**Name of Journal:** *World Journal of Diabetes*

**Manuscript NO:** 47300

**Manuscript Type:** ORIGINAL ARTICLE

***Prospective Study***

**Prospective study of total and various types of vegetables and the risk of metabolic syndrome among children and adolescents**

Hosseinpour-Niazi S *et al*. Allium and metabolic syndrome

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**Author contributions:** Mirmiran P and Hosseinpour-Niazi S designed the study; Hosseinpour-Niazi S, Bakhshi B and Betru E performed the research; Hosseinpour-Niazi S and Darand M analyzed the data; Hosseinpour-Niazi S wrote the paper; Mirmiran P and Aziz F revised the manuscript for final submission.

**Supported by** Shahid Beheshti University of Medical Sciences, Tehran, Iran, No. 12508.

**Institutional review board statement:** Study protocol was approved by the ethics committee of the Research Institute for Endocrine Sciences (RIES), Shahid Beheshti University of Medical Sciences, Tehran, Iran.

**Informed consent statement:** Written informed consent was acquired from participants prior to their inclusion in the study.

**Conflict-of-interest statement:** The authors declare that they have no conflict of interest.

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**Manuscript source:** Invited manuscript

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**Received:** March 12, 2019

**Peer-review started:** March 15, 2019

**First decision:** April 13, 2019

**Revised:** May 9, 2019

**Accepted:** May 13, 2019

**Article in press:**

**Published online:**

**Abstract**

***BACKGROUND***

Data available on the association between consumption of various types of vegetables and metabolic syndrome (MetS) remains inconsistent.

***AIM***

To investigate the association between intakes of various types of vegetables and MetS among children and adolescents.

***METHODS***

The Tehran Lipid and Glucose Study cohort included 424 children and adolescents initially free of MetS. At the 3.6 years follow-up, 47 new cases of MetS were identified. A 168-item semi-quantitative food-frequency questionnaire was used to collect information about total- and various types of vegetables consumed including, allium-, green leafy-, fruity-, root-, stalk-, potatoes, starchy, and cabbage consumption. MetS was defined according to the Cook *et al* criteria.

***RESULTS***

The median (interquartile range) of total vegetables consumption was 217 (146-344) g/d. After adjustment for demographic characteristics and dietary intake, higher total- (≥ 350 g/d) and allium vegetable consumption (≥ 30 g/d) in the 4th quartile were significantly and inversely associated with lower risk of MetS, compared to the first quartile. Consumption of green leafy vegetables in the third (21.4-38.3 g/d) *vs* thefirst quartile (≤ 13.5 g/d) demonstrated a significant inverse association with lower risk of MetS in children and adolescents; associations for other types of vegetables consumed were not significant.

***CONCLUSION***

Consumption of vegetables, especially allium and green leafy vegetables in sufficient amount may be beneficial in reducing the risk of MetS among children and adolescents.

**Key words**: Metabolic syndrome; Children and adolescents; Vegetable; Allium; Green leafy vegetables

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**Core tip:** Data on the association between vegetable intakes as an individual dietary component and metabolic syndrome (MetS) remain inconsistent. This inconsistency of findings may probably be due to a difference in the amounts and specific subgroups of vegetables in different studies. This prospective study of Iranian children and adolescents reported an inverse association between total vegetable consumption and MetS risk. Among vegetables subgroups, consumption of green leafy- and allium vegetables was inversely associated with risk of MetS after adjustment for the main potential confounders.

Hosseinpour-Niazi S, Bakhshi B, Betru E, Mirmiran P, Darand M,Azizi F. Prospective study of total and various types of vegetables and the risk of metabolic syndrome among children and adolescents. *World J Diabetes* 2019; In press

**INTRODUCTION**

Metabolic syndrome (MetS) is characterized by the clustering of metabolic abnormalities such as glucose intolerance, central obesity, hypertension, and dyslipidemia. Although there is no concurrence on a MetS definition for children and adolescents, the prevalence of MetS in obese children is documented to be approximately 30%[1]. Since MetS components show stability from childhood to adulthood, children fulfilling diagnostic criteria for MetS, may remain at high risk as they enter adulthood[2]. MetS severity in childhood has been linked to future risk of type 2 diabetes and cardiovascular disease (CVD)[3], indicating that implementing interventions for a healthy lifestyle early in childhood might be preventive against future development MetS and its complications.

The primary goal for MetS management is to alleviate all metabolic risk factors through effective lifestyle changes[4]. Research indicates healthy dietary patterns, such as the Mediterranean, and Dietary approach to stop hypertension diet, all of which recommend high intakes of vegetables, improve MetS and type 2 diabetes[5,6]; however, data on the associations between vegetable intakes as an individual dietary component and MetS, type 2 diabetes and CVD remain inconsistent[7-13]. Although one meta-analysis including twenty-six observational studies reported beneficial effects for consumption of vegetables on MetS[7], another meta-analysis of randomized controlled trials found no effect on MetS components[8]. Protective effects of vegetable consumption against other nutrition-related chronic diseases such as type 2 diabetes, are also still not clear; some report an inverse association[9], while others document none[10,11], and some others report a threshold of around two-three servings/day of vegetables, after which diabetes risk did not reduce further[12,13]. This inconsistency of findings might probably be due to differences in amounts and specific subgroups of vegetables in different studies. Biological effects of vegetables may vary due to their phytochemical profiles: Leafy vegetables as a source of nitrogen containing compounds, nitrate, and carotenoids, lutein, polyphenols, flavonoids, phenolic acids, lignans[14]; Cabbage as a source of polyphenols, flavonoids, phenolic acids, lignans; Allium vegetables as source of organosulfur compound, allyl cysteine, alliin, allicin, and allyl disulfide, flavonoids and phenolic compounds[15], and fruity vegetables as a source of carotenoids, lycopene and pro-vitamin A, beta-carotene[7]. In addition, consuming a variety of vegetables such as green leafy-, allium-, and cruciferous vegetables has been inconsistently associated with CVD risk[16-21] and type 2 diabetes[9,11,22,23].

As mentioned, subgroups of vegetables may differ in nutritional content, energy, fiber and phytochemicals[24]; considering the limited data available on the association of different types of vegetables with MetS, the aim of our study was to investigate the association between intakes of various types of vegetables and MetS after 3.6 years of follow-up in Tehranian children and adolescents, aged 6-18 years.

**MATERIALS AND METHODS**

***Subjects and methods***

This prospective population-based study was conducted within the framework of the Tehran lipid and glucose study (TLGS), an ongoing, prospective community based study, aimed at preventing non-communicable disease and reducing its risk factors through promoting healthy lifestyles. Detailed characteristics of the TLGS have been described elsewhere[25]. Briefly, phase I of the TLGS was initiated in March 1999, a multistage cluster sampling was used to randomly select > 15000 individuals, aged ≥ 3 years from residents of Tehran’s urban district 13, a group representing the urban population of Tehran. Follow-up data are collected every 3 years to update participants, data on demographics, lifestyle, biochemical, clinical, and dietary assessments; phases II, III, and IV are prospective follow-up studies conducted between 2002-2005, 2006-2008, and 2009-2011, respectively. The current prospective population-based study was conducted during a mean 3.6 years of follow-up (follow-up rate: 86%); baseline data were obtained from phase III of TLGS (2006–2008) and outcome examination data were from phase IV (2009-2011).

For the current study, of 12 523 individuals who entered survey III of TLGS, based on age and gender, 4920 subjects were randomly selected, for collection of nutritional data. This sample size was chosen owing to the cost, complexity and time involved in collection of dietary data in a large population. Characteristics of participants who had complete the dietary data were similar to those of the total population in phase III of the TLGS[26]. Of the 4920 participants enrolled in the present study, 621 children and adolescents, aged 6-18 years agreed to complete the food frequency questionnaire (FFQ). Those who had missing data on dietary intakes or MetS components (*n* = 29), those who had baseline MetS (*n* = 69), and participants who over- or under-reported (*n* = 122), were all excluded. According to the equation proposed by the institute of medicine[27], by dividing the reported energy intake by the estimated energy requirement (EER), individuals who were not within the ± 3 SD range (those in the top and bottom 1% of the energy intake to EER ratio), were defined as under and over-reporters. Finally data of 424 participants was used for analysis (response rate 68% during the 3.6 years follow-up). Anthropometric and biochemical measurements of participants who provided follow-up assessments was similar to those lost to follow-up.

The study protocol was approved by the ethics committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, and written informed consent was acquired from participants prior to their inclusion in the study.

***Dietary assessment***

Dietary intake information over the previous year was assessed using a 168-item, validated, semi-quantitative FFQ[28]. Consumption frequency of each food item was documented on a daily, weekly, monthly basis, by a trained dietitian, during face to face interviews; portion sizes were reported in household measures and converted to gram using household measures[29]. Percentages of carbohydrate, fat and protein intake were calculated by multiplying the grams of consumption of each food by the content of carbohydrate, protein and fat, the composition values of which were obtained from the US Department of Agriculture (USDA) Food Composition Table (FCT), as the Iranian FCT is incomplete (limited to only raw materials and a few nutrients). Vegetable consumption was assessed using 28 vegetables and reported as grams per day. General classification of our subgroups of vegetables (green leafy, allium, stalk, fruity, root, cabbage, starchy vegetables and potatoes) was based on the Cooper *et al*[9] researchand the classification used in the EPIC-InterAct study.

Reliability and validity of the FFQ for total vegetable consumption was acceptable (Adjusted correlation coefficient between FFQ and multiple 24 recalls was 0.69 and 0.50, respectively; between the two FFQs it was 0.46 and 0.50 in males and females, respectively[28]. Also dietary patterns derived from the FFQ have shown reasonable reliability, validity and stability over time[30].

***Biochemical measurement***

Blood samples were drawn after 12-14 h of overnight fasting, between 7:00-9:00 a.m. from all participants, at baseline and follow-up. All blood analyses were done at the TLGS research laboratory on the day of sample collection. The enzymatic colorimetric method using glucose oxidase was used to measure fasting plasma glucose (FPG). High density lipoprotein cholesterol (HDL-C) was measured after precipitation of the apolipoprotein B-containing lipoproteins with phosphotungstic acid and using the enzymatic colorimetric method with glycerol phosphate oxidase, triglycerides (TG) concentrations were measured. All analyses were performed using commercial kits (Pars Azmoon Inc., Tehran, Iran). Inter- and intra-assay coefﬁcients of variations at baseline were both 2.2% for FPG, 2% and 0.5% for HDL-C and 1.6% and 0.6% for TG, respectively.

***Assessment of other variables***

Blood pressure was measured twice, manually, using a standard mercury sphygmomanometer after a 15 min rest in supine position and the mean of two measurements was considered as the participants’ blood pressure. Height was measured without shoes, using a stadiometer, while participants were standing, with shoulders in normal alignment, and recorded to the nearest 0.1 cm. Weight was measured without shoes, with participants wearing light clothes, using a digital scale, and recorded to the nearest 0.1 kg (Seca 707; Seca Corporation, Hanover, Maryland; range 0.1-150 kg). Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m2). Waist circumference (WC) was measured at the midpoint between the iliac crest and lowest rib, recorded to 0.1 cm, in a standing position using an unstretched elastic tape. Physical activity level was calculated to metabolic equivalent task minutes per week, using the modifiable activity questionnaire, the high reliability (97%) and moderate validity (49%) of which have been verified previously for the persian translated modiﬁable activity questionnaire in adolescents[31]. Levels of physical activity were expressed as metabolic equivalent hours per week (METs h/week). Smoking history was collected using a questionnaire and categorized as smokers (smoked > 1 cigarette per day) and non-smoker/ex-smoker. Medical history and data on current use of medications, family history of diabetes, age and gender were obtained using a questionnaire, as reported previously[25].

***Definition of MetS***

Since there is no consensus regarding the criteria and definition of MetS for children and adolescents, the Cook *et al*[32]proposed definition, which defines MetS as ≥ 3 of the following criteria, was used; (1) TG ≥110 mg/dL or; (2) HDL-C < 40 mg/dL; (3) FPG ≥100 mg/dL, according to the recent recommendations of the American Diabetes Association[33]; (4) systolic blood pressure (SBP) or diastolic blood pressure (DBP) ≥90th percentile for sex, age, and height, from the cut off points recommended by the National Heart, Lung, and Blood Institute[34]; and (5) WC≥ 90th percentile for age and sex, according to national reference curves[35]. Pre-Mets has been defined as having two components of these criteria[36].

For individuals, aged > 18 years after follow-up, MetS was defined as the presence of three or more of five components, as recommended by the Joint Interim Statement of the International Diabetes Federation as follows: (1) Low serum HDL cholesterol (< 40 mg/dL in men and < 50 mg/dL in women; (2) abnormal glucose homeostasis (FPG ≥ 100 mg/dL or use of hyperglycemic medication); (3) elevated blood pressure (SBP ≥ 130 mmHg and/or DBP ≥ 85 mmHg or use of antihypertensive medication); (4) high serum triglyceride concentration (≥ 150 mg/dL or use of [antihypertriglyceridemia medication](https://www.google.com/search?q=anti+hypertriglyceridemia+medication&spell=1&sa=X&ved=0ahUKEwjaxs6viefdAhXIKewKHag1ByQQkeECCCcoAA)); and (5) enlarged WC (≥ 95 cm according to the newly introduced cut-off points for Iranian adults for both genders)[37,38].

***Statistical analysis***

Data were analyzed using the Statistical Package for Social Sciences (v. 15.0; SPSS, Chicago, Illinois, United States), with statistical significance set at as *P* < 0.05. Consumption of total- and various types of vegetables was categorized into quartiles according to their baseline intakes. One-way analysis of variance and chi-squared test were used to report baseline characteristics and dietary intakes (adjusted for energy intakes) in total vegetable categories; data are presented as means ± SE and median [interquartile range (IQR)] for continuous variables, and percentages for categorical variables. Odds ratio (ORs) and 95% CIs of incident MetS were estimated across quartiles of total- and different types of vegetable consumption using the logistic regression model, with the first quartile being used as a reference. Model 1 was crude. Model 2 was adjusted for age, gender, physical activity, family history of diabetes, total energy- and cholesterol intake at baseline. Model 3 was additionally adjusted for BMI at baseline. Tests for trend of ORs across quartiles of total and various types of vegetables were conducted by assigning the median value to each quintile as a continuous variable in the regression models. By multivariable regression models, we further performed stratified analysis by categories of number of components of MetS (0, 1 or 2 components of Mets) at baseline to estimate ORs of MetS based intake of total and various types of vegetable consumption (above/below the medians).

**RESULTS**

Among 424 children and adolescents free of MetS at baseline, 47 (11%) were diagnosed with MetS during a median follow-up period of 3.6 years. Participants (58% girls) were aged 13.5 (SD 3.7) years at baseline with BMI 20.0 (SD 3.8) kg/m2. Median ± IQR of total vegetables consumption was 217 (146-344) g/d. At baseline, the median (IQR) from highest to lowest range of various types of vegetable consumption was: Fruity vegetables 115 (69.5-211), leafy vegetables 21.4 (13.4-38.4), allium vegetables 17.6 (6.3-30.5), potatoes 10.3 (4.8-20.7), root vegetables 9.9 (4.2-22.3), other starchy vegetables 5.8 (3.3-12.6), cabbage 3.1 (0.0-6.2), and stalk vegetables 0.45 (0.0-1.1).

Table 1presents the characteristics of participants according to quartiles of total vegetable consumption. Participants in the highest quartile had low systolic blood pressure, low fasting blood glucose and high HDL cholesterol concentrations at baseline. After 3.6 years of follow-up, FBS was significantly lower and HDL cholesterol significantly higher among those in the highest quartile of total vegetable consumption, compared with those in the lowest. No statistically significant associations were found for age, gender, physical activity levels, family history of diabetes, parental education level and occupational status and BMI. The prevalence of subjects with 0, 1 and 2 components of MetS did not differ across quartiles of vegetable consumption. There was no significant difference in total vegetable consumption [median (IQR)] between participants with 0 [206 (145-322 g/d)], 1 [217 (144-351 g/d)], and 2 component of MetS [226 (161-345 g/d)] at baseline.

Table 2present energy adjusted means for dietary components across quartiles of total vegetable consumption. Participants who consumed more vegetables, also consumed more of types of vegetables. Consequently, those with a high intake of vegetables consumed more total fiber, cholesterol, magnesium, potassium, fruit, nuts, and dairy products.

Table 3 presents ORs of MetS associated with the total and various types of vegetables among children and adolescents. Compared to the first quartile, a higher consumption of total- (≥ 350 g/d) and allium (≥ 30 g/d) vegetables in the 4th quartile were significantly and inversely associated with lower risk of MetS in unadjusted (model 1), the adjusted model for demographic characteristics and dietary intake (model 2), and BMI (model 3 in allium vegetables). Consumption of green leafy vegetables in the third (21.4-38.3 g/d) *vs* thefirst quartile (≤ 13.5 g/d) was significantly and inversely associated with lower risk of MetS in the unadjusted (model 1) and the model adjusted for demographic characteristics and dietary intakes (model 2); further adjustment for BMI attenuated these associations. Among vegetables, fruity-, root-, stalk-, potatoes, starchy-, and cabbage vegetables was not associated with MetS among children and adolescents.

Table 4 presents ORs for MetS based intake of total and various types of vegetable consumption (above/below the medians) among participants with 0, 1 or 2 components of MetS at baseline. Among participants with 1 component of MetS, green leafy- and allium vegetables reducer risk of MetS by 71% (0.23, 95%CI: 0.07-0.71) and 77% (0.29, 95%CI: 0.07-0.71), after adjustment for confounding factors. No association was found between total-, fruity-, root-, stalk-, potatoes, starchy-, and cabbage vegetables and risk of MetS among participant with ≥ 2 component at baseline.

**DISCUSSION**

This prospective study of Iranian children and adolescents reported an inverse association between total vegetable consumption and MetS risk. Among vegetables subgroups, consumption of green leafy- and allium vegetables was inversely associated with risk of MetS after adjustment for the main potential confounders. In addition, we found that among participants with 1 component of MetS, consumption of allium- and green leafy vegetables reduce risk of Mets. However limited sample size in participants with 0 and 2 components of MetS may influence the association between consumption of vegetables and MetS.

Although the effects of vegetable intakes on MetS have been investigated by numerous epidemiological and interventional studies, most findings remain inconclusive[7,8]. Furthermore in relation to type 2 diabetes, the efficacy of vegetable consumption is still not clear; some studies report inverse associations[9], while others report none[10,11]; yet another documented a threshold of around two-three servings/day of vegetables, after which diabetes and CVD risk did not reduce further[12,13,16]. In the current study we found that consumption of vegetables, median intake of 440 g/wk, reduced risk of Mets by 60% among children and adolescents, findings consistent with dietary pattern studies, in which healthy diets rich in vegetables are associated with a reduced risk of MetS and its components in children and adolescents[39,40]. However in a comprehensive systematic review of studies addressing fruit and vegetable consumption and cardiovascular risk indicators in adolescents, only one-third of the studies showed significant inverse associations of fruit and vegetable intakes and MetS and its components[41]. This inconsistency of findings may be because of differences in the amounts and specific subgroups of vegetables intakes in different studies. More prospective and interventional studies are needed to specify the effects of various types of vegetables.

The association between green leafy vegetables and nutrition-related chronic disease was less consistent in prospective studies. In the “CHANCES” project, results from NIH-AARP and EPIC Elderly (All, Greece) cohorts consumption of report green leafy vegetables is associated with a reduced [OR: 0.87 (0.84–0.90)] and increased [OR: 1.23 (1.01–1.50), OR: 1.52 (1.13–2.04)] risk of type 2 diabetes, respectively; yet the pooled analysis indicated no overall association between intakes of green leafy vegetables, type two diabetes[42]and CVD risk[16]*.* Zhang *et al*[7], in a meta-analysisof observational studies concluded that consumption of green leafy vegetables might not be associated with risk of MetS. Despite the results given above, several different meta-analyses, suggest green leafy vegetable consumption significantly reduce risk of type 2 diabetes and CVD[9,11,16,18]; an increase of 0.2 serving/d of green leafy vegetables was associated with 13% reduction in type 2 diabetes[23].Our study showed that although consumption green leafy vegetables significantly reduced risk of MetS to a median intake of 27 g/wk, there was a threshold of around 30 g/d, after which this inverse association disappeared; similar reductions of associated risk until the last median intake has similarly been reported in two previous cohort studies[22,23]. In the women’s health study (median intake 0.92 serving/d), and the shanghai women‘s health study (SWHS) (median intake 94.1 g/d), type 2 diabetes risk reduced up to the 4th quantile of intake, but not further[22,23]. Green leafy vegetables contain maximum amount of nitrate, thus a risk-benefit effect of nitrate should be considered. The adequate intake for nitrate (3.7 mg/kg body weight/day equivalent to 222 mg nitrate per day for a 60 kg adult) is constantly exceeded in several dietary patterns; this overconsumption of dietary nitrate could hence be responsible for disappearance of an inverse association between green leafy vegetables intake and MetS, and the risk of type 2 diabetes after the third quartile of intake in our study and those of others[43].

In the current study, allium vegetables were inversely associated with risk for MetS among children and adolescents. Positive effects of *A. sativum* on control of MetS and its components especially dyslipidemia and diabetes have been reported previously[44]. Moreover, several prospective studies also have been conducted regarding the positive effect of allium vegetables on CVD outcomes, chronic kidney disease, hypertension, ischemic heart disease mortality, cerebral vascular disease mortality and myocardial infarction[17,19,20], but not all[21,45]. Allium is a rich source of phytonutrients including organosulfur and phenolic compounds; their consumption 2 to 3 times per day improves the cardio-metabolic risk factors among individuals with diabetes and MetS, reduces inflammation and oxidative stress and has a vasodilator effect[46-49].

Few studies have investigated the association between cruciferous vegetables and MetS risk and most of these report that dietary patterns rich in vegetables including cruciferous reduce the occurrence of MetS[50,51]. Although our findings and also those of some previous studies found no protective effects of cruciferous vegetables[21,45], others have reported a potential reduction in the risk of ischemic heart disease mortality, coronary heart disease, subclinical atherosclerosis, which may be due to lower amount of cruciferous vegetable intakes in our study compared to others[16,17].

In the current study, no association between fruity-, root-, stalk-, starchy vegetables, potatoes and Mets was found. Results of research on the consumption of these vegetables and the risk of MetS is controversial, which may be due to the differences between the amounts and preparation methods used in these studies[16,17,21,23,45,52-55]. Further investigations of various types of vegetables such as fruity-, starchy-, root vegetables consumption on MetS are needed.

***Strengths and limitations***

Major strengths of this study include the population-based prospective design of the study, participants of which were representative of Tehran’s population, the large sample size, and use of a valid and reliable FFQ administered by a trained nutritionist, reducing any potential measurement errors, and the minimized loss to follow-up bias (response rate 86%). Nevertheless, the present study has a few limitations. First, MetS is heterogeneous; despite carefully adjusting for a range of known confounding factors, other factors associated with MetS among children and adolescents including heredity and puberty status were not addressed because of a lack of information. In addition, regarding the different types of vegetables (other than allium and green leafy vegetables) included in the analysis of this study, the failure to detect associations between consumption of these types of vegetables and MetS may be due to the narrow range of dietary intakes among our participants.

In conclusion, findings of this prospective study indicate that consumption of green leafy vegetables and allium vegetables were associated with lower risk of MetS during 3 years of follow-up in children and adolescents.

**ARTICLE HIGHLIGHTS**

***Research background***

Metabolic syndrome (MetS) is characterized by the clustering of metabolic abnormalities such as glucose intolerance, central obesity, hypertension, and dyslipidemia. The primary goal for MetS management is to alleviate all metabolic risk factors through effective lifestyle changes. Research indicates healthy dietary patterns, such as the Mediterranean, and Dietary approach to stop hypertension diet, all of which recommend high intakes of vegetables, improve MetS and type 2 diabetes; however, data on the associations between vegetable intakes as an individual dietary component and MetS remain inconsistent.

***Research motivation***

This inconsistency of findings between chronic disease such as MetS and vegetable consumption might probably be due to differences in specific subgroups of vegetables in different studies. Various types of vegetables differ in nutritional content, energy, fiber and phytochemicals.

***Research objectives***

The aim of our study was to investigate the association between intakes of various types of vegetables and MetS after 3.6 years of follow-up in Tehranian children and adolescents, aged 6-18 years.

***Research methods***

This prospective population-based study was conducted within the framework of the Tehran lipid and glucose study, an ongoing, prospective community based study, aimed at preventing non-communicable disease and reducing its risk factors through promoting healthy lifestyles. Of the 4920 participants enrolled in the present study, 621 children and adolescents, aged 6-18 years greed to complete the food frequency questionnaire. Those who had missing data on dietary intakes or MetS omponents, those who had baseline MetS, and participants who over- or under-reported, were all excluded. Finally data of 424 participants was used for analysis. Dietary intake information over the previous year was assessed using a 168-item, validated, semi-quantitative food frequency questionnaire. Vegetable consumption was assessed using 28 vegetables and reported as grams per day. General classification of our subgroups of vegetables (green leafy, allium, stalk, fruity, root, cabbage, starchy vegetables and potatoes) was based on EPIC-InterAct study. Blood samples were drawn after 12-14 h of overnight fasting and glucose, triglyceride and HDL-C concentrations were measured. Blood pressure and waist circumference were assessed using standard tools. Mets was defined using Cool et al criteria for individual <18 year. For participant aged ≥ 18 years, Joint Interim Statement of the International Diabetes Federation criterial was used to define the MetS.

***Research results***

Among 424 children and adolescents free of MetS at baseline, 47 (11%) were diagnosed with MetS during a median follow-up period of 3.6 years. Higher consumption of total- (≥ 350 g/d) and allium (≥ 30 g/d) vegetables were significantly and inversely associated with lower risk of MetS after adjustment for confounding factors. Consumption of green leafy vegetables in the third (21.4-38.3 g/d) *vs* thefirst quartile (≤ 13.5 g/d) was significantly and inversely associated with lower risk of MetS in the unadjusted (model 1) and the model adjusted for demographic characteristics and dietary intakes (model 2); further adjustment for BMI attenuated these associations. Among vegetables, fruity-, root-, stalk-, potatoes, starchy-, and cabbage vegetables was not associated with MetS among children and adolescents.

***Research conclusions***

Consumption of green leafy vegetables and allium vegetables were associated with lower risk of MetS during 3 years of follow-up in children and adolescents.

***Research perspectives***

Future studies addressing the underlying mechanisms of allium and green leafy vegetables in reducing the risk of MetS is needed.

**ACKNOWLEDGEMENTS**

The authors would like to acknowledge Ms Niloofar Shiva for critical editing of English grammar and syntax of the manuscript. We express our appreciation to the participants of this study for their collaboration.

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**P-Reviewer:** Nakajima K **S-Editor:** Ji FF **L-Editor: E-Editor:**

**Specialty type:** Endocrinology and metabolism

**Country of origin:** Iran

**Peer-review report classification**

Grade A (Excellent): 0

Grade B (Very good): B

Grade C (Good): 0

Grade D (Fair): 0

Grade E (Poor): 0

**Table 1 Baseline characteristics of participants by quartiles of total vegetable consumption: Tehran Lipid and Glucose Study**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Quartiles of total vegetable consumption** | | | | ***P*1 value** |
| **1** | **2** | **3** | **4** |
| Participants (*n*) | 106 | 106 | 106 | 106 |  |
| Number of components of MetS at baseline (*n*) | | | | | |
| No component | 42 | 45 | 45 | 49 | 0.91 |
| 1 component | 40 | 41 | 40 | 47 |
| 2 components (pre-MetS) | 24 | 20 | 21 | 10 |
| Metabolic syndrome after 3.6 yr (*n*) | 17 | 12 | 10 | 8 |  |
| Age (yr) | 13.1 ± 0.3 | 13.3 ± 0.3 | 13.7 ± 0.3 | 13.9 ± 0.3 | 0.31 |
| Female (%) | 53.8 | 65.1 | 54.7 | 56.6 | 0.32 |
| Low physical activity (%) | 61 | 73 | 69 | 52 | 0.74 |
| Family history of diabetes (%) | 4.7 | 8.5 | 3.8 | 3.8 | 0.37 |
| BMI (kg/m2) | 19.6 ± 0.4 | 20.7 ± 0.3 | 20.0 ± 0.3 | 19.8 ± 0.3 | 0.18 |
| Parental academic degrees (%) | 25.2 | 26.9 | 22.8 | 25.2 | 0.48 |
| Parental occupational status, employed (%) | 83.6 | 87.4 | 81.7 | 82.2 | 0.39 |
| Systolic blood pressure (mmHg) | | | | | |
| At baseline | 99.1 ± 1.1 | 98.1 ± 1.1 | 96.2 ± 1.1 | 95.0 ± 1.1 | 0.04 |
| After 3.6 yr | 101 ± 1.2 | 100.2 ± 2 | 101.2 ± 1.2 | 98.8 ± 1.2 | 0.44 |
| Diastolic Blood pressure (mmHg) | | | | | |
| At baseline | 65.1 ± 0.9 | 65.0 ± 0.9 | 63.9 ± 0.9 | 64.3 ± 0.9 | 0.76 |
| After 3.6 yr | 66.5 ± 0.9 | 68.4 ± 0.9 | 68.2 ± 0.9 | 69.0 ± 0.9 | 0.27 |
| Fasting blood glucose (mg/dL) | | | | | |
| At baseline | 86.6 ± 0.6 | 84.3 ± 0.6 | 85.1 ± 0.6 | 84.2 ± 0.6 | 0.036 |
| After 3.6 yr | 91.8 ± 0.7 | 89.8 ± 0.7 | 89.3 ± 0.7 | 88.9 ± 0.7 | 0.037 |
| Serum triglycerides (mg/dL) | | | | | |
| At baseline | 78.0 (60.0 – 95.0) | 83.0 (63.0 – 100.0) | 83.0 (64.0 - 103.0) | 78.5 (64.0 - 105.0) | 0.64 |
| After 3.6 yr | 79.0 (60.7 – 109.0) | 73.0 (60.0 – 101.0) | 74.0 (60.0 – 96.0) | 77.0 (62.5 - 98.5) | 0.58 |
| Serum HDL-C (mg/dL) | | | | | |
| At baseline | 45.2± 1.1 | 44.8 ± 1.1 | 44.8 ± 1.1 | 48.5 ± 1.1 | 0.030 |
| After 3.6 yr | 50.5 ± 1.2 | 50.0 ± 1.2 | 51.3 ± 1.2 | 55.1 ± 1.2 | 0.014 |
| Waist circumference (cm) | | | | | |
| At baseline | 67.3± 1.0 | 68.2± 1.0 | 69.5±1.0 | 70.3± 1.0 | 0.16 |
| After 3.6 yr | 76.1 ± 1.0 | 77.0 ± 1.0 | 77.9 ± 1.0 | 77.6 ± 1.0 | 0.62 |

1mean ± SE for all these values, except for variables was determined. Serum triglycerides reported as median (interquartile range). *P* values determined using ANOVA for continuous variables and chi-square test for categorical variables. BMI: Body mass index; MetS: Metabolic syndrome; HDL-C: High density lipoprotein cholesterol.

**Table 2 Baseline dietary intakes of participants by quartiles of total vegetable consumption: Tehran Lipid and Glucose Study**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Quartiles of total vegetable consumption** | | | | ***P* value** |
| **1** | **2** | **3** | **4** |
| Fruity vegetables (g/d) | 57.5 ± 9.2 | 99.2 ± 9.2 | 156 ± 9.2 | 293 ± 9.2 | < 0.001 |
| Root vegetables (g/d) | 7.9 ± 1.9 | 14.8 ± 1.9 | 18.7 ± 1.9 | 27.3 ± 1.9 | < 0.001 |
| Stalk vegetables (g/d) | 0.7 ± 0.2 | 1.2 ± 0.2 | 1.1 ± 0.2 | 1.7 ± 0.2 | 0.002 |
| Leafy vegetables (g/d) | 19.1 ± 2.3 | 24.2 ± 2.3 | 30.8 ± 2.2 | 44.3 ± 2.4 | < 0.001 |
| Potatoes (g/d) | 9.7 ± 2.8 | 13.6 ± 2.7 | 17.7 ± 2.7 | 28.8 ± 2.9 | < 0.001 |
| Starchy vegetables (g/d) | 7.6 ± 1.3 | 8.2 ± 1.2 | 13.4 ± 1.2 | 11.3 ± 1.3 | 0.003 |
| Cabbage (g/d) | 2.4 ± 1.5 | 5.1 ± 1.4 | 8.6 ± 1.4 | 12.8 ± 1.5 | < 0.001 |
| Allium vegetables (g/d) | 13.7 ± 2.4 | 18.0 ± 2.3 | 25.3 ± 2.3 | 41.4 ± 2.4 | < 0.001 |
| Total energy (Kcal/d) | 1981 ± 113 | 2171 ± 113 | 2703 ± 113 | 3383 ± 113 | < 0.001 |
| Carbohydrate (% of total energy) | 56.5 ± 0.7 | 56.7 ± 0.7 | 57.2 ± 0.7 | 57.3 ± 0.7 | 0.82 |
| Protein (% of total energy) | 13.2 ± 0.2 | 12.8 ± 0.2 | 13.1 ± 0.2 | 13.4 ± 0.2 | 0.33 |
| Fat (% of total energy) | 32.4 ± 0.7 | 32.5 ± 0.7 | 32.3 ± 0.7 | 32.1 ± 0.7 | 0.98 |
| SFA (% of total energy) | 11.4 ± 0.3 | 11.1 ± 0.3 | 10.9 ± 0.3 | 11.1 ± 0.3 | 0.64 |
| MUFA (% of total energy) | 11.2 ± 0.3 | 11.0 ± 0.3 | 11.2 ± 0.3 | 11.1 ± 0.3 | 0.92 |
| PUFA (% of total energy) | 6.5 ± 0.2 | 6.6 ± 0.2 | 6.7 ± 0.2 | 6.5 ± 0.2 | 0.90 |
| Total fiber (g/d) | 27.4 ± 2.4 | 30.5 ± 2.4 | 42.0 ± 2.4 | 49.6 ± 2.4 | < 0.001 |
| Cholesterol (g/d) | 190 ± 14 | 205 ± 14 | 267 ± 14 | 316 ± 14 | < 0.001 |
| Magnesium (mg/d) | 301 ± 20 | 324 ± 20 | 433 ± 20 | 547 ± 20 | < 0.001 |
| Potassium (mg/d) | 2835 ± 171 | 3127 ± 171 | 4228 ± 171 | 5588 ± 171 | < 0.001 |
| Whole grain (g/d) | 90 ± 16 | 92 ± 16 | 94 ± 16 | 92 ± 16 | 0.251 |
| Refined grain (g/d) | 356 ± 26 | 354 ± 26 | 359 ± 26 | 351 ± 26 | 0.632 |
| Fruit (g/d) | 272 ± 31.6 | 308 ± 31.6 | 453 ± 31.6 | 609 ± 31.6 | < 0.001 |
| Nuts | 6.9 ± 1.4 | 7.9 ± 1.3 | 9.8 ± 1.3 | 14.5 ± 1.3 | 0.001 |
| Legumes | 11.9 ± 2.2 | 12.0 ± 2.2 | 13.9 ± 2.2 | 14.5 ± 2.2 | 0.879 |
| Dairy products | 146 ± 39.7 | 517 ± 39.7 | 609 ± 39.7 | 704 ± 39.7 | 0.005 |
| Meat, poultry, fish (g/d) | 53.8 ± 10.1 | 56.1 ± 10.1 | 59.1 ± 10.1 | 52.7 ± 10.1 | 0.548 |

Data are mean and SE, adjusted for energy intakes. SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids’ PUFA: Polyunsaturated fatty acids.

**Table 3 Multivariate adjusted odds ratio (95%CI) for metabolic syndrome across quartiles of total and various types of vegetable consumption: Tehran Lipid and Glucose Study**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Quartiles of total- and various types of vegetable consumption** | | | | ***P* value for**  **Trend1** |
| **1** | **2** | **3** | **4** |
| Total vegetables | | | | | |
| Median intake (g/d) | 104 | 179 | 265 | 441 |  |
| Range of intake (g/d) | ≤ 146 | 147-217 | 218-343 | ≥ 350 |  |
| Model 1 | 1 | 0.66 (0.30-1.47) | 0.54 (0.23–1.25) | 0.42 (0.17–0.92) | 0.06 |
| Model 2 | 1 | 0.54 (0.21-1.46) | 0.42 (0.16-1.07) | 0.36 (0.14-0.94) | 0.04 |
| Model 3 | 1 | 0.53 (0.20-1.46) | 0.41 (0.15-1.10) | 0.35 (0.13-0.95) | 0.04 |
| Allium vegetables | | | | | |
| Median intake (g/d) | 2.7 | 10.8 | 22.8 | 51.5 |  |
| Range of intake (g/d) | ≤6.2 | 6.3-17.3 | 17.4-30.5 | ≥ 30.6 |  |
| Model 1 | 1 | 0.68 (0.31-1.47) | 0.44 (0.19-1.05) | 0.34 (0.13-0.87) | 0.024 |
| Model 2 | 1 | 0.55 (0.23-1.31) | 0.27 (0.11-0.74) | 0.21 (0.11-0.64) | 0.006 |
| Model 3 | 1 | 0.56 (0.24-1.32) | 0.35 (0.13-0.89) | 0.27 (0.14-0.75) | 0.012 |
| Green leafy vegetables | | | | | |
| Median intake (g/d) | 9.1 | 17.6 | 27.3 | 54.4 |  |
| Range of intake (g/d) | ≤13.5 | 13.6-21.3 | 21.4-38.3 | ≥ 38.4 |  |
| Model 1 | 1 | 0.42 (0.18-0.98) | 0.32 (0.13- 0.80) | 0.58 (0.26-1.27) | 0.37 |
| Model 2 | 1 | 0.40 (0.16-1.02) | 0.32 (0.12-0.89) | 0.81 (0.32-2.01) | 0.98 |
| Model 3 | 1 | 0.42 (0.16-1.11) | 0.40 (0.13-0.91) | 1.12 (0.39-3.19) | 0.51 |
| Fruity vegetables | | | | | |
| Median intake (g/d) | 42 | 93 | 145 | 263 |  |
| Range of intake (g/d) | ≤ 69 | 70-115 | 116-211 | ≥ 212 |  |
| Model 1 | 1 | 0.61 (0.25-1.47) | 0.61 (0.25–1.47) | 1.08 (0.49–2.37) | 0.69 |
| Model 2 | 1 | 0.65 (0.25-1.65) | 0.64 (0.25-1.65) | 1.01 (0.38-2.68) | 0.34 |
| Model 3 | 1 | 0.71 (0.27-1.87) | 0.84 (0.32-2.23) | 1.65 (0.57-4.80) | 0.44 |
| Root vegetables | | | | | |
| Median intake (g/d) | 2.1 | 7.3 | 10.0 | 34.4 |  |
| Range of intake (g/d) | ≤ 4.2 | 4.3-9.9 | 10.0-21.9 | ≥ 22.0 |  |
| Model 1 | 1 | 0.57 (0.20-1.64) | 2.23 (0.99-5.03) | 1.11 (0.45-2.74) | 0.89 |
| Model 2 | 1 | 0.72 (0.24-2.12) | 1.74 (0.72-4.17) | 1.13 (0.43-2.97) | 0.87 |
| Model 3 | 1 | 0.68 (0.22-2.07) | 1.88 (0.75-4.72) | 1.45 (0.50-4.13) | 0.51 |
| Stalk vegetables | | | | | |
| Median intake (g/d) | 0.0 | 0.2 | 1.0 | 2.5 |  |
| Range of intake (g/d) | ≤ 0.00 | 0.1-0.5 | 0.6-1.1 | ≥ 1.2 |  |
| Model 1 | 1 | 0.57 (0.24-1.36) | 0.54 (0.23-1.29) | 0.88 (0.40-1.94) | 0.86 |
| Model 2 | 1 | 0.52 (0.20-1.36) | 0.51 (0.20-1.31) | 1.09 (0.46-2.58) | 0.51 |
| Model 3 | 1 | 0.61 (0.23-1.62) | 0.57 (0.21-1.51) | 1.32 (0.52-3.34) | 0.34 |
| Potatoes | | | | | |
| Median intake (g/d) | 2.4 | 10.3 | 20.7 | 36.3 |  |
| Range of intake (g/d) | ≤4.8 | 4.9-10.4 | 10.5-20.8 | ≥ 20.9 |  |
| Model 1 | 1 | 0.69 (0.32-1.50) | 0.97 (0.41- 2.28) | 0.80 (0.32-1.99) | 0.84 |
| Model 2 | 1 | 0.54 (0.23- 1.27) | 0.86 (0.34-2.21) | 0.68 (0.25-1.85) | 0.72 |
| Model 3 | 1 | 0.58 (0.23-1.44) | 1.03 (0.38- 2.76) | 0.55 (0.17-1.68) | 0.54 |
| Starchy vegetables | | | | | |
| Median intake (g/d) | 1.9 | 4.7 | 8.2 | 18.2 |  |
| Range of intake (g/d) | ≤ 3.3 | 3.4-5.8 | 5.-12.6 | ≥ 12.7 |  |
| Model 1 | 1 | 0.91 (0.39-2.11) | 1.0 (0.44-2.27) | 0.66 (0.27-1.62) | 0.36 |
| Model 2 | 1 | 0.92 (0.37-2.31) | 0.93 (0.38-2.26) | 0.60 (0.22-1.62) | 0.29 |
| Model 3 | 1 | 0.99 (0.38-2.56) | 0.80 (0.30-2.13) | 0.80 (0.26-2.45) | 0.41 |
| Cabbage | | | | | |
| Median intake (g/d) | 0.0 | 1.9 | 6.2 | 15.3 |  |
| Range of intake (g/d) | ≤ 0.0 | 0.1 – 3.1 | 3.2-6.2 | ≥ 6.3 |  |
| Model 1 | 1 | 0.74 (0.36-1.52) | 1.12 (0.40-3.14) | 0.54 (0.21-1.38) | 0.18 |
| Model 2 | 1 | 0.79 (0.36-1.71) | 1.25 (0.42-3.79) | 0.51 (0.18-1.45) | 0.07 |
| Model 3 | 1 | 0.94 (0.42-2.10) | 1.50 (0.48-4.69) | 0.56 (0.18-1.71) | 0.09 |

1The median intake of each quartile category was assigned and then these quartile median variables were included as a continuous variable in logistic regression. Model 1 was crude. Model 2 was adjusted for, age at baseline, gender, physical activity at baseline, family history of diabetes, total energy intake at baseline, cholesterol intake at baseline. Model 3 was additionally adjusted for body mass index at baseline.

**Table 4 Multivariable odds ratio (95%CI) for metabolic syndrome based intake of total and various types of vegetable consumption (above/below the medians) among participants with 0, 1 or 2 components of metabolic syndrome at baseline: Tehran Lipid and Glucose Study**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Model 1** | | **Model 2** | | **Model 3** | |
| **< median** | **≥ median** | **< median** | **≥ median** | **< median** | **≥ median** |
| **Total vegetables (g/d)** | | | | | | |
| 0 component | 1 | 0.48 (0.12-1.94) | 1 | 0.77 (0.14-4.05) | 1 | 0.82 (0.15-4.29) |
| 1 component | 1 | 0.68 (0.27-1.71) | 1 | 0.62 (0.21-1.83) | 1 | 0.67 (0.23-1.99) |
| 2 component | 1 | 1.98 (0.61-6.42) | 1 | 2.00 (0.49-8.18) | 1 | 2.24 (0.53-9.39) |
| **Allium vegetables** | | | | | | |
| 0 component | 1 | 0.77 (0.21-2.85) | 1 | 0.69 (0.17-2.76) | 1 | 0.54 (0.12-2.42) |
| 1 component | 1 | **0.25 (0.08-0.73)** | **1** | **0.25 (0.08-0.76)** | **1** | **0.23 (0.07-0.71)** |
| 2 component | 1 | 0.49 (0.16-1.52) | 1 | 0.51 (0.15-1.78) | 1 | 0.48 (0.13-1.69) |
| **Green leafy vegetables** | | | | | | |
| 0 component | 1 | 0.81 (0.22-2.98) | 1 | 1.04 (0.25-4.26) | 1 | 1.10 (0.25-4.72) |
| 1 component | 1 | **0.31 (0.11-0.84)** | 1 | **0.31 (0.09-0.97)** | 1 | **0.29 (0.09-0.95)** |
| 2 component | 1 | 1.01 (0.33-3.08) | 1 | 1.43 (0.39-5.18) | 1 | 1.39 (0.38-5.06) |
| **Fruity vegetables** | | | | | | |
| 0 component | 1 | 1.13 (0.31-4.07) | 1 | 1.15 (0.28-4.71) | 1 | 0.88 (0.20-3.84) |
| 1 component |  | 0.66 (0.26-1.67) | 1 | 0.60 (0.21-1.69) | 1 | 0.64 (0.22-1.82) |
| 2 component |  | 1.51 (0.48-4.67) | 1 | 2.02 (0.52-7.87) | 1 | 2.11 (0.53-8.32) |
| **Root vegetables** | | | | | | |
| 0 component | 1 | 2.36 (0.59-9.43) | 1 | 2.57 (0.58-11.3) | 1 | 2.31 (0.49-10.7) |
| 1 component | 1 | 2.20 (0.84-5.76) | 1 | 1.68 (0.61-4.75) | 1 | 1.67 (0.58-4.73) |
| 2 component | 1 | 1.97 (0.63-6.14) | 1 | 1.48 (0.43-5.08) | 1 | 1.31 (0.36-4.69) |
| **Stalk vegetables** | | | | | | |
| 0 component | 1 | 1.28 (0.35-4.72) | 1 | 1.33 (0.33-5.30) | 1 | 1.08 (0.26-4.52) |
| 1 component | 1 | 0.72 (0.28-1.81) | 1 | 0.73 (0.27-2.00) | 1 | 0.74 (0.27-2.02) |
| 2 component | 1 | 1.18 (039-3.58) | 1 | 1.09 (0.32-3.76) | 1 | 1.13 (0.32-3.97) |
| **Potatoes** | | | | | | |
| 0 component | 1 | 1.36 (0.34-5.45) | 1 | 1.97 (0.39-9.90) | 1 | 2.12 (0.39-11.4) |
| 1 component | 1 | 0.56 (0.22-1.42) | 1 | 0.45 (0.17-1.22) | 1 | 0.45 (0.16-1.24) |
| 2 component | 1 | 1.91 (0.55-6.66) | 1 | 1.35 (0.34-5.39) | 1 | 1.55 (0.36-6.65) |
| **Starchy vegetables** | | | | | | |
| 0 component | 1 | 0.64 (0.17-2.36) | 1 | 0.92 (0.21-3.90) | 1 | 1.06 (0.24-4.60) |
| 1 component | 1 | 0.78 (0.31-1.96) | 1 | 0.80 (0.29-2.18) | 1 | 0.84 (0.30-2.32) |
| 2 component | 1 | 1.08 (0.35-3.30) | 1 | 0.57 (0.15-2.11) | 1 | 0.56 (0.15-2.14) |
| **Cabbage** | | | | | | |
| 0 component | 1 | 0.64 (0.13-3.12) | 1 | 0.88 (0.16-4.92) | 1 | 0.89 (0.15-5.08) |
| 1 component | 1 | 1.19 (0.46-3.07) | 1 | 1.64 (0.59-4.59) | 1 | 1.54 (0.55-4.32) |
| 2 component | 1 | 0.48 (0.12-1.91) | 1 | 0.53 (0.18-2.43) | 1 | 0.45 (0.09-2.22) |

Median intake of: Model 1 was crude; Model 2 was adjusted for, age at baseline, gender, physical activity at baseline, family history of diabetes, total energy intake at baseline, cholesterol intake at baseline; Model 3 was additionally adjusted for body mass index at baseline.