a 10-week, pedometer-based walking intervention to improve physical activity, body composition and metabolic health indices in a sample of suburban community-dwelling adults not meeting current physical activity recommendations. After screening, 34 overweight/obese individuals (mean age: 46 ± 8 years, mean BMI: 28.3 ± 4.2 kg/m²) were accepted into the walking program conducted by the Health Promotion Community Centre, Bangi. Subjects were instructed to increase their steps by 3000 steps daily above their baseline values for 10 weeks. Daily step count, body weight, BMI, waist circumference, as well as blood pressure, fasting glucose and lipids were evaluated at baseline and following the 10-week intervention. Thirty-one participants completed the program with 100% adherence. The average daily steps recorded during the 10-week intervention was 9693 ± 2196 steps per day. Mean daily steps increased from 8679 ± 2567 steps in Week 1 to 10,766 ± 3200 steps in Week 10 (p = 0.040). Overall, there were reductions in body weight (-1.13%, p = 0.010), waist circumference (-3.5%, p = 0.001) and BMI (-1.41%, p = 0.008) as well as fasting blood glucose (-8.5%, p = 0.003) and systolic blood pressure (-4.8%, p = 0.007) following the intervention. The findings of this study demonstrated that a goal-driven, pedometer-based walking intervention for 10 weeks resulted in a modest reduction in body weight and improved metabolic health outcomes in overweight/obese, community-dwelling adults.

Keywords: Physical activity; cardiometabolic; intervention; body composition; responders

ABSTRAK

Berjalan 10,000 langkah setiap hari dikaitkan dengan peningkatan kualiti kesihatan. Bukti saintifik mencadangkan bahawa penggunaan pedometer merupakan alat yang berpotensi berkesan untuk menggalakkan aktiviti berjalan. Objektif kajian ini bertujuan untuk mengkaji keberkesanan program berjalan selama 10 minggu terhadap peningkatan aktiviti fizikal, komposisi badan dan kesihatan metabolik dalam kalangan dewasa komuniti yang tidak menepati saranan aktiviti fizikal. Selepas proses saringan, seramai 34 individu berlebihan berat badan dan obes(min umur: 46 ± 8 tahun, min indeks jisim tubuh: 28.3 ± 4.2 kg/m²) diterima untuk menyertai program berjalan yang dikendalikan oleh Pusat Promosi Kesihatan Komuniti Bangi. Subjek dikehendaki meningkatkan bilangan langkah seharian sebanyak 3000 langkah melebihi bilangan langkah asas selama 10 minggu. Bilangan langkah seharian, berat badan, index jisim tubuh, ukur lilit pinggang serta tekanan darah, kepekatan glukos dah lipid darah puasa diuji sebelum dan selepas program 10 minggu. Seramai 31 subjek menamatkan program dengan kepatuhan 100%. Purata bilangan langkah seharian selama 10 minggu adalah 9693 ± 2196 langkah sehari. Purata bilangan langkah meningkat dari 8679 ± 2567 langkah sehari dalam minggu pertama ke 10,766 ± 3200 langkah sehari dalam minggu ke-10 (p = 0.040). Secara keseluruhan, terdapat penurunan dalam berat badan (-1.13%, p = 0.010), ukur lilit pinggang (-3.5%, p = 0.001), indeks jisim tubuh (-1.41%, p = 0.008), glukos darah puasa (-8.5%, p = 0.003) dan tekanan darah sistolik (-4.8%, p = 0.007) selepas intervensi berakhir. Dapatan kajian menunjukkan bahawa program berjalan kaki berasaskan pedometer ini telah menurunkan berat badan dan meningkatkan kesihatan metabolik dalam kalangan komuniti dewasa yang berlebihan berat badan.

Kata kunci: Aktiviti fizikal; kardiometabolik; intervensi; komposisi badan

INTRODUCTION

Low levels of physical activity, coupled with increased time spent being inactive or sedentary behaviours, are among the key contributors to the onset of obesity. The current physical activity recommendation for adults, aged between 18–65 years, to promote and maintain health is to accumulate at least 30 minutes of moderate-to-intense physical activity on at least five days of the week (Haskell et al. 2007). However, meeting these guidelines may be a challenging goal for some, especially among those with chronic illness (Lidegaard et al. 2016), or physical limitations such as knee problems (Sun et al. 2014). A realistic approach to structured exercise programs in such populations would be incorporating small increases in accumulated daily physical activity through low-intensity walking and activities of daily living. Walking provides an ideal approach to combat the high levels of inactivity evident in global populations and a foundation for the most sedentary to move towards increased physical activity (Morris & Hardman 1997). Additionally, walking can be easily accumulated in short bouts spread throughout the day making it a flexible, less-structured form of physical activity which may appeal to adult population (Ogilvie et al. 2007). A popular method to increase physical activity through walking involves the use of a pedometer. Physical activity monitoring using pedometers provides instant feedback and motivation to the wearers, by trying to reach a target for steps and improve self-efficacy by setting and reaching daily goals (Tudor & Lutes 2009).

A series of pedometer-based studies evaluated the relationship between step count and adherence to physical activity guidelines and reported that less than 5000 steps per day represented sedentary behavior and taking 10,000 steps per day was consistent with a physically active lifestyle (Tudor-Locke et al. 2013). Henceforth, studies have continually shown that accumulating 10,000 steps or more per day are associated with improved physical and mental well-being states (Mantovani et al. 2016; Hori et al. 2016; Soroush et al. 2013). Due to the beneficial effects on health outcomes, pedometer interventions designed for physical activity promotion and health improvement, including weight loss, has become increasingly popular in recent years. Walking interventions using pedometers have been shown to be effective in increasing daily physical activity and improving cardiometabolic health outcomes when conducted in free-living environment with overweight/obese participants (Bravata et al. 2007). Until recently, however, there has been a limitation of pedometers in that they are not able to record the intensity of the physical activity. Since physical activity recommendations require the physical activity to be of at least moderate intensity for the prevention and treatment of obesity, the extent of amount of weight loss that a sedentary, obese adult can expect to achieve from pedometer-based walking interventions, especially in the absence of dietary modification or other nonexercise interventions is still inconsistent (Rowe et al. 2011; Richardson et al. 2008).

To the best of our knowledge, the evidence of such interventions is still lacking in Malaysia, with only one published study thus far, reporting improved metabolic parameters in overweight adults following a pedometer-based intervention, but no data on weight loss was reported (Heng Kiang Soon et al. 2014). Therefore, the purpose of this study was to evaluate the effects of a 10-week, pedometer-based walking intervention on physical activity measured by daily steps, weight loss and metabolic health in overweight and obese adults in a suburban community setting. Average daily steps and body composition were used as the primary outcome measures, while metabolic health indices such as blood pressure, glucose and blood lipids as secondary measures.

METHODOLOGY

SCREENING & RECRUITMENT

Overweight and obese inviduals between 20–60 years of age, and residents of Seksyen 3, Bandar Baru Bangi, Selangor were invited to participate in this study. Participants were excluded from the study if they were currently in an exercise program, pregnant, had multiple comorbid conditions, had any orthopedic limitations that interfered with their ability to walk with ease, or had BMI values < 23.0 kg/m^2. Overweight was defined as a body mass index (BMI) between 23 and 27.5 kg/m^2 and obese as a BMI of ≥ 27.5 kg/m^2, according to the Asian cut-off criteria (WHO 2004). Out of 60 potential participants screened, 34 were accepted into the study. Approval of the study was obtained from the National Medical Research Register, Ministry of Health Malaysia (no. NMRR-15-1414-26954), and all participants completed an approved informed consent form prior to participation. This study complied with the principles of the Declaration of Helsinki.

INTERVENTION

The 10-week walking program emphasized physical activity through pedometer use. The intervention was a collaborative effort between the Pusat Komuniti Kesihatan Komuniti (PPKK) Bangi, Klinik Kesihatan Bandar Baru Bangi dan Non-Communicable Diseases (NCD) Unit of Pejabat Kesihatan Daerah Hulu Langat. All participants received an Omron HJ-112 pedometer (Omron Healthcare, Inc, Lake Forest, IL, USA), with a 7-day recording capability. Omron pedometers have been validated as accurate measures of step count (Holbrook et al. 2009). They were also given a log book in which they were instructed to record wearing time and total number of steps taken everyday. Other pedometer wearing instructions included putting on the pedometer first thing in the morning and to only remove them when sleeping, bathing or swimming.

The walking intervention was based on a 10-week time frame, with one week prior to the intervention being used to establish a baseline of daily steps. The first two weeks of the intervention was aimed at increasing walking behavior, in which participants were asked to gradually increase their number of daily steps by 3000 from what they averaged on their baseline readings. This value is based on the assumption that moderate brisk walking produces 100 steps a minute (1,000 steps per 10 minutes), therefore 3,000 steps would equate to approximately 30 minutes of moderate physical activity (Marshall et al. 2009; Tudor-Locke et al. 2005), in line with current physical activity recommendations (Haskell et al. 2007). Furthermore, previous studies have shown significant improvements in body composition and multiple cardiometabolic risk factors with daily steps increases from 2,472 to 4,241 steps per day above baseline (Schneider et al. 2006). For the remaining eight weeks, participants were required to achieve 8000 – 10,000 steps on at least one day of the week, while maintaining the additional 3000 steps above their baseline values on other days. Brochures containing information on benefits of walking and how to increase walking behaviour were handed out to participants as part of an educational approach. Participants received daily reminders and encouragement to help reach their target step counts everyday via a mobile group messaging app. To further increase motivation and daily participation, group evening walks were organised during weekdays to help achieve targeted daily steps especially for those who did not manage to accumulate steps earlier during the day. Participants were also encouraged to participate in the weekend activities such as aerobics group exercise, treasure-hunt and hill walking organised by the PPKK Bangi to help achieve 10,000 steps each week. Log books were collected weekly to ensure adherence among participants.

BODY COMPOSITION AND METABOLIC HEALTH

Participants were subjected to physical testing prior to and after the completion of the intervention. Testing was completed in groups, in the morning at the community centre and attached clinic. Weight, height, and waist circumference were measured to the nearest 0.1 kilogram or centimeter based on a standard protocol. Body height without shoes was measured using a wall-mounted tape measure, and body weight in indoor clothing without shoes was measured with a SECA digital scale. Height and weight were then used to calculate BMI in kg/m^2. Waist circumference was measured at the smallest area around the torso, above the umbilicus and below the xiphoid process as per guidelines outlined by the American College of Sports Medicine (Pescatello 2014). Resting blood pressure was taken in duplicate after the participants had been seated for at least five minutes and the mean of two measurements was computed (Pickering et al. 2005). Overnight fasting (10–12 h) venous blood samples were obtained between 8–9 am for the measurement of glucose and lipid concentrations. Blood samples were obtained by nurses on site using standard venipuncture procedures. All bood parameters were quantified using colorimetric reagents and standards.

STATISTICAL ANALYSIS

All analyses were performed using the SPSS software (version 22.0) (SPSS Inc. IL Chicago, USA). Kolmogorov-Smirnov test was used to test normality of the data. This study used an experimental pretest-posttest design, without a control group. One-way repeated measures ANOVA was used to test differences in daily step counts across the 10 weeks. Results for body composition and metabolic health parameters at pre- and post-intervention were described as mean ± standard deviation (SD) and percentages of change from baseline. Differences were examined using Paired t-tests. Analysis of covariance (ANCOVA) was used to compare post-intervention values between weight loss groups, using pre-intervention (baseline) values as covariates. Significance was accepted at $p < 0.05$.

RESULTS

PARTICIPANTS

Three participants withdrew from the study, reducing the final number of participants to 31. Adherence rate to the intervention was 100%. Adherence was defined as averaging a minimum of 7000 steps/day at the end of the intervention. The participant's demographic characteristics are described in Table 1. Mean age of participants was 46±8 years. Only 7 participants had preexisting diagnosis of hypertension (n = 3), type 2 diabetes (n = 3), and heart disease (n = 1) and were included in the study as long as no changes were made to their medical therapy during the course of the study. None of the participants were taking medication for birth control or were on hormonal replacement therapy. All participants were Malays.

TABLE 1. Demographics characteristics of participants (n = 31)

Characteristics	Categories	n	%
Sex	Male	9	29.1
	Female	22	70.9
Age (years)	20-39	5	16.1
	40-59	26	83.9
Marital Status	Single	4	12.9
	Married	25	80.6
	Divorced	2	6.5
Educational Level	High School	7	22.6
	Diploma	9	29.1
	Degree	15	48.3

PEDOMETER-BASED PHYSICAL ACTIVITY

At baseline, participants reported an average of 2806 ± 1716 steps/day. Mean daily steps recorded during the 10-week intervention and the percentage of change from the previous week are presented in Table 2. The average daily steps recorded during the 10-week intervention was 9693 ± 2196 steps/day. There was a significant effect of time (weeks) on daily steps, F(6, 182) = 3.37, df = 6.74, p = 0.003. Mean daily steps increased 24% from 8679 ± 2567 steps/day in Week 1 to 10,766 ± 3200 steps/day in Week 10 (p = 0.040). There was a slight decline in average steps recorded in Week 3 and Week 6 but the changes were non-significant.

TABLE 2. Average step counts (steps/day) across 10 weeks

Week no.	Mean ± S.D	% of change
1	8679 ± 2567	-
2	9366 ± 2512	7.9
3	8911 ± 2853	-4.9
4	9535 ± 2552	7.0
5	9815 ± 3018	2.9
6	9658 ± 3597	-1.6
7	9807 ± 2347	1.5
8	10,119 ± 2311	3.2
9	10,279 ± 2630	1.6
10	10,766 ± 3200	4.7

S.D: standard deviation; % of change: from the previous week

BODY COMPOSITION

Overall, the 10-week intervention resulted in reductions in body weight (-0.9 ± 1.9 kg), BMI (-0.4 ± 0.7 kg/m^2) and waist circumference (-3.5 ± 0.9 cm). The highest recorded weight loss was 7.0 kg. In detail, four participants lost ≥ 5% of their initial body weight after 10 weeks (-5.0 ± 1.7 kg), 11 participants lost ≤ 5% (-1.8 ± 0.8 kg), 13 participants whose weight did not change, while three participants gained weight (+ 2.0 ± 0.7 kg). Based on the magnitude of weight loss, participants were then categorised into 'responders' (those who lost weight) and 'non-responders' (those who maintained or gained weight). The mean weight loss among the responders (n = 15) was -3.2 ± 1.9 kg (95% CI: -4.07, -2.45) while the non-responders (n = 16) gained an average of 0.5 ± 0.9 kg (95% CI: -0.27, 1.29). Changes in overall body composition are listed in Table 3. No significant differences were noted for average total step counts between the responders and non-responders.

METABOLIC HEALTH PARAMETERS

Table 4 presents data for metabolic health parameters pre- and post-intervention. Significant improvements in fasting blood glucose (p = 0.003) and systolic blood pressure (p = 0.007) were observed after 10 weeks. No changes were seen in other metabolic parameters. A detailed analysis using

TABLE 3. Changes in overall body composition pre- and post-intervention

Parameters	Mean ± S.D		% of change	*p* value
	pre	post		
Body weight (kg)	73.9 ± 9.1	72.9 ± 8.9	- 1.3	0.010
Body mass index (kg/m^2)	28.3 ± 4.2	27.9 ± 3.8	- 1.3	0.008
Waist circumference (cm)	91.8 ± 6.0	88.3 ± 6.7	- 3.8	0.001

S.D: standard deviation;% of change: from pre-intervention; *p* value: paired samples T-test

ANCOVA comparing between weight loss group, i.e. the responders and the non-responders controlling for baseline (pre-intervention) values was performed for all metabolic parameters as well as body weight (Table 5). There was a significant effect of weight loss group (responders vs. non-responders) on fasting blood glucose [F(1,29) = 14.89, p = 0.008] and body weight [F(1,29) = 44.23, p < 0.001] after controlling for baseline. No significant differences were observed between the responders and non-responders for other metabolic health variables.

TABLE 4. Metabolic health parameters pre- and post-intervention

Parameters	Mean ± S.D		% of change	*p* value
	pre	post		
Fasting glucose (mmol/l)	6.2 ± 1.1	5.6 ± 0.5	-8.5	0.003
Total cholesterol (mmol/l)	5.4 ± 1.3	5.3 ± 1.2	-1.9	0.716
HDL cholesterol (mmol/l)	1.2 ± 0.6	1.3 ± 0.6	8.3	0.094
Systolic BP (mmHg)	124 ± 20	118 ± 17	-4.8	0.007
Diastolic BP (mmHg)	80 ± 11	78 ± 12	-2.5	0.144

S.D: standard deviation; % of change: from pre-intervention; p value: paired samples T-test;
HDL: high-density lipoprotein; BP: blood pressure

DISCUSSION

This study was designed to improve physical activity and body composition through walking using a pedometer in a sample of previously sedentary, community-dwelling, overweight/obese adults. The major finding of this study was that the pedometer-based walking program over a period of 10 weeks produced a dramatic increase in physical activity of over 200% above baseline values, a much favorable boost compared with previous pedometer-based studies (Hornbuckel et al. 2016; Pillay et al. 2015; Baker et al. 2008). In their systematic review, Bravata et al. (2007) reported that pedometer users typically increase physical activity by an average of 27% over

TABLE 5. Metabolic health parameters between responders and non-responders pre- and post-intervention

Parameters	Mean ± S.D		% of change	p value
	pre	post		
Body weight (kg)				
Responders	73.5 ± 11.4	71.1 ± 10.7	-3.3	< 0.001
Non-responders	74.3 ± 6.6	74.7 ± 6.6	0.5	
Fasting glucose (mmol/l)				
Responders	6.4 ± 1.4	5.7 ± 0.6	-10.9	0.008
Non-responders	6.0 ± 0.7	5.6 ± 0.5	-6.7	
Total cholesterol (mmol/l)				
Responders	5.5 ± 1.0	5.4 ± 1.1	-1.8	0.545
Non-responders	5.3 ± 1.0	5.2 ± 1.2	-1.9	
HDL cholesterol (mmol/l)				
Responders	1.1 ± 0.5	1.2 ± 0.4	9.1	0.102
Non-responders	1.3 ± 0.3	1.4 ± 0.5	7.7	
Systolic BP (mmHg)				
Responders	128 ± 22	119 ± 19	-7.0	0.059
Non-responders	119 ± 17	117 ± 15	-1.6	
Diastolic BP (mmHg)				
Responders	81 ± 11	78 ± 11	-3.7	0.690
Non-responders	78 ± 10	78 ± 13	0.2	

n responders = 15, *n* non-responders = 16;
S.D: standard deviation; % of change: from pre-intervention;
p value: difference between responders and non-responders analysed by ANCOVA;
HDL: high-density lipoprotein; BP: blood pressure

baseline values.The participants in the study progressed from being classified as "sedentary" (< 5000 steps/day) to being classed as "somewhat active" (7500 - 9999 steps/day) according to suggested public health ranges for pedometer counts (Tudor-Locke & Bassett 2004). The overall goal was for participants to achieve 10,000 step counts at least once a week while increasing their baseline step counts at least by 3,000 steps counts on the remaining six days of the week, equating to an overall weekly increase of 25,000 steps per week, which is above the current physical activity recommendations of 15,000 steps per week which roughly translates into 3,000 steps in 30 min of moderate-intensity physical activity every day (Tudor-Locke et al. 2005).The contributions of physical activity consultations in walking or physical activity interventions has been shown to be effective at promoting physical activity (Baker et al. 2008, Bravata et al. 2007; Kirk et al. 2003). Though the current study did not employ a structured physical activity consultations, our strategies of handing out brochures containing information on how to increase walking behaviour, enhancing social support through mobile messenger apps, and organising weekly walking excursions seemed to be effective in promoting walking behaviour and encouraging participants to meet suggested public health targets. According to Ogilvie et al. (2007), the crucial factor in determining the effectiveness of physical activity intervention was for interventions to be delivered at the level of individual or through group-based approaches, the latter of which became our focus in the current study.In addition, Bravata et al. (2007) had stated that having a step goal was among the key predictors of reduced body weight and BMI among pedometer users.

With regards to weight loss, the effectiveness of obesity management interventions are typically assessed using a 5% reduction in body weight and/or waist circumference over three months as a clinical outcome measure (Stevens et al. 2006).Based on the protocol of the study, we were initially uncertain if the determined length and type of the intervention is sufficient to produce substantial weight loss,due to the fact that the success of weight loss would theoretically require applying a higher amount of physical activity (Jeffery et al. 2003). Overall, the present study recorded an overall reduction of -1.3% in body weight. Indeed, changes in body weight due to physical activity interventions were generally small, unless the prescription for exercise-induced energy expenditure was substantial (Williams et al. 2015). However, our findings provided evidence that increasing walking behaviour over a 10-week duration produced varying degrees of weight loss among the participants. According to King et al. 2009, participants of exercise-based interventions can be further divided into two groups based on the magnitude of exercise-induced weight loss: 'responders' (those who managed to lose weight) and 'non-responders' (those who maintained or gained excess weight). A systematic review by Caudwell et al. (2014) have shown that most exercise interventions produced individual variability in weight loss, between 0.6 – 4.4 kg in short- to medium-term interventions. The extent of weight loss in such interventions can be driven by a number of factors, e.g. combined diet and exercise interventions, caloric restriction, non-exercise energy expenditure, and the often ignored compensatory eating (Herrmann et al. 2015; Williams et al. 2015; Caudwell et al. 2014). The lack of dietary intervention in this present study could very well explained the variable weight loss observed among participants. The responders could be particularly motivated to change both their diet and exercise habits, and may have decreased their caloric intake on their own, compared to the non-responders. Furthermore, there is evidence that increased physical activity can influence aspects of food intake in some individuals, via modulation of appetite (King et al. 2012), though we were not able to prove this without further investigation in food intake behaviour. In addition, the beneficial effects of our intervention were not restricted by changes in body weight, but also extended to improvements in other aspects of body composition such as waist circumference. The current study recorded an overall reduction of -3.8% in waist circumference following the intervention, a finding that is consistent with previous pedometer-based studies that have shown significant reductions in waist circumference (Yu et al. 2018; Cayir et al. 2015; Chan et al. 2004). It has become increasingly clear that waist circumference, a proxy measure of visceral fat, is far superior at predicting risk of cardiovascular and metabolic diseases, and is considered a better marker of success in response to exercise interventions, compared to body weight or BMI (Janiszewski & Ross 2007). Furthermore, the European Association for the Study of Obesity recommended that the response to any obesity management intervention, should focus on changes in waist circumference and other body composition parameters rather than weight loss alone (Yumuk et al. 2014). While waist circumference is generally reduced consequent to weight loss, it is also true that reduction in waist circumference in response to exercise can occur with minimal or no weight loss (Ross & Janiszewski 2008), as demonstrated in the present study.

Exercise is a well-known lifestyle prescription for managing type 2 diabetes or impaired glucose tolerance (Miyazaki & Kotani 2015). This study adds to evidence that increased walking behaviour can improve glucose control even in normoglycemic individuals, as described in previous studies (Schulz et al. 2015; Fanous et al. 2014). Furthermore, when comparing between the responders and non-responders, the responders had greater improvements in fasting glucose levels, suggesting that the magnitude of weight loss seemed to confer added benefits for improving blood glucose. In consistence with this, the Diabetes Prevention Program study had demonstrated that overall weight loss was the strongest predictor of cardiometabolic risk factor improvement, *i.e.* fasting glucose and insulin sensitivity compared to other body weight variables (Delahanty et al. 2014). The current study also saw improvements in systolic blood pressure after 10 weeks of intervention. This finding was somewhat anticipated because physical activity has been associated a reduction in blood pressure in hypertensive and normotensive participants, as well as in overweight and normal-weight participants (Whelton et al. 2002). Thus, promoting walking behaviour should be considered an important component of lifestyle modification for prevention and treatment of high blood pressure. On the contrary, we did not observe any changes in blood lipids in this study. Cross-sectional and longitudinal exercise studies support our findings however, indicating that unless exercise is accompanied by substantial weight loss, body composition changes (especially loss of intra-abdominal adiposity), and/or dietary changes, total cholesterol typically does not change (Durstine et al. 2002). Furthermore, total cholesterol levels in the sample were within normal limits in overall, making any slight changes difficult to detect statistically. Changes in serum HDL cholesterol after the intervention were not significant either. A meta-analysis study combining 25 studies lasting an average of 27 weeks with an exercise frequency of 3 to 5 times a week for an average of 40 min per session and at an exercise intensity of 65% of VO_2max, suggested that increases in HDL levels in response to exercise occurs in a dose-dependent manner (Kodama et al. 2007). Corresponding to this, Bemelmans et al. (2012) demonstrated in their study that subjects who walked a faster walking speed (4.6 ± 0.2 km/h) had increased HDL levels compared to those who walked slower. A brisk-walking pace at about 5.0 km/h per hour requires approximately 3.3 METs of energy expenditure and is therefore considered as a low to moderate-intensity activity (Ainsworth et al. 2000). Not engaging in sufficient walking intensity may seem a plausible reason for the lack of change in HDL levels in this study. However, walking speed was not the focus of our intervention, therefore we have no data to substantiate this. In addition, other lifestyle changes are equally important in modifying serum HDL cholesterol including weight loss with either caloric restriction or specific dietary approaches and smoking cessation (Gordon et al. 2014; Durstine et al. 2002). Future studies may warrant consideration on these factors to elucidate HDL cholesterol responses to exercise interventions.

There are several important limitations and strengths to this study. A control group was not employed in the present study, therefore the analysis was based on pre- and post-intervention comparisons rather than on a comparison between randomized groups. The pooled estimate of approximately -0.98 kg of body weight loss in this study may either overestimate or underestimate the effect of the walking intervention on body weight. Due to a considerable inter-individual variability in weight loss, therefore, comparing the magnitude and direction of weight change rather than overall weight loss may provide a better insight into the efficacy of physical activity-based interventions. The study also involved participants who were all willing to change their physical activity behavior and this may presents a selection bias, as the response by motivated individuals may be different from those who were not. On the other hand, this motivated behaviour could very well explain the dramatic rise in walking activity among the participants, which exceeded the recommended 15,000 steps per week. Furthermore, the inclusion of organised weekly group excursions could have increased the intervention's appeal, as it provided social interaction among participants. Due to lack of dietary control, therefore we cannot conclude if the weight loss could be due to participants who may have decreased caloric intake on their own, rather than increased physical activity. However, we should also not be underestimating the impact of the increased energy expenditure due to the walking program on weight loss. Richardson et al. (2008) in their review have summarised that pedometer-based walking programs do lead to a modest weight loss in the absence of dietary intervention.

CONCLUSION

In conclusion, this study provides evidence that the 10-week pedometer intervention led to a modest but significantly reduced body weight and improved parameters associated with metabolic health. This study also demonstrates that significant and meaningful health benefits can be achieved even in the presence of lower-than-expected exercise-induced weight loss. Whilst our study group may not be truly representative of the Malaysian adult population, the results do support the view point that the usage of pedometers can be an effective way to increase physical activity and reduce sedentary behaviour in previously inactive, overweight/obese individuals.This study also provides valuable information that will help designing a suitable intervention for a more heterogenous and larger populations towards increased sustainability in weight loss and improved metabolic health.

ACKNOWLEDGEMENT

The authors thank the volunteers who participated in this research study. We would also like to thank the staff of Klinik Kesihatan Bandar Baru Bangi and Pusat Komuniti Kesihatan Komuniti (PPKK) Bangi for their assistance during recruitment of participants and data collection.

REFERENCES

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., O'Brien, W.L., Bassett, D.R. Jr, Schmitz, K.H., Emplaincourt, P.O., Jacobs, D. R. Jr. & Leon, A.S. 2000. Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise* 32(9 Suppl): S498-504.

Baker, G., Gray, S.R., Wright, A., Fitzsimons, C., Nimmo, M., Lowry, R. & Mutrie, M. 2008. The effect of a pedometer-based community walking intervention "Walking for Wellbeing in the West" on physical activity levels and health outcomes: a 12-week randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity* 5: 44-59.

Bemelmans, R.H., Blommaert, P.P., Wassink, A.M., Coll, B., Spiering, W., van der Graaf, Y. & Visseren, F.L. 2012. The relationship between walking speed and changes in cardiovascular risk factors during a 12-day walking tour to Santiago de Compostela: a cohort study. *BMJ Open* 2(3). pii: e000875.

Bravata, D.M., Smith-Spangler, C., Sundaram, V., Gienger, A.L., Lin, N., Lewis, R., Stave, C.D., Olkin, I. & Sirard, J.R. 2007. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA*298(19): 2296-2304.

Caudwell, P., Gibbons, C., Finlayson, G., Näslund, E. & Blundell J. 2014. Exercise and weight loss: no sex differences in body weight response to exercise. *Exercise and Sports Science Reviews* 42(3): 92-101.

Cayir, Y., Aslan, S.M. & Akturk, Z. 2015. The effect of pedometer use on physical activity and body weight in obese women. *European Journal of Sport Science* 15(4): 351-356.

Chan, C.B., Ryan, D.A. J. & Tudor-Locke C. 2004. Health benefits of a pedometer-based physical activity intervention in sedentary workers. *Preventive Medicine* 39(6): 1215-1222.

Delahanty, L.M., Pan, Q., Jablonski, K.A., Aroda, V.R., Watson, K.E., Bray, G.A. & Franks, P.W. 2014. Effects of weight loss, weight cycling, and weight loss maintenance on diabetes incidence and change in cardiometabolic traits in the Diabetes Prevention Program. *Diabetes Care* 37(10): 2738-2745.

Durstine, J.L., Grandjean, P.W., Cox, C.A. & Thompson P.D. 2002. Lipids, lipoproteins, and exercise. *Journal of Cardiopulmonary Rehabilitation* 22(6): 385-398.

Fanous, A.M., Kier, K.L., Rush, M.J. & Terrell S. 2014. Impact of a 12-week, pharmacist-directed walking program in an established employee preventive care clinic. *American Journal of Health-System Pharmacy* 71(14): 1219-1225.

Gordon, B., Chen, S. & Durstine J.L. 2014. The effects of exercise training on the traditional lipid profile and beyond. *Current Sports Medicine Reports* 13(4): 253-9.

Haskell, W.L., Lee, M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D. & Bauman A. 2007. Physical Activity and Public Health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation* 116(9): 1081-1093.

Heng Kiang Soon, Mohd Taib Mohd Nasir, Abdul Rahman Hejar, Chan Yoke Mun & Abu Saad Hazizi. 2014. Effects of a pedometer walking program on obesity and metabolic parameters in adults with abdominal obesity. *Journal of Physical Activity, Sports & Exercise* 2(1): 33-40.

Herrmann, S.D., Willis, E.A., Honas, J.J., Lee, J., Washburn, R. A. & Donnelly, J.E. 2015. Do changes in energy intake and non-exercise physical activity affect exercise-induced weight loss? Midwest Exercise Trial-2. *Obesity* 23(8): 1539-1549.

Holbrook, E.A., Barreira, T.V. & Kang, M. 2009. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Medicine Science Sports Exercise* 41(3): 670-674.

Hori, H., Ikenouchi-Sugita, A., Yoshimura, R. & Nakamura, J. 2016. Does subjective sleep quality improve by a walking intervention? A real-world study in a Japanese workplace. *BMJ Open* 6(10): e011055.

Hornbuckle, L.M., Kingsley, J.D., Kushnick, M.R., Moffatt, R. J., Haymes, E. M., Miles, R. & Panton, L. B. 2016. Effects of a 12-month pedometer-based walking intervention in women of low socioeconomic status. *Clinical Medicine Insights Women's Health* 9(Suppl 1): 75-84.

Janiszewski, P.M. & Ross, R. 2007. Physical activity in the treatment of obesity: beyond body weight reduction. *Applied Physiology & Nutrition Metabolism* 32: 512-522.

Jeffery, R.W., Wing, R.R., Sherwood, N. E & Tate, D.F. 2003. Physical activity and weight loss: does prescribing higher physical activity goals improve outcome? *American Journal of Clinical Nutrition* 78: 684-689.

King, N.A., Horner, K., Hills, A.P., Byrne, N.M., Wood, R.E., Bryant, E., Caudwell, P., Finlayson, G., Gibbons, C., Hopkins, M., Martins, C. & Blundell, J.E. 2012. Exercise, appetite and weight management: understanding the compensatory responses in eating behaviour and how they contribute to variability in exercise-induced weight loss. *British Journal of Sports Medicine* 46(5): 315-322.

Kirk, A., Mutrie, N., MacIntyre, P. & Fisher, M. 2003. Increasing physical activity in people with type 2 diabetes. *Diabetes Care* 26: 1186-1192.

Kodama, S., Tanaka, S., Saito, K., Shu, M., Sone, Y., Onitake, F., Suzuki, E., Shimano, H., Yamamoto, S., Kondo, K., Ohashi, Y., Yamada, N. & Sone, H. 2007. Effect of aerobic exercise training on serum levels of high-density lipoprotein cholesterol: a meta-analysis. *Archives of Internal Medicine* 167: 999-1008.

Lidegaard, L.P., Schwennesen, N., Willaing, I. & Faerch, K. 2016. Barriers to and motivators for physical activity among people with Type 2 diabetes: patients' perspectives. *Diabetes Medicine* 33(12): 1677-1685.

Mantovani, A.M., Duncan, S., Codogno, J.S., Lima, M. C. & Fernandes, R.A. 2016. Different amounts of physical activity measured by pedometer and the associations with health outcomes in adults. *Journal of Physical Activity & Health* 13(11): 1183-1191.

Marshall, S.J., Levy, S.S., Tudor-Locke, C.E., Kolkhorst, F.W., Wooten, K.M., Ji, M. & Ainsworh, B. E. 2009. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes. *American Journal of Preventive Medicine* 36(5): 410-415.

Miyazaki, R. & Kotani, K. 2015. Pedometer- and accelerometer-based exercise in subjects with diabetes mellitus. *Minerva Endocrinology* 40(2): 145-154.

Morris, J. & Hardman, A. 1997. Walking to health. *Sports Medicine* 23(5): 306-332.

Ogilvie, D., Foster, CE., Rothnie, H., Fitzsimons, C. F. & Mutrie, N. 2007. Interventions to promote walking: systematic review. *British Medical Journal* 334(7605): 1204.

Pescatello, L.S (ed.). 2014. ACSM's Guidelines for Exercise Testing and Prescription. 9th ed. Baltimore, MD: Wolters Kluwer/Lippincott Williams & Wilkins

Pickering, T., Hall, J., Appel, L., Graves, J., Hill, M. N, Jones, D. W., Kurtz, T., Sheps, S. G. & Roccella, E. J. 2005. Recommendations for blood pressure measurement in humans and experimental animals Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation* 111(5): 697-716.

Pillay, J.D., van der Ploeg, H.P., Kolbe-Alexander, T.L., Proper, K. I., van Stralen, M., Tomaz, S. A., van Mechelen, W. & Lambert, E. V. 2015. The association between daily steps and health, and the mediating role of body composition: a pedometer-based, cross-sectional study in an employed South African population. *BMC Public Health* 15: 174.

Richardson, C.R., Newton, T. L., Abraham, J. J., Sen A., Jimbo, M. & Swartz, A.M. 2008. A meta-analysis of pedometer-based walking interventions and weight loss. *Annals of Family Medicine* 6(1): 69-77.

Ross, R. & Janiszewski, P.M. 2008. Is weight loss the optimal target for obesity-related cardiovascular disease risk reduction? *Canadian Journal of Cardiology* 24(Suppl D): 25-31.

Rowe, D.A., Welk, G.J., Heil, D.P., Mahar, M.T., Kemble, C.D. & Calabrá, M.A.2011. Stride rate recommendations for moderate-intensity walking. *Medicine Science Sports Exercise* 43(2): 312-318.

Schneider, P.L., Bassett, D.R., Thompson, D.L., Pronk, N.P. & Bielak, K.M. 2006. Effects of a 10,000 steps per day goal in overweight adults. *American Journal of Health Promotion* 21(2): 85-89.

Schulz, A.J., Israel, B.A., Mentz, G.B., Opperman, A., Reyes, A. G., Rowe, Z., Sand, S. L. & Woods S. 2015. Effectiveness of a walking group intervention to promote physical activity and cardiovascular health in predominantly non-Hispanic Black and Hispanic urban neighborhoods: Findings from the Walk Your Heart to Health Intervention. *Health Education & Behavior* 42(3): 380-392.

Soroush, A., Der Ananian, C., Ainsworth, B.E., Belyea, M., Poortvliet, E., Swan, P.D., Walker, J. & Yngve A. 2013. Effects of a 6-month walking study on blood pressure and cardiorespiratory fitness in U.S. and Swedish Adults: ASUKI Step Study. *Asian Journal of Sports Medicine* 4(2): 114-24.

Stevens, J., Truesdale, K.P., McClain, J.E. & Cai, J. 2006. The definition of weight maintenance. *International Journal of Obesity* 30(3): 391-399.

Sun, K., Song, J., Lee, J., Chang, R. W, Eaton, C. B, Ehrlich-Jones, L., Kwoh, K. C., Manheim, L. M., Semanik, P. A., Sharma, L., Sohn, M. W. & Dunlop, D. D. 2014. Relationship of meeting physical activity guidelines with health-related utility. *Arthritis Care & Research* 66(7): 1041-1047.

Tudor-Locke, C., Craig, C.L., Thyfault, J.P. & Spence, J.C. 2013. A step-defined sedentary lifestyle index: <5000 steps/day. *Applied Physiology, Nutrition & Metabolism* 38(2): 100-14.

Tudor-Locke, C. & Lutes, L. 2009. Why do pedometers work?: a reflection upon the factors related to successfully increasing physical activity. *Sports Medicine* 39(12): 981-993.

Tudor-Locke, C., Sisson, S.B., Collova, T., Lee, S.M. & Swan, P.D. 2005 Pedometer-determined step count guidelines for classifying walking intensity in a young ostensibly healthy population. *Canadian Journal of Applied Physiology* 30: 666-676.

Tudor-Locke, C.E. & Bassett, D. R.2004. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Medicine* 34: 1-8.

Yu, Y., Lv, Y., Yao, B., Duan, L., Zhang, X. & Xie, L. 2018. A novel prescription pedometer-assisted walking intervention and weight management for Chinese occupational population. *PLoS ONE* 13(1): e0190848.

Yumuk, V., Fruhbeck, G., Oppert, J.M., Woodward, E. & Toplak, H. 2014. An EASO position statement on multidisciplinary obesity management in adults. *Obesity Facts* 7(2): 96-101.

Whelton, S.P., Chin, A., Xin, X. & He, J. 2002. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. *Annals of Internal Medicine* 136(7): 493-503.

WHO Expert Consultation. 2004. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 363: 157-163.

Williams, R.L., Wood, L.G., Collins, C.E. & Callister, R. 2015. Effectiveness of weight loss interventions – is there a difference between men and women: a systematic review. *Obesity Reviews* 16(2): 171-186.

Roselina Mokhtar
Faculty of Health Sciences,
Universiti Kebangsaan Malaysia,
Kuala Lumpur, Malaysia

Health Promotion Community Centre (Bangi)
Health District Office of Hulu Langat
Ministry of Health, Malaysia

Hazariah Abd Halim
Mohd Hanif Zailani
Health Promotion Community Centre (Bangi)
Health District Office of Hulu Langat
Ministry of Health, Malaysia

Afendi Isa
Health Education Division,
Ministry of Health, Putrajaya, Malaysia

Nor Farah Mohamad Fauzi
Occupational Therapy Program
Faculty of Health Sciences
Universiti Kebangsaan Malaysia
Kuala Lumpur, Malaysia

Corresponding Author: Nor Farah Mohamad Fauzi
E-mail: e-mail: norfarah@ukm.edu.my

Tel: 03-92897411
Fax: 03-26914304

Received: April 2017
Accepted for publication: June 2018