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The effects of whole grain intake on anthropometric measures in overweight and obese children: a crossover randomised clinical trial

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Abstract

Whole-grain foods have been reported to affect body weight and satiety. However, we are aware of no study in this regard among children. The present study aimed to determine the effects of whole grain consumption on anthropometric measures in overweight or obese children. In this randomised crossover clinical trial, forty-four overweight or obese girls participated. After a 2-week run-in period, subjects were randomly assigned to either intervention (*n* 44) or non-intervention (*n* 44) groups. Subjects in the intervention group were given a list of whole-grain foods and were asked to obtain half of their grain servings from these foods each day for 6 weeks. Individuals in the non-intervention group were asked not to consume any of these foods. A 4-week washout period was applied. Then, participants were crossed over to the alternate arm. The measurements were done before and after each phase. Mean age, weight and BMI of participants were 11·2 (SD 1·49) years, 51·2 (SD 10·2) kg and 23·5 (SD 2·5) kg/m^2, respectively. Despite the slight reduction in weight and BMI, there were no significant differences in changes in these anthropometric measures. We found a significant effect of whole grain intake on waist circumference (−2·7 *v.* 0·3 cm, $P = 0·04$). No significant changes in hip circumference were observed. Changes in the prevalence of overweight, obesity and abdominal obesity were not significantly different. This study indicated a beneficial effect of whole-grain foods on waist circumference in overweight children; however, these foods did not influence weight and BMI.

Keywords: Whole grains: Anthropometric measures: Obesity: Children

Childhood obesity has become a serious public health problem worldwide[1]. In Iran, it is estimated that >15 % of children are overweight or obese[2]. Overweight children and adolescents are at an increased risk of hypertension, dyslipidaemia, CVD, the metabolic syndrome and other chronic diseases[3,4]. Obese children are more likely to become overweight or obese adults[3,4]. Energy restriction, a key treatment for obesity, in children might prohibit them from receiving adequate nutrients for their growth[5]. Therefore, it is very important to control weight gain among children without administering an energy-restricted diet. Available documents among adults have shown that whole-grain foods may increase the bulk of the food and probably long-term satiety[6]. Many of whole grains contain high fibre content[7,8]. Previous studies have shown that greater intakes of dietary fibres are associated with suppressed appetite and enhanced satiety[9]. Furthermore, whole-grain products are less energy dense and seem to reduce body weight by delaying intestinal digestion and absorption[10]. Prior epidemiological studies have examined the effect of whole grain intake on body weight in adults. Most of these studies indicated that a high intake of whole-grain foods was associated with significantly lower BMI and waist circumference in both women and men[11–13]. In contrast, interventional studies have failed to reach such significant effects. Few interventional studies have examined the effect of whole grain intake on weight control; most of them were unable to show the efficiency of whole-grain-rich diet on weight

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management and appetite. Studies are unable to find an effect outside the context of energy-restricted diets[14]. In a crossover, randomised clinical trial in obese subjects with elevated fasting blood glucose, a whole-grain-enriched hypoenergetic diet resulted in the same reduction in body weight, BMI and weight:hip ratio as the hypoenergetic control diet[15]. The same results were found in a 12-week parallel study in obese adults with the metabolic syndrome[16]. Available data among children and adolescents are limited to observational studies that examined the relationship between whole grain consumption and body weight. Findings from several cross-sectional studies in children and adolescents have demonstrated an inverse association between whole grain intake and central obesity, BMI and waist circumference[17–19]. It seems that the inclusion of whole-grain foods in the diet is particularly relevant for overweight children because whole grains can help children to meet the recommended amounts of nutrients for their appropriate growth. Moreover, these foods might prohibit weight gain in obese children. We are aware of no interventional study examining the effect of whole grain intake on weight control among children and adolescents. The present study was conducted to determine the effect of whole grain intake on anthropometric measurements in overweight or obese children and adolescents.

Methods

Participants

In this randomised, crossover clinical trial, forty-four overweight or obese (BMI >85th percentile for age and sex according to cut-points suggested by the WHO[20]) girls aged 8–15 years who did not lose weight significantly (>5 %) in the past 6 months were studied. Individuals with a history of chronic diseases and medication use were not included. All participants were recruited from a private clinic of a paediatrician. Participants were not on a weight loss diet in the past 6 months. Sample size for the study was calculated based on the formula suggested for crossover trials ($n = ((z_{1-\alpha/2} + z_{1-\beta})^2 \times SD^2)/2\Delta^2$). We considered type 1 error of 5 %, type 2 error of 20 % (power 80 %) and body weight as a key variable and reached the sample size of thirty-one participants for the whole intervention[21]. Considering the high dropouts in crossover trials, we enrolled forty-four children based on the abovementioned inclusion criteria. Participants were randomly assigned to intervention (n 44) or non-intervention groups (n 44) for 6 weeks (Fig. 1). Random assignment was done using computer-generated random numbers. The study was approved by the Regional Bioethics Committee of Isfahan University of Medical Sciences, Iran (ethics committee reference number 191044), and all participants as well as their parents provided written informed consent.

Study design

To obtain detailed information about the lifestyle of study participants as well as to assess the compliance of study participants to the whole grains, all subjects were placed on a 2-week run-in period. A dietitian met individually with each participant during this period to discuss the dietary intervention; she also provided educational materials to facilitate understanding and adherence. Subjects were asked to continue their habitual diet and physical activity and to consume one serving per d of whole grains during this period to prepare them for intervention and to increase their compliance throughout the study. Two dietary records (non-consecutive days) as well as a 2-d physical activity records were obtained from each participant during the run-in period. Participants were trained in advance on how to record their dietary intakes, and in this regard, written instructions were given to them. In the case of young children, one of the parents completed the dietary records. Special forms and instructions were provided to guide subjects in recording the appropriate level of food description. At the end of this period (study baseline), all measurements were done. Then, participants were randomly assigned to intervention and non-intervention groups, each for 6 weeks. Treatment periods were separated by a 4-week washout period, in which patients returned to their usual diet. Then, participants were crossed over to the alternate arm for an additional 6 weeks. However, a 2-week washout period is long enough to allow the effects of a treatment to wear-off; it should be noted that our study population were children, and due to a fear of blood sampling among them or their families, we chose a 4-week washout period. During the washout period, subjects were asked to avoid whole grain intake they were consuming during the intervention. Participants were asked not to alter their routine physical activity or usual diets throughout the study and not to consume any supplements. All measurements were taken at the beginning and end of each phase. Compliance with the consumption of whole grains was monitored once a week through phone interviews. By this procedure, dietary records were checked, and participants were asked about their adherence and any possible problems in their diets and recommendations. All participants provided dietary records once every 2 weeks during the study. Therefore, each participant had 3 d of dietary records in each phase of the study (2 week days and 1 weekend day) and two dietary records during the run-in period. The days were given by a dietitian. Then, we converted the reported portion sizes in the records to grams using household measures. All dietary data were based on the average of three dietary records. The grams of food intake data were linked with Nutritionist IV software to derive nutrient intake data. The nutrient database of Nutritionist IV software was based on US Department of Agriculture food composition database that has been modified for Iranian foods. Earlier studies have shown that consecutive days of dietary records cannot capture all the variations in dietary intakes and have suggested the use of non-consecutive days for dietary assessment[22]. So, we used non-consecutive days to capture the usual intakes of participants. We think that these 3 d were enough to represent participants' usual diet. The main purpose of collecting these records was to evaluate participants' adherence. Previous studies showed that at least 3 d of records would be adequate to estimate usual intake. Participants were asked to record their daily physical activity during run-in and both intervention and control periods. Furthermore, participants were instructed to note their daily physical activities in a way that sum of the recorded hours reached up to 24 h. Then, metabolic equivalent of task (MET) was calculated for each participant by a trained dietitian. In order to make sure there is no change in a participant's routine physical

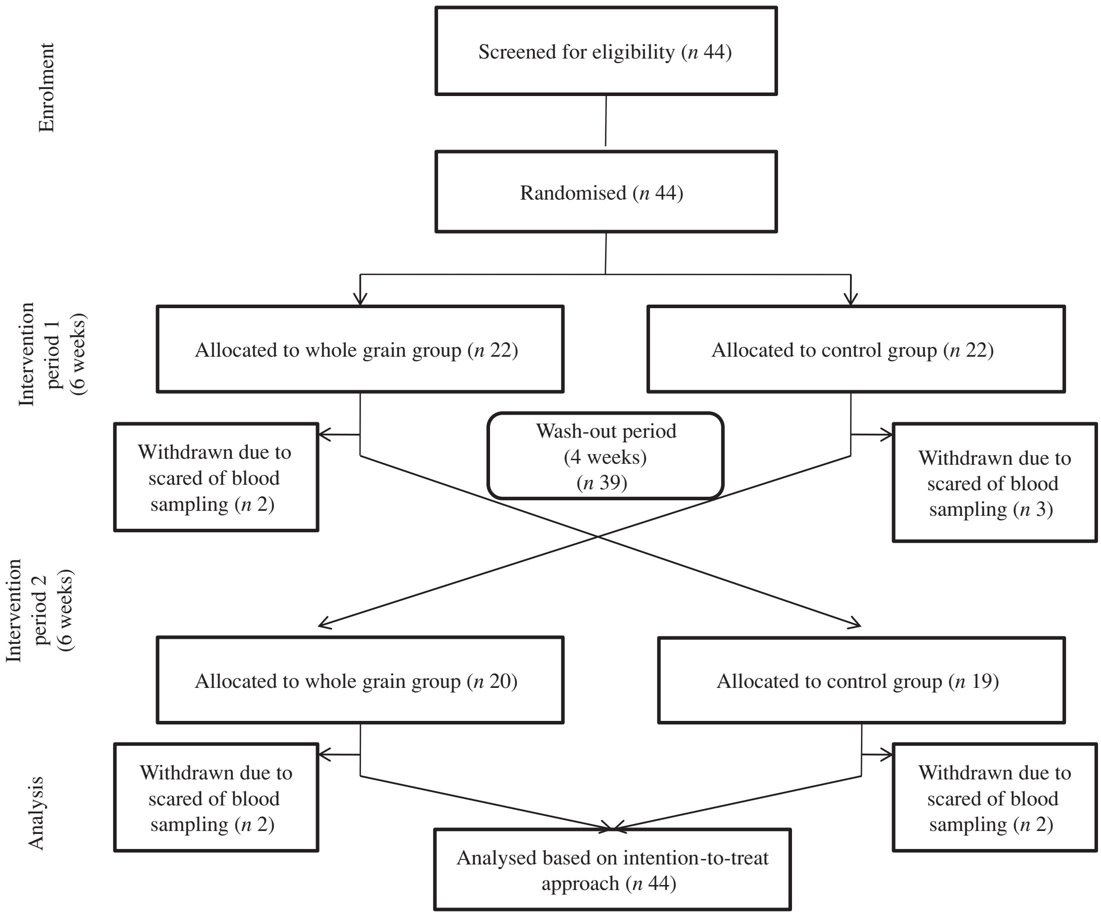

Fig. 1. Study flow diagram.

activity during the various periods, the mean MET-h/d was calculated[23].

The dietary records were based on estimated values in household measurements. No particular intervention was done in terms of dietary intakes and physical activity throughout the study, which means that except for recommendations for whole grain intake, there has not been any other dietary intervention (for instance, we did not prepare a menu cycle for participants to achieve weight loss).

Interventions

In the present study, we did not provide menu cycles to the participants. First, individual energy requirements for each participant were calculated based on recommendations of the Institute of Medicine[24]. Energy requirement was based on weight maintenance. Then, based on the macronutrient composition of 53 % of energy from carbohydrates, 30 % from dietary fats and 17 % from dietary proteins, we computed the total servings of grains (and also other food groups) needed for each participant. Then, the number of servings of grain products needed for each individual was given to the participants. Subjects in the intervention group were given a list of whole-grain foods that are available in Iran (dark breads (Iranian local breads like Sangak), brown rice, whole-meal biscuits, bulgur, barley bread, popcorn) and were asked to obtain half of their total grain servings from whole-grain foods each day. In case of young children, we gave a list of whole-grain foods to one of the parents and instructed them as to how to gain the required amount of whole grain. Individuals in the non-intervention group were also given a list of whole-grain foods and were asked not to consume any of these foods during the intervention phase of the study. Foods were defined as whole grains based on the definition of the American Association of Cereal Chemists International[25], if at least 8 g per 30 g of their weight was from whole grains. Most of the foods in our list of whole grains were from whole wheat.

Anthropometric assessment

The measurement of height of each participant, in standing position and shoulders relaxed, was done using a tape without shoes. Weight was measured to the nearest 100 g using a digital scale in light clothing (Seca). BMI was calculated as weight in kg divided by height in metres-squared. Overweight and obesity were defined based on the cut-off points of the World Health Organisation as BMI ≥85th to <97th percentile and ≥97th percentile for age and sex, respectively[20]. Waist circumference was measured at the smallest circumference, and hip circumference was measured at the maximum level using an unstretched tape. Abdominal obesity was defined as having a waist circumference above the 75th percentile of age- and sex-specific nationally suggested cut-off points[26]. To avoid subjective error, all measurements were made by the same person.

Statistical methods

All statistical analyses were performed using Statistical Package for Social Sciences (SPSS Inc, version 16). Normal distributions of variables were examined by means of the Kolmogrov–Smirnov test. The analyses were done based on intention-to-treat analysis. Missing values were treated based on last-observation-carried-forward method. Data on dietary intakes and physical activity were compared by paired *t* test. We applied one-way repeated-measures ANOVA to identify the effect of whole-grain foods on anthropometric measures. The treatment (whole grain *v.* refined grain) was regarded as between-subject factor, and time with two time-points (baseline and week 6 of intervention) was considered as within-subject factor. We also assessed if the carryover effect was significant. The carryover effect was tested by computing the average of the end-of-trial values of each variable for the two treatments (two different groups) and comparing the two treatment orders using the *t* test. *P* values <0·05 were considered significant.

Results

Mean age of study participants was 11·2 (SD 1·49) years (range 8–14 years). At baseline, mean weight and BMI were 51·2 (SD 10·2) kg and 23·5 (SD 2·5) kg/m^2, respectively. Mean waist circumference was 80·6 (SD 7·9) cm. At baseline, 45 % of girls were overweight and 55 % were obese. In order to evaluate participants' adherence, we used 3 d of dietary records. Based on the average of dietary intakes from these dietary records, it seems that the adherence of participants to our dietary recommendations was relatively good.

Dietary intakes of participants during intervention, obtained from the average of three dietary records (Table 1), revealed that individuals in the intervention consumed 1629 *v.* 1454 kcal/d (6816 *v.* 6084 kJ/d) compared with the non-intervention group (*P* = 0·27). The percentage of energy intake from carbohydrates, proteins and fats among individuals in the intervention group was 56·72, 14·97 and 30·38 %, respectively. The corresponding figures for those in the non-intervention group were 55·84, 14·58 and 31·56 %, respectively.

There were no significant differences between the intervention and non-intervention groups in terms of macronutrient intakes, except for carbohydrate intake that was significantly higher in the intervention group than in the non-intervention group (231 *v.* 203 g/d, *P* = 0·03). No significant differences in dietary intakes of SFA, PUFA, K, Ca, vitamin C and folate were observed between the intervention and non-intervention groups. However, individuals in the intervention group consumed higher amounts of vitamin D (2·2 *v.* 0·8 μg/d, *P* = 0·04), Cu (1·3 *v.* 0·7 mg/d, *P* = 0·03) and Se (1·4 *v.* 0·8 mg/d, *P* = 0·04) than the non-intervention group. Mg (205 *v.* 184 mg/d, *P* = 0·09) and Zn intake (8·9 *v.* 6·6 mg/d, *P* = 0·09) tended to be higher among those in the intervention group than the non-intervention group. The mean whole grain intake in the intervention and non-intervention groups throughout the study was 98 and 11 g/d, respectively (*P* = 0·01). The corresponding figures for refined grain intake were 112 and 208 g/d, respectively (*P* = 0·02).

Table 1. Dietary intakes of participants obtained from 3 d of dietary records throughout the study
(Mean values and standard deviations)

	Intervention* (*n* 44)		Non-intervention† (*n* 44)		
	Mean	SD	Mean	SD	*P*‡
Energy (kcal/d)§	1629	434	1454	445	0·27
Fat (g/d)	55	20	51	19	0·34
Carbohydrate (g/d)	231	64	203	67	0·03
Mg (mg)	205	54	184	65	0·09
Vitamin D (μg)	2·2	2·1	0·8	1·1	0·04
Ca (mg)	664	342	613	318	0·42
Fe (mg)	14	5	13	7	0·48
K (mg)	2191	782	2142	656	0·72
Dietary fibre (g)	13	6	13	4	0·95
Vegetables (g/d)	161	71	153	82	0·36
Fruits (g/d)	221	85	243	95	0·21
Meats (g/d)	84	39	81	31	0·55
Whole grains (g/d)	98	25	11	19	0·01
Refined grains (g/d)	112	66	208	79	0·02

* Intervention group: consumed half of their needed servings of grains from whole-grain foods each day.
† Individuals in the non-intervention group were also given a list of whole-grain foods and were asked not to consume any of these foods during the whole grain phase of the study.
‡ By paired *t* test.
§ To convert kcal to kJ, multiply by 4·184.

No significant difference was found in terms of physical activity between the two phases (intervention: 33·9 (SD 4·5) *v.* 34·3 (SD 4·2) MET-h/d for non-intervention, *P* = 0·52).

The effects of whole grain intake on anthropometric measures are shown in Table 2. Despite a slight reduction in weight (changes from baseline in the intervention *v.* non-intervention groups (*n* 44): −0·5 (SD 6·45) *v.* 0·5 (SD 6·51) kg, *P* = 0·21) and BMI (*n* 44: −0·6 (SD 1·55) *v.* 0·2 (SD 1·59) kg/m^2, *P* = 0·35), there were no significant differences in changes in these anthropometric measures between the intervention and non-intervention groups. Whole grain intake resulted in a significant reduction in waist circumference compared with the non-intervention group (changes from baseline (*n* 44): −2·7 (SD 4·96) *v.* 0·3 (SD 4·99) cm, *P* = 0·04). No significant changes in hip circumference were observed (0·3 (SD 4·68) *v.* 0·1 (SD 4·64) kg, *P* = 0·98). The effect of time was significant for weight and waist circumference. No significant interaction term was found for time × group for any dependent variable.

The effects of whole grain intake on the prevalence of obesity, overweight and abdominal obesity in the study participants are shown in Fig. 2. At study baseline, the prevalence of obesity was 63·6 % in the intervention group, which reduced to 50 % after intervention. The prevalence of obesity in the non-intervention group was 50 % at the beginning of the study, which increased to 52·3 % at the end of the study. These changes were not significant. In addition, 36·5 % of participants in the intervention group and 41 % in the non-intervention group were overweight at study baseline, which were changed to 41 and 38·6 %, respectively, at the end of the trial. These changes were not statistically significant either. The prevalence of abdominal obesity in both intervention and non-intervention groups at

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Table 2. Effects of whole grain intake on metabolic profiles in overweight children
(Mean values and standard deviations)

	Intervention* (*n* 44)				Non-intervention† (*n* 44)				*P*‡		
	Baseline		6th week		Baseline		6th week				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Time	Group	Time × group
Weight (kg)	52·4	10·3	51·9	10·1	52·2	10·3	52·7	10·3	0·001	0·21	0·87
BMI (kg/m^2)	23·7	2·5	23·1	2·4	23·6	2·4	23·8	2·6	0·57	0·35	0·72
Waist circumference (cm)	81·9	7·8	79·2	7·9	80·8	7·9	81·1	7·9	0·002	0·04	0·24
Hip circumference (cm)	92·1	7·4	92·4	7·4	92·3	7·4	92·4	7·3	0·72	0·98	0·76

* Intervention group: consumed 50 % of their grain servings from whole-grain foods each day.
† Individuals in the non-intervention group were given a list of whole-grain foods and were asked not to consume any of these foods during the intervention phase of the study.
‡ Results of repeated-measures ANOVA.

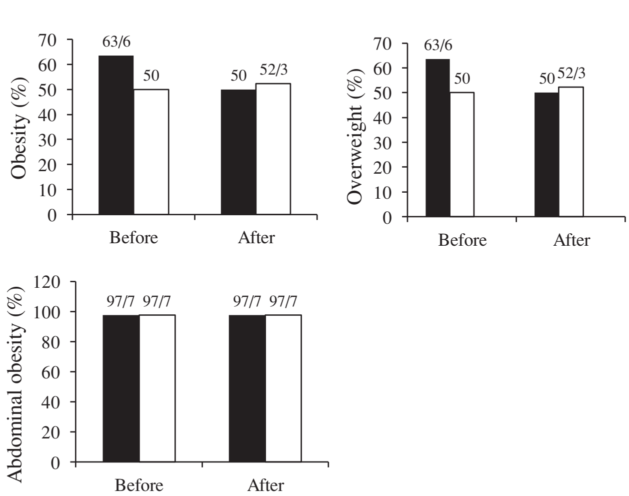

Fig. 2. Prevalence of overweight, obesity and abdominal obesity at study baseline and after intervention. Overweight and obesity were defined based on the cut-off points of the WHO[19] as BMI ≥85th to <97th percentile and ≥97th percentile for age and sex, respectively. Abdominal obesity was defined as having a waist circumference above the 75th percentile of age- and sex-specific nationally suggested cut-off points[20]. ■, Intervention group; □, non-intervention group.

study baseline was 97·7 %, which did not change in either group after intervention.

Discussion

In this randomised, crossover clinical trial among overweight children, we found that the consumption of whole-grain foods for 6 weeks significantly reduced waist circumference, but did not influence weight and BMI. To the best of our knowledge, this study is the first interventional study among children examining the effect of whole-grain foods on anthropometric measurements in overweight or obese children and adolescents.

Although we found the statistically significant difference in waist circumference, it was not clinically considerable. Waist circumference is easy to measure and is a low-cost indicator of abdominal obesity that is associated with several chronic diseases such as CVD and diabetes[27]. Even a small change in waist circumference in a short duration could have a positive effect on the risk of chronic diseases. So, increasing whole grain intake for a longer duration could have considerable clinical effects.

Whole-grain foods contain several components that help in curbing childhood obesity[28]. In the present study, we found that whole grain intake for 6 weeks significantly affected waist circumference, but did not influence weight and BMI. Although no interventional studies are available indicating the effect of whole grain intake on waist circumference in children, this finding is in line with several observational studies. Findings from cross-sectional studies in adolescents have indicated that whole grain consumption is inversely associated with central obesity, appetite and energy intake[17–19]. Steffen *et al.*[19] showed that increased consumption of whole grains was associated with a lower BMI and greater insulin sensitivity among 357 healthy children.

Few interventional studies examining the efficacy of whole-grain foods on weight control have been done among adults. Furthermore, most of these studies have used hypoenergetic diets that might confound the independent effect of whole grains[14]. Findings of these studies have indicated that whole-grain-rich, energy-restricted diets had no further effect on weight compared with a conventional hypoenergetic diet alone in overweight adults. In a 24-week pilot study, Melanson *et al.*[29] showed that a energy-restricted diet rich in whole-grain cereals resulted in the same degree of weight reduction compared with a control diet. Investigators of a parallel study in obese men and women with the metabolic syndrome found the same reduction in body weight, waist circumference and percentage of body fat with the consumption of a low-energy diet with or without whole grains for 12 weeks[16]. Fatahi *et al.*[30] indicated that the consumption of a energy-restricted diet containing different sources of fibre (fruits, vegetables and whole grains) in overweight and obese women resulted in both weight and waist circumference reduction. Such findings have also been reported by another interventional study[15].

We are aware of just few clinical trials that have directly compared whole grain and refined grain intakes without any energy restriction in the diet[31–35]. In a crossover clinical trial, the consumption of whole-grain wheat for 3 weeks in healthy adults had no significant effects on body weight, percentage of body fat, waist or hip circumferences compared with refined grain[31]. A double-blind crossover trial in forty overweight or obese men and women showed the same reduction in body weight and fat loss in both whole grain and refined grain diets[32]. Another study by Lankinen *et al.*[33] with a crossover design in adults has shown that body weight did not differ between intervention diets of whole-grain rye bread and white wheat bread. However, there was a slight (and significant effect, $P = 0·013$) decrease in body weight during the rye bread period, but which did not differ between diet periods. Such findings have also been reported by other randomised studies[34,35]. In a feeding trial, a comparison of three high-fibre diets (whole grain diet; fruit and vegetable diet; and a combined whole grain and fruit and vegetable diet) for 10 weeks showed a significant reduction in weight[36].

It must be kept in mind that we did not prescribe weight loss diet to our participants. This is in apposite with other interventional studies done in adults. Most of the previous studies on adults have prescribed weight loss diets, and the effect of whole grain intake has been compared with a weight loss diet. This difference might explain why we observed a significant effect of whole grain intake on waist circumference but others have not. One might expect to see the significant effect of whole grain intake on weight and BMI in our study as well; however, the short duration of our intervention might have resulted in the lack of observing any significant effect on these measures of general obesity.

The reporting amounts of fibre per 30 g of Iranian common breads (sangak (a kind of dark bread), barbari (a kind of dark bread), taftoon (a kind of refined bread) and lavash (a kind of refined bread)) and 80 g of white rice by the applied N4 software were 0·390, 0·144, 0·393, 0·474 and 0·400 g, respectively. So, based on these values, whole and refined grain had almost the same amounts of dietary fibre. Therefore, the dietary fibre content of the intervention and non-intervention groups was not significantly different. Due to this limitation in the food composition table, we were unable to assess the exact amount of total fibre and fibre from whole grains in the two groups. However, we found that individuals in the intervention group consumed higher amounts of vitamin D. Reported dietary intakes of vitamin D in Table1 are in small amounts (µg/d), and it should be noted that these small significant changes in vitamin D intakes are not clinically considerable.

Several mechanisms have been suggested to underlie the protective effects of whole grain intake on body weight, energy intake and satiety. Whole-grain foods have lower glycaemic index than refined grain foods. This could in turn lead to lower blood glucose and insulin response and might explain the favourable effects of whole-grain foods on satiety[37,38]. Whole-grain foods have low energy density, leading to lower energy intake[8]. The favourable effects of whole grains may be mediated through their high fibre content[39–42].

This study has several advantages. The main strength of the present study was its crossover design. This is the first crossover clinical trial that directly compared the effects of whole grain consumption on anthropometric measures in children in a developing country. Furthermore, dietary intakes and physical activity of subjects were assessed before and throughout the study, which enabled us to explore the changes in these variables. Several limitations must also be taken into account in the interpretation of our findings. We could not design a feeding trial to ensure compliance with whole-grain foods. We asked our participants to consume the recommended amounts of whole grains at home. However, the compliance to whole-grain foods seems relatively good based on the dietary records we took throughout the study. Furthermore, we applied intention-to-treat analysis to take into account the probable low adherence. In addition, feeding trials have their own limitations due to the compulsory changes in dietary intakes. Although the plasma concentrations of alkyl resorcinol has been suggested to be a biochemical biomarker of dietary whole grain intake, we could not measure this biomarker in our study due to budget limitations. The limitations typically associated with crossover designs cannot be excluded in the present study. Crossover trials are still the best means of assessing dietary effects, because each individual acts as his/her own control, but these studies have some limitations, including carryover effect. Although we did not find any evidence of carryover effect in the present study, the complexity of crossover trials might limit the interpretation of the findings. Furthermore, the study was conducted among girls due to their willingness to lose weight, better compliance and better cooperation in a nutritional project. However, the findings would be more difficult to be generalised to all adolescents, including boys. However, the subjects were recruited from a well-known private paediatric clinic of the city, which was located in the central part of Isfahan, and most overweight and obese children in the city had been referred to this clinic; however, this point might limit the generalisability of our findings. Finally, although the present study has adequate power to detect the significant effects, further studies with a longer duration of intervention might be needed to confirm the long-term health benefits of whole grains in children.

In summary, our findings suggested that whole grain consumption for 6 weeks in overweight children did significantly reduce waist circumference, but did not influence weight and BMI. Further long-term studies are needed to confirm these results.

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P. H. and A. E. designed and conducted the research, performed the formal analysis, and participated in data acquisition and manuscript drafting. L. A., M. H. and R. K. contributed to the conception, design, and manuscript drafting. P. S. contributed to the writing – review and editing. A. E. supervised the study. All authors read and approved the final manuscript for submission.

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