Effects on weight loss in adults of replacing diet beverages with water during a hypoenergetic diet: a randomized, 24-wk clinical trial

Ameneh Madjd,1,2,3 Moira A Taylor,2 Alireza Delavari,4 Reza Malekzadeh,4 Ian A Macdonald,2 and Hamid R Farshchi2,3 *

ABSTRACT
Background: Obese people believe that drinking diet beverages (DBs) may be a simple strategy to achieve weight loss. However, nutritionists advise drinking water when attempting to lose weight. It is unclear how important drinking water instead of DBs is during a weight-loss program.

Objective: In this study, we compared the effect on weight loss of either replacing DBs with water or continuing to consume DBs in adults during a 24-wk weight-loss program.

Design: Overweight and obese women [n = 89; body mass index (BMI; in kg/m²): 27–40; age: 18–50 y] who usually consumed DBs in their diet were asked to either substitute water for DBs (water group) or continue drinking DBs 5 times/wk after their lunch for 24 wk (DB group) while on a weight-loss program.

Results: Sixty-two participants (71%) completed the trial (32 in the DB group, 30 in the water group). Baseline variables were not statistically significantly different between groups. A statistically significant reduction in anthropometric measurements and statistically significant improvements in cardiometabolic risk characteristics were observed over 24 wk in both groups. Compared with the DB group, the water group had a greater decrease in weight (mean ± SD: water: −8.8 ± 1.9 kg; DBs: −7.6 ± 2.1 kg; P = 0.015, time × group), fasting insulin (mean ± SD: water: −2.84 ± 0.77 mU/L; DBs: −1.78 ± 1.25 mU/L, P < 0.001), homeostasis model assessment of insulin resistance (mean ± SD: water: −0.097 ± 0.049; DBs: −0.057 ± 0.042, P < 0.001), and 2-h postprandial glucose (mean ± SD: water: −1.02 ± 0.25 mmol/L; DBs: −0.72 ± 0.27 mmol/L; P < 0.001) over the 24 wk. However, there was no significant time × group interaction for waist circumference, fasting plasma glucose, and lipid profiles within both groups over 24 wk.

Conclusions: Replacement of DBs with water after the main meal may lead to greater weight reduction during a weight-loss program. It may also offer clinical benefits to improve insulin resistance. This trial was registered at www.irct.ir as IRCT201402177754N5. Am J Clin Nutr 2015;102:1305–12.

Keywords: diet beverages, insulin resistance, obesity, water, weight loss

INTRODUCTION
Total energy consumption has increased in recent decades (1), and sugar-sweetened beverages (SSBs)5 potentially contribute to this increase (2). Increased consumption of SSBs is frequently associated with increased cardiometabolic disorders, specifically with obesity and metabolic syndrome, around the world (3). Some health professionals recommend that a decrease in consumption of SSBs may have a positive effect on weight control (4), but this has not been confirmed by others (5). Low-energy sweeteners are of interest as a dietary tool (6), because they offer sweet taste without the extra energy delivered from foods and drinks containing sugar (7–12). However, some studies presented an opposing outcome on energy intake and body weight (13).

On the other hand, increasing daily water drinking is generally recognized as a weight-loss strategy by the general public, but few data are available to support this practice. Epidemiologic studies suggest that energy intake is significantly lower in water drinkers than in non–water drinkers (14), which may contribute to weight gain. In an interventional study (15), researchers showed that premeal water consumption in subjects after a weight-loss diet may cause them to lose more weight than control subjects.

The general population believes that diet beverages (DBs) can help them to lose weight, and many obese people drink DBs, believing that this simple strategy would be helpful in reducing weight. A recent study (16) has claimed that replacement of energy-containing beverages with DBs resulted in mean weight...
losses of 2–2.5% without any weight-loss diet program. Nonetheless, this study failed to indicate any significant differences in weight loss during 3- and 6-mo interventions when replacing DBs or water for SSBs compared with the control group. However, fasting blood glucose was only significantly reduced in the water group, not in the DB group, compared with control.

Nutritionists recommend that people drink only water as a replacement for SSBs to lose weight. Concurrent with the present study, a recently published study (17) claimed that obese people drinking DBs lost significantly more weight than the water group while they were on a cognitive behavioral therapy (CBT) weight-loss plan without any personalized detailed dietary recommendations for 12 wk. However, to our knowledge, no study has compared the effects of replacing DBs with water on weight-loss management in obese people who usually drank DBs after a comprehensive weight-loss diet program for 24 wk. The purpose of this study was to examine the effects of replacing DB consumption with water on human energy metabolism in overweight/obese habitual DB consumers after a comprehensive 24-wk weight-loss program.

METHODS

Subjects

Healthy overweight and obese subjects were selected between March 2014 and June 2014 from participants attending NovinDiet Clinic, Tehran, Iran, to lose weight. Inclusion criteria were as follows: women aged 18–50 y, BMI (in kg/m²) of 27–40, and self-reported habitual consumers of DBs who were willing to introduce a dietary change to lose weight that might include changing beverage consumption. All participants were required to be nonsmokers and free of established cardiovascular diseases, stroke, diabetes, liver diseases, kidney diseases, depression, cancer, or autoimmune disease. Subjects included those who were able to demonstrate that they were able to keep an adequate 4-d food record and readiness to safely participate in daily physical activity.

Exclusion criteria were pregnancy or lactation during the previous 6 mo or planned pregnancy in the next 6 mo, weight loss ≥10% of body weight within the 6 mo before enrollment in the study, participating in a research project involving weight loss or physical activity in the previous 6 mo, and taking medication to lower lipids/cholesterol or that could affect metabolism or change body weight. Participants reporting heart disorders, frequent chest pains, or faintness or dizziness on the Physical Activity Readiness Questionnaire were excluded, and other medical conditions required a physician’s consent to participate.

The study was approved by the Ethical Committee of The Digestive Research Institute, Tehran University of Medical Science. All subjects provided their signed consent before study enrollment. This trial was registered at www.irect.ir as IRCT201402177754NS.

Study design and interventions

The study was a 2-arm, single-blind, randomized clinical trial. Eligible participants were randomly assigned after baseline measures by using a computer-generated random-numbers method by the project coordinator with allocation concealed from the participants and dietitians until randomization was revealed to the study participants at the initial intervention clinic appointment. The groups were the water group, in which subjects replaced habitual intake of DBs with a glass of water (250 mL) after the main meal (lunch), and the DB group, in which subjects were instructed to drink DBs once a day (250 mL) after their main meal (lunch) 5 times a week and then water only after the main meal (lunch) on the remaining days of the week. Fluid intakes were matched between the 2 groups in their main meal, but both groups were free to drink water as the beverage during the rest of the days but were not allowed to consume DBs. In addition, both groups were asked not to drink DBs or water during the meal and also not add low-calorie sweeteners such as aspartame or sucralose to beverages such as tea or coffee. Biweekly visits to the dietitian were required to promote adherence to the hypoenergetic diet and beverage substitution. Those in the DB group were given beverages at their biweekly treatment visits. 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.

Screening visit

At the screening visits, subjects underwent a physical examination by a general medicine physician, completed the Beck Depression Inventory (18), and completed the Physical Activity Readiness Questionnaire (19). Potential subjects were instructed by a research nutritionist on how to keep a 4-d food record. In the 30-min lesson, emphasis was placed on the necessity of time recording and accurate food and drink recordkeeping 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 the record was not sufficiently detailed. Three subjects were excluded by Beck Depression Inventory scores (>9), and 5 subjects were excluded because they produced a food record with insufficient detail.

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 engage in research as well as provide the clinical services. Subjects who participated in this 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 weight loss of 7–10% of starting body weight, at a rate of 0.5–1 kg/wk over 24 wk. The individual diet programs were based on the subject food diary records and their food preferences, with gradual modification to bring their diet in line with the NovinDiet protocol. Subjects were assigned to 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]. The diet program was designed to introduce a 500- to 1000-kcal energy deficit based on estimated energy requirements at the start of the study. Physical activity was encouraged; the objective was to gradually increase activity levels to achieve 60 min of moderate activity 5 d/wk. Predominant behavior change strategies applied included stages of change, goal setting, self-monitoring with food diaries, waist measurements, and physical activity (20, 21).

At biweekly sessions, the subjects’ reported behavior problems regarding their 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, subjects completed the feedback form regarding their adherence to diet and their physical activity. Subjects also had access to a website, weekly Internet magazines, and one-to-one telephone/online support from a consultant, if needed.

Measurements

Anthropometric measurements of all subjects were taken at baseline, 12 wk, and 24 wk (except height, which was taken only at the screening visit) by the dietitian.

Energy and macronutrient intake at baseline and the last week of the intervention (week 24) was analyzed by Nutritionist IV software (version 4.1; Hearst). Blood samples of all subjects were taken after overnight (10–12 h) fasting, between 0700 and 0900, at baseline and 24 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 by using a digital calibrated scale (Omron Health Care) while subjects wore light clothing and no shoes. Body height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer (SECA) while participants were barefoot and in a freestanding position. Waist circumference (WC) was measured with a rigid measuring tape and recorded at the level of the lower rib and the iliac crest (the natural waist) or, in case of an indeterminable waist narrowing, halfway between the circumference between the ribs and iliac crest (22). BMI was calculated from measurements. Fasting blood samples were collected by venipuncture according to a standard protocol.

Blood sample measurements

Blood samples from an antecubital vein via a venipuncture were taken while the subjects were in a sitting position, according to the standard protocol, and were centrifuged at 2000 g at room temperature within 30–45 min. Blood samples for 2-h postprandial (2hpp) glucose were taken 2 h after ingesting 75 g glucose according to the standard method, and the American Diabetes Association’s criteria were used for excluding diabetes (23). Fasting plasma glucose (FPG) and 2hpp glucose concentrations were measured using the enzymatic colorimetric method. Insulin was measured by using a radioimmunoassay with 125I-labeled human insulin and a human insulin antiserum in an immunoradiometric assay (IRMA; Biosource) with a γ-counter system (Gamma I; Genesys). Insulin resistance was evaluated by HOMA-IR, which was calculated by using the following formula (24):

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

Glycated hemoglobin (HbAlc) was measured by a colorimetric method after an initial separation by ion exchange chromatography (Biosystem). Biochemical analysis of the serum total cholesterol (TC), triglyceride, and HDL cholesterol was carried out on a Selectra E auto analyzer (Vita Laboratory) following standard procedures of the Pars Azmoon diagnostic kits. LDL cholesterol was calculated by using the Friedewald formula (25):

\[
\text{LDL cholesterol} = \text{TC} - \text{HDL cholesterol} + (\text{TG} ÷ 2.2)
\]

Statistical analyses

The primary outcome addressed in this study was the difference in body weight loss during the 24-wk weight loss program. The power calculation was based on that described by Dennis et al. (15), except we chose a power of 0.85 (α = 0.05), which was performed based on expected differences in weight loss between weight loss diet groups (mean ± SD: 2.0 ± 2.5 kg) to determine the targeted final sample size (n = 56). Considering a dropout rate of 20%, the sample size required was 67.

Statistical methods

Baseline values of cardiovascular disease risk factors (including weight, WC, LDL cholesterol, HDL cholesterol, TC, FPG, triglycerides, fasting insulin, HOMA-IR, HbAlc, 2hpp glucose) and food intake data were compared within the water and DBs groups by using unpaired t tests. At baseline, distribution was normal for all variables. Repeated-measures 2-factor ANOVA with diet groups (water or DBs) and time (weeks 0 and 24) as a within-subject factor was used to assess the effects of dietary intervention by comparing changes in the dependent variables between the groups over time. Where there was a significant main effect but no interaction, post hoc comparisons were performed as appropriate with Bonferroni’s adjustment for multiple comparisons to determine differences between group means. Statistical significance was set at P ≤ 0.05. All data are presented as means ± SDs unless otherwise stated. Associations between variables were assessed by simple correlational analyses (Pearson’s r). All statistical analyses were performed by using SPSS 22.0 for Windows (SPSS Inc.).

RESULTS

Baseline characteristics

Of 89 obese and overweight subjects recruited, 62 completed the 24-wk intervention (71% of the original population, Figure 1). Of 89 individuals who were interested in participating in the study, 2 were excluded from the study because of the results of the Beck Depression Inventory. Five potential subjects were excluded because they stopped keeping the dietary record or filled it in insufficiently. Blood test results at baseline revealed that 11 patients were ineligible because they had ≥1 exclusion criterion. The remaining 71 subjects gave written consent, and then 35 subjects were randomly allocated to the water and to the DB group. After starting the intervention, a total of 9 subjects dropped out because they did not wish to continue or they moved. At week 12, the retention rates were 97% for the DB group and 91% for the water group, and at week 24, those rates were 89% for DBs and 86% for water. Because 2 subjects in the water group were eliminated because of one unexpected pregnancy and the other diagnosed with asthma, it could be said that the retention rates did not differ between groups.
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**

All subjects in both groups lost weight during the first 12 wk of the study and continued to lose weight until the final 24-wk point, although at a slower rate (Figure 2). As shown in Table 2, there was a significant weight reduction in each group after 24 wk ($-7.6 \pm 2.1$ kg for DBs vs. $-8.8 \pm 1.9$ kg for water, time effects, $P < 0.001$). As shown in Figure 2, there was a significant group $\times$ time interaction for weight loss over 24 wk ($P = 0.015$).

BMI reduction in each group was in the expected direction, with significant effects over 24 wk for both groups (time effects, $P < 0.001$). However, the decline in BMI was larger in the water group than the in DB group after 24 wk ($-3.4 \pm 0.7$ for water vs. $-2.9 \pm 0.8$ for DBs; Table 2). There was a significant group $\times$ time interaction in BMI reduction over 24 wk ($P = 0.002$).

In both groups, WC had decreased significantly after 24 wk of intervention (time effects, $P < 0.001$). WC decline was $-8.6 \pm 3.4$ cm in the water group and $-7.9 \pm 2.7$ cm in the DB group at 24 wk. However, there was no group $\times$ time interaction in the reduction in WC over 24 wk ($P = 0.35$).

**Lipid profiles**

Reductions in TC, LDL cholesterol, and triglyceride concentration and an increase in HDL cholesterol were detected over the 24 wk of study in each group ($P < 0.001$), but there were no significant differences in these results between the groups over 24 wk (Table 2).

TC after 24 wk had decreased by $-0.53 \pm 0.16$ mmol/L in the water group vs. $-0.49 \pm 0.17$ mmol/L in the DB group (no significant group $\times$ time interaction, $P = 0.268$).
TABLE 1
Subject characteristics before the intervention

<table>
<thead>
<tr>
<th></th>
<th>Water group (n = 35)</th>
<th>DB group (n = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>32.2 ± 6.9</td>
<td>31.7 ± 6.8</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>88.2 ± 8.8</td>
<td>87.6 ± 9.8</td>
</tr>
<tr>
<td>Height, cm</td>
<td>161.3 ± 4.9</td>
<td>161.7 ± 4.2</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>33.9 ± 3</td>
<td>33.5 ± 3.6</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>104.6 ± 5.8</td>
<td>103.5 ± 5.9</td>
</tr>
<tr>
<td>Married, %</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>4.8 ± 0.4</td>
<td>4.7 ± 0.4</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.3 ± 0.2</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>2.8 ± 0.4</td>
<td>2.7 ± 0.5</td>
</tr>
<tr>
<td>Triglycerides, mmol/L</td>
<td>1.7 ± 0.2</td>
<td>1.6 ± 0.2</td>
</tr>
<tr>
<td>FPG, mmol/L</td>
<td>5.2 ± 0.5</td>
<td>5.3 ± 0.4</td>
</tr>
<tr>
<td>2hpp, mmol/L</td>
<td>6.9 ± 0.7</td>
<td>6.7 ± 0.7</td>
</tr>
<tr>
<td>HbA1c, %</td>
<td>5.1 ± 0.4</td>
<td>5 ± 0.4</td>
</tr>
<tr>
<td>Insulin, mU/L</td>
<td>13.7 ± 2.1</td>
<td>13.1 ± 3.1</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>3.2 ± 0.6</td>
<td>3.1 ± 0.8</td>
</tr>
</tbody>
</table>

1Group difference, P > 0.05. There were no significant differences between groups at baseline. DB, diet beverage; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; 2hpp, 2-h postprandial.

HDL cholesterol concentration after 24 wk had increased by 0.125 ± 0.045 mmol/L in the water group vs. 0.124 ± 0.050 mmol/L in the DB group (no significant group × time interaction, P = 0.912), whereas LDL cholesterol had decreased by −0.534 ± 0.164 mmol/L (water) and −0.551 ± 0.191 mmol/L (DBs; no significant group × time interaction, P = 0.761).

Triglyceride concentrations after 24 wk had decreased by −0.281 ± 0.109 mmol/L (water) and −0.280 ± 0.122 mmol/L (DBs; no significant group × time interaction, P = 0.994).

Glucose metabolism measurement

Data analysis showed that FPG, fasting serum insulin, 2hpp glucose, HbA1c, and HOMA-IR all decreased over time in both groups (P < 0.001 for time effect of all variables). However, between-groups differences were significant only for insulin, 2hpp, and HOMA-IR (Table 2). The mean reduction in fasting plasma glucose over 24 wk was −0.767 ± 0.278 mmol/L (water) and −0.681 ± 0.169 mmol/L (DBs). However, there was no significant group × time interaction in fasting glucose reduction over 24 wk (P = 0.143).

In terms of 2hpp differences during the 24 wk of intervention, the mean reduction of 2hpp was −1.024 ± 0.254 mmol/L (water) and −0.719 ± 0.275 mmol/L (DBs). As shown in Table 2, there was a significant group × time interaction in 2hpp glucose effects over 24 wk (P < 0.001).

HbA1c decline over 24 wk in the water group was −0.54% ± 0.12%, whereas this reduction was −0.47% ± 0.17% in DBs group at week 24. But as shown in Table 2, there was no significant difference in the changes between the groups after 24 wk (P = 0.066).

Fasting serum insulin concentrations decreased significantly over time, with differences between the 2 groups (P < 0.001). The reduction of insulin was −2.8 ± 0.8 mU/L (water) and −1.8 ± 1.3 mU/L (DBs) after 24 wk. Furthermore, there was a significant improvement in insulin resistance in the water group compared with the DB group over 24 wk (time × group interaction, P < 0.001). HOMA-IR decreased by −0.097 ± 0.049 in the water group compared with −0.057 ± 0.042 in the DB group over the 24 wk (Table 2). There was a significant group × time interaction (P < 0.001).

Food intake measurement

At baseline, there was no significant difference in energy intake. Estimated energy intake measurements showed a significant reduction over time in both groups (P < 0.001 for time effect). As shown in Table 3, there was a significant group × time interaction for total energy intake over 24 wk (P = 0.015).

In addition, macronutrient intake measurements showed no significant differences between the 2 groups at baseline. However, there was a greater carbohydrate deficit in the water group than in the DB group during the 24 wk of intervention (group × time interaction, P = 0.001, Table 3).

DISCUSSION

The aim of this study was to compare the effects of DBs and water consumption after the lunch as a main meal on weight loss.

FIGURE 2 Mean ± SEM body weight before and after 24 wk of energy restriction with either drinking water (n = 30) or diet beverages (n = 32) in the participants who completed the study. P < 0.001 for the main effect of time, and P = 0.015 for the time × group interaction (repeated-measures ANOVA). DB, diet beverage.
and also indexes of carbohydrate and lipid metabolism in overweight and obese women attending the weight loss program for 24 wk. We found that drinking water may lead to more weight loss and a greater improvement in insulin sensitivity, measured by HOMA-IR and 2 hpp glucose concentrations, than may drinking DBs after the main meal in overweight and obese female adults.

To our knowledge, this is the first randomized controlled trial in which the effect on weight loss of either replacing DBs with water or continuing to consume DBs is investigated in overweight and obese women who regularly consume DBs with their meal while undertaking a voluntary integrated weight-reduction program for 24 wk. Although some previous intervention studies compared the effects of water consumption on weight loss, their protocols were different. In some studies, the effects of either water or DB consumption and SSB consumption without any hypocaloric diet (26) were compared. In other studies, the effects of drinking premeal water were evaluated during a hypolnergetic diet (15). In a very recent study (17), drinking water and DBs was compared in subjects receiving CBT for only a short period of 12 wk.

All participants in our integrated weight-loss program significantly lost weight in a consistent way with their prescription assignment. In more intensive clinic-based behavioral lifestyle modification programs, 5–10% weight losses have been detected at 6 mo (27–29), which were similar to the weight losses that we observed in the current study. This is not unexpected because our weight-loss program includes energy restriction, activity monitoring, and frequent patient visits and consultation in the clinic. It has been shown that these approaches are more consistently effective than others recommending small but theoretically sustainable lifestyle modifications that can be made to improve health (30).

Subjects in the water group of our study consumed 250 mL water after their lunch over 24 wk, and they lost 1.2 kg more (13.6% greater weight loss) than those in the DB group. Stookey and colleagues (31) reported a 2-kg greater weight loss in water consumers (drinking 1 L water/d) on a hypoenergetic diet than those in the DB group.

## Table 2

<table>
<thead>
<tr>
<th></th>
<th>Water group (n = 30)</th>
<th>DB group (n = 32)</th>
<th>P for time × group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Week 24</td>
<td>Baseline</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>88.7 ± 8.9</td>
<td>79.9 ± 8.3</td>
<td>87.9 ± 9.9</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>33.9 ± 3.3</td>
<td>30.6 ± 2.8</td>
<td>33.5 ± 3.6</td>
</tr>
<tr>
<td>WC, cm</td>
<td>104.9 ± 5.9</td>
<td>96.3 ± 5.7</td>
<td>103.7 ± 6.2</td>
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<tr>
<td>TC, mmol/L</td>
<td>4.9 ± 0.4</td>
<td>4.3 ± 0.4</td>
<td>4.7 ± 0.5</td>
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<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.3 ± 0.2</td>
<td>1.4 ± 0.2</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>2.8 ± 0.4</td>
<td>2.3 ± 0.3</td>
<td>2.7 ± 0.5</td>
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<tr>
<td>Triglycerides, mmol/L</td>
<td>1.7 ± 0.2</td>
<td>1.4 ± 0.2</td>
<td>1.6 ± 0.2</td>
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<td>FPG, mmol/L</td>
<td>5.3 ± 0.5</td>
<td>4.5 ± 0.5</td>
<td>5.3 ± 0.4</td>
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<td>2hpp, mmol/L</td>
<td>6.7 ± 0.7</td>
<td>5.7 ± 0.5</td>
<td>6.6 ± 0.6</td>
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<tr>
<td>HbA1c, %</td>
<td>5.1 ± 0.4</td>
<td>4.5 ± 0.5</td>
<td>4.9 ± 0.4</td>
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<td>Insulin, mU/L</td>
<td>13.6 ± 2.2</td>
<td>10.8 ± 1.9</td>
<td>13 ± 3.3</td>
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<td>HOMA-IR</td>
<td>3.2 ± 0.7</td>
<td>2.2 ± 0.5</td>
<td>3.1 ± 0.8</td>
</tr>
</tbody>
</table>

1DB, diet beverage; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; TC, total cholesterol; WC, waist circumference; 2hpp, 2-h postprandial.

## Table 3

<table>
<thead>
<tr>
<th>Intake</th>
<th>Water group (n = 30)</th>
<th>DB group (n = 32)</th>
<th>P for time × group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Week 24</td>
<td>Baseline</td>
</tr>
<tr>
<td>Total energy, kcal</td>
<td>2457 ± 303</td>
<td>1871 ± 203</td>
<td>2438 ± 295</td>
</tr>
<tr>
<td>Protein, g</td>
<td>90.2 ± 7.3</td>
<td>79.6 ± 8.7</td>
<td>87.5 ± 7.6</td>
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<tr>
<td>Protein, %</td>
<td>14.9 ± 2.2</td>
<td>17.1 ± 1.6</td>
<td>14.5 ± 2.1</td>
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<tr>
<td>Fat, g</td>
<td>96.5 ± 18.4</td>
<td>66.8 ± 9.8</td>
<td>95.1 ± 19.5</td>
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<tr>
<td>Fat, %</td>
<td>35.1 ± 3.1</td>
<td>32.2 ± 2.6</td>
<td>34.8 ± 3.9</td>
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<tr>
<td>Carbohydrate, g</td>
<td>306.8 ± 37.4</td>
<td>237.9 ± 28.7</td>
<td>308.2 ± 36.5</td>
</tr>
<tr>
<td>Carbohydrate, %</td>
<td>50 ± 1.7</td>
<td>50.9 ± 2.5</td>
<td>50.6 ± 2.7</td>
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<tr>
<td>Fiber, g</td>
<td>20.6 ± 5.5</td>
<td>22 ± 5.6</td>
<td>20.75 ± 3.2</td>
</tr>
</tbody>
</table>

1DB, diet beverage.

# Table 3

Self-reported dietary intake in water and DB groups before and after the 24-wk interventions

<table>
<thead>
<tr>
<th>Intake</th>
<th>Water group (n = 30)</th>
<th>DB group (n = 32)</th>
<th>P for time × group</th>
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</thead>
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<tr>
<td></td>
<td>Baseline</td>
<td>Week 24</td>
<td>Baseline</td>
</tr>
<tr>
<td>Total energy, kcal</td>
<td>2457 ± 303</td>
<td>1871 ± 203</td>
<td>2438 ± 295</td>
</tr>
<tr>
<td>Protein, g</td>
<td>90.2 ± 7.3</td>
<td>79.6 ± 8.7</td>
<td>87.5 ± 7.6</td>
</tr>
<tr>
<td>Protein, %</td>
<td>14.9 ± 2.2</td>
<td>17.1 ± 1.6</td>
<td>14.5 ± 2.1</td>
</tr>
<tr>
<td>Fat, g</td>
<td>96.5 ± 18.4</td>
<td>66.8 ± 9.8</td>
<td>95.1 ± 19.5</td>
</tr>
<tr>
<td>Fat, %</td>
<td>35.1 ± 3.1</td>
<td>32.2 ± 2.6</td>
<td>34.8 ± 3.9</td>
</tr>
<tr>
<td>Carbohydrate, g</td>
<td>306.8 ± 37.4</td>
<td>237.9 ± 28.7</td>
<td>308.2 ± 36.5</td>
</tr>
<tr>
<td>Carbohydrate, %</td>
<td>50 ± 1.7</td>
<td>50.9 ± 2.5</td>
<td>50.6 ± 2.7</td>
</tr>
<tr>
<td>Fiber, g</td>
<td>20.6 ± 5.5</td>
<td>22 ± 5.6</td>
<td>20.75 ± 3.2</td>
</tr>
</tbody>
</table>

1DB, diet beverage.

P values are for the water relative to DB group (time × group interaction) by repeated-measures 2-factor ANOVA.

Mean ± SD for the 62 participants who completed the study (all such values).

Significant main effect of time, P < 0.001.
study by Dennis et al. (15), subjects who were randomly assigned to drink premeal water lost ∼2 kg more weight than subjects on the hypocaloric diet alone. The current study showed a significant interaction between beverage use and time for weight loss, suggesting a benefit from water compared with DB consumption. These results are consistent with the outcome of the study by Dennis et al. However, in our study, subjects in both groups had either water or DBs after their meal rather than before the meal, which is more representative of normal behavior in this group. On the other hand, our results are contradictory with some other studies that showed no significant difference in effects on weight loss (16) between water and DBs or reported a superior impact on weight loss with DBs compared with water (17). However, it should be noted that these previous studies had a different design in terms of not including any weight-loss plan (16) or had only CBT for weight loss during a short period of 12 wk (17). Furthermore, the volume of beverage and the time of drinking water and beverage were different in these studies. Future studies could assess whether the amount of water, the timing (i.e., consumption before the meal compared with during or after the meal), or other factors could influence the effects of replacement of DB with water on weight loss.

In our study, the effect of substitution of DBs with water on weight loss may reflect better adherence to the weight-loss diet in the water group. The greater weight loss in the water group might be explained by a greater reduction in energy intake in this group than in the DB group. The greater reduction in absolute carbohydrate consumption in the water group than in the DB group might also contribute to the greater weight loss in the water group. However, finding underlying mechanisms for better weight loss in the water group compared with the DBs group needs further long-term studies.

In the current study, major reductions in WC and significant improvements in cardiometabolic risk characteristics were observed in both groups over 24 wk, as would be expected given the weight loss observed. Interestingly, despite similar changes in fasting glucose concentrations in both groups, insulin sensitivity appeared to be improved more with the water group than with the DB group over the 24 wk.

These findings may have clinical implications, indicating that drinking only water, not DBs, could improve weight loss when people use a weight-loss program. Nutritionists and popular weight-loss programs usually advise individuals who are keen to lose weight to increase their water consumption (32, 33). On the other hand, most obese people believe that they can drink DBs during a low-caloric diet without any deleterious effects on their weight management. It has been claimed, based on the results of previous studies on replacement of energy-containing beverages with either water or DBs, that both DBs and water would be effective weight-loss strategies. However, the results do not appear to support these claims (16). In the recent study (17) with the opposite results compared with the present study, subjects received only CBT, and the intervention period was as short as 12 wk. In addition, participants had at least 3 DBs during the week, with no limitation on other beverage consumption, whereas subjects in the present study habitually drank DBs before the study. Future research is required to examine the longer-term health effects of consuming water as a replacement for DBs to establish whether the benefits that we have demonstrated are sustained.

The principal strength of this study is that it was a randomized, outpatient clinical trial while subjects were on a comprehensive diet plan for weight control in a long-term intervention (i.e., 24 wk). Second, subjects wished to lose weight and included middle-aged overweight and obese women who were able to comply with a weight-loss plan; hence, they demonstrated that they were motivated to adhere to the weight-loss diet protocol (34). Third, providing the DBs for the DBs group and water for the water group was an incentive for regular biweekly visits with the dietitian when compliance could be encouraged in both groups.

On the other hand, without long-term follow-up, it is not known whether subjects could comply with only water as the beverage or whether the beneficial effects would be sustained in the longer term. In conclusion, replacing DBs with water consumption would appear to have a beneficial impact on weight loss and insulin sensitivity in overweight and obese subjects adhering to a weight-loss diet. Longer-term studies are now required, in both healthy overweight and obese patients, and in those whose insulin sensitivity is compromised (e.g., prediabetic and diabetic patients).

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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; HRF: designed the research, conducted the research, contributed to data interpretation, revised the manuscript, and provided medical supervision; MAT and IAM: refined the study design and contributed to data interpretation and redrafting of the manuscript; AD and RM: provided advice and consultation for the study design, conducted the research; and all authors: read and approved the final manuscript. None of the authors reported any financial or personal conflicts of interest.

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