EFFECTS OF COMBINED PHYSICAL ACTIVITY AND DIETARY INTERVENTION ON OBESITY AND METABOLIC PARAMETERS IN ADULTS WITH ABDOMINAL OBESITY

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Abstract. A twelve-week controlled intervention trial was carried out to evaluate the effects of combined physical activity and dietary intervention on obesity and metabolic risk factors among employees of Universiti Putra Malaysia. Participants consisted of adults aged 25-55 years with no reported chronic diseases but with abdominal obesity. They were assigned to either a combined physical activity and dietary intervention group or a control group. The final sample consisted of 56 participants, with an equal number of 28 for each study group. No significant group effect was observed for any variable except for hip circumference (HC) and fasting plasma glucose (FPG). There was a significant increase in HC (p=0.007) and reduction in FPG (p=0.02) in the intervention group compared to the control group. In the intervention group, HC (p=0.002), triglycerides (TG) (p=0.0001), total cholesterol (TC) (p=0.0001), LDL cholesterol (LDLC) (p=0.0001) and FPG (p=0.005) were significantly reduced, while waist circumference (WC) (p=0.025) and the waist-to-hip ratio (WHR) (p=0.027) were significantly reduced in the control group. No significant change in steps/day or calorie intake was observed in either group. Taken together, these data indicate that the combined physical activity and dietary intervention was not effective at improving diet or physical activity level. However, the intervention was effective in improving FPG among participants with abdominal obesity. The significant increase in HC in the interventions group warrants further study. These findings will be useful to further improve group-based intervention for the prevention and management of obesity.

Keywords: physical activity, dietary intervention, obesity, metabolic risk factors, Malaysia

INTRODUCTION

The occurrence of obesity is closely associated with genetics, unhealthy diet, and physical inactivity (WHO, 2009). Physical activity and diet are important for the prevention and management of overweight and obesity. Several large-scale intervention studies have demonstrated the benefits of physical activity and diet on obesity and obesity-related co-morbidity. In a study in Da Qing, China (Pan *et al*, 1997), the risk of diabetes over a six-year follow-up was significantly

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reduced by 31% in the diet group, 46% in the exercise group, and 42% in the diet plus exercise group.

Results from the US Diabetes Prevention Program have also shown that a diet and exercise intervention resulted in an average of 5.6 kg weight loss in 2.8 years, compared to 0.1kg in the placebo and 2.1 kg in the metformin group (Knowler *et al*, 2002). Similarly, the Finnish Diabetes Prevention Study found that diet and exercise intervention resulted in weight reductions of 4.5 and 3.5 kg in the intervention group after one and three years, compared to only 1.0 and 0.9 kg, respectively, in the control group (Lindstrom *et al*, 2003). All of these studies strongly support the effectiveness of physical activity and dietary intervention in the prevention and management of obesity.

Despite the overwhelming evidence of the benefits of physical activity and diet for a good health status, in Malaysia, the population is generally sedentary, with a high prevalence of sedentary lifestyles. Only 11.6% of Malaysian adults participate in regular and adequate exercise (Ministry of Health Malaysia, 2007). In terms of diet, an average of 72.8% of Malaysian adults aged 25-64 years have unhealthy diets, with inadequate vegetable and fruit intake (Ministry of Health Malaysia, 2007). The current obesity epidemic in the country along with the unhealthy diet and lifestyle has heightened the need for dietary and physical activity intervention.

To date, no controlled study of dietary and physical activity intervention for Malaysian adults has been published. Diet and physical activity are behavioral factors that are influenced by many factors, such as culture, ethnicity, values, and socioeconomic status, and research carried out in some countries might not produce similar findings when applied to other communities. Therefore, local research focusing on different methods of intervention is warranted to help combat the obesity problem in Malaysia.

The present study examined the effects of combined physical activity and dietary intervention on obesity and metabolic risk factors. The anticipated outcomes of the study were to provide important data about the effects of physical activity and dietary modification on obesity and metabolic risk factors in Malaysian adults with abdominal obesity.

To the authors' knowledge, this is the first intervention study using combined physical activity and dietary approaches in a local population with abdominal obesity. The group-based educational intervention implemented in the study could also serve as a reference in designing intervention programs for the prevention and management of obesity at the community level. Group-based intervention is considered more applicable for community settings because it is less costly than individualized intervention.

MATERIALS AND METHODS

Study design

This controlled intervention trial was designed to investigate the effects of combined physical activity and dietary intervention on obesity and metabolic risk factors. Two groups of participants were recruited, consisting of an intervention group (n=28) and a control group (n=28). The intervention group was a physical activity plus diet group. Prior to the screening of participants, ethical approval was obtained from the Medical Research Ethics Committee, Faculty of Medicine and Health Sciences, Universiti Putra

Malaysia (Ref N° UPM/FPSK/PADS/T7-MJKEtikaPer/F01(LECT_MAC(08), 2008 04 11). Upon screening, eligible participants were given participant information sheets. Each of them signed and returned a consent form when they agreed to participate in the study.

Institutions in Universiti Putra Malaysia were grouped into two geographic regions. The purpose of grouping by region was to minimise the possibility of participants from different groups influencing each other. This technique has previously been used to avoid exposure of the control group to the intervention effect and reduce the risk of an intervention being contaminated by another group (Christie *et al*, 2009).

Two clusters containing institutions were identified. The two clusters were then randomly assigned for recruiting participants for the two groups. Screening and recruitment of participants was conducted in the particular cluster. The final sample consisted of 56 participants, with an equal number of 28 for each study group.

Participants

The study participants were selected by screening the participants who voluntarily agreed to join the study with a screening questionnaire. The inclusion criteria for potential participants were as follows: male or female, having abdominal obesity (waist circumference ≥90 cm for men and ≥80cm for women), aged between 25 and 55 years, physically inactive (exercising at most 30 minutes per week, once a week), and willing to participate in the study with informed consent. The exclusion criteria for potential participants were as follows: being pregnant; on a medication that may affect body weight, lipid and lipoprotein profile, glucose level and blood pressure; with medical history such as hyperthyroidism, cardiovascular disease or cancer; with physical impairment which may affect intervention of physical activity.

Measurement of outcomes

Data were collected for the participants in both groups to obtain baseline data. With the exception of the socio-demographic questionnaire that was used once at baseline only, the same methods and instruments were used again at the end of twelve weeks to collect data.

Socio-demographic information

The questionnaire was self-administered. The respondents were asked about their age, ethnicity, marital status, education level, monthly income, and contact information. The socio-demographic information was obtained at baseline only.

Physical examinations

Anthropometric and blood pressure measurements were conducted in physical examinations. Weight was measured to the nearest 0.1kg in light clothing without shoes using a digital weighing scale (Tanita, Tokyo, Japan). Height was measured to the nearest 0.1cm with a height-measuring rod (SECA, Hamburg, Germany). Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. BMI was categorized as 'normal' (18.5 $kg/m^2 \leq BMI \leq 25.0\ kg/m^2$), 'overweight' ($25.0\ kg/m^2 < BMI \leq 30.0\ kg/m^2$) or 'obese' ($>30.0\ kg/m^2$) (WHO, 2000).

Waist circumference was measured at the high point of the iliac crest at minimal respiration to the nearest 0.1cm at the end of normal expiration using a measuring tape. Waist circumference was categorised into 'normal' (<90 cm for men and <80 cm for women) and 'high risk' (≥90 cm for

Table 1
Classification of biochemical data.

Biochemical parameters	Low	Normal	Elevated
Triglycerides (mmol/l)[a]	-	<1.70	≥1.70
Total cholesterol (mmol/l)[b]	-	<5.13	≥5.13
LDL cholesterol (mmol/l)[b]	-	<3.33	≥3.33
HDL cholesterol (mmol/l)[a]	<1.03 males <1.29 females	≥1.03 males ≥1.29 females	-
Fasting plasma glucose (mmol/l)[a]	<3.90	3.90-5.60	>5.60

[a]Based on criteria of metabolic syndrome by IDF (2006).
[b]Based on guidelines by NCEP-ATPIII (Antonopoulos, 2002).

men and ≥80 cm for women) according to the cut-offs point proposed by the International Diabetes Federation (2006). Hip circumference was measured at the widest part of the hip. Waist-to-hip ratio (WHR) was calculated by dividing waist circumference by hip circumference. A WHR of more than 1.0 in men and more than 0.85 in women was used as the threshold for the 'high-risk' category (WHO, 2000). All anthropometric measurements were done in duplicate, and the average of the two readings was used for analysis.

The percentage of body fat was assessed using a TBF-300 Body Composition Analyzer (Tanita, Tokyo, Japan). The classification of the percentage of body fat was based on guidelines reviewed by Gallagher *et al* (2000), in which the range of the percentage of body fat varies with gender and age.

Blood pressure (BP) was measured in duplicate using an IA2 Omron Automatic Blood Pressure Monitor (Omron, Tokyo, Japan) with the participants rested and seated. The systolic and diastolic BP reading was then classified as 'normal' (systolic BP 100-129 mmHg, diastolic BP 60-84 mmHg) or 'elevated' (systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg), as defined by the International Diabetes Federation (2006). Elevated blood pressure was defined as either 'elevated' systolic BP or diastolic BP alone or the combination of both.

Biochemical assessment

A total of 5 ml morning fasting venous blood was collected from each participant by the venipuncture method. The blood sample was centrifuged at 20°C for 10 minutes at a relative centrifugal force of 1,008*g* within four hours of collection. Routine enzymatic methods were used to analyse the serum with an Automated Clinical Chemistry Analyzer (Roche Diagnostic, Plymouth Meeting, PA). Appropriate reagents from the manufacturer were used. The analysis outcomes obtained were the levels of triglycerides, total cholesterol, HDL cholesterol and fasting plasma glucose. LDL cholesterol was then determined by the Friedewald equation:

LDL cholesterol = Total cholesterol - [HDL cholesterol + (0.46 x triglycerides)]

All biochemical readings were classified as depicted in Table 1.

Based on the data from the physical examination and biochemical tests, individuals with metabolic syndrome were identified based on the criteria proposed by the International Diabetes Federation (2006). The percentages of individuals with metabolic syndrome before and after the intervention were calculated. A similar method was used in a study by Anderssen *et al* (2007) in a combined diet and exercise intervention for metabolic syndrome subjects who did not use drugs that might interfere with intervention outcomes.

Physical activity assessment

A Lifecorder accelerometer (Suzuken, Japan), an objective measure, was used to quantify physical activity. Participants were instructed to clip the accelerometer onto the belt, trouser, or skirt waistband on the right side and centerd over the foot. They were asked to wear the accelerometer throughout the day except for bathing, swimming, or sleeping. Physical activity levels differed considerably between weekdays and weekend days (Gretebeck and Montoye, 1992); therefore, activity for both weekdays and weekends was recorded and analysed. Three to five days of monitoring is required to reliably measure physical activity using an accelerometer (Trost *et al*, 2005). Therefore, participants were asked to wear the accelerometer for three days: two consecutive weekdays and one weekend day. The mean number of steps/day was then calculated as the average of the step counts on those three days.

The mean steps/day data were classified as 'sedentary' (<5,000 steps/day), 'low active' (5,000-7,499 steps/day), 'somewhat active' (7,500-9,999 steps/day), 'active' (10,000-12,500 steps/day) or 'highly active' (>12,500 steps/day) according to the classification of Tudor-Locke and Bassett (2004).

Dietary assessment

A two-day 24-hour dietary recall was used to collect information on all foods and beverages consumed by the participants over a two-day period. Details about the names of foods and drinks, portion sizes, and any ingredients added to the foods and drinks were obtained and written in a table. For portion size estimation, household measurement cups and spoons were shown to the participants. Upon completion of the interview, all records were checked for discrepancies or omissions. If discrepancies or omissions were found, the participants were asked again to recall their food and beverage intake.

To estimate under-reporting of energy intake from the dietary recall, the ratio of reported total daily energy intake (EI) to basal metabolic rate (BMR) was calculated (Macdiarmid and Blundell, 1998). The basal metabolic rate was obtained with a TBF-300 Body Composition Analyzer. A ratio of EI/BMR below 1.2 was used as a cut-off point to identify under-reporting of energy intake, as suggested by Black (2000).

Interventions: combined physical activity and dietary intervention

A Yamasa pedometer (Yamasa Tokyo, Japan) was distributed to each of the participants on the first day of the intervention, and they were requested to wear the pedometer for 12 weeks. Instruction was given on how to wear the pedometers and log their daily steps in the diary. The intervention activities consisted of lectures and group discussion sessions, a telephone call reminder, a diary, and an intervention booklet. During the twelve-week intervention, the participants in the intervention group were invited to attend a two-hour lecture and a discussion session once a month. The lecture was a Power Point presentation delivered in the Malay language by a nutritionist.

The content of the lecture included the health benefits of physical activity, strategies and tips to increase physical activity, benefits of walking, and ways to increase the number of daily steps.

The participants were required to bring the step diary for review and feedback during each session of the lecture and discussion. The goal for the participant in this group was to increase physical activity through walking at least 10,000 steps per day. If the baseline steps fell short of this value, participants were instructed to increase their physical activity level by 1,000 steps per day every week until reaching the goal. A gradual increase in steps/day has been suggested for sedentary individuals for better adherence and efficacy (Hart, 2009).

For the diet regime, a healthy, balanced diet as advocated in the Malaysian Dietary Guidelines (Ministry of Health Malaysia, 1999) was used as the basis for the intervention. In addition, recommendations for the prevention and management of metabolic syndrome (Antonopoulos, 2002) were included as part of the dietary recommendations. The goals for the dietary intervention included reduced daily calorie intake; reduced intake of saturated fat, trans-fat and cholesterol; increased fiber intake; and minimized salt intake. Problems and solutions in following the recommendations were discussed in groups. In addition to monthly meetings, participants were called by the researcher via telephone in the eighth week of the intervention as a follow-up measure.

Control group

No intervention was given to the control group, as it served as a comparison to the outcomes of the intervention group. However, to improve adherence to the program, an informal group meeting was held in week six for the control group.

Data analysis

Data were analysed using SPSS for Windows© (version 16, SPSS, Chicago IL). *Nutritionist Pro*™ software was used to analyse nutrient intake from the two-day 24-hour dietary recall. Interval or ratio values are presented as the mean ± standard deviation (SD) and percentage (%). Nominal or ordinal variable values are presented as the frequency and percentage (%). An independent sample *t*-test was used to test whether there was a significant difference between the groups at baseline. If there was no significant difference, a general linear model (GLM) repeated measures analysis of variance (ANOVA) for the two groups at baseline and at three months was used to determine if any significant differences existed between groups at each time point, as well as within groups over time for selected variables. If a significant difference was found, analysis of covariance (ANCOVA) was used with baseline data as covariates. A paired-samples *t*-test was used to examine the outcome by comparing baseline and follow-up assessments following ANCOVA. Correlation analyses were used to assess the relationship between changes in caloric intake and steps/day and the changes in dependent variables. A statistical probability level of $p<0.05$ (two-sided) was considered significant.

RESULTS

Adherence to intervention program

Adherence to the intervention program was based on the attendance of participants at the lecture and discussion sessions, which were conducted once a month. Attending two out of the three sessions, or an attendance rate of 67%

Table 2
Participants recruited, number of drop-outs, final sample and adherence by group.

Group	Participants recruited n (%)	Drop-out n (%)	Final sample n (%)			Adherence n (%)
			Male	Female	Total[a]	
Intervention group	32 (46.4)	4 (30.8)	8 (53.3)	20 (48.8)	28 (50.0)	26 (92.9)
Control group	37 (53.6)	9 (69.2)	7 (46.7)	21 (51.2)	28 (50.0)	
Total	69 (100.0)	13 (100.0)	15 (100)	41 (100)	56 (100.0)	

[a]No significant difference between males and females (χ^2=0.091; p=0.763)

during the course of the intervention, was adopted as a criterion for adherence. A total of 69 eligible participants were selected for the study. At twelve weeks, after deducting the number of participants who dropped out, the final sample consisted of 56 participants, with an equal number of 28 for each study group (Table 2).

As there was no significant difference in the proportion of males and females among the groups (χ^2=0.091; p=0.763), further analyses were performed on the combined-gender sample in each group.

Baseline socio-demographic characteristics of the participants

All of the participants were Malaysians, consisting of Malay (94.6%), Chinese (1.8%) and Indian (3.6%). More than half (53.6%) of the participants were 20-39 years of age. A large proportion of the participants (98.2%) were non-academic staff of the university. A majority of the participants (98.2%) earned a monthly income of MYR 3000 or less. Their education level was university or college graduate (44.6%), upper secondary school (32.9%), lower secondary school (17.9%), primary school (1.8%), or pre-university (3.6%). A majority of the participants (89.3%) did not smoke, and none of the participants consumed alcohol. There was no significant difference between groups in the above categorical variables. Descriptive data for the participants are presented in Table 3.

Comparisons of pre-intervention and post-intervention parameters

Table 4 shows the results from ANCOVA and GLM repeated measures ANOVA. No significant group effect was observed for any variable except for hip circumference (HC) and fasting plasma glucose (FPG). HC (p=0.007) and FPG (p=0.02) were significantly more reduced in the intervention group compared to the control group. Looking at within-group differences throughout the twelve-week intervention, HC (p=0.002), TG (p=0.0001), total cholesterol (TC) (p=0.0001), LDL cholesterol (LDLC) (p=0.0001) and FPG (p=0.005) were significantly reduced in the intervention group. Waist circumference (WC) (0.025) and the waist-to-hip ratio (WHR) (p=0.027) were significantly reduced in the control group. No significant change in steps/day or calorie intake was observed in either of the groups.

DISCUSSION

The twelve-week physical activity and dietary intervention did not yield a significant improvement in steps/day or

Table 3
Descriptive data of socio-demographic characteristics[a].

	Intervention group (*n*=28)	Control group (*n*=28)	Total (*n*=56)	χ^2	*p*
Ethnic					
Malay	28 (100.0)	25 (89.3)	53 (94.6)	3.170	0.205
Chinese	0 (0)	1 (3.6)	1 (1.8)		
Indian	0 (0)	2 (7.1)	2 (3.6)		
Age (year)					
20-29	11 (39.3)	12 (42.9)	23 (41.0)	0.655	0.884
30-39	5 (17.9)	3 (10.7)	8 (14.3)		
40-49	8 (28.5)	8 (28.5)	16 (28.6)		
≥50	4 (14.3)	5 (17.9)	9 (16.1)		
Employment					
Academic	0 (0.0)	1 (3.6)	1 (1.8)	1.018	0.313
Non-academic	28 (100.0)	27 (96.4)	55 (98.2)		
Monthly income (MYR)					
≤1,500	9 (32.1)	12 (42.9)	21 (37.5)	3.429	0.330
1,501-3,000	16 (57.1)	16 (57.1)	32 (57.1)		
3,001-4,500	2 (7.1)	0 (0)	2 (3.6)		
>4,500	1 (3.5)	0 (0)	1 (1.8)		
Education					
Primary	0 (0)	1 (3.6)	1 (1.8)	3.360	0.499
Lower secondary	5 (17.9)	5 (17.9)	10 (17.9)		
Higher secondary	9 (32.1)	9 (32.1)	18 (32.1)		
Pre-university	0 (0)	2 (7.1)	2 (3.6)		
University/college	14 (50.0)	11 (39.3)	25 (44.6)		
Smoking					
Yes	3 (10.7)	3 (10.7)	6 (10.7)	0.000	1.000
No	25 (89.3)	25 (89.3)	50 (89.3)		

[a]Values are expressed as the number (and percentage) of participants.

caloric intake. In previous studies that adopted increasing daily steps as a mean to increase physical activity (Elley *et al*, 2003; Schneider *et al*, 2006), significant increases in walking steps and physical activity level were reported. The main differences in the execution of the intervention between those studies and the present study were that previous studies adopted a longer duration of intervention, for example, nine months or twelve months, coupled with closer monitoring of the intervention program. Even with a short duration of intervention compared to the present study, Chan *et al* (2004) demonstrated a significant daily step count increase of 3,451±2,661 steps/day in twelve weeks. In that study, weekly group educational discussions by facilitators (30-60 minutes per session) were conducted. Compared to the monthly two-hour meetings in this study, the significant increase in steps/day in that study most likely came from the closer monitoring and supervision than the present study employed.

The dietary data show that there was no significant reduction in caloric intake in the intervention group compared with the control group. Although these findings differ from some previous studies involving dietary intervention (Read *et al*, 2004; Azadbakht *et al*, 2005; Nasser *et al*, 2006; Qian *et al*, 2007), they are consistent with the study by Ren *et al* (2007), who found minimal changes in dietary intake in the health education group. A major similarity of the present study to the study by Ren *et al* (2007) was that education on healthy eating was implemented in a group-based intervention.

The studies that have recorded significant improvements in dietary intake adopted either an individually prescribed diet or a personal dietary counselling approach. Therefore, it seems possible that using a personal approach instead of group education might have resulted in better improvement in the dietary practices of the participants in the present study. However, the present study adopted a group-based approach; therefore, individually prescribed diet or personal dietary counselling may not have been feasible. To overcome this shortcoming, more frequent group meetings and intensive follow-up efforts could be adopted. A study by Nasser *et al* (2006) showed that weekly 90-minute nutrition lectures weekly significantly reduced weight, BMI, WC, TC, LDLC, and TG after 40 weeks. That regimen was far more intensive than the lectures of the present study, which consisted only of a 120-minute meeting once every four weeks throughout the twelve-week study period.

It is commonly accepted that changing a health behavior and maintaining a new habit requires a long time to achieve, as humans tend to resist changes (Proschaska *et al*, 2002). Therefore, it may be the case that a duration longer than twelve weeks is required to allow the participants to move through the stages of change, and adopt and maintain a healthy lifestyle. In addition, the outcome of a change in physical activity level may have improved if the intervention had been designed at the individual level and been tailored to each individual's baseline condition. In fact, some intervention studies have used the transtheoretical model to successfully improve the physical activity level of their subjects (Clarke *et al*, 2007; Greaney *et al*, 2008).

Furthermore, some environmental barriers may influence the participants' commitment to increase their daily steps. Changes in physical activity behavior can be influenced by many factors, including the individual, social, and physical environment (Giles-Corti and Donovan, 2002). The local tropical climate could be one of the barriers to the participants increasing their outdoor walking during daytime. A lack of local environments conducive to walking activity, such as shady pedestrian paths, may be one of the determinants of their participation in outdoor walking. Establishing an environment that is friendly for walking activities might encourage walking and prevent obesity in the community (Frank *et al*, 2007).

Public transportation has been associated with walking for transportation (Sallis *et al*, 2004). Walking to and from public transit contributes to increasing daily physical activity and attaining recommended physical activity levels (Besser and Dannenberg, 2005). In the present study, although data on the transportation of the participants were not available, public transportation availability and

Table 4
Changes in anthropometric and metabolic parameters (post- *vs* pre-intervention).

Variable	Intervention group (*n*=28)	Control group (*n*=28)	F	*p*[a]
Weight (kg)				
Pre-	79.1 ± 15.6	67.2 ± 12.8		
Post-	79.8 ± 15.2	67.7 ± 12.8	0.733	0.396
Difference	0.6 ± 2.0	0.5 ± 1.6		
BMI (kg/m^2)				
Pre-	30.4 ± 4.8	26.3 ± 4.2		
Post-	30.7 ± 4.8	26.4 ± 4.1	3.950	0.052
Difference	0.3 ± 0.7	0.2 ± 0.6		
Body fat (%)				
Pre-	39.4 ± 8.3	34.0 ± 6.8		
Post-	39.5 ± 8.0	34.3 ± 6.9	0.035	0.853
Difference	0.1 ± 2.3	0.4 ± 2.2		
WC (cm)				
Pre-	97.7 ± 9.8	91.0 ± 7.0		
Post-	96.4 ± 12.0	88.4 ± 9.7[c]	0.557	0.459
Difference	-1.3 ± 8.7	-2.5 ± 5.6		
HC (cm)				
Pre-	109.2 ± 7.9	102.9 ± 7.4		
Post- [b]	111.2 ± 8.0[a c]	103.0 ± 7.5	7.928	0.007[a]
Difference	2.1 ± 3.1	0.1 ± 2.8		
WHR				
Pre-	0.9 ± 0.1	0.9 ± 0.1		
Post-	0.9 ± 0.1	0.9 ± 0.1	0.320	0.574
Difference	-0.0 ± 0.1	-0.0 ± 0.1[c]		
SBP(mmHg)				
Pre-	129.8 ± 13.0	121.6 ± 14.1		
Post-	129.6 ± 14.5	124.2 ± 12.3	0.043	0.837
Difference	-0.1 ± 8.7	2.6 ± 10.7		
DBP(mmHg)				
Pre-	80.8 ± 8.0	73.2 ± 9.5		
Post-	79.0 ± 10.8	77.6 ± 8.2[c]	1.031	0.315
Difference	-1.6 ± 7.5	4.3 ± 10.9		
TG (mmol/dl)				
Pre-	1.4 ± 1.4	1.2 ± 0.8		
Post-	0.8 ± 0.7[c]	1.1 ± 0.6	0.016	0.899
Difference	-0.6 ± 0.8	-0.1 ± 0.6		
TC (mmol/dl)				
Pre-	4.6 ± 1.1	4.6 ± 1.7		
Post-	3.7 ± 1.0[c]	4.4 ± 0.9	2.376	0.129
Difference	-1.0 ± 1.0	-0.2 ± 1.8		
HDLC (mmol/dl)				
Pre-	0.9 ± 0.3	0.8 ± 0.2		
Post-	0.9 ± 0.3	1.0 ± 0.3	0.001	0.977
Difference	-0.0 ± 0.2	0.1 ± 0.4		

Table 4 (Continued).

Variable	Intervention group (n=28)	Control group (n=28)	F	p[a]
LDLC (mmol/dl)				
Pre-	3.4 ± 1.0	3.6 ± 1.5		
Post-	2.6 ± 0.9[c]	3.3 ± 0.9	2.603	0.112
Difference	-0.8 ± 0.8	-0.3 ± 1.5		
FPG (mmol/dl)				
Pre-	4.9 ± 0.6	5.3 ± 1.0		
Post- [b]	4.4 ± 0.5[c d]	5.1 ± 1.3	5.730	0.020[a]
Difference	-0.5 ± 0.8	-0.3 ± 0.9		
Calorie intake (kcal)				
Pre-	1,994 ± 815	2,313 ± 1,272		
Post-	1,986 ± 670	2,124 ± 873	1.265	0.266
Difference	-8 ± 145	-189 ± 399		
Steps/day				
Pre-	5,857 ± 22,189	6,916 ± 21,552		
Post-	6,595 ± 219	6,536 ± 300	0.760	0.387
Difference	738 ± 1,980	-381 ± 2475		

BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; TC, total cholesterol; HDLC, HDL cholesterol; LDLC, LDL cholesterol; FPG, fasting plasma glucose

Difference = value post-intervention - value pre-intervention, expressed as the mean ± SD

[a]Results from ANCOVA with baseline values as covariates (weight, BMI, body fat, waist circumference, hip circumference, SBP, and DBP) and GLM repeated measures ANOVA.

[b]Significant group effect as determined by F-test ($p \leq 0.05$).

[c]Significant within-group difference between baseline and post-intervention values as determined by paired-samples t-test ($p<0.05$) or F-test ($p<0.05$).

[d]Significantly different from control group ($p \leq 0.05$).

accessibility for the participants might be one of the factors that influenced their behavioral changes. Therefore, further research should include a study on the types of transportation usually used by the participants and the public transportation available in the community.

In the intervention group, although no significant change in weight, BMI, or percentage of body fat was observed, a significantly greater increase in HC was detected compared to the control group. This indicates a trend in a change of body shape from an 'apple' shape towards a 'pear' shape. Increased hip circumference can produce protective effects against type 2 diabetes independent of BMI, age, and waist circumference (Snijder *et al*, 2003). Although the underlying mechanisms are still unclear, changes in the distribution of fat within the body and greater muscle mass are thought to be responsible for these protective effects (Snijder *et al*, 2004). One of the issues that emerge from these findings is that weight loss alone perhaps should not be the only focus of the intervention program. Instead, increases in hip circumference, as demonstrated in this group, should be further studied.

A greater reduction in weight tends to produce greater improvements in metabolic risk factors (Muzio *et al*, 2005). However, the findings are not conclusive, as increasing physical activity level without substantial weight loss or even no weight loss can still be helpful in reducing health risks (Ross and Bradshaw, 2009). In the present study, a significantly greater reduction in FPG was observed in the intervention group compared to the control group. These findings support the previous finding of a significantly greater improvement in FPG following a lifestyle intervention (Lindstrom *et al*, 2003). Within the intervention group, there were significant improvements in TG, TC, and LDLC. However, the magnitudes of changes were not significantly different from those of the control group.

To improve the outcomes of the combined physical activity and dietary intervention, closer supervision of the intervention may be required. In the present study, meeting with the participants occurred only once every four weeks, for a total of three times. This seemed insufficient to monitor the participants' adherence to the intervention program. In a four-month randomized controlled trial by Lutes *et al* (2008), two different intensities and methods of executing the intervention were studied between two groups. One of the groups pursued an educational program on nutrition and physical activity plus resistance and aerobic training. The other group attended additional meetings with more hands-on programs coupled with resistance and aerobic training. The latter group lost more weight and reduced waist circumference more than the education group did. These findings indicate that a closer supervision and monitoring of the intervention may be required to produce greater improvements in health parameters.

Taken together, the data of the present study indicate that the physical activity and dietary intervention was not effective at eliciting improvements in diet or physical activity level. However, the intervention was effective in improving FPG among participants with abdominal obesity. These results suggest that greater behavioral changes in physical activity and diet may require longer than twelve weeks to occur. Additionally, closer supervision and more effective monitoring were identified as possible means to improve the outcomes of interventions. These findings will be valuable to further improve group-based interventions for the prevention and management of obesity.

The major limitation of this study was the relatively short duration. The intervention was only conducted for twelve weeks, which may be too short a period for significant changes in obesity and metabolic risk factors to have been observed. Additionally, the relatively small sample size in the study might have reduced the power to detect between-group differences.

In collecting dietary data using two-day dietary recall, there was under-reporting of food intake. For physical activity assessment, the accelerometer does not detect movement in certain forms of activity, such as cycling and swimming. Therefore, the data from accelerometers might not reflect the total physical activity carried out by the participants. Furthermore, there was a possibility of improper use of the accelerometer. For example, some of the participants might not have worn the accelerometers for the full-day specified time during the period of assessment.

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