Original Article

Comparative dietary effectiveness of a modified government-recommended diet with avoidance of ultra-processed foods on weight and metabolic management in children and adolescents: An open-label, randomized study

Fei Chen BS[1], Ke Huang PhD[2], Qi Long MD[1], Ming Ma MD[1], Ting Zhang MD[1], Guanping Dong MD[2], Wei Wu PhD[2], Yan Ni PhD[2], Chi-chung Hui PhD[3], Junfen Fu PhD[2]

[1]*Departments of Clinical Nutrition, the Children's Hospital, Zhejiang University School of Medicine, National Clinical Research Center for Child Health, Hangzhou, Zhejiang, China*
[2]*Departments of Endocrinology, the Children's Hospital, Zhejiang University School of Medicine, National Clinical Research Center for Child Health, Hangzhou, Zhejiang, China*
[3]*Department of Molecular Genetics (CH), University of Toronto, Toronto, Ontario, Canada*

Background and Objectives: Childhood obesity is rapidly rising in China and effective diet interventions are needed. Here, we determine whether the Chinese government-recommended diet (GRD) or a modified diet of further restriction of sugar and ultra-processed food but without energy restriction, minimally processed diet (MPD) is effective on weight loss in children and adolescents with obesity/overweight. **Methods and Study Design:** This open-label, randomized study included 60 children and adolescents between 5-18 years old with overweight/obesity. Participants were randomized 1:1 to the GRD or MPD and self-managed at home for 12 weeks. Both groups received general recommendations in physical activities. The changes were evaluated in body weight, fasting glucose and insulin, lipid metabolism and serum uric acid between baseline and week 12. **Results:** The results indicated great reductions by time for BMI, BMI z-score, fat mass percentage and fat mass index in both groups. An obvious decrease by time for weight was found in the MPD group ($p<0.001$) as well as fasting glucose ($p=0.005$), fasting insulin ($p=0.001$), total cholesterol ($p=0.007$) and serum uric acid ($p=0.006$). As for the amount of visceral fat, greater reduction by time was observed in MPD group compared with GRD group. **Conclusions:** A 12-week self-intervention combining the Chinese government-recommended diet with physical activities was effective on weight loss in children and adolescents with overweight/obesity. The minimally processed diet was more effective on decreasing visceral fat mass and may be beneficial to improving insulin resistance. Further studies are required to assess long-term outcomes of the general public.

Key Words: sugar, ultra-processed food, obesity, diet intervention, children

INTRODUCTION

Obesity is becoming a worldwide epidemic. In the United States, it is estimated that approximately one-third of adults and about 15-20% of children and adolescents were affected by obesity.[1,2] In China, while only 1% of children (aged 6 to 18 years) were identified as overweight/obese (BMI ≥85th percentile) and 0.1% of children were obese (BMI ≥95th percentile) in 1985,[3,4] we observed that obesity/overweight rates in Chinese children and adolescents (aged 6 to 17) increased dramatically to 19% (7.9% as obesity) in 2019.[5] Furthermore, this rapid increase in obesity/overweight among Chinese children continues to rise. Since childhood obesity is associated with increased risks of metabolic syndrome, cardiovascular disease, steatohepatitis, early puberty and polycystic ovary syndrome,[6] it is of paramount importance to develop effective interventions in the population level.

With rapid economic development and urbanization, the diet of Chinese citizens has been influenced by Western culture. Chinese children have experienced BMI increments as their dietary pattern has become more highly processed.[7] China Nutrition and Health Surveys, indicate that the total energy intake of urban residents has decreased since 1992, while the frequency of snacking and

Corresponding Author: Dr Junfen Fu, Department of Endocrinology, the Children's Hospital, Zhejiang University School of Medicine, National Clinical Research Center for Child Health, 57 Zhugan Avenue, Yanan road, Hangzhou, Zhejiang, China, 310003.
Tel: 0571-86670013; Fax: 0571-86670013
Email: fif68@zju.edu.cn
Manuscript received 15 December 2021. Initial review completed 15 February 2022. Revision accepted 03 May 2022.
doi: 10.6133/apjcn.202206_31(2).0014

its contribution to energy intake has increased rapidly since 2004, especially among children. Sugar-sweetened beverages, ultra-processed grain products and fruits were the most prevalent choices for snacks.[8] In 2014, a national intervention program against obesity in Chinese children and adolescents reported that consumption of sugar-sweetened beverages is associated with a higher risk of abdominal obesity and accumulated hepatic fat.[9] It is postulated that overconsumption of sugar-sweetened beverages and ultra-processed food, which are both prevalent in the Western diet, contributes to childhood obesity in China. Meanwhile, a study based on two successive Nutrition and Health Surveys in Taiwan indicated that, at a later time, adolescents consumed less energy from original foods, with more from processed foods and ultra-processed foods, resulting in higher saturated fat and lower monounsaturated and polyunsaturated fat, dietary fiber, and micronutrient intakes.[10] Aiming to prevent obesity at the population level, the Chinese government has recommended a plant-based diet consisting of grains, fruits and vegetables, egg, meat, fish, soybean and milk. This Chinese government-recommended diet (GRD) also advises against the frequent consumption of sugar-sweetened beverages and ultra-processed food.

There have been several weight loss studies of Chinese children with multicomponent management programs including energy-restricted diets, mandatory exercise, and health education, that have demonstrated a general improvement in body weight, insulin resistance, and quality of life.[11-14] However, in consideration of the starvation response comprised of rising hunger, falling metabolic rate, and elevated stress hormone levels, long-term benefits of conventional energy-restricted diets remain controversial. Recently, the Carbohydrate-Insulin Model (CIM) of obesity had been proposed, emphasizing the consumption of processed, high-glycemic load carbohydrates leads to hormonal changes that promote energy deposition in adipose tissue, exacerbate hunger, and lower energy expenditure.[15] Thus, low-glycemic carbohydrate diets are predicted to show superiority on long-term clinical weight loss outcomes. In this study, we conducted a randomized trial accessing the effects of the GR diet and a modified GR diet with further restriction on the consumption of sugar and ultra-processed food, minimally processed diet (MPD), on children with overweight or obesity. We emphasized the importance of satiety without imposing limitations of food amount of the minimally processed diet, and self-management at home.

METHODS

Participants and study design

This study was a randomized parallel open-label study of a total of 60 children and adolescents with overweight or obesity. The trial was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved the Ethics Committee of the Children's Hospital of Zhejiang University School of Medicine (2019-IRB-024) and informed consent was taken from the parents/guardians of all individual participants. The study was registered on the Chinese Clinical Trial Registry (ChiCTR190002174). Participants were enrolled at the Department of Endocrinology in the Children's Hospital of Zhejiang University School of Medicine from June 2019 to August 2019 and the final date of follow-up was November 2019. The participants were randomly assigned to 2 groups; each group received an informal recommendation of 60 min/day of moderately vigorous physical activity but with different diet recommendations (GRD or MPD) and were followed up for 12 weeks. Randomization assignments were computer generated by the study statistician prior to the start of the study using random permuted block sizes of 2 or 4. Participants managed themselves at home and members of each group shared their experience as well as their daily menu on WeChat (a social communication platform) every day. Details of the trial protocol appear in Supplementary figure 1.

Inclusion criteria

The inclusion criteria were as follows: participants between 5 and 18 years old, with a BMI z-score of >2 or BMI z-score >1 combined with metabolic syndrome, no psychiatric disturbance, and commitment to participate in the study.

Exclusion criteria

Participants who were diagnosed with cardiovascular, pulmonary, renal, hepatic digestive system disease or chronic infection, or receiving medications known to alter body composition or metabolism were excluded. Those who had attended other weight loss programs in the past 3 months were also not included in the study.

Details on diet consultation

At the initiation of the trial, a registered dietitian (RD) invited each participant and his/her family to attend a face-to-face interview. One group was given advice on the GRD and the other was advised on the MPD. The key features of these two diets are summarized in Figure 1.

Participants of the GRD group were recommended to managing their daily energy intake ranging from 1,100 kcals to 2,300 kcals by age. Based on the target energy, specific amounts of different types of food were suggested. Frequent consumption of sugar-sweetened beverages and ultra-processed food was not recommended except for packaged breads, steamed buns and dumplings. The original recommendation letter for children and their families was provided with Supplementary figure 2.

Participants of MPD group were recommended to meticulously avoid sugar-sweetened beverages and ultra-processed food, as well as a moderate reduction of starchy foods such as grains, potato and banana, but with no restriction on the amount and type of non-starchy vegetables, protein-containing food, and cooking oil. The original recommendation letter for children and their families was provided with Supplementary figure 3.

Based on the NOVA food classification system, ultra-processed foods were defined as formulations of ingredients that result from a series of industrial processes, which colors, flavors, emulsifiers and other additives are frequently added in. Examples of ultra-processed foods were showed in Table 1.[16]

For better understanding and execution, each participant received a note listing the food types that are allowed or not, and a weekly diet recipe for reference. They

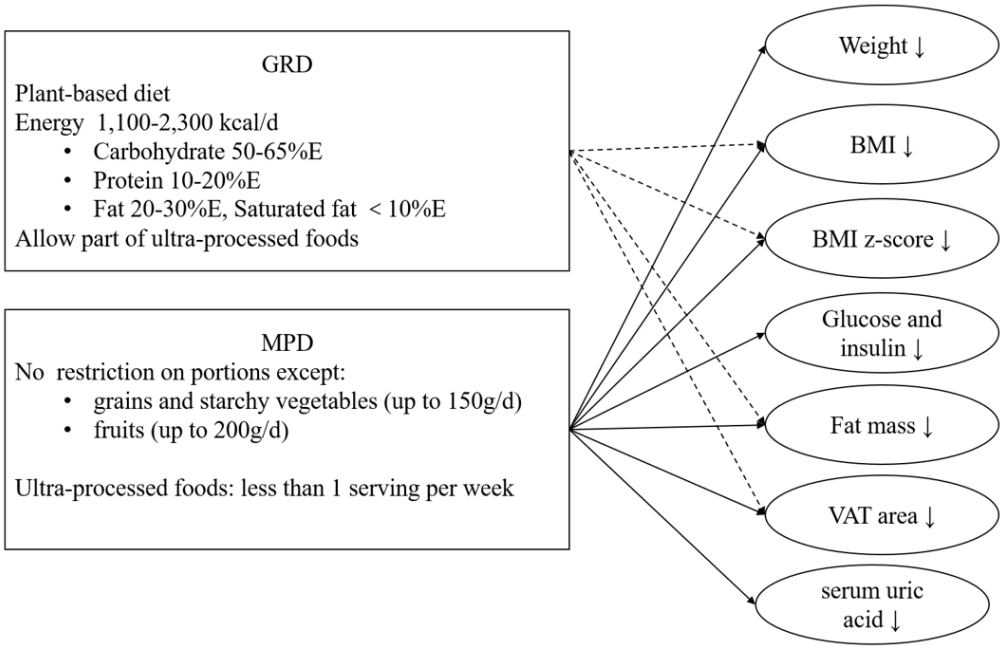


Figure 1. Key features of GRD and MPD and the findings of the study.

Table 1. Examples for ultra-processed foods

Food types	Examples
Grains	Mass-produced packaged breads and buns; cookies (biscuits), pastries, cakes, breakfast 'cereals', 'cereal' and 'energy' bars; ready to heat products including pre-prepared pies and pasta and pizza dishes; packaged 'instant' noodles and desserts
Dairy products	Ice-cream; margarines, milk drinks, 'fruit' yoghurts, infant formulas, follow-on milks
Meat and fish	Poultry and fish 'nuggets' and 'sticks', sausages, burgers, hot dogs, and other reconstituted meat products
Drink	Carbonated soft drinks, 'energy' drinks, 'fruit' drinks, 'cocoa' drinks
Others	Sweet or savoury packaged snacks, chocolate, candies (confectionery), spreads

were also trained in estimating food portions by a series of food replicas. In the next 12 weeks, the RD contacted the family on the phone or WeChat every 4 weeks to evaluate their compliance and to provide supportive advice.

Clinical and follow-up evaluations

Study visits were set at baseline and at 12 weeks after diet intervention. Each visit consisted of an anthropometric assessment and fasting blood collection for determining glucose and insulin, lipid metabolism and serum uric acid. Body composition was further examined by dual X-ray absorptiometry (DXA, HOLOGIC®).

Primary outcomes

Study participants were required to fast for more than 8 hours prior to laboratory examinations. The primary outcomes were changes in height, height for age z-score, weight, BMI z-score, fasting glucose and insulin, total cholesterol, triglyceride and serum uric acid. Anthropometric measurements were taken twice, and the average value was used for the analysis. Height for age z-score and BMI z-score were calculated using the WHO Anthro Plus software (www.who.int/en/).

Secondary outcomes

The secondary outcomes consisted of changes in fat mass %, fat mass index (FMI=fat mass [in kg]/ height^2 [in m^2]), visceral adipose tissue area (VAT area) and lean mass index (LMI=lean mass [in kg]/ height^2 [in m^2]). All outcomes were compared between baseline and week 12 in 17 subjects from the MPD group and 11 subjects from the GRD group. 3 subjects from the MPD group and 9 from the GRD group refused to do the DXA.

Statistical analysis

The outcome variables were described using mean (standard deviation, SD) for continuous variables with normal distribution, median (interquartile range, IQR) for continuous variables with non-normal distribution and n (%) for categorical variables. An independent t test and chi-square test were used to compare the two groups with respect to baseline data. Primary and secondary outcomes at the end of the intervention of each group were compared by two-way repeated measures ANOVA, including the effect of time, group, and the interaction of group and time, and further analysis was made by simple effect test. Non-normal-distributed variables were log-transformed to meet the normality assumptions of t test and ANOVA. A p-value of 0.05 was considered to indicate statistical significance. All analyses were conducted using SPSS Statistics v.20.

RESULTS

Study participants

As shown in Figure 2, a total of 60 overweight or obese subjects were included in this study and were randomly assigned into two groups of diet intervention. In the STJ diet group, one child participated in another weight-loss program during the trial and was excluded; 29 participants had successfully completed the 12-week STJ diet intervention. In the GR diet group, one child participated in another weight-loss program and two took metformin, and all three were eliminated. In addition, two other participants refused to finish the follow-up interview. Thus, a total of 25 participants in the GR diet group had successfully completed this study.

Primary outcomes

Demographic, anthropometric and clinical characteristics were similar at baseline between the MPD group and the GRD group (p>0.05, Table 2). The average age of the 54 participants was 10.8 (±1.9) years old, and 70.4% of them were men. After the 12-week intervention, their growth of height was obvious (two-way ANOVA, main effect of time, p<0.001), and their height for age z-score remained stable (two-way ANOVA, main effect of time, p=0.104). Meanwhile, significant group×time interactions were found for weight, BMI and BMI z-score. Further analysis of simple effect indicated an obvious decrease by time for weight in the MPD group (p<0.001) and a less significant change in the GRD group (p=0.053). BMI decreased significantly from 27 to 24.5 kg/m2 in the MPD group, and from 27 to 26 kg/m2 in the GRD group (p<0.001) while no differences were found between groups of week 12 (p=0.166). Similarly, BMI z-score decreased significantly by time for two groups (p<0.001) while no differences were found between groups of week 12 (p=0.339).

As depicted in Table 2 and 3, distinct improvements by time were observed for fasting glucose from 5.6 to 4.9 mmol/L and fasting insulin from 20.9 to 12.9 only in the MPD group (p=0.005, p=0.001 respectively). In addition, total cholesterol and serum uric acid decreased significantly by time in the MPD group (p=0.007, p=0.006 respectively); the GRD group only showed improvement on triglyceride (p=0.028). Nonetheless, there was no significant difference by group of week 12 for fasting glucose, fasting insulin, total cholesterol, triglyceride or serum uric acid.

The changes in BMI z-score, fasting glucose, fasting insulin, and serum uric acid for each participant are shown in Figure 3. In the MPD group, 28 participants showed a reduced BMI z-score and 5 of them had a reduction of more than one unit. In the GRD group, 23 participants had a reduced BMI z-score and 1 of them had a reduction of more than one unit. In terms of the improvement in fasting glucose and fasting insulin, 11 participants in the MPD group showed improvement from abnormal to normal levels, 13 participants remained normal (fasting glucose <5.6 mmol/L and fasting insulin <24.9 μIU/mL), and only 1 participant in the MPD group had a normal to abnormal change of fasting glucose. In the GRD group, 8 participants changed from abnormal to normal, 8 participants remained normal, and 3 participants showed a normal to abnormal change. In comparison, both groups showed a similar trend in the normalization of fasting glucose and insulin (p=0.359) at week 12. Furthermore, 22 participants in the MPD group had a reduction of serum uric acid, whereas 13 participants in

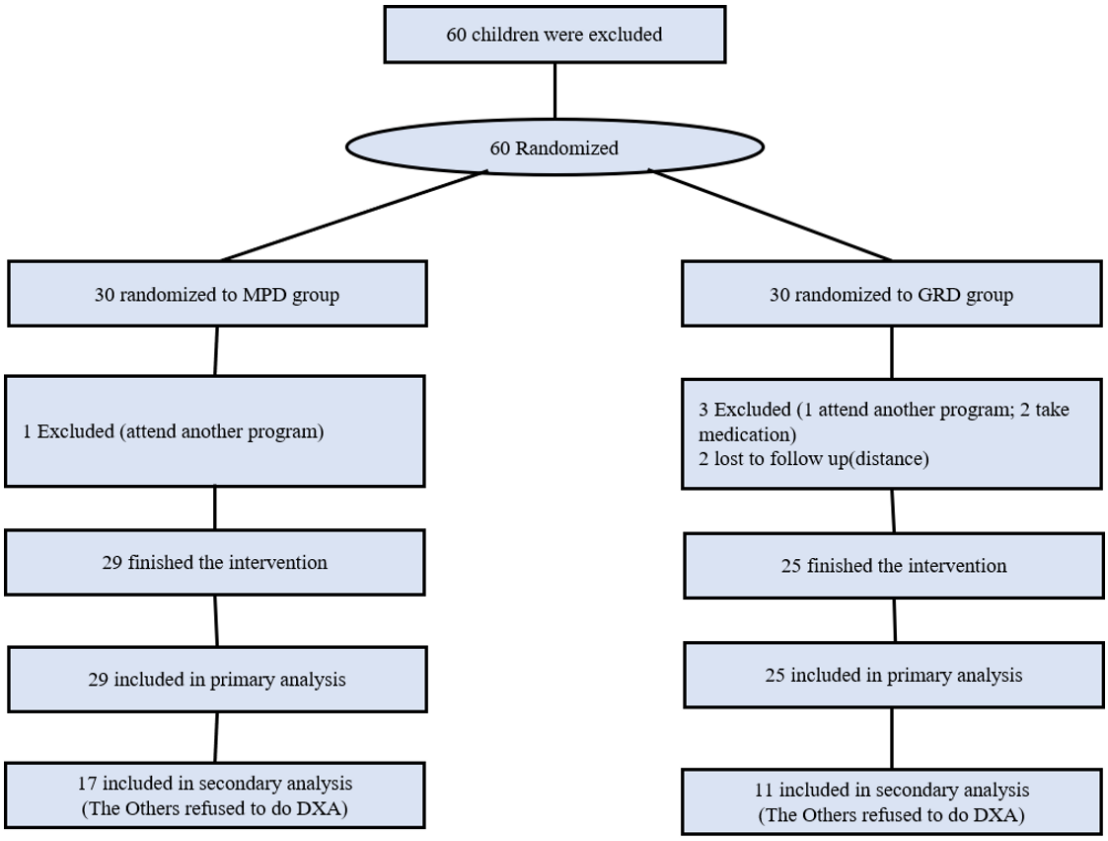


Figure 2. Study design.

Table 2. Baseline and week 12 comparisons for primary outcomes

Outcomes	Baseline	Week 12	F	*p* value
Age, mean (SD), y				0.290
MPD	10.5 (1.8)			
GRD	11.1 (2.1)			
Gender				0.810
MPD	Men 20; Women 9			
GRD	Men 18; Women 7			
Height, mean (SD), cm				
MPD	149 (13.0)	151 (12.9)		
GRD	153 (12.3)	154 (12.3)		
Time			155	<0.001
Group			1.22	0.275
Time × Group			0.081	0.776
Height z-score, mean (SD)				
MPD	1.2 (0.9)	1.2 (0.9)		
GRD	1.3 (0.8)	1.2 (0.9)		
Time			2.73	0.104
Group			0.022	0.883
Time × Group			0.206	0.652
Weight, median (IQR), kg				
MPD	58 (19.6)	54 (18.9)		
GRD	62 (23.3)	59.8 (23)		
Time			48.65	<0.001
Group			1.11	0.297
Time × Group			16.57	<0.001
BMI†, mean (SD), kg/m^2				
MPD	27.0 (4.1)	24.5 (3.9)		
GRD	27.0 (4.1)	26.0 (4.0)		
Time			103	<0.001
Group			16.6	0.470
Time × Group			16.9	<0.001
BMI Z-score, mean (SD)				
MPD	2.9 (0.7)	2.3 (0.7)		
GRD	2.8 (0.8)	2.5 (0.7)		
Time			115	<0.01
Group			0.048	0.827
Time × Group			9.05	0.004
Fasting glucose, median (IQR), mmol/L				
MPD	5.6 (1.3)	4.9 (0.7)		
GRD	5.5 (1.3)	5.3 (0.8)		
Time			9.8	0.003
Group			0.746	0.392
Time × Group			0.809	0.372
Fasting insulin, median (IQR), μIU/mL				
MPD	20.9 (15.4)	12.9 (10.9)		
GRD	21.5 (23. 8)	17.4 (12.5)		
Time			10.0	0.003
Group			0.859	0.358
Time × Group			2.83	0.099

MPD: minimally processed diet; GRD: government-recommended diet; IQR: inter quartile range; BMI: body mass index.
†Calculated as weight in kilograms divided by height in meters squared.

the GRD group showed a reduction.

Secondary outcomes

For further understanding of the effects of diet intervention on fat mass and lean mass, 17 participants of the MPD group and 11 participants of the GRD group had taken examination of body composition at baseline and week 12 (Table 4). The results indicated great reductions by time for fat mass percentage and fat mass index in both group and no significant difference was found by group of week 12. As for the amount of visceral fat, great reductions by time were observed in both group and a significant difference was found by group of week 12 (p=0.041). However, a slight reduction of lean mass index by time was observed in MPD group (p=0.009), while no significant changes were observed in the GRD group.

DISCUSSION

Here, we conducted a randomized parallel open-label study to evaluate the effectiveness of the Chinese GR diet in overweight or obese children and examine the effects of further restriction on sugar and ultra-processed food (minimally processed diet) over the GR diet. An important recommendation is the emphasis on satiety without limiting energy intake of the participants in the MPD group. According to recent reports, most studies on a diet intervention in children with obesity used an energy restriction approach with energy intake below the govern-

Table 3. Baseline and week 12 comparisons for primary outcomes

Outcomes	Baseline	Week 12	F	*p* value
Triglyceride, median (IQR), mmol/L				
MPD	1.1 (0.7)	0.9 (0.5)		
GRD	1.0 (0.9)	0.9 (0.3)		
Time			5.23	0.026
Group			0.004	0.950
Time × Group			1.06	0.308
Total cholesterol, mean (SD), mmol/L				
MPD	4.5 (0.8)	4.2 (0.7)		
GRD	4.1 (0.8)	4.0 (0.9)		
Time			6.19	0.016
Group			1.98	0.166
Time × Group			1.73	0.194
Serum uric acid, mean (SD), μmol/L				
MPD	409 (86.8)	370 (93.6)		
GRD	404 (93.7)	390 (87.5)		
Time			6.89	0.011
Group			1.11	0.739
Time × Group			1.65	0.204

MPD: minimally processed diet; GRD: government-recommended diet; IQR: inter quartile range.

Table 4. Body composition comparisons between MPD and GRD

Outcomes	Baseline	Week 12	F	*p* value
Fat mass percentage[†], mean (SD), %				
MPD	40.9 (5.6)	35.3 (6.6)		
GRD	39.4 (6.2)	36.7 (7.1)		
Time			51.9	<0.001
Group			0.001	0.969
Time × Group			6.45	0.017
Fat mass index[‡], median (IQR), kg/m^2				
MPD	10.9 (2.6)	8.7 (2.7)		
GRD	10.4 (4.8)	9.2 (3.8)		
Time			71.6	<0.001
Group			0.063	0.804
Time × Group			13.0	0.001
VAT area, mean (SD), cm^2				
MPD	101 (22.6)	74.3 (24.8)		
GRD	110 (39.7)	99.1 (36.6)		
Time			55.0	<0.001
Group			2.19	0.151
Time × Group			9.96	0.004
Lean mass index[§], mean (SD), kg/m^2				
MPD	15.8 (3.3)	15.2 (3.0)		
GRD	16.0 (1.8)	16.2 (2.1)		
Time			1.69	0.205
Group			0.304	0.586
Time × Group			4.91	0.036

MPD: minimally processed diet; GRD: government-recommended diet; IQR: inter quartile range; VAT area: visceral adipose tissue area.
[†]Calculated as fat mass in kilograms divided by weight in kilograms the multiplied by 100%.
[‡]Calculated as fat mass in kilograms divided by height in meters squared.
[§]Calculated as lean mass in kilograms divided by height in meters squared.

ment recommendation and varied macronutrient combinations. These studies indicated that a reduced-energy diet could provide a weight reduction in children and adolescents with obesity and overweight.[17,18] In our study, we observed that the GR diet could promote effective weight loss in children and adolescents with obesity/overweight with an energy intake appropriated for sex and age. Intriguingly, our results also showed that a 12-week self-intervention using the minimally processed diet, which has no imposed restriction of energy intake, could lead to a more significant decrease on weight and visceral fat mass among overweight/obese children and adolescents. In addition, there were no adverse effects of the minimally processed diet on triglycerides and cholesterol even if the amounts of fat and protein were not limited in the diet. No imposed restriction of energy intake, protein or fat can ensure satiety and make children more satisfied, which is conducive to the continuation of the diet. Although previous studies have demonstrated that intensive diet interventions are effective,[17-19] they are not easy to implement into the daily lives of children. Our study here illustrates the effectiveness of this self-managed diet intervention program with minimum interference on weight loss of children and adolescents with obesity/overweight, sug-

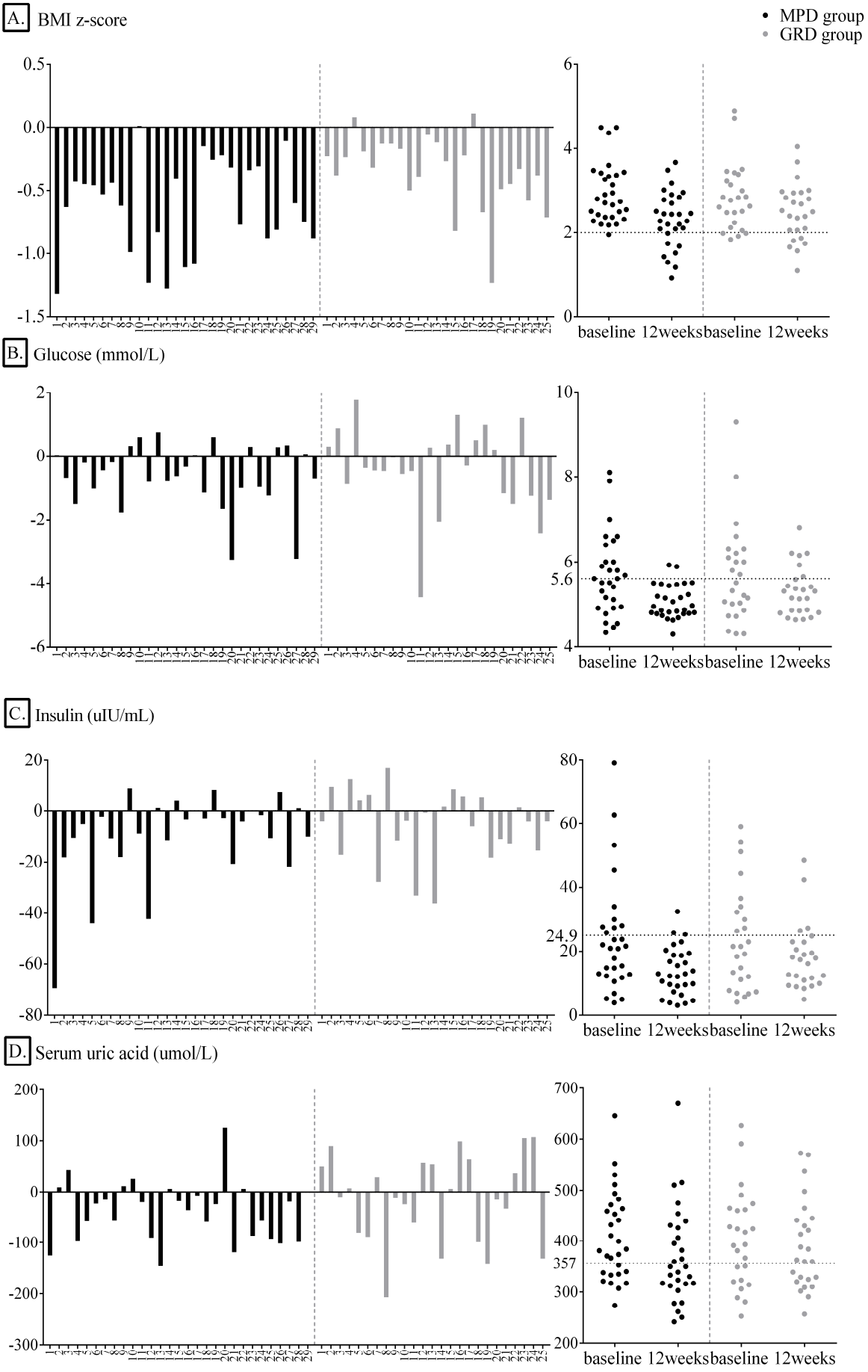


Figure 3. Change of individual measurement for the primary outcomes. Each bar represents 1 child sorted by treatment and baseline value. The dotted line means the change is 0.

gesting possible implementation at the community level.

The consumption of industrially processed food has been considered a dietary risk factor associated with obesity and metabolic disorders among children, adolescents, and adults. A recent inpatient randomized controlled trial of 20 weight-stable adults receiving either the ultra-processed or unprocessed diets for 2 weeks, then altered to the other one in the next 2 weeks, showed a greater energy intake during the consumption of the ultra-processed diet leading to significant weight gain and body fat mass.[20] Several epidemiological investigations in children have indicated that the consumption of industrially processed food is associated with a higher risk of abdominal obesity, adverse changes in glucose and lipid profiles, and food addiction.[21-23] Such findings have also been observed in similar studies on sugar-sweetened beverages.[24] Sucrose and high-fructose corn syrup (HFCS) are common sweeteners in industrially processed food and sugar-sweetened beverages, which contain 50% and 55% of fructose respectively. Overconsumption of fructose has been shown to promote dyslipidemia, hepatic steatosis, insulin resistance, increased risk of hepatocellular damage, and a disposition towards continuous food intake.[25,26] Several randomized clinical trials have revealed an improvement in BMI and non-alcoholic fatty liver disease with a low fructose intake.[27-30] In addition, Fructose is known to induce uric acid production by increasing ATP degradation to AMP and accelerating de novo purine synthesis. Greater soft drink and fructose consumption is associated with increased serum uric acid.[31] It can be said that fructose overconsumption favors obesity and reduction of ultra-processed food and sugar-sweetened beverage encourages weight loss. Our findings support a dietary approach which emphasizes an intake of minimally processed foods and beverages (with little if any added fructose) in order to reduce body fat mass and visceral fat, along with improved fasting glucose, fasting insulin and serum uric acid, in contrast to the GR diet. As our dietary intervention was based on education rather than prescription or enforcement, adherence to it is likely to be more acceptable and successful across communities.

Lack of physical activity has been an important factor contributing to obesity.[32] Physical activity have been shown to positively affect body composition by reducing body fat while increasing fat-free mass.[33] In this study, both groups received a recommendation on daily physical activity but its efficacy on weight loss was not evaluated. Future research should be carried out to compare diet-only intervention with combination of physical

The study has several limitations. First, there was a lack of dietary intake assessments the at baseline and throughout the trial. Thus, we were unable to provide convincing evidence about the effectiveness of our diet consultation. Second, the number of participants qualified for this study was small since many obese children we received at the hospital are school-aged and usually have breakfast and lunch at school, and therefore could not be carefully managed by their parents. Third, in despite daily self-reporting, physical activity was not quantified and available for analysis. Further research for longer, with a larger sample and improved documentation of dietary intake and exercise should provide useful insight into the utility of the test intervention used here.

Conclusion

A 12-week self-intervention combining the Chinese government-recommended diet with physical activities was effective for weight loss in children and adolescents with obesity/overweight. Consistent with recent studies on the adverse effects of sugar-sweetened beverages and ultra-processed foods on obesity, further restriction of these foods in the minimally processed diet was found to be more effective on weight loss and may be beneficial for improving insulin resistance. More research is needed to assess the long-term effectiveness of these diet interventions on weight loss in children and adolescents with obesity/overweight, and their applicability to the general public.

AUTHOR DISCLOSURES

All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

This work was supported by National Key Research and Development Programme of China [2016YFC1305301 to J.F.], National Natural Science Foundation of China [81570759, 81270938 to J.F.], and Zhejiang Provincial Key Disciplines of Medicine (Innovation Discipline) [11-CX24 to J.F.].

REFERENCES

1. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, Flegal KM. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. JAMA. 2016;315:2292-9. doi: 10.001/jama.2016.6361.
2. Craig MH, Margaret DC, Cheryl DF, Cynthia LO. Prevalence of obesity among adults and youth: United States, 2015-2016. NCHS Data Brief. 2017;288:1-8.
3. Song Y, Wang HJ, Dong B, Ma J, Wang Z, Agardh A. 25-year trends in gender disparity for obesity and overweight by using WHO and IOTF definitions among Chinese school-aged children: a multiple cross-sectional study. BMJ Open. 2016;6:e011904. doi: 10.1136/bmjopen-2016-011904.
4. Wang S, Dong YH, Wang ZH, Zou ZY, Ma J. Trends in overweight and obesity among Chinese children of 7-18 years old during 1985-2014. Chinese Journal of Preventive Medicine. 2017;51:300-5. doi: 10.3760/cma.j.issn.0253-9624.2017.04.005. (In Chinese)
5. Pan XF, Wang L, Pan A. Epidemiology and determinants of obesity in China. Lancet Diabetes Endocrinol. 2021;9(6): 373-92. doi: 10.1016/S2213-8587(21)00045-0.
6. Louisa JE, Karen R, Tamara B, Emma M, Lena AK, Liane A et al. Interventions for treating children and adolescents with overweight and obesity: an overview of Cochrane reviews. Int J Obes (Lond). 2018;42:1823-33. doi: 10.1038/s41366-018-0230-y.
7. Liu D, Zhao LY, Yu DM, Ju LH, Zhang J, Wang JZ, Zhao WH. Dietary patterns and association with obesity of children aged 6 - 17 years in medium and small cities in China: findings from the CNHS 2010 - 2012. Nutrients. 2018;11:3. doi: 10.3390/nu11010003.
8. Wang ZH, Zhai FY, Zhang B, Popkin BM. Trends in Chinese snacking behaviors and patterns and the social-demographic role between 1991 and 2009. Asia Pac J Clin Nutr. 2012;21:253-62. doi: 10.6133/apjcn.2012.21.2.13
9. Gui ZH, Zhu YN, Cai L, Sun FH, Ma YH, Jing J, Chen YJ. Sugar-sweetened beverage consumption and risks of obesity and hypertension in Chinese children and adolescents: a

national cross-sectional analysis. Nutrients. 2017;9:1302. doi: 10.3390/nu9121302.
10. Chen YC, Huang YC, Lo YC, Wu HJ, Wahlqvist ML, Lee MS. Secular trend towards ultra-processed food consumption and expenditure compromises dietary quality among Taiwanese adolescents. Food Nutr Res. 2018;62: 1565. doi: 10.29219/fnr.v62.1565.
11. Cao ZJ, Wang SM, Chen Y. A randomized trial of multiple interventions for childhood obesity in China. Am J Prev Med. 2015;48:552-60. doi: 10.1016/j.amepre.2014.12.014.
12. Diao H, Wang H, Yang L, Li T. The impacts of multiple obesity-related interventions on quality of life in children and adolescents: a randomized controlled trial. Health Qual Life Outcomes. 2020;18:213. doi: 10.1186/s12955-020-01459-0.
13. Hao M, Han W, Yamauchi T. Short-term and Long-term effects of a combined intervention of rope skipping and nutrition education for overweight children in Northeast China. Asia Pac J Public Health. 2019;31:348-58. doi: 10.1177/1010539519848275.
14. Jiang Z, Liu Q, Huang R, Qing L, Yu T, Zhang D, Peng L, Li X. Effects of lifestyle intervention on diet, physical activities and health outcomes of obese children and adolescent. Chinese Journal of Clinical Nutrition. 2020;28: 33-8. doi: 10.3760/cma.j.cn115822-20190729-001 01. (In Chinese)
15. Ludwig DS, Ebbeling CB. The carbohydrate-insulin model of obesity: beyond "calories in, calories out". JAMA Intern Med. 2018;178:1098-103. doi: 10.1001/jamainternmed. 2018.2933.
16. Monteiro CA, Cannon G, Levy RB, Moubarac JC, Louzada ML, Rauber F et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutr. 2019;22:936-41. doi: 10.1017/S1368980018003762.
17. Ho M, Garnett SP, Baur LA, Burrows T, Stewart L, Neve M, Collins C. Impact of dietary and exercise interventions on weight change and metabolic outcomes in obese children and adolescents: a systematic review and meta-analysis of randomized trials. JAMA Pediatr. 2013;167:759-68. doi: 10.1001/jamapediatrics.2013.1453.
18. Gow ML, Ho M, Burrows TL, Baur LA, Stewart L, Hutchesson MJ, Cowell CT, Collins CE, Garnett SP. Impact of dietary macronutrient distribution on BMI and cardiometabolic outcomes in overweight and obese children and adolescents: a systematic review. Nutr Rev. 2014;72: 453-70. doi: 10.1111/nure.12111.
19. van der Baan-Slootweg O, Benninga MA, Beelen A, van der Palen J, Tamminga-Smeulders C, Tijssen JG, van Aalderen WM. Inpatient treatment of children and adolescents with severe obesity in the Netherlands: a randomized clinical trial. JAMA Pediatr. 2014;168:807-14. doi: 10.1001/ jamapediatrics.2014.521.
20. Kevin DH, Alexis A, Robert B, Hongyi C, Thomas C, Kong YC et al. Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of ad libitum food intake. Cell Metab. 2019;30:226. doi: 10. 1016/j.cmet.2019.05.020
21. Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. Nutr Metab Cardiovasc Dis. 2015;25:116-22. doi: 10.1016/j. numecd.2014.08.001.
22. Costa CS, Rauber F, Leffa PS, Sangalli CN, Campagnolo PDB, Vitolo MR. Ultra-processed food consumption and its effects on anthropometric and glucose profile: a longitudinal study during childhood. Nutr Metab Cardiovasc Dis. 2019; 29:177-84. doi: 10.1016/j.numecd.2018.11.003.
23. Filgueiras AR, Pires de Almeida VB, Koch Nogueira PC, Alvares Domene SM, Eduardo da Silva C, Sesso R, Sawaya AL. Exploring the consumption of ultra-processed foods and its association with food addiction in overweight children. Appetite. 2019;135:137-45. doi: 10.1016/j.appet.2018.11. 005.
24. Shearrer GE, Daniels MJ, Toledo-Corral CM, Weigensberg MJ, Spruijt-Metz D, Davis JN. Associations among sugar sweetened beverage intake, visceral fat, and cortisol awakening response in minority youth. Physiol Behav. 2016;167:188-93. doi: 10.1016/j.physbeh.2016.09.020.
25. Lustig RH. Fructose: it's "alcohol without the buzz". Adv Nutr. 2013;4:226-35. doi: 10.3945/an.112.002998.
26. Nier A, Brandt A, Conzelmann IB, Ozel Y, Bergheim I. Non-alcoholic fatty liver disease in overweight children: role of fructose intake and dietary pattern. Nutrients. 2018; 10:1329. doi: 10.3390/nu10091329.
27. Vos MB, Weber MB, Welsh J, Khatoon F, Jones DP, Whitington PF, McClain CJ. Fructose and oxidized low-density lipoprotein in pediatric nonalcoholic fatty liver disease: a pilot study. Arch Pediatr Adolesc Med. 2009; 163:674-5. doi: 10.1001/archpediatrics.2009.93.
28. Maier IB, Stricker L, Ozel Y, Wagnerberger S, Bischoff SC, Bergheim I. A low fructose diet in the treatment of pediatric obesity: a pilot study. Pediatr Int. 2011;53:303-8. doi: 10. 1111/j.1442-200X.2010.03248.x.
29. Mager DR, Iniguez IR, Gilmour S, Yap J. The effect of a low fructose and low glycemic index/load (FRAGILE) dietary intervention on indices of liver function, cardiometabolic risk factors, and body composition in children and adolescents with nonalcoholic fatty liver disease (NAFLD). JPEN J Parenter Enteral Nutr. 2015;39: 73-84. doi: 10.1177/0148607113501201.
30. Jeffrey BS, Patricia UN, Jean AW, Jorge EA, Maria C, Kathryn EH et al. Effect of a Low free sugar diet vs usual diet on nonalcoholic fatty liver disease in adolescent boys: a randomized clinical trial. JAMA. 2019;321:256-65. doi: 10. 1001/jama.2018.20579.
31. Rho YH, Zhu Y, Choi HK. The epidemiology of uric acid and fructose. Semin Nephrol. 2011;31:410-9. doi: 10.1016/j. semnephrol.2011.08.004.
32. Keane E, Li X, Harrington JM, Fitzgerald AP, Perry IJ, Kearney PM. Physical activity, sedentary behavior and the risk of overweight and obesity in school-aged children. Pediatr Exerc Sci. 2017;29:408-18. doi: 10.1123/pes.2016-0234.
33. Psaltopoulou T, Tzanninis S, Ntanasis-Stathopoulos I, Panotopoulos G, Kostopoulou M, Tzanninis IG, Tsagianni A, Sergentanis TN. Prevention and treatment of childhood and adolescent obesity: a systematic review of meta-analyses. World J Pediatr. 2019;15:350-81. doi: 10.1007/s12519-019-00266-y.

Trial Protocols

I. Trail's objective

To determine whether, self-management of the Chinese government-recommend diet (GRD) or a modified diet with further restriction of sugar and ultra-processed foods (minimally processed diet, MPD) in the absence of energy restriction, is effective at achieving weight loss in obese/overweight children and adolescents.

II. Design

It was an open-label, randomized parallel study of overweight/obese children and adolescents. A total of 60 overweight/obese children and adolescents aged 5 to 18 were randomized 1:1 to an education of GRD or MPD and self-managed at home for 12 weeks. During the 12-week period, compliance of the participants was evaluated by phone or WeChat (a social communication media) every 4 weeks and participants of each group shared their experience as well as daily menu on WeChat.

Inclusion criteria

Participants of age between 5 and 18, with Body Mass Index (BMI) z-score of > 2 or BMI z-score of > 1 combined with metabolic syndrome, no psychiatric disturbance, and commitment to participate in the study.

Exclusion criteria

Participants who were diagnosed with cardiovascular, pulmonary, renal, hepatic digestive system disease or chronic infection, or receiving medications known to alter body composition or metabolism were excluded. Those who had attended other weight loss programs in the past 3 months were also not included in the study.

III. Outcomes

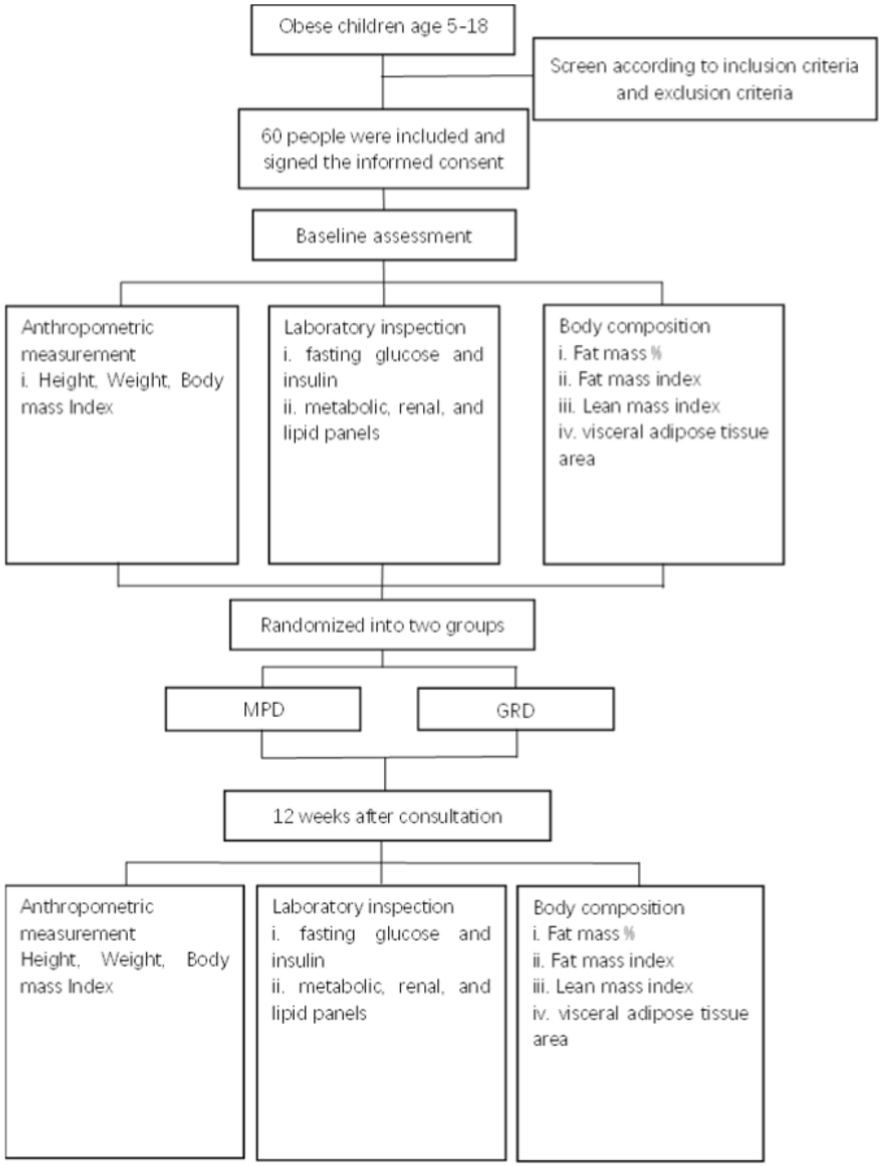
Primary Outcomes

Study participants were required to fast for more than 8 hours prior to laboratory examinations. The primary outcomes were changes in height, height for age z-score, weight, BMI z-score, fasting glucose and insulin, total cholesterol, triglyceride and serum uric acid. Anthropometric measurements were taken for two times, and the average value was used for the analysis. Height for age z-score and BMI z-score were calculated using the WHO Anthro Plus software (www.who.int/en/).

Secondary Outcomes

The secondary outcomes consisted of changes in fat mass %, fat mass index (FMI=fat mass [in kg]/ height2 [in m2]), visceral adipose tissue area and lean mass index (LMI=lean mass [in kg]/ height2 [in m2]). The laboratory measurements were performed by the clinical laboratory at the Children's Hospital of Zhejiang University School of Medicine.

IV. Methodology



Supplementary figure 1. Trial protocols.

Dear parents and kids:

For better control on children' s weight, please change your diet following these recommendations:

Choose a balance diet appropriate to age:

Types	Units	2-3y	4-6y	7-10y	11-13y	14-18y
Grain	g/d	85-100	100-150	150-200	225-250	250-300
Vegetable	g/d	200-250	250-300	300	400-450	450-500
Fruit	g/d	100-150	150	150-200	200-300	300-350
Meat Egg Aquatic product	g/d	50-70	70-105	100-120	150	150-200
Dairy	g/d	500	350~500	300	300	300
Soybean	g/d	5-15	15	15	15	15-25
Nut	g/d			7-10		
Oil	g/d	15-20	20-25	20-25	25-30	

For extra meal, we recommend low-caloric-dense food such as vegetables and fruits.

Reduce the consumption of sugar-sweetened beverages and proceed food contain added sugar such as cake, chocolate, cookies and candied fruit.

Reduce the intake of saturated fats, trans fats, and cholesterol. On the other hand, monounsaturated fats, polyunsaturated fats, and omega-3 fats is recommended.
- Sources of saturated fat
bacon, pork intestines, high-fat meats (such as sausages, hot dogs, pork ribs and preserved meat), the skins of poultry, chocolate, coconut, coconut oil, butter, lard, ghee, palm oil and palm kernel oil.
- Sources of trans fat
hydrogenated vegetable oils and foods containing them (some baked goods and snacks), margarine, ghee, some fast food such as French fries.
- Sources of cholesterol
high-fat meat and poultry, crab roe, organ meats
- Sources of monounsaturated fat
Avocado, nuts (such as almonds, cashews, pecans, peanuts, walnuts), olive oil and olives, peanut butter and peanut oil, sesame, canola oil
- Sources of polyunsaturated fat
Corn oil, sesame, pumpkin seeds, cotton seed oil, sunflower and sunflower seed oil, walnuts, linseed, safflower seed oil, sesame paste
- Sources of omega-3 fats
Albacore tuna, sardines, herring, salmon, rainbow trout, mackerel, flaxseed, soybean oil, canola oil, walnuts

Be more active.
- Aim for a goal of 60 minutes of activity daily. It can start with 15 minutes than increase gradually to 60 minutes.
- Optional exercises include:
• aerobic exercise: hiking, skateboarding, rollerblading, cycling, brisk walking, rowing, hiking, chasing, jumping rope, martial arts, ball games, swimming, dancing
• muscle-strengthening activities: tug-of-war, push-ups (kneeling on the floor), resistance exercises (using weights or resistance bands), sit-ups, swings, rock climbing
• bone strengthening activities: hopscotch, jumping, rope skipping, running, gymnastics, ball games
- Limit TV and screen time to less than 2 hours daily
- Encourage reading or crafts rather than TV time. After 60 minutes of inactivity your child should be encouraged to be active.
- Avoid having the TV on during mealtimes. Don't put a TV in your child's bedroom.

Avoid eating outside and enjoy home-made food.

Thank you for your corporation.

Supplementary figure 2. Chinese government-recommended diet (GRD) recommendation letter.

Dear parents and kids:

For better control on children's weight, please change your diet following these recommendations:

Limit sugar-sweetened beverages and processed food contain added sugar such as cake, chocolate, cookies and candied fruit. Less than 1 serving per week.

No fried food or other unhealthy fat such as puffed food, processed meat. However, there is no limitation on amount of fat from meat, fish, nuts, avocado and plant oil cooking in a healthy way.

We suggest to take fruits no more than 200g or juices no more than 50ml per day.

We also advice to reduce the intake of grains and starchy vegetables to 150g per day. The starchy vegetables include potatoes, sweet potatoes, corn, pumpkin, yams, taro, peas, broad beans and chestnuts.

When cooking porridge, use broth, chicken soup, fish soup instead of water to increase hunger tolerance.

There are only three meals a day but child can decide how much he will have that makes him feel full and satisfied. Vegetables, fish, poultry, meat and eggs can be provided according to child's needs, as the intake of grains and starchy vegetables per meal is limited.

A five-day recipe designed by dietitian is provided for reference.

Be more active.
- Aim for a goal of 60 minutes of activity daily. It can start with 15 minutes than increase gradually to 60 minutes.
- Optional exercises include:
• aerobic exercise: hiking, skateboarding, rollerblading, cycling, brisk walking, rowing, hiking, chasing, jumping rope, martial arts, ball games, swimming, dancing
• muscle-strengthening activities: tug-of-war, push-ups (kneeling on the floor), resistance exercises (using weights or resistance bands), sit-ups, swings, rock climbing
• bone strengthening activities: hopscotch, jumping, rope skipping, running, gymnastics, ball games
- Limit TV and screen time to less than 2 hours daily
- Encourage reading or crafts rather than TV time. After 60 minutes of inactivity your child should be encouraged to be active.
- Avoid having the TV on during mealtimes. Don't put a TV in your child's bedroom.

Thank you for your corporation.

Five-day recipe

meals	breakfast	lunch	dinner
Day 1	• Fish congee (made with rice 30g and fish) • egg • milk • cucumber salad (made with olive oil, cucumber and walnut) • a piece of pomelo	• Rice 50g • Pork and cauliflower • Radish soup • Beef	• Rice cakes with pork and cabbage (rice cakes 50g) • Mushroom soup • Shrimp (boiled) • Streaky pork stewed with carrot
Day 2	• Sweet potato 50g • scrambled eggs with tomatoes • yogurt • blueberry 1/2 cup	• Rice 50g • spinach • Roasted chicken wings • Tofu and fish soup	• Rice 50g • Belt fish braise in soy sauce • Amaranth • Chicken soup
Day 3	• century egg and pork porridge (rice 30g) • Streamed egg custard with clam • Wood ear fungus salad (made with olive oil, peanut, wood ear fungus and vinegar) • chees • 1/2 orange	• Rice 50g • shrimp with lettuce stem (lettuce stem, shrimp, carrot, walnut) • seaweed and egg soup • pork and broccoli	• Sweet potato starch noodle 70g • Curry Chicken • Beef and tomato • Pigeon soup
Day 4	• Taro 50g • Kelp salad (olive oil, kelp) • nuts • egg • mill • 1/2 apple	• Rice 50g • twice-cooked pork • winter melon and rib soup • chrysanthemum crown daisy	• Konjac noodle with cabbage (konjac 50g) • gingko with celery stem and lily • Beef and green pepper • Radish and fish soup
Day 5	• Rice noodles (egg, cabbage, pork, carrot, mushroom rice noodles 50g) • peanuts • milk • 1 kiwi fruit	• Rice 50g • Kalimeris and pork liver • celery and pork • tomato egg soup	• Potato 50g • crab • egg with Chinese chives • duck and bamboo shoot soup

Supplementary figure 3. Minimally processed diet (MPD) recommendation letter.