

# The role of dietary patterns in the pathogenesis of metabolic syndrome in adolescents

Shahnaz Taghizadeh,<sup>a</sup> Mohammad Alizadeh<sup>a</sup>

<sup>a</sup> Department of Biochemistry and Diet Therapy, Faculty of Nutrition, Tabriz University of Medical Sciences, Tabriz, Iran

## ABSTRACT

### Article History

**Received:**

10-June-2016

**Revised:**

30 August 2016

**Accepted:**

08 November 2016

### key words:

?????

The increasing worldwide trend in childhood obesity is a driving force behind the increase in metabolic syndrome (MetS) in adolescents. Although there is no clear definition of the pediatric MetS, it is very common among adolescents, characterized by insulin resistance (IR), dyslipidemia, abdominal obesity, and hypertension—all associated with a high risk of type 2 diabetes mellitus and CVD in adulthood. The role of nutritional factors, especially dietary patterns, in the development of obesity and MetS is explored. Also, the evidence that proinflammatory stressors may predispose to obesity-induced insulin resistance is reviewed. The present article examines the notion that decreasing nutritional risk factors in dietary patterns and reducing the impact of metabolic and inflammatory stressors may reduce the adverse health effects of obesity and slow the progression towards the MetS and CVD in adolescents. Evidence from pediatric dietary epidemiological and interventional studies that have investigated the potential preventive and therapeutic effects of dietary patterns modification is limited. The present article reviews the current knowledge about the effects of dietary patterns in the pathogenesis and progression of MetS in adolescents.

## Introduction

The increasing worldwide trend in the prevalence of pediatric obesity is one of the most epidemic alarming concerns [1]. Childhood obesity, especially abdominal obesity, is associated with insulin resistance and metabolic syndrome (MetS) in adolescence [2]. Although many attempts have been made to define MetS in the pediatric population, no concrete definition has been proposed to date. Indeed, more than 40 definitions have been offered for MetS, but none of them has been universally accepted [2]. The International Diabetes Federation (IDF), the US National Cholesterol Education

Program's Adult Treatment Panel III (ATP), and the World Health Organization (WHO) criteria are among the widely accepted classifications. Recently, the use of IDF criteria has been suggested [3]. The IDF definition of MetS in children and adolescents is different according to age groups (6 to <10, 10 to <16, and ≥16 years). Below the age of 10 years, the MetS is not diagnosed; from 10 to 16 years the diagnosis requires the presence of abdominal obesity (waist circumference ≥ 90th percentile) plus the presence of two or more of the following criteria: triglycerides ≥ 150 mg/dL, HDL-cholesterol < 40 mg/dL, systolic blood pressure ≥ 130 or diastolic blood pressure ≥ 85 mm Hg, and fasting plasma glucose ≥ 100 mg/dL or known Type 2 diabetes mellitus (T2DM). In adolescents aged ≥ 16 years, the IDF adult criteria can be alternatively used [4].

The overall pathophysiology of the MetS in adolescents is similar to adults, although some age-specific factors exist. For example, in adolescents, a hormonal process such as pubertal development may

### Corresponding author:

Mohammad Alizadeh,  
Department of Nutrition, Faculty of Nutrition, Tabriz University of  
Medical Sciences  
Attar Nishabouri St., Tabriz, Iran, Postal code: 5166614711,  
POB: 14711, Tel: +98-41-33362117, Fax: +98-41-33340634,  
Email: mdalizadeh@tbzmed.ac.ir

increase insulin resistance, while pregnancy and aging may be the main reasons in adults [5]. One of the most effective hormones in adolescence is growth hormone (GH). The similarity between the characteristics of GH deficiency and MetS have led to the hypothesis that abnormalities in GH secretion and action may predispose individuals to MetS [5].

Sex hormone levels are the other hormonal effects related to MetS and may play an important role in determining MetS risk among children and adolescents. It has been shown that male adolescents with MetS have significantly lower sex hormone-binding globulin and higher free estradiol index levels [6]. The etiology of MetS is not completely clear; however, the evidence indicates that insulin resistance, inflammation, and obesity are three principal factors linked to metabolic changes contributing to the development of MetS. Diet and physical activity are important factors that affect these three factors [7]. Aside from restricting total calories, manipulation of distribution and type of dietary macronutrient has been associated with varying degrees of efficacy in prevention of MetS.

Dietary patterns reflect the effect of the diet as a whole and, thus, may provide insight beyond the effects characterize for single nutrients or foods [8]. Some dietary patterns like vegetarian diet reduce HDL cholesterol [9]. Unhealthy dietary intakes during adolescence contribute to the development of early risk factors for chronic disease in adulthood [10]. Designing desirable dietary patterns is very important in strengthening and promoting public health. However, the Western lifestyle has caused an increase in obesity in adolescents over the last decades and have negatively influenced healthy eating behaviors, especially among children and adolescents [11]. Childhood obesity, especially abdominal obesity, is associated with insulin resistance and metabolic syndrome in adolescents [12]. Kafeshani et al showed that socio-demographic characteristics are related to dietary patterns in Iranian adolescents [13]. Thus, some dietary patterns comprising different foods are considered in this section to evaluate their effects on the incidence of MetS in adolescents.

One of the most common food constituents associated with obesity and MetS is dietary fat. Higher dietary fat intake is associated with higher prevalence of abdominal obesity, hypertension, and impaired fasting glucose [14]. Waist circumference shows a positive correlation with visceral adipose tissue and a negative association with subcutaneous adipose tissue [15]. Several studies have suggested that restriction in dietary fat has a positive impact on the prevention of the metabolic syndrome [16]. Other studies have shown that the amount of dietary fat intake is a specific risk factor for abdominal

adiposity in adolescence [16,17]. Carlson and associates suggested that, to reduce the risk for MetS in adolescents, it is more important to emphasize a dietary paradigm that promotes inclusion of fiber-rich, nutrient-dense, plant-based foods instead of what foods to restrict or exclude, which is commonly done when the focus is on total fat, cholesterol, or saturated fat intake [18]. The latest US Department of Agriculture Dietary Guidelines emphasizes optimizing types of dietary fat rather than decreasing total fat intake [19]. In some of the studies, a role for fat-soluble vitamins in the prevention of metabolic syndrome has been suggested [20].

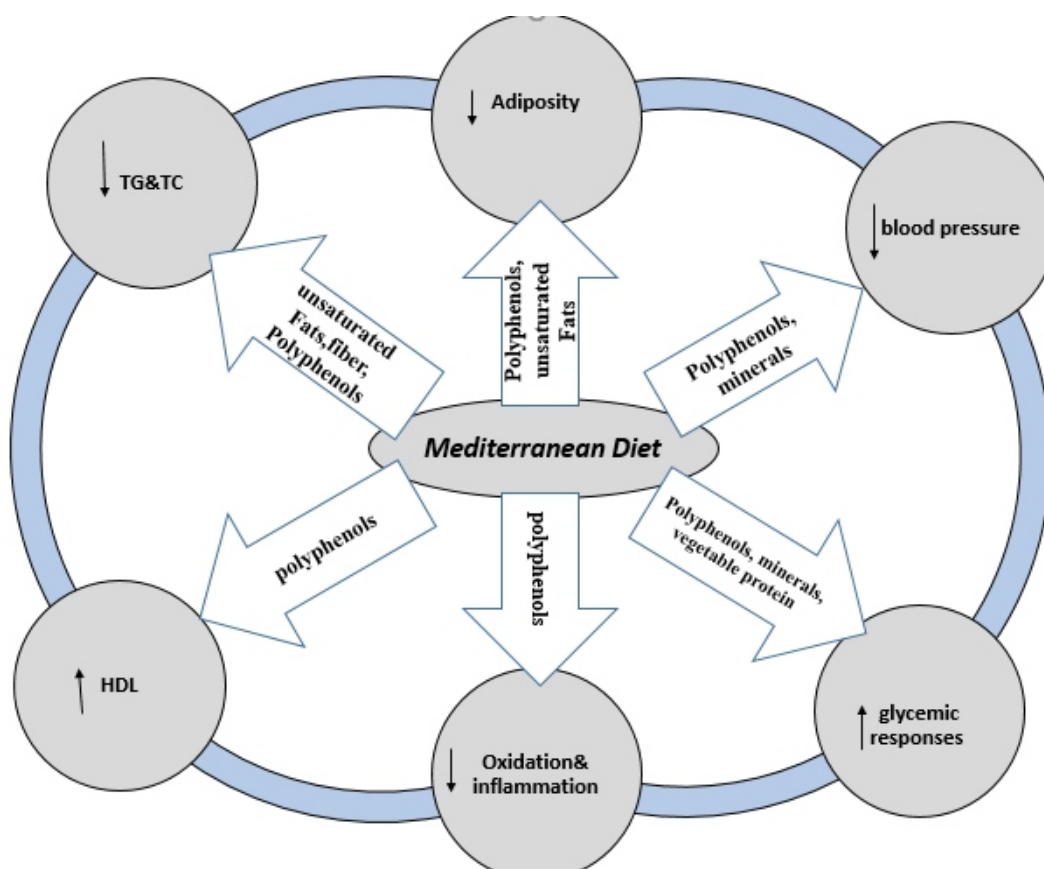
The present review is now to briefly summarize findings from epidemiological and interventional studies retrieved from Google Scholar, PubMed, Scopus, and Web of Science databases, from 2000 to May 2016, using the terms “the metabolic syndrome,” “insulin resistance,” “glucose metabolism alterations,” “dyslipidemia,” “dietary pattern,” and “food pattern” to assess the role of dietary patterns in the development of metabolic syndrome in adolescents.

### **The Mediterranean diet and metabolic syndrome in adolescents**

The Mediterranean diet (MD) is rich in polyunsaturated fatty acids and olive oil and contains fish, wheat, olives, grapes, fiber, flavonoids, and antioxidants [21]. The beneficial effects of the MD have been proven in adults with cardiovascular risk factors [22]. Steffen et al showed that the risk of developing MetS is lower when consuming a diet rich in fruits, vegetables, whole grains, nuts, and fish [23]. The MD has been shown to efficiently decrease MetS risk by 20% to 43%, regardless of age, sex, physical activity, lipid levels, and blood pressure. The effect of the MD on cardiometabolic risk factors has been assessed in pediatric populations in few studies. Velazquez-Lopez and colleagues reported that the MD improves BMI, glucose, and lipid profile in children and adolescents with obesity and other components of MetS [21]. Similarly, in a study on 362 adolescents aged 12-17, a high adherence to the MD was correlated with a low prevalence of the MetS [24]. However, Cuenca-Garcia et al showed in European adolescents (n = 2340; 12.5-17.5 years) that adherence to the MD was inversely related to systolic blood pressure, concluding that the MD alone is an insufficient contributor to reduced adiposity and improved cardiometabolic health in adolescents [25]. Grosso et al, in a cross-sectional survey of adherence to the Mediterranean diet in children and adolescents in Spain, Greece, and Italy, found that social and demographic factors were the major determinants of adherence. Among the former, high socioeconomic and cultural status of

participants' parents (especially mothers) were associated with higher adherence [26]. In another study, gender, age, and low parental education were found to be linked to low adherence to the MD, so that male and younger adolescents were more likely to have low adherence to the MD [27]. Also, Kafeshani et al showed an inverse relationship between urbanization and Mediterranean dietary patterns and a positive relationship between nutrition knowledge and Mediterranean diet in adolescents [13]. As Salas-Salvado and colleagues have shown, polyphenols play a very important role in the prevention of MetS [28]. A summary of the mechanisms of the MD impact on components of

MetS and T2DM are shown in Figure 1. The MD improves cardiometabolic health through its rich content of phytochemicals and bioactive nutrients, with synergistic effects on metabolic pathways. The net effects on intermediate markers of cardiometabolic disease shown for these nutrients in clinical trials include improved lipid profile, glycemic control, decreased blood pressure, reduced adiposity, and antioxidant and anti-inflammatory actions. The overall result is a reduced MetS and T2DM risk. Hence, according to studies cited, Mediterranean dietary patterns could have a role in the prevention and treatment of MetS and its components in adolescents.



**Figure 1:** A summary of the mechanisms through which the Mediterranean diet impacts components of metabolic syndrome and type 2 diabetes

### The DASH diet and metabolic syndrome in adolescents

The Dietary Approaches to Stop Hypertension (DASH) diet, which is rich in vegetables, fruits, whole grains, low-fat dairy products, magnesium, potassium, calcium, and fiber and low in saturated fats, trans fats, and cholesterol, was originally proposed by the US National Heart, Lung, and Blood Institute to reduce blood pressure [29]. Several studies in adults have shown that adherence to a DASH diet has positive effects on cardiovascular

health, including reduced risk of hypertension, T2DM, coronary heart disease, stroke, and overall mortality [30]. Besides, the beneficial effect of the DASH diet on better glycemic control and liver enzymes in T2DM has also been documented [31]. Moore et al, using data from 2185 girls followed up over 10 years (until the girls were 18-20 years of age), showed that adherence to the DASH diet prevents high blood pressure in adolescents [32]. Similarly, Saneei et al indicated that a DASH eating pattern for 6 weeks among adolescent girls with

MetS led to a reduced prevalence of MetS [33]. Also, Günther et al showed that a higher adherence to DASH was inversely related to hypertension independent of demographic, clinical, and behavioral characteristics [34]. Another study on 57 adolescents with a clinical diagnosis of prehypertension or hypertension showed that the DASH intervention proved more effective than nutrition care in improving systolic blood pressure and diet quality in adolescents with elevated blood pressure [35]. In a cross-sectional study among 2130 youth with type 1 diabetes, Liese et al found that the greater adherence to the DASH diet was inversely associated with the LDL:HDL ratio and glycated hemoglobin. However, they failed to find significant associations with serum triglyceride and LDL-cholesterol levels [36]. Liese suggested that higher levels of adherence to the DASH diet were significantly associated with race/ethnicity, higher income, not smoking, more vigorous physical activity, and less television watching, but not with age or gender, in youth with diabetes mellitus. So all studies indicated in this paper show that adherence to the DASH diet prevents high blood pressure and other components of metabolic syndrome in adolescents.

### **The Western diet and metabolic syndrome in adolescents**

The Western dietary pattern is high in total fat [37] and saturated fatty acids and refined grains, which is associated with increased risk of overweight in adolescents [9,38] and increased risk of MetS [39]. With globalization, Western-style fast food intake is increasingly being adopted in developing countries [40] due to easy accessibility, familiarity and influence of mass media [41]. This low-quality diet [42], characterized by high consumption of red meat, trans and saturated fats, and high energy density, has been known as a predominant factor leading to the development of insulin resistance and MetS [43]. Nourmohammadi et al showed that low intake of saturated fatty acids along with increased intake of omega-3 polyunsaturated fatty acids may be useful in reducing the risk of MetS and its consequences [44]. Marlatt et al studied 367 adolescents (11 to 18 years old) and showed that fast food consumption was associated with higher BMI, body fat, low-density lipoprotein cholesterol, triglycerides, glucose, insulin, HOMA-IR index, and MetS cluster score [45]. Ahluwalia et al also indicated that a Western dietary pattern was associated with a greater risk for MetS in adolescents [46]. Ambrosini showed that a higher adherence to the Western dietary pattern is associated with greater odds for the MetS and its components in adolescents [47]. Similarly, Oddy et al indicated that a Western dietary pattern in 14-year-

old adolescents in a general population sample was associated with an increased risk of non-alcoholic fatty liver disease at age 17, particularly in obese adolescents [48]. Nevertheless, in the study of three dietary patterns including traditional Korean, modified, and Western diet in 944 adolescents, Kim and colleagues showed that the prevalence of the MetS was not significantly different among dietary patterns [49][37].

### **Conclusions**

A growing number of scientific data support the notion that visceral fat distribution and insulin resistance represent important markers of MetS in adolescents. The available evidence in children from both interventional and longitudinal studies indicates that dietary patterns play an integral role in the prevention, pathogenesis, and treatment of the MetS in adolescents. Our review shows that adherence to the MD, rich in n-9 fatty acids, and the DASH diet, rich in n-6 and n-3 fatty acids, may attenuate MetS risk factors in adolescents. On the contrary, the Western dietary pattern, because of the low content of vegetables, fruits, whole grains, high-fat dairy products, and fibre and higher content of saturated fat, trans fat, and cholesterol, is associated with MetS in children and adolescents. Besides the contribution of these dietary patterns to the incidence of MetS in adolescents, it is better that evaluate the dietary macronutrient that is associated with prevention of MetS in adolescents. The full specification of the mechanisms involved in the development of MetS in adolescents could help in the identification of preventive and therapeutic strategies.

### **Acknowledgments**

This work was supported by a grant from Tabriz University of Medical Science, Tabriz, Iran

### **Conflict of interest**

The authors declare that they have no competing interests.

### **Funding**

The study has no Fund.

### **References**

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA*. 2012;307(5):483-90.
2. Russell FD, Bürgin-Maunders CS. Distinguishing health benefits of eicosapentaenoic and docosahexaenoic acids. *Mar Drugs*. 2012;10(11):2535-59.
3. Friend A, Craig L, Turner S. The prevalence of metabolic syndrome in children: a systematic review of the literature. *Metab Syndr Relat*

- Disord. 2013;11(2):71-80.
4. Zimmet P, Alberti KGM, Kaufman F, Tajima N, Silink M, Arslanian S, et al. The metabolic syndrome in children and adolescents—an IDF consensus report. *Pediatr Diabetes*. 2007;8(5): 299-306.
  5. Byrne CD, Wild SH. *The metabolic syndrome*: John Wiley & Sons; 2011.
  6. Agirbasli M, Agaoglu NB, Orak N, Caglioz H, Ocek T, Poci N, et al. Sex hormones and metabolic syndrome in children and adolescents. *Metabolism*. 2009;58(9):1256-62.
  7. Steinberger J, Daniels SR, Eckel RH, Hayman L, Lustig RH, McCrindle B, et al. Progress and challenges in metabolic syndrome in children and adolescents a scientific statement from the American Heart Association atherosclerosis, hypertension, and obesity in the young committee of the council on cardiovascular disease in the young; council on cardiovascular nursing; and council on nutrition, physical activity, and metabolism. *Circulation*. 2009;119(4):628-47.
  8. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol*. 2002;13(1):3-9.
  9. Gadgil MD, Anderson CA, Kandula NR, Kanaya AM. Dietary patterns in Asian Indians in the United States: an analysis of the metabolic syndrome and atherosclerosis in South Asians Living in America study. *J Acad Nutr Diet*. 2014;114(2):238-43.
  10. Ambrosini G, Huang R-C, Mori T, Hands B, O'Sullivan T, de Klerk N, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. *Nutr Metab Cardiovasc Dis*. 2010;20(4):274-83.
  11. Yu Y, Song Y. Three clustering patterns among metabolic syndrome risk factors and their associations with dietary factors in Korean adolescents: based on the Korea National Health and Nutrition Examination Survey of 2007-2010. *Nutr Res Pract*. 2015;9(2):199-206.
  12. He F, Rodriguez-Colon S, Fernandez-Mendoza J, Vgontzas A, Bixler E, Berg A, et al. Abdominal obesity and metabolic syndrome burden in adolescents--Penn State Children Cohort study. *J Clin Densitom*. 2014;18(1):30-6.
  13. Kafeshani O, Sarrafzadegan N, Nouri F, Mohammadifard N. Major dietary patterns in Iranian adolescents: Isfahan Healthy Heart Program, Iran. *ARYA Atheroscler*. 2015;11 (Suppl 1):61.
  14. Narasimhan S, Nagarajan L, Vaidya R, Gunasekaran G, Rajagopal G, Parthasarathy V, et al. Dietary fat intake and its association with risk of selected components of the metabolic syndrome among rural South Indians. *Indian J Endocrinol Metab*. 2016;20(1):47.
  15. Glueck CJ, Wang P, Woo JG, Morrison JA, Khoury PR, Daniels SR. Adolescent and young adult female determinants of visceral adipose tissue at ages 26-28 years. *J Pediatr*. 2015; 166(4):936-46. e3.
  16. Labayen I, Ruiz JR, Ortega FB, Huybrechts I, Rodríguez G, Jiménez-Pavón D, et al. High fat diets are associated with higher abdominal adiposity regardless of physical activity in adolescents; the HELENA study. *Clin Nutr*. 2014;33(5):859-66.
  17. Sasaki A, De Vega W, Sivanathan S, St-Cyr S, McGowan P. Maternal high-fat diet alters anxiety behavior and glucocorticoid signaling in adolescent offspring. *Neuroscience*. 2014;272: 92-101.
  18. Carlson JJ, Eisenmann JC, Norman GJ, Ortiz KA, Young PC. Dietary Fiber and Nutrient Density Are Inversely Associated with the Metabolic Syndrome in US Adolescents. *J Am Diet Assoc*. 2011;11(111):1688-95.
  19. McGuire S. Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Washington, DC: US Departments of Agriculture and Health and Human Services, 2015. *Adv Nutr*. 2016;7(1):202-4.
  20. Kim EY, Hwang T, Yi KH. Association of serum 25-hydroxyvitamin D concentration and metabolic syndrome in Korean children and adolescents. *Int J Pediatr Endocrinol*. 2015;2015(1):P70.
  21. Velazquez-Lopez L, Santiago-Diaz G, Nava-Hernandez J, Munoz-Torres AV, Medina-Bravo P, Torres-Tamayo M. Mediterranean-style diet reduces metabolic syndrome components in obese children and adolescents with obesity. *BMC Pediatr*. 2014;14:175.
  22. Babio N, Bulló M, Salas-Salvadó J. Mediterranean diet and metabolic syndrome: the evidence. *Public Health Nutr*. 2009;12(9A):1607-17.
  23. Steffen LM, Van Horn L, Daviglius ML, Zhou X, Reis JP, Loria CM, et al. A modified Mediterranean diet score is associated with a lower risk of incident metabolic syndrome over 25 years among young adults: the CARDIA (Coronary Artery Risk Development in Young Adults) study. *Br J Nutr*. 2014;112(10):1654-61.
  24. Bibiloni MM, Martínez E, Llull R, Maffiotte E, Riesco M, Llopart I, et al. Metabolic syndrome in adolescents in the Balearic Islands, a Mediterranean region. *Nutr Metab Cardiovasc Dis*. 2009;20:1e9.
  25. Cuenca-García M, Ruiz J, Ortega F, Labayen I, Huybrechts I, Moreno L, et al. A Mediterranean diet is not enough for cardio-metabolic health:

- physical activity and physical fitness are major contributors in European adolescent. *Revista Andaluza de Medicina del Deporte*. 2015;8(1):26-7.
26. Grosso G, Galvano F. Mediterranean diet adherence in children and adolescents in southern European countries. *NFS Journal*. 2016;3:13-9.
  27. Ozen AE, del Mar Bibiloni M, Murcia MA, Pons A, Tur JA. Adherence to the Mediterranean diet and consumption of functional foods among the Balearic Islands' adolescent population. *Public Health Nutr*. 2015;18(04):659-68.
  28. Salas-Salvadó J, Guasch-Ferré M, Lee C-H, Estruch R, Clish CB, Ros E. Protective effects of the Mediterranean diet on type 2 diabetes and metabolic syndrome. *J Nutr*. 2016;146(4):920S-7S.
  29. Obarzanek E, Sacks FM, Vollmer WM, Bray GA, Miller ER, Lin P-H, et al. Effects on blood lipids of a blood pressure-lowering diet: the Dietary Approaches to Stop Hypertension (DASH) Trial. *Am J Clin Nutr*. 2001;74(1):80-9.
  30. Liese AD, Nichols M, Sun X, D'agostino RB, Haffner SM. Adherence to the DASH Diet is inversely associated with incidence of type 2 diabetes: the insulin resistance atherosclerosis study. *Diabetes Care*. 2009;32(8):1434-6.
  31. Azadbakht L, Surkan PJ, Esmailzadeh A, Willett WC. The Dietary Approaches to Stop Hypertension eating plan affects C-reactive protein, coagulation abnormalities, and hepatic function tests among type 2 diabetic patients. *J Nutr*. 2011;141(6):1083-8.
  32. Moore LL, Bradlee ML, Singer MR, Qureshi MM, Buendia JR, Daniels SR. Dietary Approaches to Stop Hypertension (DASH) eating pattern and risk of elevated blood pressure in adolescent girls. *Br J Nutr*. 2012;108:1678-85.
  33. Saneei P, Hashemipour M, Kelishadi R, Rajaei S, Esmailzadeh A. Effects of recommendations to follow the Dietary Approaches to Stop Hypertension (DASH) diet v. usual dietary advice on childhood metabolic syndrome: a randomised cross-over clinical trial. *Br J Nutr*. 2013;110(12):2250-9.
  34. Günther AL, Liese AD, Bell RA, Dabelea D, Lawrence JM, Rodriguez BL, et al. Association between the dietary approaches to hypertension diet and hypertension in youth with diabetes mellitus. *Hypertension*. 2009;53(1):6-12.
  35. Couch SC, Saelens BE, Levin L, Dart K, Falciiglia G, Daniels SR. The Efficacy of a Clinic-Based Behavioral Nutrition Intervention Emphasizing a DASH-Type Diet for Adolescents with Elevated Blood Pressure. *J Pediatr*. 2008;152(4):494-501.
  36. Liese AD, Bortsov A, Günther AL, Dabelea D, Reynolds K, Standiford DA, et al. Association of DASH Diet With Cardiovascular Risk Factors in Youth With Diabetes Mellitus The SEARCH for Diabetes in Youth Study. *Circulation*. 2011;CIRCULATION.110.955922.
  37. Kim JA, Kim SM, Lee JS, Oh HJ, Han JH, Song Y, et al. Dietary patterns and the metabolic syndrome in Korean adolescents: 2001 Korean National Health and Nutrition Survey. *Diabetes Care*. 2007;30(7):1904-5.
  38. Naja F, Hwalla N, Itani L, Karam S, Sibai AM, Nasreddine L. A Western dietary pattern is associated with overweight and obesity in a national sample of Lebanese adolescents (13–19 years): a cross-sectional study. *Br J Nutr*. 2015;114(11):1909-19.
  39. Esmailzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *Am J Clin Nutr*. 2007;85(3):910-8.
  40. Cheng TO. Effects of fast foods, rising blood pressure and increasing serum cholesterol on cardiovascular disease in China. *Am J Cardiol*. 2006;97(11):1676-8.
  41. Seubsman Sa, Kelly M, Yuthapornpinit P, Sleight A. Cultural resistance to fast-food consumption? A study of youth in North Eastern Thailand. *Int J Consum Stud*. 2009;33(6):669-75.
  42. Kirkpatrick SI, Reedy J, Kahle LL, Harris JL, Ohri-Vachaspati P, Krebs-Smith SM. Fast-food menu offerings vary in dietary quality, but are consistently poor. *Public Health Nutr*. 2014;17(04):924-31.
  43. Kochan Z, Karbowska J, Babicz-Zielińska E. [Dietary trans-fatty acids and metabolic syndrome]. *Postepy higieny i medycyny doswiadczalnej (Online)*. 2009;64:650-8.
  44. Nourmohammdi M, Ejtahed H-S, Mirmiran P, Hekmatdoost A. Dietary fatty acid composition and metabolic syndrome: a review. *Journal of Nutritional Sciences and Dietetics*. 2015;1(1):28-36.
  45. Marlatt KL, Farbaksh K, Dengel DR, Lytle LA. Breakfast and fast food consumption are associated with selected biomarkers in adolescents. *Prev Med Rep*. 2016;3:49-52.
  46. Ahluwalia N, Andreeva V, Kesse-Guyot E, Hercberg S. Dietary patterns, inflammation and the metabolic syndrome. *Diabetes Metab*. 2013;39(2):99-110.
  47. Ambrosini GL, Huang R-C, Mori TA, Hands BP, O'Sullivan TA, de Klerk NH, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. *Nutr Metab Cardiovasc Dis*. 2010;20(4):274-83.
  48. Oddy WH, Herbison CE, Jacoby P, Ambrosini GL, O'Sullivan TA, Ayonrinde OT, et al. The Western dietary pattern is prospectively associated with

- nonalcoholic fatty liver disease in adolescence. *The Am J Gastroenterol.* 2013;108(5):778-85.
49. Kim JA, Kim SM, Lee JS, Oh HJ, Han JH, Song Y, et al. Dietary patterns and the metabolic syndrome in Korean adolescents. *Diabetes Care.* 2007;30(7):1904-5.