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Beneficial effect of high energy intake at lunch rather than dinner on weight loss in healthy obese women in a weight-loss program: a randomized clinical trial[1]

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ABSTRACT

Background: The association between the time of nutrient intake and health has been described in a few studies. To our knowledge, no study has evaluated the relation between high energy intakes at lunch compared with at dinner on weight loss in overweight and obese subjects.

Objective: We compared the effect of high energy intake at lunch with that at dinner on weight loss and cardiometabolic risk factors in women during a weight-loss program.

Design: Overweight and obese women [n = 80; body mass index (BMI; in kg/m^2): 27–35; age: 18–45 y] were asked to eat either a main meal at lunch (LM) or a main meal at dinner (DM) for 12 wk while in a weight-loss program.

Results: A total of 80 participants were randomly assigned to one of 2 intervention groups. Sixty-nine subjects (86%) completed the trial (34 subjects in the DM group, and 35 subjects in the LM group). Baseline variables were not significantly different between groups. A significant reduction in anthropometric measurements and significant improvements in cardiometabolic risk characteristics were observed over 12 wk in both groups. Compared with the DM group, the LM group had greater mean ± SD reductions in weight (LM: −5.85 ± 1.96 kg; DM: −4.35 ± 1.98 kg; P = 0.003), BMI (LM: 2.27± 0.76; DM: 1.68 ± 0.76; P = 0.003), homeostasis model assessment of insulin resistance (LM: −0.66 ± 0.33; DM: −0.46 ± 0.24; P = 0.001), and fasting insulin (LM: −2.01 ± 1.10 mIU/mL; DM: −1.16 ± 0.72 mIU/mL; $P < 0.001$) after 12 wk. However, there were no significant differences for fasting plasma glucose and lipid profiles within both groups after 12 wk.

Conclusions: The consumption of higher energy intake at lunch compared with at dinner may result in favorable changes in weight loss in overweight and obese women after a weight-loss program of 12 wk. The consumption may also offer clinical benefits to improve insulin resistance. This trial was registered at clinicaltrials.gov as NCT02399280. *Am J Clin Nutr* doi: 10.3945/ajcn.116.134163.

Keywords: dinner, insulin resistance, lunch, obesity, weight-loss diet

INTRODUCTION

There is an interest in discovering the effects of eating patterns on body weight and energy metabolism (e.g., the frequency of eating and timing of consumption throughout the day) (1). Indeed, previous studies have investigated different aspects of the meal pattern including the daily meal frequency and circadian distribution of intake (2), irregular meal frequency (3–5), and omission of breakfast (6) on weight control and cardiometabolic risk factors.

There is an association between breakfast skipping, late-night eating, and obesity as has been defined in cross-sectional (7, 8) and longitudinal (9–13) studies. Previous studies have indicated that obese people tend to eat less in the morning and more in the evening than do lean controls (10, 11, 14, 15). However, these results were not confirmed by other authors (16).

Until now, few recommendations have existed for the appropriate distribution of intake of energy across the day (17). There has also been limited research describing the distribution of energy and macronutrients at a population level (18, 19). Nevertheless, there has been evidence that the timing of energy and nutrient intake has shifted slightly over time with a greater proportion of intake later in the day (20). Data from a recent observational study (21) also indicated that eating more of daily total energy intake at midday was associated with lower risk of being overweight or obese, whereas consuming more in the evening was associated with higher risk. Health professionals and nutritionists generally recommend that obese people who desire to lose weight should eat their main meal at lunch rather than at dinner. However, this recommendation seems to have been on only a few studies. A clinical study showed that eating late in the day was associated with reductions in resting energy expenditure, fasting carbohydrate oxidation, and glucose tolerance (22). Additional evidence indicated that late-lunch eating may have deleterious effects on the success of weight-loss therapy (23). In addition, a recent study on the effects of a high-energy breakfast

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with reduced intake at dinner showed beneficial results on the management of obesity and metabolic syndrome (24).

To our knowledge, there are few studies that have evaluated whether higher energy intake at lunch than at dinner results in greater weight loss in overweight and obese subjects when they are consuming an energy-restricted diet. In addition, this comparison has not been made with respect to lipid and glucose metabolism in this group. Thus, the purpose of this study was to compare the effects of a high energy intake at lunch with those at dinner with respect to body weight [and waist circumference (WC)[5]] as a primary outcome and carbohydrate and lipid metabolism as a secondary outcome in overweight and obese women after a comprehensive 12-wk weight-loss program.

METHODS

Subjects

Healthy overweight and obese women were selected between March 2015 and October 2015 from participants who were attending the NovinDiet Clinic to lose weight. Inclusion criteria were as follows: women who were aged 18–45 y with BMI (in kg/m^2) from 27 to 35 who were willing to introduce a dietary change to lose weight and had the ability to have moderate exercise. All subjects were required to be nonsmokers and free of an established self-reported history of cardiovascular diseases, stroke, diabetes, liver diseases, kidney diseases, depression, cancer, or autoimmune disease. Subjects included women who were able to demonstrate that they were able to keep an adequate 4-d food record and showed a readiness to safely participate in daily physical activity (PA).

Exclusion criteria were as follows: pregnancy or lactation during the previous 6 mo or planned pregnancy in the next 6 mo; weight loss $\geq$10% of body weight $\leq$6 mo before enrollment in the study; participation in a research project involving weight loss or PA in the previous 6 mo; and taking a medication to lower lipids or cholesterol or that could affect metabolism or a change body weight. Subjects who report heart disorders, frequent chest pains, or faintness or dizziness on the Physical Activity Readiness Questionnaire were excluded.

The study was approved by the Ethical Committee of the Digestive Research Institute, Tehran University of Medical Science. All subjects provided signed consent before study enrollment. This trial was registered at clinicaltrials.gov as NCT02399280.

Study design and interventions

The study was a 2-arm randomized clinical trial. Appropriate subjects were randomly assigned in a 1:1 ratio after baseline measures with the use of a computer-generated random-numbers method by the project coordinator with allocation concealed from the subjects and dietitians until the random assignment was revealed to the study subjects at the initial intervention clinic appointment. Groups were separated into subjects who had their main meal at dinner (DM) and subjects who had their main meal at lunch (LM). Subjects were assigned to consume 15% of their energy intakes at breakfast and 15% of their energy intakes with their snacks, with either 50% of daily energy intake at lunch and 20% of daily energy intake at dinner (LM group) or vice versa (DM group). Both groups started a hypoenergetic diet according to the NovinDiet protocol, which included advice to gradually increase activity levels to achieve 60 min of moderate activity 5 d/wk. Biweekly visits to the dietitian were required to promote adherence to the hypoenergetic diet and meal pattern. In addition, a registered dietitian had a telephone conversation with each subject every weekday during the study to check adherence to the meal pattern and diet.

Screening visit

At screening visits, a general medicine doctor examined subjects. All subjects completed the Beck Depression Inventory (25) and the Physical Activity Readiness Questionnaire (26). Potential subjects were instructed in how to keep a 4-d food record by a research nutritionist. In the 30-min lesson, emphasis was placed on the necessity of the time recording and of keeping an accurate food and drink record for 4 consecutive days, which included 3 weekdays and 1 weekend day. The food record was evaluated for completeness at the next visit, and subjects were excluded if it was not sufficiently detailed.

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 clinic staff engages in research as well as providing clinical services. Participants in the study did not pay Clinic fees. The NovinDiet protocol is based on developing a problem solving approach for each member individually and addresses both diet and exercise. In this study, the program was designed to enable a weight loss of 7–10% of the starting body weight at a rate of 0.5–1 kg/wk over 12 wk. The individual diet programs were based on the participants' food diary records and their food preferences with gradual modification to bring their diets in line with the NovinDiet protocol. Participants were assigned to receive a hypoenergetic diet with a mainly high-carbohydrate, low–saturated fat dietary pattern [17% of energy from protein, 23% from fat ($<$10% from saturated fat), and 60% from carbohydrate, with $\geq$400 g fruit and vegetables to achieve a fiber intake recommendation of 25g/d]. Subjects were encouraged to gradually increase activity levels to achieve 60 min of moderate activity (mostly brisk walking) 5 d/wk. They were asked to report their daily PA levels at biweekly sessions in which subjects were encouraged to follow the PA instruction by the dietitians. Predominant behavior-change strategies applied included stages of change, goal setting, self-monitoring with food diaries, waist measurements, and PA (27, 28).

At biweekly sessions, each participant's reported behavior problems regarding the weight-loss program were discussed. Resources were provided as home booklets for each subject to record adherence to the diet protocol. During the intervention period, participants completed the feedback form regarding their adherence to the diets and their PA levels and had access to a website, weekly Internet magazines, and

[5] Abbreviations used: DM, main meal at dinner; LM, main meal at lunch; PA, physical activity; WC, waist circumference; 2hpp, 2 h postprandial.

one-to-one telephone and online support from a consultant physician if needed.

Measurements

Anthropometric measurements were taken at baseline and after 12 wk (except for height, which was taken only at the screening visit) by the dietitian.

Energy and macronutrient intakes at baseline and at the last week of the intervention (week 12) were analyzed with the use of Nutritionist IV software (version 4.1; Hearst). Blood samples of all subjects were taken after overnight (8–10-h) fasting between 0700 and 0900 at baseline and 12 wk for biochemical, cellular, and hormonal measurements. Fasting blood samples were collected by venipuncture according to a standard protocol.

Anthropometric measurements

Body weight was taken to the nearest 0.1 kg with the use of a digital calibrated scale (Omron Healthcare with participants

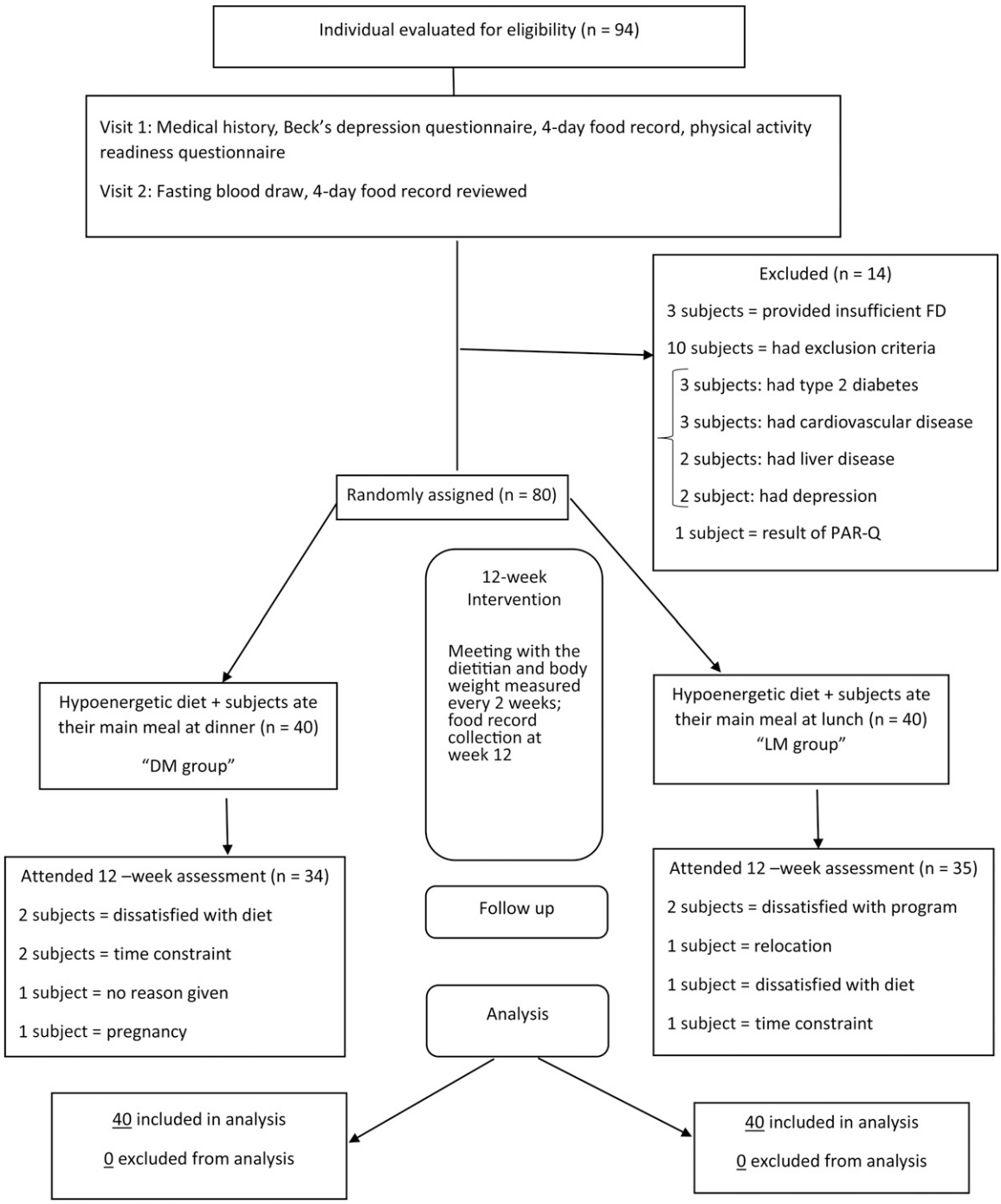

FIGURE 1 Screening, enrollment, random assignment, and follow-up of study participants. DM, main meal at dinner; FD, food-diary record, LM, main meal at lunch; PAR-Q, Physical Activity Readiness Questionnaire.

TABLE 1
Subject characteristics before the intervention[1]

	DM group (n = 40)	LM group (n = 40)
Age, y	33.29 ± 6.71[2]	33.93 ± 7.30
Body weight, kg	83.05 ± 6.98	84.02 ± 7.25
Height, cm	160.83 ± 4.22	161.53 ± 5.27
BMI, kg/m^2	32.10 ± 2.31	32.21 ± 2.24
WC, cm	101 ± 8.3	100 ± 7.98
Married, %	65	63
Total cholesterol, mmol/L	4.56 ± 0.48	4.59 ± 0.46
HDL cholesterol, mmol/L	1.2 ± 0.13	1.22 ± 0.17
LDL cholesterol, mmol/L	2.64 ± 0.49	2.66 ± 0.55
Triglyceride, mmol/L	1.58 ± 0.24	1.57 ± 0.27
FPG, mmol/L	5.02 ± 0.4	5.03 ± 0.42
2hppG, mmol/L	6.25 ± 0.5	6.27 ± 0.61
HbA1c, %	5.36 ± 0.54	5.4 ± 0.61
Insulin, mU/L	13.7 ± 2.34	14.04 ± 2.89
HOMA-IR	3.07 ± 0.64	3.16 ± 0.42

[1]Group difference, $P > 0.05$. There were no significant differences between groups at baseline. DM, main meal at dinner; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; LM, main meal at lunch; WC, waist circumference; 2hppG, 2-h postprandial glucose.
[2]Mean ± SD (all such values).

wearing light clothing and no shoes. Body height was measured to the nearest 0.1 cm with the use of a wall-mounted stadiometer (SECA) with participants barefoot and in a free-standing position. WC was measured with a flexible, nonstretching 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 (29). BMI was calculated from measured weight divided by the square of height.

Blood sample measurements

Blood samples from an antecubital vein via a venipuncture were taken while subjects were in a sitting position according to the standard protocol (30) and were centrifuged at 2000 × at room temperature within 30–45 min. Blood samples for 2-h postprandial (2hpp) glucose were taken 2 h after subjects ingested 75 g glucose according to the standard method, and the criteria of the American Diabetes Association were used for excluding diabetes (31, 32). Fasting plasma glucose and 2hpp concentrations were measured with the use of the enzymatic colorimetric method. Insulin was measured with the use of 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). Insulin resistance was evaluated with the use of the HOMA-IR, which was calculated as follows (33):

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

Glycated hemoglobin was measured with the use of a colorimetric method after an initial separation by ion-exchange chromatography (Biosystem).

Biochemical analyses of the serum total cholesterol, triglyceride, and HDL cholesterol were carried out with the use of a Selectra E autoanalyzer (Vita Laboratory) according to standard procedures of diagnostic kits (Pars Azmoon) (34). LDL cholesterol was calculated with the use of Friedewald's formula (35) as

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

Statistical analyses

Baseline values of cardiovascular disease risk factors (including weight, WC, LDL cholesterol, HDL cholesterol, total cholesterol, fasting plasma glucose, triglyceride, fasting insulin, HOMA-IR, glycated hemoglobin, and 2hpp glucose were compared between DM and LM groups with the use of unpaired t tests.

At baseline, the distribution was normal for all variables. All participants who were randomly assigned and completed an initial assessment were included in the final results in an intention-to-treat analysis. Multiple imputations with the use of linear regression were used to impute missing values from 12 wk and were based on the assumption that data were missing at random. We used an ANCOVA to compare outcomes between the 2 groups by adjustment of baseline values as covariates. In addition, an ANOVA with repeated measures was used for within-group comparisons.

The primary outcome of this study was the difference in bodyweight loss after a 12-wk weight-loss program. The power calculation was based on the results described by Jakubowicz et al. (24) ($\alpha = 0.05$, power = 0.9), which were performed on the basis of expected mean ± SD differences in weight loss between diet groups of 5 ± 10 kg to determine the targeted final sample size (n = 43). With consideration of a dropout rate of 40%, the sample size required was 74. Therefore, 80 subjects were randomly assigned to the 2 groups of the intervention.

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

RESULTS

Baseline characteristics

From 94 individuals who were interested in participating in the study, 2 subjects were excluded from the study because of the results of the Beck depression questionnaire (Beck Depression Inventory Score >9). Three potential subjects were excluded because they stopped keeping a dietary record or filled it in insufficiently. Blood test and questionnaire results at baseline revealed that 8 patients were ineligible because of having one or more of the following exclusion criteria: 3 subjects had type 2 diabetes (fasting plasma glucose concentrations ≥7 mmol/L), 3 subjects had a history of cardiovascular disease, and 2 subjects had liver diseases (aspartate aminotransferase concentrations >34 IU/L; alanine aminotransferase concentrations >38 IU/L). One subject was excluded as a result of the PA questionnaire. The remaining 80 subjects gave written consent, and 40 subjects were randomly allocated to each group. At total of 69 subjects completed the 12-wk intervention (86% of the randomly assigned population) (**Figure 1**). After the start of the intervention, a total of

TABLE 2
Anthropometric and blood measurement characteristics in LM and DM groups before and after 12-wk interventions ($n = 80$)[1]

	DM group ($n = 40$)[2]		LM group ($n = 40$)[2]		Δ (0–12 wk)[3]		
	Baseline	Week 12	Baseline	Week 12	DM group	LM group	Between-group comparison[4]
Weight, kg	83.05 ± 6.98	78.75 ± 7.18	84.02 ± 7.25	78.28 ± 6.88	−4.31 ± 1.93 (<0.001)	−5.73 ± 1.91 (<0.001)	−1.42 (−2.29, −0.56) [0.002]
BMI, kg/m^2	32.10 ± 2.31	30.45 ± 2.44	32.21 ± 2.24	30.02 ± 2.36	−1.67 ± 0.74 (<0.001)	−2.21 ± 0.75 (<0.001)	−0.53 (−0.86, −0.19) [0.003]
WC, cm	101 ± 8.3	95.75 ± 8.07	100 ± 7.98	94.38 ± 8.57	−5.33 ± 1.95 (<0.001)	−6.05 ± 2.14 (<0.001)	−0.73 (−1.65, 0.19) [0.118]
Total cholesterol, mmol/L	4.56 ± 0.48	4.27 ± 0.43	4.59 ± 0.46	4.22 ± 0.50	−0.32 ± 0.14 (<0.001)	−0.38 ± 0.19 (<0.001)	−0.06 (−0.13, 0.02) [0.133]
HDL cholesterol, mmol/L	1.2 ± 0.13	1.28 ± 0.13	1.22 ± 0.17	1.29 ± 0.16	0.07 ± 0.04 (<0.001)	0.06 ± 0.04 (<0.001)	−0.01 (−0.02, 0.01) [0.419]
LDL cholesterol, mmol/L	2.64 ± 0.49	2.34 ± 0.45	2.66 ± 0.55	2.29 ± 0.58	−0.32 ± 0.16 (<0.001)	−0.37 ± 0.20 (<0.001)	−0.05 (−0.13, 0.03) [0.238]
Triglyceride, mmol/L	1.58 ± 0.24	1.43 ± 0.21	1.57 ± 0.27	1.41 ± 0.24	−0.13 ± 0.06 (<0.001)	−0.15 ± 0.06 (<0.001)	−0.02 (−0.04, 0.01) [0.19]
FPG, mmol/L	5.02 ± 0.4	4.66 ± 0.37	5.03 ± 0.42	4.63 ± 0.34	−0.35 ± 0.18 (<0.001)	−0.40 ± 0.17 (<0.001)	−0.05 (−0.12, 0.02) [0.133]
2hppG, mmol/L	6.25 ± 0.5	5.75 ± 0.45	6.27 ± 0.61	5.72 ± 0.54	−0.49 ± 0.23 (<0.001)	−0.56 ± 0.23 (<0.001)	−0.05 (−0.13, 0.04) [0.288]
HbA1c, %	5.36 ± 0.54	5.08 ± 0.49	5.4 ± 0.61	5.11 ± 0.57	−0.30 ± 0.16 (<0.001)	−0.34 ± 0.19 (<0.001)	−0.03 (−0.10, 0.04) [0.364]
Insulin, mU/L	13.7 ± 2.34	12.59 ± 2.33	14.04 ± 2.89	12.01 ± 2.91	−1.16 ± 0.68 (<0.001)	−2.03 ± 1.07 (<0.001)	−0.84 (−1.23, −0.45) [<0.001]
HOMA-IR	3.07 ± 0.64	2.62 ± 0.56	3.16 ± 0.42	2.49 ± 0.68	−0.46 ± 0.23 (<0.001)	−0.68 ± 0.31 (<0.001)	−0.20 (−0.30, −0.1) [<0.001]

[1]ANCOVA was used to compare intervention groups (DM and LM). Analyses were adjusted for baseline values. ANOVA with repeated measures was used for within-group comparisons. DM, main meal at dinner; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; LM, main meal at lunch; WC, waist circumference; 2hppG, 2-h postprandial glucose.
[2]All values are mean ± SDs.
[3]All values are mean ± SDs; *P* values in parentheses. *P* values represent within-group differences from baseline to 12 wk.
[4]All values are mean differences; 95% CIs in parentheses; *P* values in brackets. *P* values represent between-group differences from baseline to 12 wk after adjustment for the baseline value.

11 subjects dropped out because they did not wish to continue or because of unexpected situations. At week 12, retention rates were 87% in the LM group and 85% in the DM group. At baseline, there were no significant differences in physical characteristics or biochemical measurements between intervention groups (**Table 1**).

Body weight, BMI, and WC

As shown in **Table 2**, there was a significant weight reduction in each group after 12 wk ($P < 0.001$). There was also a significant difference in weight reduction between the 2 groups after 12 wk ($P = 0.002$) (Table 2).

BMI reduction in each group was in the expected direction with significant effects over 12 wk for both groups ($P < 0.001$). However, the decline in BMI was greater in the LM group than in the DM group after 12 wk (Table 2) with a significant difference in BMI effects between the 2 groups ($P = 0.003$). In both groups, WC had decreased after 12 wk of intervention ($P < 0.001$) with no significant difference in WC effects between the 2 groups after the intervention. ($P = 0.118$).

Lipid profiles

Reductions in total-cholesterol, LDL-cholesterol, and triglyceride concentrations and an increase in HDL cholesterol were detected over 12 wk of the study in each group ($P < 0.001$), but there were no significant differences between groups after 12 wk (Table2).

Glucose metabolism measurement

Fasting plasma glucose, fasting serum insulin, 2hpp glucose, glycated hemoglobin, and HOMA-IR all decreased over time in both groups ($P < 0.001$). However, between-group differences were only significant for insulin and HOMA-IR after 12 wk of intervention (Table 2).

There was a significant difference in changes in fasting serum insulin concentrations between the 2 groups after 12 wk ($P < 0.001$) (Table 2) and a significant improvement in insulin resistance in the LM group compared with in the DM group after 12 wk ($P < 0.001$).

Food intake measurement

At baseline, there was no significant difference in energy and macronutrient intakes. Estimated energy intake measurements showed a significant reduction over time in both groups (*P*-time effect < 0.001). As shown in **Table 3**, there were no significant differences between groups for total energy and macronutrient intakes from baseline to 12 wk.

DISCUSSION

The aim of the current study was to evaluate the effects of higher energy intake at lunch compared with at dinner on weight loss and also on indexes of carbohydrate and lipid metabolism in overweight and obese women who were attending a weight-loss program for 12 wk. We showed that consumption of the main meal at lunch led to more weight loss and a greater improvement in insulin sensitivity as measured by

TABLE 3
Self-reported dietary intake in LM and DM groups before and after 12-wk interventions[1]

	LM group (n = 40)		DM group (n = 40)		
Intake	Baseline	Week 12	Baseline	Week 12	P
Total energy, kcal	2329 ± 264	1946 ± 257	2316 ± 260	1984 ± 191	0.156
Protein					
g	83.4 ± 8.9	75.8 ± 11.4	81.8 ± 15.6	77 ± 10.1	0.212
%	14.4 ± 1.8	15.7 ± 1.9	14.1 ± 1.6	15.6 ± 1.6	—
Fat					
g	90 ± 16.5	63.9 ± 12.1	88.6 ± 12.5	65.2 ± 9.9	0.173
%	34.7 ± 4	29.5 ± 2.9	34.4 ± 2.9	29.5 ± 2.7	—
Carbohydrate					
g	296.4 ± 36.6	267 ± 35.4	297.9 ± 33.5	272.3 ± 26.7	0.398
%	50.9 ± 3.2	54.9 ± 2.4	51.5 ± 2.7	55 ± 2.7	—

[1]All values are means ± SDs for 80 participants. P values are for the LM group relative to the DM group and were determined with the use of an ANCOVA with baseline values as covariates.

HOMA-IR and fasting insulin concentrations than did eating the main meal at dinner in overweight and obese women. To our knowledge, this is the first randomized controlled trial of the effect on weight loss of the timing of the main meal.

A recent cross-sectional analysis indicated that eating more of the day's total energy intake at midday than in the evening is associated with lower risk of obesity (21).

The results of the current study on the effect of high energy intake at dinner on weight are in agreement with those of 2 recent interventional studies (24, 36) that indicated the favorable effects of early eating throughout the day on weight loss. However, the 2 studies compared a high-energy breakfast with a high-energy dinner (24) or eating breakfast and lunch compared with eating 6 meals/d (36), whereas the current study compared a high-energy lunch with a high-energy dinner. In addition, the previous studies involved obese and overweight participants with metabolic syndrome and type 2 diabetes, whereas we recruited healthy obese and overweight women.

All of the participants in our weight-loss program lost weight in a way that was consistent with their energy prescription. In intensive, clinic-based behavioral lifestyle–modification programs, weight losses of 5–10% have been detected at 6 mo (37–39), which were approximately similar to the weight losses that we observed during 12 wk in the current study. This finding was not unexpected because our weight-loss program included energy restriction, activity monitoring, and frequent patient visits and consultations in the clinic. It has been shown that these approaches are more consistently effective than other methods that recommend small but theoretically sustainable lifestyle modifications that can be made to improve health (40).

Our results are consistent with the study of Garaulet et al. (23), which showed late eaters lost less weight than was lost by early eaters (23). These findings confirm that the timing of the main meal independently seems to be an important factor in weight-loss success. Thus, the timing of eating may be an appropriate factor to consider in weight-loss treatments.

In our study, the positive effect on weight loss of high energy intake at lunch compared with at dinner may reflect better adherence to the diet in the LM group. The explanation for greater weight loss in the LM group might have been that, when subjects eat a larger energy intake early in the day, they eat significantly less over the entire day. Conversely, when subjects eat a higher proportion of their total intake during the evening, they eat significantly more over the entire day (41). However, our data on estimated energy intakes and macronutrient compositions did not confirm this assumption and showed no differences between the 2 groups. Thus, additional long-term studies with more accurate energy intakes and PA measurements are needed to find the underlying mechanisms that resulted in better weight loss in the LM group than in the DM group.

In the current study, reductions in WC and significant improvements in cardiometabolic risk characteristics were observed in both groups as was expected because of the weight loss observed. Despite similar changes in fasting glucose concentrations in both groups, insulin sensitivity appeared to be improved more in the LM group than in the DM group over 12 wk because of larger changes in fasting insulin.

The current study also showed a strong change in circulating insulin concentrations after the weight-loss intervention over 12 wk as expected. However, fasting insulin after the intervention was higher when the large energy load was given in the evening as dinner than at midday as lunch. This result might indicate that higher energy intake at dinner may cause a significantly greater insulin response than would the same meal consumed at lunch. This outcome was consistent with a previous short-term study (42) that was conducted in healthy volunteers with a different design and evaluated the short-term effects of high energy intake at breakfast compared with at dinner in combination with the effect of the glycemic index.

A previous study by Morgan et al. (43) also showed an impaired postprandial lipid tolerance when meals were consumed at night compared with during the daytime. However, our results failed to show any significant difference in lipid profiles between LM and DM groups. Note that our recommended diet for weight loss contained a low percentage of fat, whereas the study by Morgan et al. (43) had a different design in terms of not including any weight-loss plan.

Nutritionists and popular weight-loss programs usually advise individuals who are keen to lose weight to have their main meal at lunch. In contrast, many obese people who are trying to lose weight are used to eating a higher-energy meal at dinner because of work commitments during the day and believe that they can have their main meal at dinner in a low-energy diet without any deleterious effects on their weight management. The findings of our current study may have practical implications indicating that

the consumption of a main meal at lunch and not at dinner could improve weight loss when people use a weight-loss program.

The principal strengths of this study are, first, that it was a randomized, outpatient, clinical trial, in which subjects were following a comprehensive diet plan for weight control. Second, subjects wished to lose weight, and the study included middle-aged overweight and obese women who were able to comply with a weight-loss plan; thus, the women showed that they were motivated to adhere to the protocol of the weight-loss diet (44). Third, the provision of a free diet plan and a daily telephone call from a dietitian to each subject was an encouragement for regular biweekly visits with the dietitian when compliance could be encouraged in both groups. Also, because this study was conducted in a free-living population, the results can be directly related to obese and overweight women who seek to lose weight. In contrast, the limitation of the current study is the short-term intervention period. Future research is required to examine the long-term health effect of a high-energy lunch relative to a high-energy dinner to establish whether the benefits that we showed are sustained and result in an accumulative, clinically relevant difference in weight. In addition, this study was performed only in overweight and obese women who were attending a formal weight-loss program. Longer-term studies are required in a broader range of participants both in subjects in a formal weight-loss program and in individuals who are attempting to lose weight with less formal, intensive support.

In conclusion, the consumption of the main meal at lunch appears to provide beneficial effects on weight loss and insulin sensitivity in overweight and obese women who are adhering to a weight-loss program over the shorter term. Longer-term studies are required in both healthy overweight and obese patients and in individuals whose insulin sensitivity is compromised (e.g., prediabetic and diabetic patients).

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