



Dietary Patterns and Metabolic Syndrome in Children and Adolescents: A Systematic Review

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Received 2017 June 28; Revised 2017 August 11; Accepted 2017 August 23.

Abstract

Context: Given the high prevalence of metabolic syndrome (MetS) among children and adolescents, the role of dietary habits on MetS development, and formation of food preferences from childhood, it is highly important to determine the association of dietary habits with pediatric MetS.

Objective: This study aimed at systematically reviewing the association of different dietary patterns with MetS in a pediatric age group.

Data Sources and Study Selection: An electronic search was conducted in international electronic databases including PubMed, Cochrane, Scopus, Google Scholar, and domestic data sources. The following keywords were used ;(("Child"(Mesh) OR "Adolescent"(Mesh) AND ("Metabolic Syndrome"(Mesh) AND "Diet"(Mesh) OR "Dietary Pattern" (Mesh)).We included all published data on the association of MetS (presence of a cluster of 3 or more metabolic abnormalities) with dietary pattern in the pediatric age group aged 3 to 18 years.

Data Extraction: At first, 4194 articles were identified (PubMed: 566; Scopus: 60; Google scholar: 3550; domestic data source: 18).

Results: After quality assessment, 17 studies were selected for text appraisal, of which 15 qualified articles were evaluated at the final step. The number of total population and points of data were 19 298. From reported studies, 10 had a cross-sectional design, 3 were interventional studies, 1 was cohort study, and 1 was a systematic review on Korean adolescents.

Conclusion: Our results indicated that the Mediterranean diet or diets with a higher score of healthy eating index, i.e., with higher content of grains, vegetables, fruits, milk, and meat/meat alternatives, have inverse associations with the prevalence of MetS, whereas Western type diets are associated with higher frequency of MetS in children and adolescents.

Keywords: Metabolic Syndrome, Dietary Pattern, Pediatrics, Child, Adolescents, Review

1. Context

Metabolic syndrome (MetS) is a clustering of metabolic risk factors including hypertension, central obesity, dyslipidemia, and fasting hyperglycemia, which is associated with different cardio metabolic disorders in childhood as well as many noncommunicable diseases (NCD) in adulthood (1, 2).

The prevalence of MetS is increasing worldwide in all age groups, and it is suggested to be mainly due to the nutritional transition state (3).

Prevalence of pediatric MetS has been reported to be 3% to 4% worldwide. The incidence of MetS has been increasing, especially in developing countries (4, 5).

A growing number of evidences suggest that MetS originates from early life and is associated with increased risk

of NCDs, and mainly cardiovascular disease (CVD) in adulthood (6). Previous reports have indicated that lifestyle including nutritional habits and physical activity are considered as the most important independent risk factors for MetS (7).

Evaluation of dietary pattern is now considered a more appropriate approach than evaluating the role of isolated nutrients in this field (8). Different dietary patterns have been introduced in this regard including Mediterranean dietary pattern (MDP), low carbohydrate diet score (LCD), Western diet, dietary approaches to stop hypertension (DASH), etc. (9).

Several studies have documented the effectiveness of different dietary habits in the management of MetS in pediatric population; however, the results are controversial.

A systematic review has supported the protective effects of the MDP on development of MetS (10). In the pediatric age group, such studies are scarce and inconclusive (11). Thus, it is a priority to determine the impact of different dietary patterns on MetS in children and adolescents to design more interventional studies.

2. Objectives

Given the high prevalence of MetS with its increasing trend among children and adolescents and given the role of different components of life style including dietary habits, in this study we aimed at systematically reviewing the association of different dietary patterns with MetS among pediatric population.

3. Data Sources

The protocol of this study was approved by the pediatric and nutrition board reviews and the regional ethics committee of Isfahan University of Medical Sciences. We conformed to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) checklist for reporting systematic reviews (12).

4. Study Selection

The inclusion criteria for this study were as follows: (1) human studies; (2) cohort (both prospective and retrospective), systematic reviews, and case-control studies; (3) studying the association of MetS (presence of a cluster of three or more metabolic abnormalities) with dietary pattern; (4) participants aged younger than 18 years; and (5) studies reporting sufficient data including odds ratios, hazard ratios, and standardized incidence ratio with 95% confidence interval for calculating a common effect size. We did not consider any time limitation and included articles published in English up to May 2015.

An electronic search was conducted in international electronic databases including PubMed, Cochrane, Scopus, and Google Scholar, moreover, Iranmedex, Irandoc, and Scientific Information Database (SID) were used for Persian document searches. The following keywords were used: (“Child” (Mesh) OR “Adolescent” (Mesh) AND (“Metabolic Syndrome” (Mesh) AND “Diet” (Mesh) OR “Dietary Pattern” (Mesh))).

5. Data Extraction and Quality Assessment

After reviewing and studying the summary and titles of all searched articles, the repeated and irrelevant items

were excluded, and then, the full texts of articles were carefully studied by researchers. The related articles were selected and the irrelevant ones were excluded.

The quality of the documents was evaluated independently by 2 research experts for the objective of each research project, study method, sample size, sampling method, data collection tool, variable evaluation status, and the studied target group. Disagreements were resolved by consensus and mutual discussion. Using Cohen’s kappa statistic (606) (13), the kappa statistic for agreement for quality assessment was 0.96.

The following information were extracted for each finally included article: first author, place of the study, year of publication, study population (including sample size, age, sex), study design, dietary assessment, definition of MetS, dietary patterns, and main findings.

6. Results

At first, 4194 articles were identified (PubMed: 566; Scopus: 60; Google scholar: 3550, and Domestic data source: 18). During 3 refined steps and after removing duplicates, 44 articles related to the study domain were selected. After quality assessment, 17 studies were selected for text appraisal, of which 15 (7, 14-27) were evaluated at the final step (Figure 1).

The numbers of total population was 19 298. The age range of studied population was 3 to 18 years.

From reported studies, 10 had a cross-sectional design (7, 15-17, 19, 20, 22, 24-26), 3 were interventional studies (14, 23, 27), 1 was a cohort study (18), and 1 was a systematic review (21). Table 1 demonstrates the details of the 15 included studies.

7. Discussion

In the present study, we systematically reviewed the association of dietary pattern with MetS in children and adolescents. Our results indicated that the MDP or diets with a higher score of HEI contain higher content of grains, vegetables, fruits, milk, and meat/meat alternatives have an inverse association with the prevalence of MetS, whereas Western diets or diets with similar content are associated with higher frequency of MetS in children and adolescents.

Dietary modification is the most important component in managing MetS. One of the reviewed studies revealed that compared to physical activity, the dietary pattern could have a better effect in the prevention and control of MetS in children and adolescents (17).

Limitations exist to examine the separate effects of nutrients on MetS, this might be because of the correlation

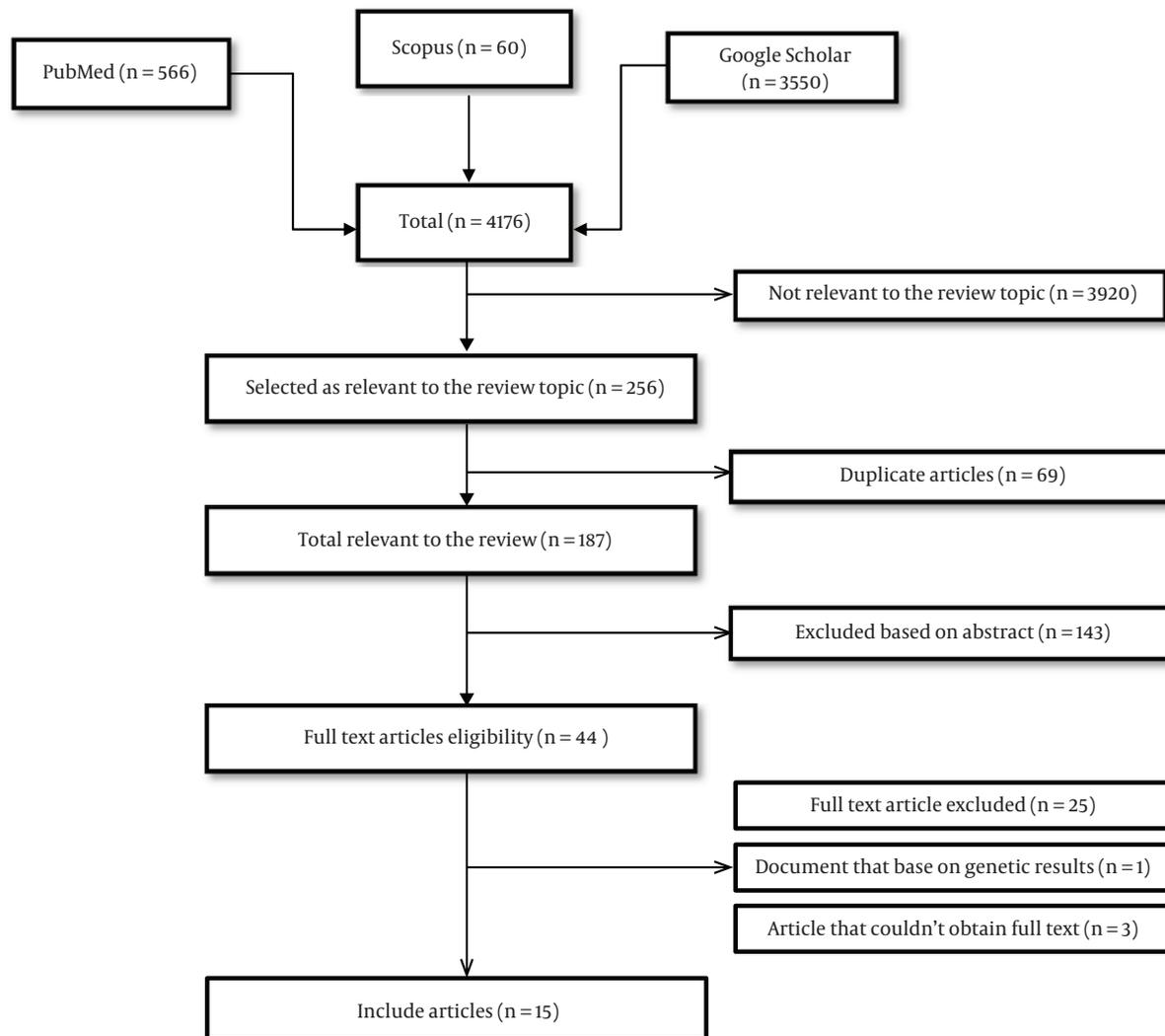


Figure 1. Flow Diagram of Study Selection

and interaction between some nutrients. When the independent variations of the nutrients were entered simultaneously into a model, their degree was markedly reduced. The effect of a single nutrient may be too small to detect, but the effects of multiple nutrients in a dietary pattern may be large enough to be detectable (8, 10).

In our literature review, we found some relevant papers among adult population (29-32) and only 1 review study among Korean adolescents (21).

A review study that investigated the protective effect of different dietary patterns against MetS indicated that the main components of various diets are monounsaturated fatty acids, omega-3 fatty acids, fruits, vegetables, whole

grains, dairy and dairy components, calcium, vitamin D, and whey protein, which could explain their potential protective effects against MetS (28). Almost all studies on adult populations have supported the protective effect of MDP, DASH, or other high-quality diets as well as the harmful effects of the Western diet (28-31).

The results of the current review have also represented similar results. Most of the reviewed studies had a cross-sectional design and mostly supported the beneficial effect of MDP and those with higher score of HEI on the MetS in the pediatric population (7, 15-17, 19, 20, 22, 24-26).

A study from Iran did not document any association between the HEI and MetS in females aged 10 to 19 years

(25). Likewise, the findings of another study from the same population did not indicate any association between low carbohydrate diet (LCD) and occurrence of the MetS (26). Three of the reviewed studies were interventional (14, 23, 27). Chen et al. evaluated the effectiveness of a 14-day healthy dietary pattern (high-fiber, low-fat, low sodium diet) with exercise in 16 children, from whom 7 had MetS. MetS was reversed in all 7 children (14). Saneei et al. in a randomized cross-over clinical trial compared the outcome of DASH diet for 6 weeks with usual dietary advice (UDA). DASH diet had a significant effect in reduction of the prevalence of MetS (23). Velazquez-Lopez et al. compared the effectiveness of Mediterranean style diet (MSD) with standard diet on the occurrence of MetS. Their result showed the beneficial effect of MSD on the MetS (27).

The only cohort study, which was included in our review, was conducted by Ambrosini et al. on 593 males and 546 females aged 14 years, and indicated that the Western dietary pattern is associated with high-risk metabolic cluster (18).

There was no report on the effectiveness of certain dietary patterns on MetS in different sexes, ages, and regional (urban/rural) groups, and most of these studies have evaluated the association in the entire population.

The diets reported to have a protective effect on the occurrence of pediatric MetS are considered to be plant food based diets, which are rich in fruits, vegetables, legumes and whole grains, nuts, low fat dairy products, fish, and vegetable oils. These foods contain nutrients and fiber that may have an effect on glucose metabolism and weight regulation. They are also rich in micronutrients (vitamins, fatty acids, essential minerals) and other bioactive components such as antioxidants, phytoestrogens, and phenolic compounds that have a protective effect on most of the chronic disorders including MetS. In fact, the mentioned healthy diets (DASH, MDP or high-quality diet) are labeled differently according to the country of origin or study design, but their main components are similar (32, 33).

In contrast, the most dominant components of Western diets, which are shown to have a direct association with increased risk of MetS in children and adolescents, are meat or meat products, sugar-sweetened beverages, junk foods, refined cereals, sweets, processed and ultra-processed foods. These foods contain high amounts of saturated fatty acids, simple carbohydrates, fructose, and low amount of micronutrients and bioactive substances (34, 35).

Given the role of gene-nutrient interaction in the occurrence and prevention of MetS, the association between MetS and ethnic groups and culture and changes in food preferences, food availability, and the dietary pattern over time (36-38), it is recommended to provide new dietary pat-

terns that would obtain their main components from the mentioned healthier diets such as MDP or DASH and have more complementary items that are derived from the regional studies of each population as well as the findings of recent studies. Thus, taking such dietary patterns in early life, which should be updated frequently, would properly prevent the increasing occurrence of MetS both during childhood and adulthood.

It is well established that the major contributors of MetS are different in various regions and populations (39). Therefore, it seems that reviewing different reports from each population and considering their findings in current healthy diets would be an appropriate approach for each population.

The limitations of this review should be taken into account. One of the limitations was the cross-sectional design of most included studies; such a study design could not provide enough inferences about causality. The other limitation was using different definitions for pediatric MetS and different methodologies in mentioned studies, which result in heterogeneity in our obtained results. Moreover, using self-reported food frequency questionnaires for recording the dietary patterns in some studies as well as questionnaire completed by parents in some other studies were the other limitations of the current review.

Using various questionnaires for recording dietary information could be subject of bias, mainly underreporting of non-healthy foods and over-reporting of healthy foods.

The strength of the current study is that this type of review has not been reported yet among the pediatric population. Thus, considering the early origin of many noncommunicable diseases in adulthood, our data could be used to design a more interventional study for evaluating the effectiveness of new dietary patterns based on our results.

8. Conclusion

Reviewing current evidences indicated that dietary patterns such as Mediterranean and/or DASH, or other dietary patterns with higher score of HEI have a protective effect for occurrence of pediatric MetS, while the Western dietary pattern is associated with a higher risk of pediatric MetS. Furthermore, considering the importance of some components such as unprocessed foods, low salt intake, and whole grain, which were reported in some studies, it is recommended to design further interventional studies to evaluate new healthy dietary patterns with the aforementioned characteristics.

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Table 1. Details of Studies Investigated the Association Between Dietary Pattern and Metabolic Syndrome in Children and Adolescents

No.	Author (Year and Country)	Study Design	Study Population (Sample Size, Age, Sex)	Dietary Assessment	Definition of MetS	Dietary Patterns	Main Findings
1	Chen et al. 2006; USA	Interventional	Total: 7; Age: 10 - 17	-	National Cholesterol Education Program's Adult Treatment Panel III and the World Health Organization	A 14-day diet and exercise intervention 12% to 15% of energy from fat (polyunsaturated-saturated fatty acid ratio, 2.4:1), 15% to 20% of energy from protein, and 65% to 70% of energy from unrefined carbohydrate. Carbohydrates contain high-fiber whole grains, vegetables, and fruits. Protein was derived from plant sources, with nonfat dairy and fish. The diet contained less than 100 mg of cholesterol, without any caffeinated beverages. Sodium intake was limited to less than 1600 mg/d.	After intervention, MetS was not present whatsoever in the population that was studied (100% improvement of MetS).
2	Linaridakis et al. 2008; Greece	Cross-sectional	Total: 1209; Age: 3 - 17; Sex: 542 boys and 667 girls	A 24-h dietary recall interviews using a face-to-face interactive interview	Cruz and Goran	Diet quality was determined by the HEI score by dietary recalls. It comprises 10 components that correspond to intakes of saturated fat, total fat, cholesterol, sodium, grain, fruit, vegetable, dairy, meat, and dietary variety. Each of these components contributes up to 10 points to the maximum possible score of 100. Scores of < 51, 51 - 80, and > 80 classify the overall diet quality as "poor", "needs improvement", and "good", respectively.	MetS was present in 4.3% of males and 4.0% of females. Presence of 3 or more factors related to the MetS was strongly associated with poor diet quality. Clustering of risk factors was associated with lower odds for adequate HEI score in fruits, vegetables, milk, and meat.

8	3	Pan et al. 2008; USA	Cross-sectional study from the National Health and Nutrition Examination Survey 1999 - 2002	Total: 4450. Age: 12 - 19; Sex: 2260 boys and 2190 girls	A standardized, interviewer-administered 24-hour dietary recall	Modified standards of the Adult Treatment Panel III specified by national cholesterol education program (NCEP)	The healthy eating index (consists of 10 components) was used as an indicator of the quality of the diet of each participant. Components 1 to 5 measure the degree to which a person's diet conforms to the food guide pyramid recommendations for 5 major food groups: Grains, vegetables, fruits, milk, and meat/meat alternatives. Components 6 to 9 measure intake of fat, saturated fat, cholesterol, and sodium. Component 10 measures the degree of variety in a person's diet. A higher overall HEI score was representative of a better diet quality.	They indicated inverse relationship between MeTS and overall diet quality. HEI had overall score among adolescents. Diets high in fruits were associated with lower prevalence of MeTS in adolescents.
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4	Kelishadi et al. 2009; Iran	Cross-sectional	Total; 374, Age; 10-18, Sex; 191 boys and 183 girls	Three 24-h food records (once per week; two school days and one weekend)	Insulin resistance by HOMA-IR	<p>HEI was used to determine the participants' diet quality. The index consisted of 10 components based on the analysis of the three 24-h dietary records.</p> <p>Components 1 to 5 measured the degree to which a participant's diet conformed to the Food Guide Pyramid serving recommendations for the 5 major food groups and were based on the average number of servings from the 3 days of data intake. Similarly, components 6 to 9, which measured total fat, saturated fat, cholesterol, and sodium intakes, were based on 3-day averages; component 10 measured variety in participants' diets by examining the number of different foods consumed over the 3 days of dietary intake. A maximum score of 10 was obtained if 16 or more different food items were consumed over the 3 days. The other components of the index were scored similarly with maximum scores of 10 and minimum scores of 0, where high scores were closer to recommended ranges or amounts; maximum score was 100. The association between HEI and insulin resistance was evaluated.</p>	In the highest quartile of the HEI score, the odds ratio of HOMA-IR was decreased.
5	Casazza et al. 2009; Birmingham	Cross-sectional	Total; 202, Age; 7-12, Sex; 107 boys and 95 girls	two 24-hour diet recalls	Definition of Cook et al.	<p>The dietary intake data using Nutrition Data System for Research Software Version 2006. A dietary analysis program designed for the collection and analysis of 24-hour dietary recalls. The average of the individual daily intakes for each nutrient was used in subsequent analysis.</p>	Diet had a greater influence on MetS and its components than did physical activity.

6	Ambrosini et al. 2010; Australia	Cohort study; Raine study	Total: 1139, Age: 14, Sex: 593 Boys and 546 girls	A semi-quantitative food frequency questionnaire	The participants classified in two high and low risk metabolic cluster	Two dietary patterns 'Western' and 'Healthy' were identified using factor analysis. The association between these dietary patterns and high and low metabolic clusters was evaluated. In the healthy pattern, the mean percentage of total energy intake from total fat, saturated fat, monounsaturated fat, and refined sugars decreased, while percentage of total energy from protein, total carbohydrate, natural sugars, fiber, and folate increased. By increasing the Western' pattern score, the mean percentage of total energy intake from total fat, monounsaturated fat, saturated fat, refined sugars, and sodium increased and percentage of energy from total carbohydrate, natural sugars, folate, and fiber decreased. Vegetables, fruits, legumes, and whole grains were dominant in the Healthy dietary pattern.	Higher Western dietary pattern scores were associated with greater odds for the high risk metabolic cluster. Scores of Healthy dietary pattern were not related to the high risk metabolic cluster, but were inversely associated with serum glucose in males and females and were positively associated with HDL-C in males.
7	Kelishadi et al. 2009; Isfahan-Iran	Case-control study	Total: 825, Age: 6- 17, Sex: 359 boys and 466 girls	A questionnaire for recording weekly dietary recalls for 5 major food groups: grains, vegetables, fruits, milk, and meat/meat alternatives	Modified ATP III	The relation between the major food groups and MetS was evaluated.	There was an inverse relationship between MetS and the consumption of grains, fruits, milk, and meat/meat alternatives.
8	Tavares et al. 2011; Brazil	Cross-sectional	Total: 210, Age: 12- 19, Sex: 100 boys and 110 girls	A semi-quantitative FFQ, containing 90 food items and 17 questions about eating habits	De Ferranti et al.	Foods were grouped as (1) unprocessed or minimally processed foods (2) processed culinary and food industry ingredients (3) ultra-processed foods. The relationship between the consumption of the 3 different food groups and MetS were estimated.	Crude analysis showed higher average daily intakes of energy, carbohydrates, and ultra-processed foods among adolescents with MetS. After statistical adjustment, the intake of ultra-processed foods (> 3rd quartile) remained associated with MetS (prevalence ratio = 2.5; P = 0.012). High consumption of ultra-processed foods was associated with the prevalence of MetS in this adolescents group.

9	Joung et al. 2012; Korea	Systematic review from 4 consecutive Korean nutrition health and nutrition examination surveys (1998, 2001, 2005, and 2007 to 2009).	Total; 3,168 . Age:13 - 18	A 24-hour recall categorized into 23 groups based on common food groups classified in the Korean Nutrient Database	International diabetes federation (IDF)	3 dietary patterns were derived using the dietary intake data as follows: "Rice and Kimchi" pattern, which is similar to a traditional dietary pattern and contains high consumption of white rice, kimchi, beans, vegetables, and fish. -The "Bread , Meat , Fruit and Milk" pattern, which is similar to Western dietary pattern, which contains high intake of grain, flour, bread, pizza, hamburgers, snacks, sugar, candy, meat and meat products, fruit, milk, and dairy products. The "Noodle and Mushroom" pattern, which had intermediate diet features that ranged between the "Rice and Kimchi" and "Bread, Meat, Fruit and Milk" patterns and is similar to a modified dietary pattern	Western dietary patterns are positively associated with MetS risk factors such as obesity and elevated TG, while traditional dietary patterns are negatively associated with MetS risk factors.
10	Shang et al. 2012; China	Cross-sectional	Total; 5267; Age; 6 - 13, Sex 2643 boys and 2624 girls	A 24-hour dietary recall for 3 consecutive days	International diabetes federation (IDF)	Three patterns were labeled as - the healthy dietary pattern, with high positive loadings on milk, yogurt, eggs, fruit, and vegetables, and high negative loadings on sugar, beef, lamb, and other red meat - The transitive dietary pattern, with high positive loadings on organ meat, pork, seafood, processed meat, edible fungi, and algae, and light vegetables -The Western dietary pattern, with high positive loadings on rice, refined grains, deep color vegetables, pork, sugar, fish and shrimp, beef, lamb, and other red meat and high positive loadings on beef/lamb/other red meat, wheat, starch tubers, and light color vegetables	The prevalence of obesity and abdominal obesity was relatively lower among children with healthy dietary pattern, The Western dietary Pattern was associated with a higher prevalence of obesity and abdominal obesity and the level of plasma glucose, LDL, and TG, and a lower level of plasma HDL cholesterol.

11	Saneei et al. 2013; Iran	A randomized cross-over clinical trial	Total:60, Age: 11- 18, Sex: girls	3 d dietary record (2 week days and 1 weekend day)	Adult: Treatment Panel III (ATPIII)	Participants randomly were allocated to receive the DASH diet or usual dietary advice (UDA) for 6 weeks. After a 4-week washout period, the participants were crossed over. -The DASH group was rich in fruits, vegetables, and low-fat dairy products and had low level of saturated fats, total fats, and cholesterol. -The UDA consisted of general oral and written recommendations about healthy food choices based on healthy My Plate.	Reduction in the prevalence of the MetS was significantly higher in DASH diet than UDA. A 6- week DASH diet among adolescent females with the MetS resulted in significant reduction of the MetS and improvement of diet quality in comparison with UDA.
12	Park et al. 2013; Korea	A cross-sectional study (a sub-study of the Korea metabolic syndrome research initiatives (KMSRI))	Total: 1008, Age: 8- 19, Sex: 513 boys and 495 girls	A 3-day food records	National cholesterol education program adult treatment panel (NCEP ATP) III definition	The food classified in 24 groups and 2 dietary patterns as follows: (1) balanced pattern, which contains a higher intake of white rice, other grains, vegetables, potatoes, legumes, red meat, seasoning, plant oil, fruits, and fish and a lower intake of fast food. 2: Western pattern, which contains higher intake of bread, cereal, noodles, poultry, sweet snacks, and animal fat, and lower intake of fish, white rice, kimchi, seaweed, and eggs.	Girls with highest Western dietary pattern scores had a higher incidence of MetS. The adverse association between the risk of MetS and Western dietary pattern was observed among females, not males.
13	Mohseni-Takalloo et al. 2014; Iran	A cross-sectional study (The Tehran lipid and glucose study (TLGS))	Total:706, Age: 10- 19, Sex: 321 boys and 385 girls	A validated semi-quantitative food frequency questionnaire (FFQ) with 168 food items	Modified de Ferranti definition	The HEI-2005 has been used to evaluate diet quality. It contains 12 food components such as total fruit, whole fruit, total vegetables, dark green and orange vegetables, and legumes, total grain, whole grain, milk, meat and beans, oil, saturated fat, sodium, and percent of calorie intake from solid fats, alcoholic beverages, and added sugars. The maximum score in HEI-2005 is 100 .Higher scores indicate a better diet quality.	There was not any significant relationship between HEI-2005 score and MetS.

14	Eslamian et al. 2014; Iran	The Tehran lipid and glucose study (TLGS) cohort	Total; 621, Age; 6-19, Sex; 282 boys and 339 girls	A validated semi-quantitative food frequency questionnaire (FFQ) with 168 food items	Cook et al.	The low carbohydrate diet score (LCD) was used to predict MetS occurrence. The LCD was calculated based on intake of carbohydrate, monounsaturated fatty acids, refined grains, and vegetable protein intake. The incidence of MetS and its components was calculated 3 years later.	Participants with highest adherence to LCD showed an odds ratio of 0.74 (95% CI: 0.24 - 2.28) in comparison to those with the lowest adherence for MetS incidence (P for trend = 0.793). There was no relationship between MetS and LCD after 3.6 years of follow-up.
15	Velazquez-Lopez, 2014; Mexico	Randomized interventional trial	Total; 49 (25 in mediterranean style diet (MDS) and 24 in SD), Age; 3-18, Sex; 23 boys and 26 girls	A 24-hour recalls and NUTRIPAC software	Modified international diabetes federation (IDF) criteria	A 16-week intervention for 1: (MDS) rich in polyunsaturated fatty acids, fiber, flavonoids and Antioxidants. (60% of energy from carbohydrate, 25% from fat, and 15% from protein. 2: Standard diet (SD) containing 55% of carbohydrate, 30% from fat, and 15% from protein	Prevalence of MetS-At baseline 66.7% in MDS group and 40% in SD group-After intervention: 20.8% in MDS group and 44% in SD group