Original Research

Can a Dairy-Rich Diet Be Effective in Long-Term Weight Control of Young Children?

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Key words: childhood obesity, randomized trial, dairy products, energy, insulin resistance, cardio-metabolic risk factors

Objective: To determine the long-term effect of a randomized controlled trial of a dairy-rich diet on generalized and abdominal obesity, as well as on the components of the metabolic syndrome, among obese prepubescent children.

Methods: This trial was conducted among a population-based sample of 120 obese prepubescent children who were randomly assigned to 3 groups of equal number. In addition to attending 6 consecutive monthly family-centered education sessions about healthy lifestyle, an isocaloric dairy-rich diet (>800 mg ca/d) was recommended to the children of one group (DR: dairy-rich diet), the second group was placed on a caloric-restricted regimen (ER: energy-restricted), and the third group received no additional recommendation (C: controls). The groups were then followed-up twice a year for 3 years.

Results: The mean age of the children was 5.6 ± 0.5 years. Of 120 participants, 95 (75%) completed the study; the DR group had the highest retention rate. In all groups, body mass index-standard deviation score (BMI-SDS) and waist circumference decreased significantly after the 6-month trial, but had a sustained significant rise during the follow-up period to the end of the study; however, in the DR group, this rise was significantly lower than in the 2 other groups. After the 6-month trial, in all groups, serum triglycerides (TG) and insulin levels decreased, and serum high-density lipoprotein cholesterol (HDL-C) level and homeostasis model assessment of insulin resistance (HOMA-R) increased. In the DR group, the TG, insulin and HOMA-R levels remained significantly lower than baseline until the 12-month follow-up.

Conclusions: We suggest that in addition to lifestyle changes, an isocaloric diet rich in dairy products may be a well-accepted regimen and can be a safe and practical strategy for weight control in young, overweight children.

INTRODUCTION

Childhood obesity is a global epidemic and rising trends in overweight and obesity are apparent in both developed and developing countries [1,2]. Childhood malnutrition and obesity coexist in many developing nations. The rapidly increasing prevalence of overweight and obesity among preschool age children in developing countries is well documented. The Middle East is one of the regions with the highest prevalence of such disorders [2,3]. The prevalence of overweight and obesity in preschool-aged Iranian children is reported to be 23.5% and 10.9% in the 2–3-year-old age group, and 18.3% and 7.5% in the 4–5-year-old age group, respectively [4].

Obesity that begins in childhood may be more closely associated with severe obesity in adulthood than obesity that begins later in life. Prevention and early treatment of young children who are overweight may decrease the trajectory of weight gain in childhood and may affect later-life weight status. Most interventions directed to the prevention of childhood obesity have been conducted with school-aged children, an age at which adiposity rebound has already occurred [5] and a time at which children have food

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preferences and have begun to determine their dietary choices [6,7]. Therefore, prevention and control of obesity should begin earlier, at an age when children's lifestyle, notably eating patterns, may be more easily influenced.

Although the early and late complications of childhood obesity confirm the importance of weight control from early childhood, the evidence is insufficient to provide effective and practical guidelines for controlling obesity in young children [8].

Much effort has been devoted to studying the effect of macronutrients on weight control; the role of micronutrients remains controversial. Different studies have demonstrated that dairy products, but not supplemental calcium, might play a pivotal role in weight control [9]. It is documented that in the absence of energy deficits, diets rich in dairy products might result in improvements in body composition among adults [10], but such experience is limited among young children.

A longitudinal study on the effect of dairy intake in early childhood on the acquisition of body fat throughout childhood showed that suboptimal dairy intake during preschool in this cohort was associated with greater gains in body fat throughout childhood [11]. Another study among preschool-aged children revealed that higher longitudinal intake of calcium and servings of dairy products were associated with lower amounts of body fat [12]. The intake of calcium is generally low in the Iranian population [13], including preschool-aged children, with an intake of about 650 mg/d [14].

The objective of the current study was to determine the short- and long-term results of a randomized controlled trial of a dairy-rich diet on generalized and abdominal obesity, and the components of the metabolic syndrome among obese prepubescent children during a 6-month intervention and 3 years of follow-up.

METHODS

Study Population

This randomized controlled intervention trial was conducted from October 2003 to October 2006 among 120 obese children. By considering a power of 95%, the sample size was calculated as 90 (30 in each group), but considering the attrition of participants during the follow-up period, 120 children were initially included in the study. This population-based sample was randomly selected from among children who had been identified as obese during their routine physical examination at preschool entry and had been referred to the Obesity Research Clinic, Preventive Pediatric Cardiology Department, Isfahan Cardiovascular Research Center (ICRC), a collaborating center of the World Health Organization (WHO) located in Isfahan, Iran. Research assistants working with the project selected participants by a randomization procedure from among obese children referred from different parts of the city, taking into consideration the proportion of the different clusters in the city to avoid socioeconomic bias. The random allocation was conducted by computer-generated random numbers, using the numbers of the children's health records that were filled in for school entry.

The Ethics Committee of ICRC (NIH Code: FWA 0000t8578) approved the study. After providing detailed oral information to children and parents, we obtained written informed consent from the parents of all eligible children.

Eligibility criteria for children's participation included having a body mass index (BMI) $\geq$ age and sex-specific 95th percentile, according to the revised Centers for Disease Control and Prevention (CDC) growth charts [15] and being in the prepubertal stage (Tanner stage 1) [16,17]. Potential subjects with pubertal stage $>$SMR 1, syndromal obesity, endocrine disorders, presence of any physical disability, and/or history of chronic medication use were excluded from the survey.

Protocol

The age, calculated from birth until the interview date, was recorded. Weight (Wt) and height (Ht) were measured by a calibrated scale and stadiometer (Seca, Tokyo, Japan) with subjects lightly clothed and barefoot to the nearest 0.1 cm and 0.1 kg, respectively. BMI was computed as Wt (kg) divided by Ht (m) squared. BMI was calculated on the basis of the revised CDC growth charts [15]. Because of the non-normal distribution of BMI in childhood, the LMS method was conducted to calculate SDS-BMI as the measurement of degree of overweight, which summarizes the data in terms of 3 smooth, age-specific curves called L (lambda), M (mu), and S (sigma). The M and S curves correspond to the median and coefficient of variation of BMI at each age and for both sexes, whereas the L curve allows for the substantial age-dependent skewness in the distribution of BMI by using the software package LMS Chart Maker Pro, version 2.3, April 2006 [18]. Waist circumference (WC) was measured at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration.

A pediatrician determined the pubertal developmental stage by careful physical examination according to the Marshall and Tanner score [16,17]. The percentage of body fat was determined using dual-energy absorptiometry by using Omron body fat monitor instrument (HBF-300; Omron, Kyoto, Japan) that was validated in our previous studies [19]. All measurements were made by the same trained general physician and under the supervision of the same pediatrician.

For the assessment of dietary intake of children, a 3-day dietary record that was validated in this age group was filled in by the parents [20]. Daily energy intake (kcal/d) was computed by the means of software designed for Iranian foods [21].

The physical activity (PA) pattern was assessed by the questionnaire in which 9 different metabolic equivalent (MET) levels were ranged on a scale from sleep/rest (0.9 METs) to high-intensity physical activities (>6 METs); this instrument was assessed by comparison with measurement of physical activity by accelerometry and by keeping a PA diary [22]. The questionnaire had previously been modified and validated among Iranian children [23]. For each activity level, the MET value was multiplied by the time spent at that particular level. The MET time at each level was added to obtain a total over 24-hour MET time, representing the PA level on an average weekday. Energy expenditure was estimated by multiplying the total 24-hour MET time by the body weight.

Blood pressure (BP) was measured using mercury sphygmomanometers under standard protocol. The readings at the first and fifth Korotkoff phases were taken as systolic and diastolic BP (SBP and DBP), respectively. The average of the 2 BP measurements was recorded and included in the analysis [24].

Children were instructed to fast for 12 hours before the screening; compliance with fasting was determined by interview on the morning of examination. While one of the parents accompanied his/her child, blood samples were taken from the antecubital vein between 08:00 and 09:00. Blood samples were centrifuged for 10 minutes at 3000 rpm within 30 minutes of venipuncture. Fasting blood sugar (FBS), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) were measured by an enzymatic method using an auto-analyzer (Model 902; Hitachi, Tokyo, Japan). HDL-C was determined after dextran sulphate-magnesium chloride precipitation of non–HDL-C [25]. Low-density lipoprotein-cholesterol (LDL-C) was calculated in serum samples with TG ≤400 mg/dl according to the Friedewald equation [26]. Plasma insulin was measured by radioimmunoassay (LINCO Research Inc., St. Charles, MO), which is 100% specific for human insulin with less than 0.2% cross-reactivity with human proinsulin and no cross-reactivity with c-peptide or insulin-like growth factor. Insulin resistance (IR) was calculated on the basis of homeostasis model assessment of IR {HOMA-R = [fasting $\text{insulin}_{(\text{mU/L})} \times$ fasting $\text{glucose}_{(\text{mmol/L})}$]/22.5} [27].

Laboratory tests were performed in the ICRC central laboratory, which meets the standards of the National Reference laboratory (WHO Collaborating Center in Tehran) and is under the quality control of the CDC and the Department of Epidemiology, St. Rafael University, Leuven, Belgium.

Since no universally accepted definition of the metabolic syndrome exists for children, we used a definition based on criteria analogous to Adult Treatment Panel III guidelines, which define the metabolic syndrome as ≥3 of the following: (1) fasting TG ≥110 mg/dL; (2) HDL-C ≤40 mg/dL; (3) WC ≥90th percentile for age and sex in the population studied; (4) SBP/DBP >90th percentile for sex, age, and height from the National Heart, Lung, and Blood Institute's recommended cut-off point; and (5) FBS ≥100 mg/dL [28]. This definition included a cut-off of FBS ≥110 mg/dL, but we used the latest recommendation of the American Diabetes Association [29].

Intervention Program

After baseline testing, children were randomly assigned to 3 groups of equal numbers. Research assistants working with the project conducted random allocation by computer-generated random numbers, using the children's record numbers in our clinic. All participants attended 6 consecutive monthly family-centered education sessions about healthy lifestyle (healthy nutrition and increasing physical activity) that were conducted by a pediatrician and a nutritionist [20]. These sessions were organized on different days for the 3 groups under study. In addition, a dairy-rich diet (>800 mg ca/d), with no change in energy or macronutrient intake, was recommended to the children of this group (DR: dairy-rich diet group). Children were advised to obtain most of their calcium from low-fat and regular milk, cheese, and yogurt, as well as liquid and solid curd. In addition to participating in similar nutrition education sessions as the DR group, the children of the other intervention group (ER: energy-restricted group) were placed on a caloric restriction regimen with an energy content restricted to the calorie requirement for height [20,30]. In order to ensure equal treatment intensity between these 2 groups that received specific dietary instruction, the same team provided diet recommendations through educational sessions of the same number, duration, and interval. The third group (C: control group) received no dietary recommendation other than what was discussed in the healthy lifestyle education sessions; the 3 groups were then followed-up twice a year until 3 years after the baseline survey.

The whole program was offered free of charge. All participants were recalled after the baseline study. Testing sessions, including physical examinations as well as filling out food records and PA questionnaires, were conducted at baseline and 6, 12, 18, 24, 30, and 36 months. Biochemical parameters were examined at baseline, 6, 12, 24, and 36 months. In order to conceal allocation to the study group assignments, all follow-up procedures were conducted by a physician and a research assistant who were not included in the intervention team. These outcome assessors and data analysts were unaware of group allocation

Data Analysis and Statistics

One-way analysis of variance (ANOVA) and χ^2 tests were used to determine the significance of any baseline differences between different groups. We compared data at baseline and each follow-up study separately for each group by using

repeated-measurement ANOVA and Bonferroni *post hoc* test. Linear regression analysis was used to assess mean changes in anthropometric and biochemical parameters. All analyses were conducted using SPSS version 14.0 (SPSS, Inc., Chicago, IL).

RESULTS

This trial was conducted on 120 obese children with a mean age of 5.6 ± 0.5 years. Of these, 95 participants (75%) completed the 36-month period of follow-up. Fig. 1 shows the participants' retention versus attrition throughout the study. There was no significant difference between the baseline characteristics of children assigned to the 3 groups under study (Table 1).

Energy and calcium intake, as well as energy expenditure of the 3 groups during the study period, are demonstrated in Fig. 2. Mean daily calcium intake was significantly greater in the DR group than in the 2 other groups throughout the study. During the 6-month interventional trial, mean daily energy intake was lower in the ER group than the other groups, but this difference was not sustained during the follow-up study. Mean daily energy expenditure did not differ significantly by group at each time period throughout the study.

Mean change of anthropometric and biochemical parameters over time is presented in Fig. 3. The data show that, in all groups studied, BMI-SDS decreased significantly after the 6-month trial. The mean (SD) changes from the baseline were −0.6 (0.01) in the DR group ($p = 0.01$), −0.6 (0.01) in the ER group ($p = 0.01$), and −0.5 (0.01) in the control group ($p = 0.01$), without significant differences between groups. These mean changes had a sustained significant rise during the follow-up period to the end of the study when they reached −0.1 (0.004) in the DR group, 0.7 (0.01) in the ER group, and 0.6 (0.02) in the control group, i.e., in the DR group, this rise was lower than in the 2 other groups ($p = 0.001$), and it remained lower than the baseline value until the 12-month follow-up (p for trend = 0.01). Similarly, in all groups, WC decreased significantly after the trial; the mean (SD) change was higher in the ER group (−2.5 [0.2] cm), followed by the DR group (−2 [0.1] cm) and controls (−1.7 [0.2] cm) ($p = 0.01$). During the follow-up period, in the DR group, WC remained lower than the baseline values, with a mean change of −1.2 (0.01) cm until 12 months after the study ($p = 0.04$); it then increased to 4.1 (0.3) cm to the end of the study. In the ER and control groups, the mean WC had a sustained rise that was significant until the 24-month follow-up study ($p = 0.01$).The increase in the mean WC was significantly lower in the DR group than in the control and ER groups (4.1 [0.3] versus 4.8 [0.2] and 5.2 [0.4] cm, respectively, $p = 0.04$).

After the trial, the changes in percent body fat were similar to the changes in BMI and WC; in all groups, it decreased significantly. The mean (SD) change was −5.2%, without a significant difference between groups. During the follow-up period, in the DR group, this change remained lower than the baseline values, until 12 months after the study ($p = 0.04$), with a mean change of −0.8 (0.01)% versus baseline. Meanwhile, in the ER and control groups, the mean change reached 1.2% versus the baseline survey. Then, in all groups, the mean change increased to 4.1% (0.4) at the 24-month follow-up evaluation and had no significant change until the end of the study.

As presented in Fig. 3, in all groups, serum TG levels decreased significantly after the 6-month trial and had a mean (SD) change of 16.5 (2.7) mg/dL ($p < 0.0001$), without a significant difference between groups. Then, the mean change had a sustained significant rise (6–9 mg/dL) until 24 months after the study and remained nearly constant until the end of the study. In the DR group, the TG level remained lower than the baseline value until the 12-month follow-up, with a mean change of −5.7 (1.1) mg/dL versus the baseline ($p = 0.01$).

The serum insulin level and HOMA-R followed a trend of changes similar to those of serum TG. In all groups, they decreased after the 6-month trial, with a mean change of −6.4 (0.7) μU/L for insulin and −0.7 (0.01) for HOMA-R, without significant differences between the groups. They values then rose significantly until the 24-month follow-up study and, thereafter, followed a plateau pattern until the end of the study. In the DR group, the insulin and HOMA-R levels remained lower than the baseline values until the 12-month follow-up, when the mean changes were −4.5 (0.8) μU/L for insulin and −0.2 (0.04) for HOMA-R.

In all groups, serum HDL-C levels increased after the 6-month trial; the mean change versus the baseline value was 3.2 (0.8) mg/dL ($p = 0.01$), without significant differences between the groups. It then had a sustained decline; this decrease was significant until 24 months after the study, when the mean change reached −2.7 (0.8) mg/dL in the DR group, −3.1 (0.7) mg/dL in the ER group, and −3.8 (0.9) mg/dL in the control group, without significant differences between the groups. In the DR group, the HDL-C level remained higher than the baseline value, and was significantly higher than in the ER and control groups (1.2 [0.5] versus −1.1 [0.04] and −1.4 [0.03] mg/dL, respectively, $p = 0.04$). There were no significant changes in SBP, DBP, FBS, and C-reactive protein (CRP) (data not shown).

DISCUSSION

We found that an isocaloric diet rich in dairy products may be a safe and practical strategy for weight control and improvement of insulin resistance and some components of the metabolic syndrome in young, overweight children. To the best of our knowledge, no previous similar long-term trial has been conducted in young children, but conflicting results are reported from studies performed among adults; while some of

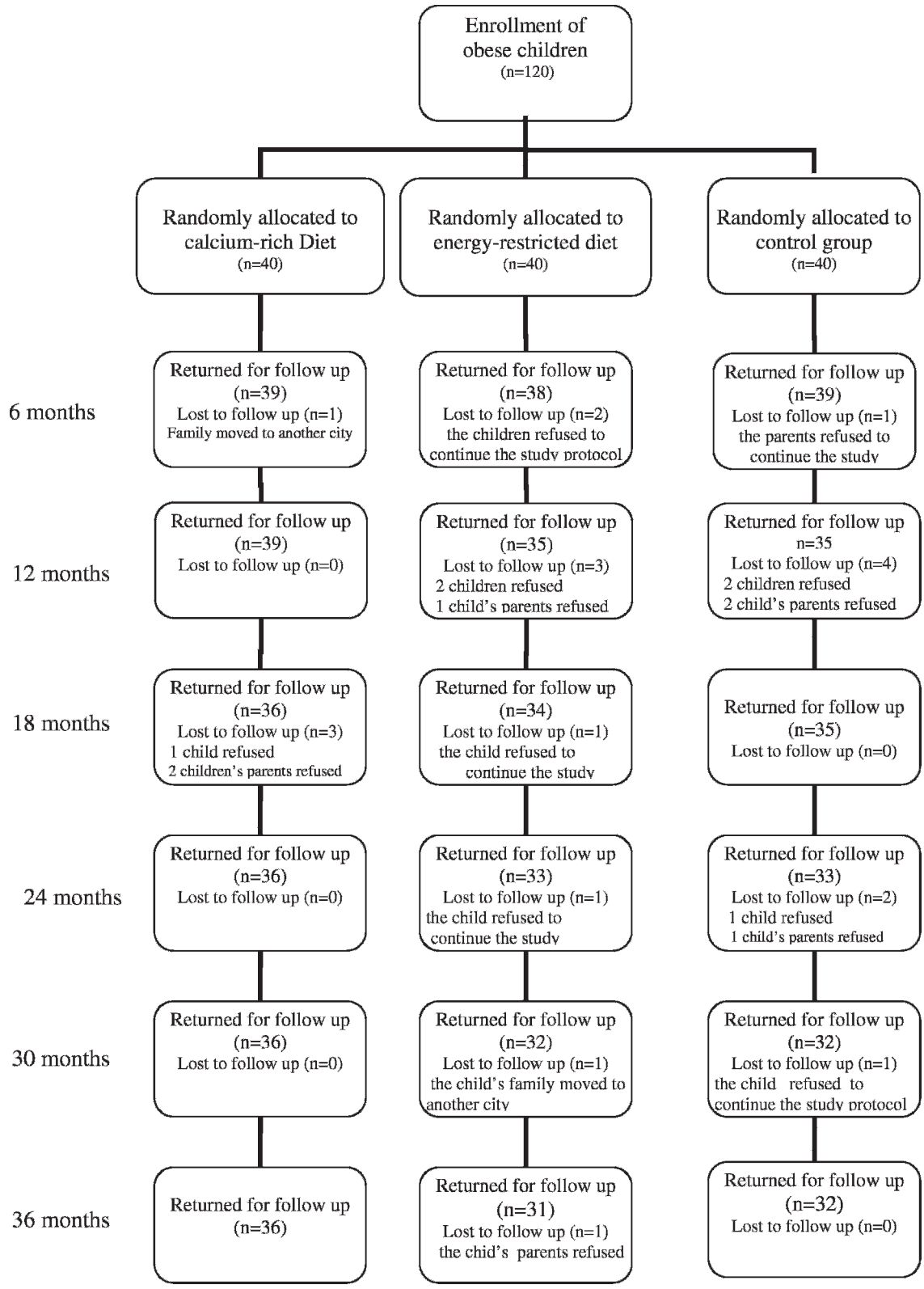

Fig. 1. Participants' retention versus attrition.

Table 1. Baseline Characteristics of the Participants*

	Dairy-rich diet n = 40	Energy-restricted diet n = 40	Controls n = 40
Age (years)	5.4 (0.2)	5.5 (0.7)	5.7 (0.3)
Body mass index (kg/m^2)	22.1 (0.9)	22.7 (0.8)	22.4 (0.5)
BMI-SDS	2.4 (0.01)	2.3 (0.04)	2.4 (0.01)
Waist circumference (cm)	68.1 (4.2)	68.4 (3.5)	68.6 (4.1)
Waist-to-height ratio	0.6 (0.09)	0.59 (0.05)	0.6 (0.07)
Percent body fat (%)	39.7 (2.4)	39.2 (2.7)	38.9 (1.5)
Energy intake (kcal/d)	1570 (325)	1550 (355)	1560 (375)
Total calcium intake (mg/d)	650 (70)	670 (50)	650 (50)
Dairy calcium (mg/d)	470 (20)	480 (40)	470 (50)
Non-dairy calcium (mg/d)	180 (30)	190 (20)	180 (20)
Energy expenditure (kcal/d)	975 (140)	950 (250)	950 (220)
Fasting blood glucose (mg/dL)	82.1 (7.4)	81.2 (6.5)	82.4 (7.1)
Total cholesterol (mg/dL)	159.2 (21.4)	161.2 (17.4)	158.4 (19.1)
LDL-C (mg/dL)	90.7 (18.5)	91.5 (17.4)	91.1 (25.3)
HDL-C (mg/dL)	36.2 (4.5)	37.1 (5.4)	37.4 (5.1)
Triglycerides (mg/dL)	122.7 (17.4)	122.5 (18.1)	120.1 (15.7)
C-reactive protein (mg/L)	0.9 (0.02)	0.9 (0.01)	0.9 (0.03)
Insulin (μU/L)	17.1 (2.5)	17.5 (2.1)	17.2 (1.8)
HOMA-R	1.9 (0.5)	1.8 (0.4)	1.8 (0.6)
Systolic blood pressure (mm Hg)	108.4 (25.7)	108.1 (27.2)	108.6 (26.1)
Diastolic blood pressure (mm Hg)	65.2 (10.7)	65.7 (10.1)	65.1 (11.4)

* Values are mean ± SD; no significant differences were found between the groups.

BMI-SDS = body mass index-standard deviation score, HDL-C = high-density lipoprotein cholesterol, HOMA-R = [fasting insulin $_{(mU/L)}$ × fasting glucose $_{(mmol/L)}$]/22.5, LDL-C = low-density lipoprotein cholesterol.

the studies support the hypothesis that dairy calcium intake might decrease body fat mass and improve metabolic risks [31–33], others did not confirm this effect [34–36].

Our findings are consistent with those of a 2-year exercise intervention among young women in showing an impact of dairy intake on reducing body fat. However, contrary to that study, in which total and dairy calcium had a negative impact on change in body fat only in women with energy intakes below the mean of the participants [37], we found an inverse association between dairy intake and BMI in children following an isocaloric diet. This finding confirms the suggestion that the impact of dairy products in the absence of energy restriction appears to result in a repartitioning of dietary energy from adipose tissue to lean body mass, resulting in a net reduction in fat mass [38,39].

Similar trials are limited in children, and most previous studies have observed the association between dairy intake and body composition. As reviewed by Heaney et al., some longitudinal studies have documented negative associations between calcium intake and body fat accumulation during childhood [40]. In a longitudinal study on children aged 2–96 months, higher intake of calcium and dairy products has been associated with lower body fat [12]. The study of Skinner et al. showed that increasing the calcium intake with skim milk or yogurt each day was associated with a reduction in body fat [41]. However, a 12-year cohort study of older children, aged 9–14 years, found that children who drank more than 3 servings a day of milk, even 1% and skim milk, gained more in BMI than did those who drank smaller amounts. This association was suggested to be due to excess energy intake [42]. The conflicting results of these longitudinal studies might be explained in part by the large difference of the age groups studied, as well as other differences in the energy intake and expenditure of the children studied.

Consistent with some previous studies which demonstrated that dietary modification may have beneficial effects on metabolic measures related to obesity, the metabolic syndrome, and insulin resistance among older children, we found improvement in components of the metabolic syndrome, i.e., TG and HDL-C, in young children [43,44]. However, although studies conducted among adolescents showed that dietary intervention might be effective in decreasing the obesity-related pro-inflammatory state [45,46], we did not document such improvement. The latter is suggested because CRP, measured as the inflammatory marker, was not considerably high in the young children studied.

Of special interest in the context of our study is the persistent compliance of children and families in the use of higher amounts of dairy products. Usually, one of the main barriers for weight loss is the low compliance of children and their families with the advice on restricted diets; we suggest that our intervention in increasing the dairy intake of children could promote a positive dietary behavior rather than using a prohibitive approach.

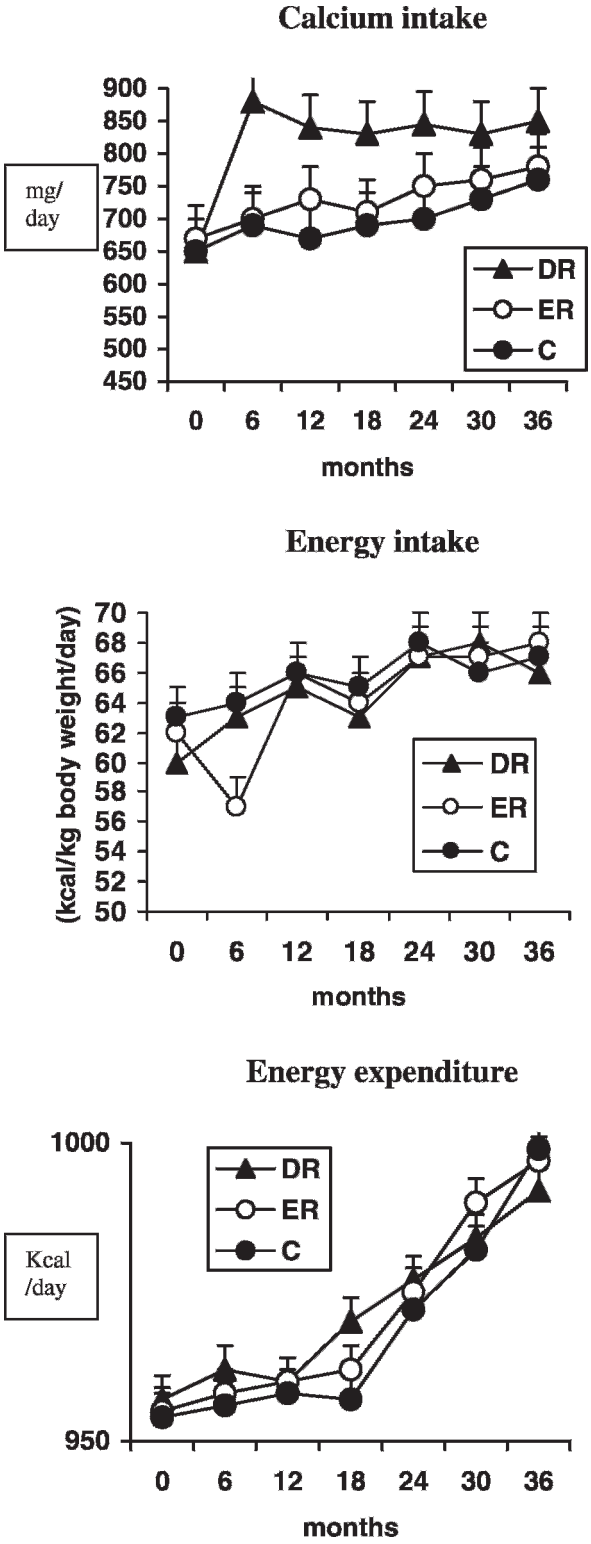

Fig. 2. Mean (SD) calcium and energy intake and energy expenditure by group assignment over 36 months. DR = dairy-rich diet, ER = energy-restricted diet, C = controls.

We advised families to encourage their children to eat yogurt and curd, which are traditionally used in Iran by nearly all families on a regular basis, and many families still prepare them at home. Curd is a very nourishing food, rich in protein, essential vitamins, and minerals that in its liquid form, is used in numerous ways in Iranian culinary art, and its solid type is a delicious, beloved snack for children. Moreover, we encouraged families to replace soft drinks with a traditional beverage called *dough*, which is prepared by diluting yogurt with water. As some types of curd and *dough* are prepared traditionally by adding large amounts of salt, we advised families to consume low-salted products. Although the role of dairy products in controlling appetite is not confirmed [47], we suggest that by reaffirming to families that dairy products are beneficial for different aspects of their children's health, one will encourage them to increase their dairy intake even as healthy snacks and beverages, and keep them from depending on other drinks and snacks. All of these factors are to be considered by dietetics professionals and pediatricians in making recommendations for use of dairy products in the diet of young children.

Our study has some limitations; the first is the potential recall bias in the process of recalling and recording food intake and PA. The other limitation is that we estimated energy expenditure by the means of a questionnaire; however, this questionnaire has been validated against accelerometry, and its validity and reliability were confirmed in previous studies [17,20]. In addition, we measured the percentage of body fat with dual-energy absorptiometry; the instruments used are reported to have results closely correlated with an ''underwater weighing method'' and the dual-energy X-ray absorptiometry method, and this method was used in our previous study among young children [17].

CONCLUSIONS

The compliance of children with calorie restriction was low; however, we suggest that in addition to lifestyle modification and improvement of dietary and physical activity habits, an isocaloric diet rich in dairy products may be a well-accepted regimen for children and their families. Such a diet can be recommended as a safe and practical strategy for weight control and improvement of insulin resistance and some components of the metabolic syndrome in young, overweight children.

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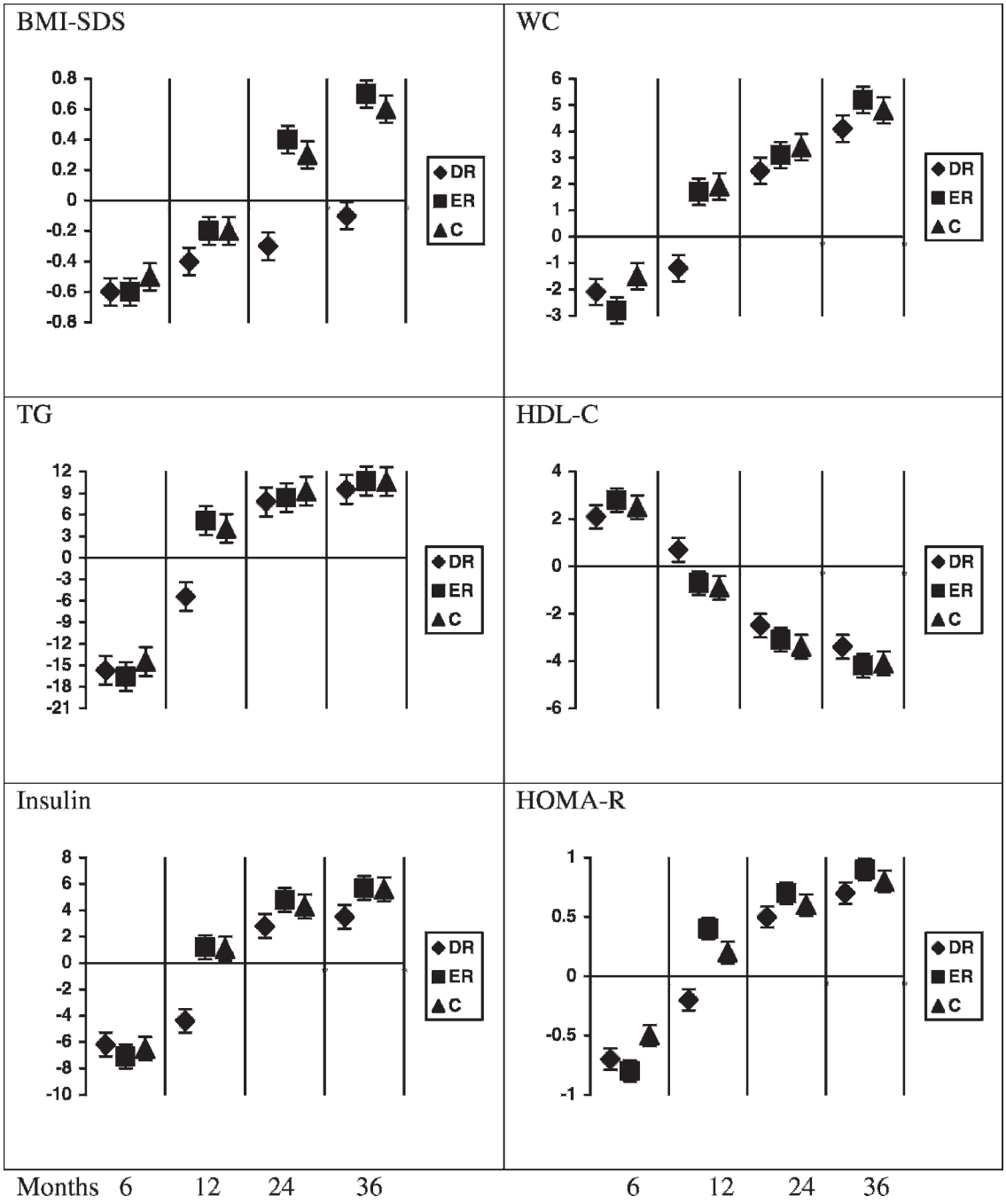

Fig. 3. Mean change (95% CI) in anthropometric and biochemical parameters by group assignment over 36 months. In all groups: p for trend <0.05 for BMI-SDS and WC in all comparisons, and for other variables, from 0 to 24 months. DR = dairy-rich diet, ER = energy-restricted diet, C = controls, BMI-SDS = body mass index-standard deviation score, WC = waist circumference (cm), TG = triglycerides (mg/dL), HDL-C = high-density lipoprotein cholesterol (mg/dL), insulin (μU/L), HOMA-R = [fasting insulin$_{(mU/L)}$ × fasting glucose$_{(mmol/L)}$]/22.5.

REFERENCES

1. de Onis M, Blossner M: Prevalence and trends of overweight among preschool children in developing countries. Am J Clin Nutr 72:1032–1039, 2000.
2. Yoon KH, Lee JH, Kim JW, Cho JH, Choi YH, Ko SH, Zimmet P, Son HY: Epidemic obesity and type 2 diabetes in Asia. Lancet 368:1681–1688, 2006.
3. Kelishadi R: Childhood overweight, obesity, and the metabolic syndrome in developing countries. Epidemiol Rev 29:62–76, 2007.
4. Dorosty AR, Siassi F, Reilly JJ: Obesity in Iranian children. Arch Dis Child 87:388–391, 2002.
5. Lyznicki JM, Young DC, Riggs JA, Davis RM, and the Council on Scientific Affairs, American Medical Association: obesity: assessment and management in primary care. Am Fam Physician 63:2185–2196, 2001.

6. Summerbell CD, Waters E, Edmunds LD, Kelly S, Brown T, Campbell KJ: Interventions for preventing obesity in children. Cochrane Database Syst Rev:CD001871, 2005.
7. Collins CE, Warren J, Neve M, McCoy P, Stokes BJ: Measuring effectiveness of dietetic interventions in child obesity: a systematic review of randomized trials. Arch Pediatr Adolesc Med 160:906–922, 2006.
8. Bluford DA, Sherry B, Scanlon KS: Interventions to prevent or treat obesity in preschool children: a review of evaluated programs. Obesity (Silver Spring) 15:1356–1372, 2007.
9. Teegarden D: Calcium intake and reduction in weight or fat mass. J Nutr 133:249S–251S, 2003.
10. Zemel MB, Richards J, Milstead A, Campbell P: Effects of calcium and dairy on body composition and weight loss in African-American adults. Obes Res 13:1218–1225, 2005.
11. Moore LL, Bradlee ML, Gao D, Singer MR: Low dairy intake in early childhood predicts excess body fat gain. Obesity (Silver Spring) 14:1010–1018, 2006.
12. Carruth BR, Skinner JD: The role of dietary calcium and other nutrients in moderating body fat in preschool children. Int J Obes Relat Metab Disord 25:559–566, 2001.
13. Davudi K, Volkova L: Structure of nutrition in Iranian population [Russian]. Vopr Pitan 76:56–61, 2007.
14. Salek M, Rafati H, Hashemipour M, Memar Ardestani P: Is vitamin D deficiency prevalent in healthy 6-year-old children in Isfahan city? [Farsi]. J Isfahan Medical School 25:95–103, 2007.
15. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL: 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11:1–190, 2002.
16. Marshall WA, Tanner JM: Variations in the pattern of pubertal changes in girls. Arch Dis Child 44:291–303, 1969.
17. Marshall WA, Tanner JM: Variations in the pattern of pubertal changes in boys. Arch Dis Child 45:13–23, 1970.
18. Cole TJ: The international growth standard for preadolescent and adolescent children: statistical considerations. Food Nutr Bull 27(4 Suppl Growth Standard):S237–S243, 2006.
19. Kelishadi R, Sharifi M, Khosravi A, Adeli K: Relationship between C-reactive protein and atherosclerotic risk factors and oxidative stress markers among young persons 10–18 years old. Clin Chem 53:456–464, 2007.
20. Kelishadi R, Hashemipour M, Mohammadifard N, Alikhassy H, Adeli K: Short- and long-term relationships of serum ghrelin with changes in body composition and the metabolic syndrome in prepubescent obese children following two different weight loss programs. Clin Endocrinol (Oxf) 69:721–729, 2008.
21. Rafiei M, Boshtam M, Jalali A, Marandi A: The Iranian Food Consumption Program (IFCP), a unique nutritional software in Iran. Iranian J Pub Health 3:101–105, 2002.
22. Aaddahl M, Jorgensen T: Validation of a new self-report instrument for measuring physical activity. Med Sci Sport Exerc 35:1196–1202, 2003.
23. Kelishadi R, Razaghi EM, Gouya MM, Ardalan G, Gheiratmand R, Delavari A, Motaghian M, Ziaee V, Siadat ZD, Majdzadeh R, Heshmat R, Barekati H, Arabi MS,Heidarzadeh A, Shariatinejad K: CASPIAN Study Group: Association of physical activity and the metabolic syndrome in children and adolescents: CASPIAN study. Horm Res 67:46–52, 2006.
24. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents: The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. Pediatrics 114:555–576, 2004.
25. McNamara JR, Schaefer EJ: Automated enzymatic standardized lipid analyses for plasma and lipid lipoprotein fractions. Clin Chem Acta 166:1–8, 1987.
26. Friedewald WT, Levy RI, Fredrickson DS: Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 8:499–502, 1972.
27. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC: Homeostasis model assessment: insulin resistance and beta cell function from fasting plasma glucose and insulin concentration in man. Diabetologia 28:412–419, 1985.
28. Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH: Prevalence of a metabolic syndrome phenotype in adolescents: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. Arch Pediatr Adolesc Med 157:821–827, 2003.
29. Genuth S, Alberti KG, Bennett P, Buse J, Defronzo R, Kahn R, Kitzmiller J, Knowler WC, Lebovitz H, Lernmark A, Nathan D, Palmer J, Rizza R, Saudek C, ShawJ, Steffes M, Stern M, Tuomilehto J, Zimmet P: Expert Committee on the Diagnosis and Classification of Diabetes Mellitus: Follow-up report on the diagnosis of diabetes mellitus. Diabetes Care 26:3160–3167, 2003.
30. Lucas B: Nutrition in Childhood. In Mahan LK, Escott Stump S (eds): ''Krause's Food, Nutrition & Diet Therapy.'' 10th ed. Philadelphia: Saunders, pp 242–245, 2000.
31. Zemel MB, Shi H, Greer B, Dirienzo D, Zemel PC: Regulation of adiposity by dietary calcium. FASEB J 14:1132–1138, 2000.
32. Jacqmain M, Doucet E, Despres JP, Bouchard C, Tremblay A: Calcium intake, body composition, and lipoprotein-lipid concentrations in adults. Am J Clin Nutr 77:1448–1452, 2003.
33. Eagan MS, Lyle RM, Gunther CW, Peacock M, Teegarden D: Effect of 1-year dairy product intervention on fat mass in young women: 6-month follow-up. Obesity (Silver Spring) 14:2242–2248, 2006.
34. Barr SI: Increased dairy product or calcium intake: is body weight or composition affected in humans? J Nutr 133:245S–248S, 2003.
35. Gunther CW, Legowski PA, Lyle RM, McCabe GP, Eagan MS, Peacock M, Teegarden D: Dairy products do not lead to alterations in body weight or fat mass in young women in a 1-y intervention. Am J Clin Nutr 81:751–756, 2005.
36. Venti CA, Tataranni PA, Salbe AD: Lack of relationship between calcium intake and body size in an obesity-prone population. J Am Diet Assoc 105:1401–1407, 2005.
37. Lin YC, Lyle RM, McCabe LD, McCabe GP, Weaver CM, Teegarden D: Dairy calcium is related to changes in body composition during a two-year exercise intervention in young women. J Am Coll Nutr 19:754–760, 2000.
38. Zemel MB, Richards J, Milstead A, Campbell P: Effects of calcium and dairy on body composition and weight loss in African-American adults. Obes Res 13:1218–1225, 2005.
39. Zemel MB, Richards J, Mathis S, Milstead A, Gebhardt L, Silva E: Dairy augmentation of total and central fat loss in obese subjects. Int J Obes (Lond) 29:391–397, 2005.

40. Heaney RP, Davies KM, Barger-Lux MJ: Calcium and weight: clinical studies. J Am Coll Nutr 21:152S–155S, 2002.
41. Skinner JD, Bounds W, Carruth BR, Ziegler P: Longitudinal calcium intake is negatively related to children's body fat indexes. J Am Diet Assoc 103:1626–1631, 2003.
42. Berkey CS, Rockett HR, Willett WC, Colditz GA: Milk, dairy fat, dietary calcium, and weight gain: a longitudinal study of adolescents. Arch Pediatr Adolesc Med 159:543–550, 2005.
43. Roberts CK, Chen AK, Barnard RJ: Effect of a short-term diet and exercise intervention in youth on atherosclerotic risk factors. Atherosclerosis 191:98–106, 2006.
44. Monzavi R, Dreimane D, Geffner ME, Braun S, Conrad B, Klier M, Kaufman FR: Improvement in risk factors for metabolic syndrome and insulin resistance in overweight youth who are treated with lifestyle intervention. Pediatrics 117:E1111–E1118, 2006.
45. Kelishadi R, Hashemi M, Mohammadifard N, Asgary S, Khavarian N: Association of changes in oxidative and proinflammatory states with changes in vascular function after a lifestyle modification trial among obese children. Clin Chem 54:147–153, 2008.
46. Roberts CK, Chen AK, Barnard RJ: Effect of a short-term diet and exercise intervention in youth on atherosclerotic risk factors. Atherosclerosis 191:98–106, 2007.
47. Lorenzen JK, Nielsen S, Holst JJ, Tetens I, Rehfeld JF, Astrup A: Effect of dairy calcium or supplementary calcium intake on postprandial fat metabolism, appetite, and subsequent energy intake. Am J Clin Nutr 85:678–687, 2007.

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