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Effect of weekly physical activity frequency on weight loss in healthy overweight and obese women attending a weight loss program: a randomized controlled trial[1]

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ABSTRACT

Background: The effect of intensity and duration of physical activity (PA) on weight loss has been well described. However, the effect of the frequency of weekly PA on weight loss is still unknown.

Objective: The purpose of this study was to evaluate the effect of the frequency of weekly PA sessions while maintaining the same total activity time on weight loss during a 24-wk weight loss program.

Design: Overweight and obese women [n = 75; body mass index (BMI; in kg/m^2): 27–37; age: 18–40 y] who had a normally sedentary lifestyle were randomly allocated to 1 of 2 intervention groups: a high-frequency physical activity (HF) or a low-frequency physical activity (LF) group. The HF group included 50 min/d PA, 6 d/wk (300 min/wk). The LF group included 100 min/d PA, 3 d/wk (300 min/wk). Both groups were advised to follow the same dietary weight loss program.

Results: Both groups showed a significant decrease in anthropometric measurements and significant improvements in cardiometabolic disease risk characteristics over the 24 wk of the study. Compared with the HF group, the LF group had a greater decrease in weight (mean ± SD; LF: 9.58 ± 3.77 kg; HF: 7.78 ± 2.68 kg; P = 0.028), BMI (LF: 3.62 ± 1.56; HF: 2.97 ± 1.02; P = 0.029) and waist circumference (LF: 9.36 ± 4.02 cm; HF: 7.86 ± 2.41 cm; P = 0.031). However, there were no significant differences in carbohydrate metabolism characteristics or lipid profile after the 24 wk of intervention.

Conclusion: Weekly PA undertaken over fewer sessions of longer duration during the week could be more effective for weight loss than when undertaken as more frequent shorter sessions in overweight and obese women on a weight loss program. This may be helpful for those who are neither willing nor able to schedule time for PA almost every day to achieve weight loss. This trial was registered at www.irct.ir as IRCT201402157754N4. *Am J Clin Nutr* doi: 10.3945/ajcn.116.136408.

Keywords: physical activity pattern, obesity, weight loss diet, waist circumference, cardiometabolic disease risk

INTRODUCTION

Physical activity (PA)[6] is recommended as a component of weight management (1, 2), as well as in the treatment of abdominal obesity (3). It is well known that weight loss interventions that include PA are more effective than dietary instruction alone for promoting long-term weight loss (4, 5).

Previous guidelines recommended 150 min of moderate to vigorous PA achieved by participating in ≥30 min of moderate to vigorous PA on most or all days of the week (6). Present guidelines (7–9) advise that adults undertake moderate to vigorous PA for ≥150 min/wk, in sessions of ≥10 min (7, 8). However, The American College of Sports Medicine recommended 200–300 min/wk for long-term weight loss (10). Current practice guidelines include recommendations that PA be undertaken for 30 min/d for most days of the week, increasing, when appropriate, to 60 min/d (11, 12). In the more recent guidelines, however, there is no recommendation about the frequency of PA throughout the week (9, 13). Limited studies have assessed the frequency of PA participation during the week and its relation with health, not weight loss. A cohort study (14) compared the effect of being a "weekend warrior" (1–2 d/wk) with being active regularly with respect to the risk of mortality. There was some indication that more frequent PA could deliver additional health benefits (14). However, a recent observational study (15) found that the frequency of moderate to vigorous PA during the week is not as important as the total length of time spent being physically active.

Therefore, although the implications of total time and intensity of PA have been studied, it is less clear whether frequency of sessions matters. Activity pattern may have important implications for compliance with an activity program during weight management. A lack of time is often mentioned as a barrier to PA. Advocating any one pattern of activity over the week, without

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[6] Abbreviations used: FPG, fasting plasma glucose; HF, high-frequency physical activity; LF, low-frequency physical activity; PA, physical activity; TC, total cholesterol; WC, waist circumference; 2hpp, 2-h postprandial.

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evidence of it being particularly beneficial, would unnecessarily limit flexibility and the opportunity to undertake activity around other fixed commitments, hence reducing compliance. It is important to establish, e.g., whether it is necessary to be physically active every day of the week or whether similar weight loss benefit can be obtained with less frequent PA, providing the total amount of weekly PA is the same.

To our knowledge, no clinical trials have evaluated the effects on weight loss of different frequencies of weekly PA sessions, with a fixed duration of total activity, when combined with a restricted energy diet. Thus, the primary objective of the present study was to compare the effects on weight loss and anthropometric measures of brisk walking for a fixed total duration per week, when undertaken either over 6 d of the week, or over 3 d of the week, in healthy overweight and obese women who were following a comprehensive 24-wk weight loss program. The secondary objective was to examine the effect of weekly PA frequency on biochemical indicators of cardiometabolic disease risk.

METHODS

Participants

Healthy overweight and obese participants were selected between March 2014 and April 2015 from patients attending the NovinDiet Clinic in Tehran, Iran, to lose weight. Inclusion criteria were the following: women aged 18–40 y, BMI (in kg/m^2): 27–35, sedentary lifestyle [reported exercising $<$3 d/wk for $<$20 min/d for the previous 6 mo (16, 17)] and willing to introduce dietary changes to lose weight. All participants were required to be nonsmokers who were free of established cardiovascular diseases, stroke, diabetes, liver or kidney disease, depression, cancer, or autoimmune disease. Moreover, participants included those who were able to prove that they could keep an adequate 4-d food record and record details of their total daily steps, and who were considered fit to participate in the physical exercise program by the study physician. Exclusion criteria were pregnancy or lactation during the previous 6 mo or planning a pregnancy in the next 6 mo; depression as defined by Beck's Depression Inventory (18); weight loss $\geq$10% of body weight within the 6 mo before enrollment in the study; participation in a research project involving weight loss or PA in the previous 6 mo; taking medication to lower lipids or cholesterol or medication that could affect metabolism or change body weight, including birth control medication; reported heart disorders, frequent chest pains, or faintness or dizziness on the Physical Activity Readiness Questionnaire (19); or being considered unfit to participate by the study physician as a result of any other medical condition.

The study (IRCT201402157754N4) was approved by the ethical committee of the Digestive Research Institute, Tehran University of Medical Science. All participants provided their informed, signed consent before participating in this study.

Study design and interventions

The study was a 24-wk, 2-arm, single-blind randomized clinical trial. Eligible participants were allocated randomly after baseline measurements by the project director with the use of a computer-generated random-numbers method. Allocation was concealed from the participants and dietitians until randomization was revealed to the study participants at the first intervention clinic appointment. Seventy-five subjects were randomly assigned to 1 of the 2 study groups: *1*) diet plus high-frequency physical activity (HF) (n = 38), or *2*) diet plus low-frequency physical activity (LF) (n = 37). To control the effects of menstrual cycle on measurements, participants started the study at the same phase of their menstrual cycle. Subjects in the HF group were requested to perform 50 min/d brisk walking, 6 d/wk (300 min/wk). Subjects in the LF group were instructed to perform 100 min/d brisk walking, 3 d/wk (300 min/wk).

To become conditioned to the level of exercise a week before the start of the study, participants were asked to increase their daily step count and record their total daily step count. To standardize the intensity of the PA sessions, participants were asked to walk $\geq$100 steps/min during the brisk walking sessions (20). Participants were asked to do brisk walking on a flat surface outdoors in their neighborhood or in a park while wearing loose-fitting and comfortable clothing appropriate for weather conditions.

To encourage the participants to achieve the requested PA goal, their treatment included encouragement to recruit a partner from their group of friends and family members to participate in the activity part of the study with them. Biweekly visits to the dietitian and exercise coach were required to promote adherence to the hypoenergetic diet and recommended PA protocol. To promote adherence to the PA intervention, participants were provided with a 3-dimensional pedometer. Participants were instructed to wear the pedometer for the whole day except when having a bath and in bed. They were asked to keep a written record of their daily step counts and time of their structured PA in their log book. Both groups were advised on a hypoenergetic diet according to the NovinDiet Protocol.

Dietary and activity intervention sessions

The NovinDiet Clinic is a private weight loss clinic that uses an integrated approach (dietary, behavioral, exercise, and medical treatments). The NovinDiet Protocol is based on helping each member develop his or her own problem solving approach. The program was designed to enable weight loss of 7–10% of initial body weight at a rate of 0.5–1 kg/wk over 24 wk. The individual diet programs were based on the participant's food diary records, which reflected their food preferences. Gradual modifications were made to bring their diet in line with the NovinDiet protocol. Participants were encouraged to eat mainly foods with low energy density to achieve satiety, some low-fat dairy products, fiber-rich foods, and controlled amounts of high energy–dense foods. The main behavior change strategies applied included assessing and discussing stages of change, goal setting, self-monitoring with food diaries, and giving feedback on waist measurement changes (21, 22).

At weekly sessions, the participants were encouraged to describe any problems complying with their weight loss program, and these were discussed. Resources were provided as home booklets that indicated the individual dietary and PA goals. During the intervention period, participants completed a feedback form regarding their adherence to diet and PA. At weekly clinic visits, the dietitian reviewed their progress and also checked their PA adherence and reported their step counts during the previous week. Participants also had access to a Website, weekly Internet

magazines, and one-on-one telephone or online support from a consultant, if they felt that they had difficulty with compliance.

Measurements

Anthropometric measurements were taken at baseline and at 24 wk (except height, which was taken only at the screening visit), by the dietitian.

Participants recorded their food intake at baseline, week 11, and toward the end of the intervention (week 24). The records were analyzed with the use of Nutritionist IV software (version 4.1; Hearst). Estimated daily PA measurements of all participants were taken at baseline and weeks 4, 8, 12, 16, 20, and 24 by using the 3D pedometer. Blood samples were taken after an overnight (10–12 h) fast, between 0700 and 0900, at baseline and 24 wk. Blood was obtained from an antecubital vein via a venipuncture while the participants were sitting, according to the standard protocol; this was centrifuged within 30–45 min. Blood samples were also taken 2 h after ingesting 75 g glucose according to the standard method for 2-h postprandial (2hpp) glucose (23). Blood samples were analyzed for biochemical, cellular, and hormonal variables.

Anthropometric measurements

Body weight was measured to the nearest 0.1 kg with the use of a digital calibrated scale (Omron Health Care) while the participants wore light clothing, with no shoes. Body height was measured to the nearest 0.1 cm by using a wall mounted stadiometer (SECA) without shoes, and with participants in a free-standing position. Waist circumference (WC) (24) was measured with a rigid measuring tape and recorded to the nearest 0.5 cm. WC was measured at the smallest horizontal circumference between the ribs and iliac crest (the natural waist), or, in case of an indeterminable waist narrowing, halfway between the lower rib and the iliac crest (25). BMI was calculated from measured weight in kilograms divided by the square of height in meters.

Blood sample measurements

Fasting plasma glucose (FPG) and 2hpp glucose concentrations were measured with the use of the enzymatic colorimetric method, with intra- and interassay CVs $<2\%$. Insulin was measured by using a radioimmunoassay with ^{125}I-labeled human insulin and a human insulin antiserum in an immunoradiometric assay (Biosource) with a γ-counter system (Gamma I; Genesys), with intra- and interassay CVs $<2.3\%$. Insulin resistance was evaluated by HOMA-IR, which was calculated by using the following formula (26):

$$\text{HOMA-IR} = [\text{fasting insulin}(\text{mU/L}) \times \text{FPG}(\text{mmol/L})]/22.5 \quad (1)$$

Glycated hemoglobin was measured by a colorimetric method after an initial separation by ion exchange chromatography (Biosystem), with intra- and interassay CVs $<1.7\%$.

Biochemical analysis of serum total cholesterol (TC), triglycerides, and HDL cholesterol was carried out on a Selectra E auto analyzer (Vita Laboratory) while following standard procedures for the Pars Azmoon diagnostic kits (Iran). Both inter- and intra-assay CVs were $<1.8\%$, 2.9%, and 2.4% for TC, HDL cholesterol, and triglycerides, respectively. LDL cholesterol was calculated with the use of the Friedewald formula (27):

$$\text{LDL cholesterol} = \text{TC} - \text{HDL cholesterol} + (\text{TG} \div 2.2) \quad (2)$$

Statistical methods

Baseline values of cardiovascular disease risk factors (including weight, WC, LDL cholesterol, HDL cholesterol, TC, FPG, triglycerides, fasting insulin, HOMA-IR, glycated hemoglobin, 2hpp glucose, food intake data, and step count data) were compared between the HF and LF groups with the use of unpaired *t* tests.

At baseline, distribution was normal for all variables. All participants who were assigned randomly and completed an initial assessment were included in the final results by using an intention-to-treat analysis. Multiple imputations with the use of linear regression were used to impute missing values from 24 wk and were based on the assumption that data were missing at random. We used ANCOVA to compare the mean of postintervention outcomes between the 2 groups by adjustment of baseline values as a covariate. Repeated-measures 2-factor ANOVA with intervention groups (HF and LF) and time (weeks 0, 4, 8, 12, 16, 20, and 24) as a within-subject factor was used to assess the effects of the interventions by comparing changes in the PA level measured by using the step count data between the groups over time.

The primary outcome addressed in this study was the difference in body weight loss after the 24-wk weight loss program. The power calculation was based on prior data [$\alpha = 0.05$, power $(1 - \beta) = 0.8$], and was performed on the basis of expected differences in weight loss between the intervention groups of 1.3 and an SD of ± 1.9 kg to determine the targeted final sample size ($n = 66$). When considering a dropout rate of 10%, the sample size required was 73. Thus, 75 subjects were randomly assigned to each of the 2 intervention groups.

Statistical significance was set at $P \leq 0.05$. All data are presented as means $\pm$ SDs unless otherwise stated. All statistical analyses were performed with the use of SPSS 22.0 for Windows.

RESULTS

Baseline characteristics

Of 97 individuals who were interested in participating in the study, 2 were excluded from the study because of their results on Beck's Depression Inventory. Three potential participants were excluded because they stopped keeping the dietary record or filled it in insufficiently before random assignment. Five were excluded because they decided that they were not interested in participating in the study. Blood test results at baseline revealed that 12 patients were ineligible because they had ≥ 1 of the exclusion criteria. The remaining 75 eligible participants gave written consent, and then 38 subjects were randomly allocated to the HF group and 37 were allocated to the LF group. Fifty-nine completed the 24-wk intervention (79% of the randomly assigned population) (**Figure 1**). After the intervention started, a total of 16 participants dropped out [5 because of illness ($n = 2$ in the LF group and $n = 3$ in the HF group), 3 because they could not meet the time commitment ($n = 1$ in the LF group and $n = 2$ in the HF group), 1 because she experienced an unexpected pregnancy (LF group), 6 because they subsequently lost interest ($n = 4$ in the LF group and $n = 2$ in the HF group), and 1 because she moved away from the area (HF group)].

At baseline, there were no statistically significant differences in physical characteristics or biochemical measurements between the intervention groups or between those who completed or did not complete the study once recruited (**Table 1**).

Body weight, BMI, and WC

There was significant weight reduction in each group after 24 wk of study ($P < 0.001$) (**Table 2**). There was a significant difference between groups after 24 wk of the intervention ($P = 0.028$) (Table 2).

BMI reduction in each group was in the expected direction, with significant effects over 24 wk for both groups ($P < 0.001$). Also, there was a significant difference between groups in BMI reduction after 24 wk ($P = 0.029$) (Table 2).

In both groups, WC had decreased significantly after 24 wk of intervention ($P < 0.001$). The mean WC decline was 9.36 ± 4.02 cm in the LF group and 7.86 ± 2.41 cm in the LF group at 24 wk of the intervention ($P = 0.031$).

Lipid profiles

Reductions in total cholesterol, LDL cholesterol, and triglyceride concentrations and an increase in HDL cholesterol were seen over the 24 wk of study in each group ($P < 0.001$). However, there were no significant differences in these results between the groups over 24 wk (Table2).

Glucose metabolism measurement

Data analysis showed that FPG, 2hpp glucose, glycated hemoglobin, fasting serum insulin, and HOMA-IR all declined over the 24 wk of study in each group ($P < 0.001$). However, between-group comparisons were not significant for any variable (Table 2).

Food intake measurement

At baseline, there was no significant difference in energy and macronutrient intake (**Table 3**). Estimated energy intake measurements showed a significant reduction over time in both groups ($P < 0.001$ for time effect). There were no significant differences in energy and macronutrient intake between the 2 groups at the end of the 24-wk intervention, as shown in Table 3.

PA measurements

At baseline, both groups had similar mean daily steps of ~3757 ± 315 in the HF group and 3608 ± 550 in the LF group,

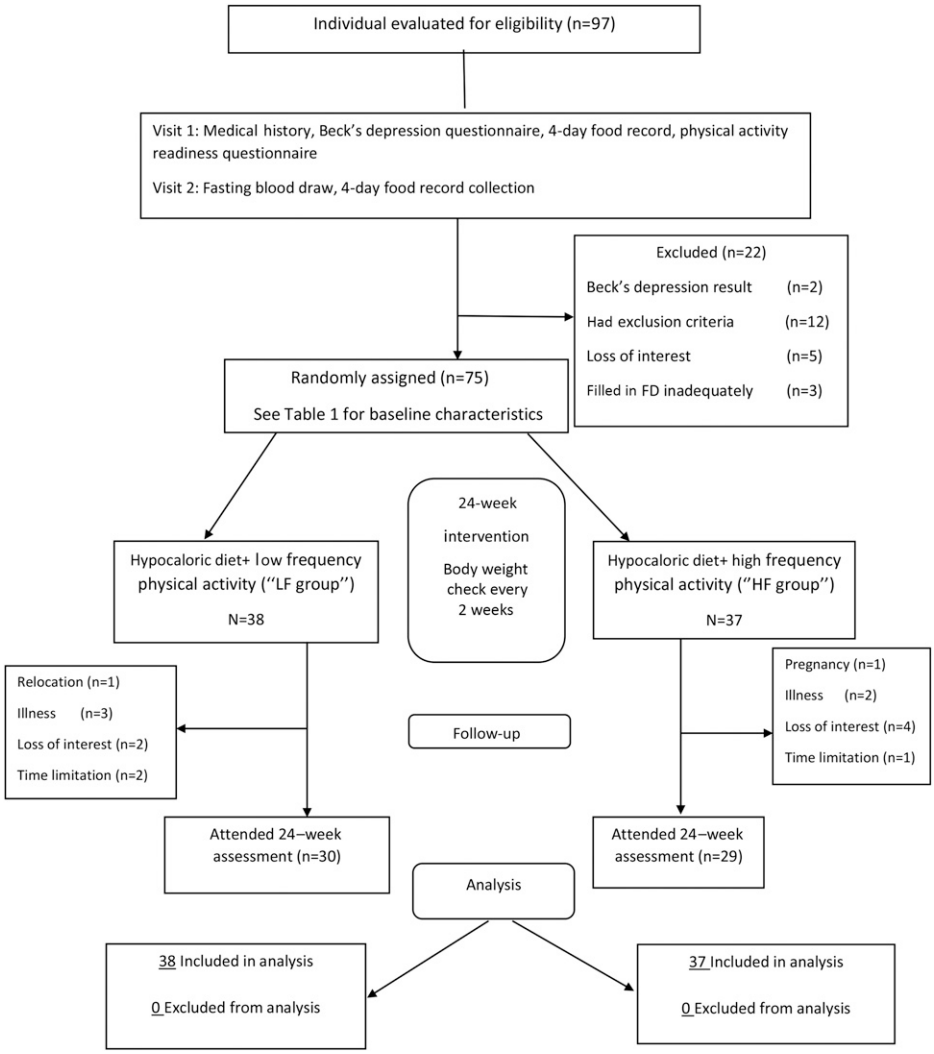

FIGURE 1 Screening, enrollment, random assignment, and follow-up of study participants. FD, food diary.

TABLE 1
Baseline characteristics of the study groups[1]

	LF group (n = 38)	HF group (n = 37)
Age, y	29.4 ± 5.7	29.7 ± 5.8
Married	62	58
Anthropometric measures		
Body weight, kg	82.6 ± 7.3	81.4 ± 7.5
Height, cm	160.5 ± 3.9	159.7 ± 4.0
BMI, kg/m^2	32.1 ± 2.6	31.9 ± 2.6
WC, cm	98.3 ± 8.9	98.2 ± 9.0
Biochemical measures		
TC, mmol/L	4.42 ± 0.51	4.48 ± 0.51
HDL cholesterol, mmol/L	1.16 ± 0.20	1.18 ± 0.14
LDL cholesterol, mmol/L	2.57 ± 0.51	2.59 ± 0.49
TGs, mmol/L	1.52 ± 0.33	1.54 ± 0.23
FPG, mmol/L	5.18 ± 0.48	5.14 ± 0.45
2hpp glucose, mmol/L	6.38 ± 0.62	6.40 ± 0.44
HbA1c, %	5.29 ± 0.40	5.06 ± 0.53
Insulin, mU/L	13.36 ± 3.05	13.22 ± 2.61
HOMA-IR	3.11 ± 0.88	3.04 ± 0.73

[1] Values are means ± SDs or percentages, n = 75. Group difference (with the use of an unpaired t test), $P > 0.05$. There were no significant differences between groups at baseline. FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; HF, high-frequency physical activity; LF, low-frequency physical activity; TC, total cholesterol; TG, triglyceride; WC, waist circumference; 2hpp, 2-h postprandial.

as shown in **Figure 2**. Compared with baseline, both groups had higher mean daily steps over time ($P < 0.001$ for time effect). In addition, there was a significant group × time interaction for mean daily steps over 24 wk between the 2 groups ($P < 0.001$, 2-factor ANOVA).

DISCUSSION

The main finding of the present study was that LF resulted in significantly higher weight loss than did HF, with the same total of 300 min/wk for period of activity (11.7% compared with 9.5%) in overweight and obese women while they were on a multidisciplinary weight loss program.

The current guideline from the American College of Sports Medicine that recommends moderate intensity PA of >250 min/wk has been associated with clinically significant weight loss (28). A recent clinical trial (29) also showed a beneficial effect of moderate to vigorous exercise for 300 min/wk compared with 150 min/wk for reducing adiposity measures and body weight. However, so far, the effects of different weekly patterns of PA on weight loss are unknown.

A recent cross-sectional study (15) found that the frequency of moderate to vigorous PA during the week is not as important as the total volume of moderate to vigorous PA. However, this study examined the association between the frequency of PA throughout the week and metabolic syndrome in physically active adults, not sedentary people who were following a weight loss program (15).

Unlike this previous observational study, to our knowledge, there has not been a randomized controlled trial examining the consequence for weight loss of either a weekly high- or low-frequency PA pattern in overweight and obese premenopausal women who were undertaking a voluntary integrated weight reduction program for 24 wk.

The current study included a dietary intervention that has been proven previously to achieve weight loss. Study participants lost an amount of weight that was consistent with the dietary prescription. In such intensive clinic-based behavioral lifestyle modification programs, 5–10% weight losses have been detected at 6 mo (30–32), which is similar to the weight losses that we detected in the present study. This is not unexpected, because our weight loss program includes energy restriction, frequent patient visits to the clinic, and controlled and regular PA according the protocol for each group. The results of the present study are also in agreement with a study by Jakicic et al. (33) that demonstrated that a combination of dietary modification and PA can improve long-term weight loss.

Interestingly, participants in the LF group in our study lost 1.9 kg more weight than those in the HF group. It should be noted

TABLE 2
Anthropometric and blood measurement characteristics in the HF and LF groups before and after the 24-wk interventions[1]

	LF group (n = 38)		HF group (n = 37)		
	Baseline	Week 24	Baseline	Week 24	P^2
Weight,[3] kg	82.62 ± 7.30	73.05 ± 6.49	81.35 ± 7.49	73.57 ± 7.14	0.028
BMI,[3] kg/m^2	32.09 ± 2.57	28.94 ± 2.47	31.90 ± 2.61	28.47 ± 2.18	0.029
WC,[3] cm	98.32 ± 8.85	88.96 ± 7.58	98.24 ± 8.99	90.38 ± 8.37	0.031
TC,[3] mmol/L	4.42 ± 0.51	3.97 ± 0.49	4.48 ± 0.51	4.05 ± 0.49	0.662
HDL cholesterol,[3] mmol/L	1.16 ± 0.20	1.30 ± 0.21	1.18 ± 0.14	1.32 ± 0.14	0.754
LDL cholesterol,[3] mmol/L	2.57 ± 0.49	2.12 ± 0.48	2.59 ± 0.51	2.12 ± 0.48	0.858
TGs,[3] mmol/L	1.52 ± 0.33	1.30 ± 0.18	1.54 ± 0.22	1.33 ± 0.23	0.55
FPG,[3] mmol/L	5.18 ± 0.48	4.79 ± 0.52	5.14 ± 0.45	4.80 ± 0.42	0.672
2hpp glucose,[3] mmol/L	6.38 ± 0.62	5.71 ± 0.53	6.40 ± 0.44	5.71 ± 0.43	0.841
HbA1c,[3] %	5.29 ± 0.40	4.86 ± 0.43	5.06 ± 0.53	4.68 ± 0.52	0.424
Insulin,[3] mU/L	13.36 ± 3.05	11.46 ± 2.91	13.22 ± 2.61	11.50 ± 2.70	0.422
HOMA[3]	3.11 ± 0.88	2.42 ± 0.77	3.04 ± 0.73	2.41 ± 0.66	0.476

[1] Values are means ± SDs, n = 75. FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; HF, high-frequency physical activity; LF, low-frequency physical activity; TC, total cholesterol; TG, triglyceride; WC, waist circumference; 2hpp, 2-h postprandial.

[2] For LF relative to HF group with the use of ANCOVA with baseline values as a covariate.

[3] Significant main effect of time, with the use of repeated-measures ANOVA, $P < 0.001$.

TABLE 3
Self-reported dietary intake in LF and HF groups before and after the 24-wk interventions[1]

	LF group (n = 38)		HF group (n = 37)		
Intake	Baseline	Week 24	Baseline	Week 24	P^2
Total energy,[3] kcal	2476 ± 286	1947 ± 181	2408 ± 296	1913 ± 290	0.805
Protein,[3] g	91.1 ± 8.8	79.4 ± 9.4	87.2 ± 8	74.3 ± 10.1	0.141
Protein,[3] %	14.9 ± 2.1	16.4 ± 2	14.7 ± 2.1	15.6 ± 1.8	
Fat,[3] g	97.6 ± 17	69.7 ± 9.4	92.8 ± 20.3	65.6 ± 13.2	0.287
Fat,[3] %	35.3 ± 2.9	32.1 ± 2.3	34.4 ± 4.3	30.7 ± 2.3	
Carbohydrate,[3] g	308.3 ± 35.3	250.7 ± 26.5	306.2 ± 35.4	256.3 ± 38	0.201
Carbohydrate,[3] %	49.8 ± 1.6	51.5 ± 2.4	51 ± 2.9	53.6 ± 1.8	
Fiber,[3] g	20.5 ± 5.5	21.9 ± 5.5	20.75 ± 3.2	22.14 ± 3.24	0.394

[1] Values are means ± SDs, n = 75. HF, high-frequency physical activity; LF, low-frequency physical activity.
[2] For LF relative to HF group with the use of ANCOVA with baseline values as a covariate.
[3] Significant main effect of time, with the use of repeated-measures ANOVA, $P < 0.001$.

that no significant differences in estimated energy intake were seen between the 2 groups. Thus, the significant difference in weight loss after 24 wk may be a result of differences in PA between the groups outside the study protocol. Participants in the LF group may have undertaken physical activity on the other days of the week, which we did not request, perhaps because they had developed a new PA habit. It is possible that there was better compliance with the protocol in the LF group. In addition, during prolonged, moderate-intensity, constant-rate exercise, a cardiovascular drift can occur that may explain the weight loss difference between the 2 groups of the intervention. The results of the present study are consistent with a previous control study which indicated that subjects lost more weight when they played golf 2–3 times/wk compared with sedentary control group (34). However, when elucidating the underlying mechanisms, finding an explanation for the greater weight loss in the LF group than in the HF group needs further long-term studies with accurate accelerometer data or the use of doubly labeled water.

In the present study, major changes in lipid profiles and carbohydrate metabolism characteristics were significant in each group, as we would expect, given the weight loss observed, but these changes were similar in both groups. These results are similar to the results of recent observational studies that indicate

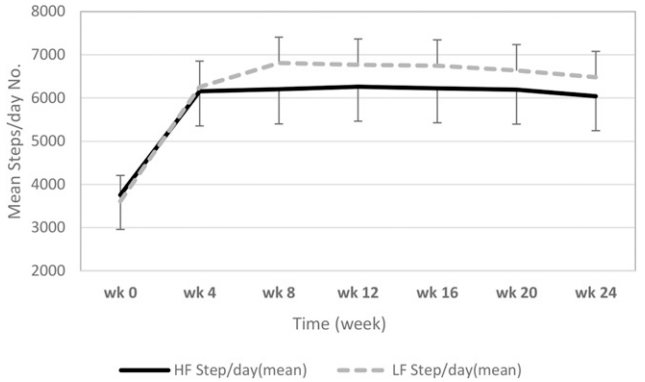

FIGURE 2 Mean ± SEM step calculations with the use of a 3D pedometer over the 24 wk of the intervention. At baseline, there were no differences in step counts between the HF plus diet (n = 37) and LF plus diet (n = 38) groups. There was a significant group × time interaction for mean daily steps over 24 wk ($P < 0.001$; 2-factor ANOVA). HF, high-frequency physical activity; LF, low-frequency physical activity.

the beneficial effects of accumulated moderate to vigorous PA of ≥150 min/wk on cardiometabolic disease risk factors and metabolic syndrome regardless of the frequency of PA throughout the week (35).

These findings have clinical implications for the prescription of PA that are consistent with the current guideline of >250 min/wk PA for weight loss when sedentary overweight and obese adults engage in an integrated weight loss program that includes an energy-restricted diet and PA. Our results suggest that spending the recommended length of time being active across a lower frequency of PA sessions during a week could be associated with more weight loss than being active most days of the week, as recommended in the previous guidelines (6). Thus, people with obesity who wish to lose weight but who either cannot or choose not to undertake PA on most days may in fact experience benefit if they undertake PA on 3 d for longer periods of time. It may also indicate that the LF group was better able to comply with PA protocol than the HF group, or that the LF group may have undertaken more nonprescribed PA during the rest of the week. Future research is required to examine the longer-term health effects of LF compared with HF to establish whether the benefits of LF are sustained.

There are limitations to this study that should be considered when interpreting the results. First, this study was designed to test whether LF would result in greater weight loss than would HF throughout the week. However, accurate objective measurements of PA characteristics, e.g., intensity and length of PA in the intervention groups, were not made during the structured PA sessions or over the rest of the day. These should be included in future studies. Furthermore, because the majority of PA achieved in this study was brisk walking, the effect of other forms of activity on weight loss could not be determined. In addition, without long-term follow-up, it is not known whether participants could comply with the longer bouts of PA in the longer term.

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The authors' responsibilities were as follows—AM: contributed to the initial study design, study protocol setup, data collection, data analysis, and writing of the first draft of the manuscript; MAT and IAM: refined the study design and contributed to the redrafting of the manuscript; LSN: contributed to

the initial study design, study protocol setup, and data collection; MAT, IAM, and HRF: contributed to data interpretation; HRF: designed the research, revised the manuscript, and provided medical supervision; AD, RM, and HRF: conducted the research; AD and RM: provided advice and consultation for the study design; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

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