Micronutrient Intake and the Presence of the Metabolic Syndrome

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Abstract

Background: Dietary micronutrients have been proposed to protect against oxidative damage and related clinical complications. **Aims:** We aimed to compare the micronutrient intake between individuals with and without metabolic syndrome (MS). **Materials and Methods:** This cross-sectional study included 3800 men and women who were aged between 35 and 65 years. The diagnosis of the MS was based on International Diabetes Federation criteria. Dietary intake of participants was assessed using a questionnaire for 24 h dietary recall. Student's *t*-test and Mann–Whitney U-tests were used for comparing the micronutrient intake of subjects with or without the MS and the odds ratio for the presence of the MS was calculated for each micronutrient by control for total energy intake adjusted by the residue method. **Results:** The mean age of MS subjects and the control group was 48.8 ± 7.9 years and 47.6 ± 7.6 years, respectively. Energy-adjusted intake of vitamin E ($P < 0.05$), B2 ($P < 0.01$), and B12 ($P < 0.05$) was higher in normal women compared with women with MS. Energy-adjusted intake of vitamin B1 was significantly higher in women with MS. After logistic regression analysis, no significant association between micronutrient intake and MS was shown. **Conclusion:** We found no significant association between micronutrient intake and MS.

Keywords: Dietary assessment, metabolic syndrome, micronutrients

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Introduction

Micronutrients are key factors in a range of cellular and biochemical functions including the release of energy for the synthesis, movement, and other functions, which function as coenzymes, cocatalysts, and buffers.[1] Subclinical deficiency of several micronutrients, for example, antioxidants (vitamin C, E, A, and selenium) and others, for example, folic acid, vitamin B12, and vitamin B6 may lead to effects on intracellular homocysteine concentration, that may have important consequences on the progression of chronic diseases by affecting inflammation and presence oxidative stress.[1-3] Significant chronic metabolic disruption may occur when consumption of a micronutrient is below the current recommended dietary allowance (RDA).[3]

The interaction of inflammation and oxidative stress is thought to be related to the risk for metabolic syndrome (MS) and the risk of several related conditions.[1,4-6] Several studies have reported the potential role of dietary antioxidant intake in the protection against oxidative stress and accompanied clinical complications.[2,4,7]

The prevalence of micronutrient deficiencies have been reported in obese individuals, and have included magnesium (Mg), vitamin B6, iron, vitamin D, vitamin E, vitamin B12, folic acid, selenium, copper, and zinc (Zn),[8-10] which may result from inadequate nutrient

intake (diet, supplements) and/or alterations in nutrient absorption or metabolism.[11] It has been suggested that high energy intake along with micronutrient deficiencies may lead to an increase in the production of toxic byproducts of incomplete biochemical reactions, this could contribute to further weight gain or the development of associated metabolic diseases.[12,13]

A significant positive association between the dietary total antioxidant capacity (TAC) and the intake of fiber, folic acid, vitamin A, vitamin C, Mg, selenium, and Zn and a negative correlation between TAC and systolic blood pressure, serum glucose, and free fatty acids, independent of gender and daily caloric intake has been reported.[4]

Yet little is known about the adverse relationships between micronutrient intake and MS. Thus, studying the role that these nutrients may play in MS may provide additional motivation for intervention strategies that could reduce the morbidity of MS and subsequent cardiovascular disease (CVD). Therefore, the aim of this manuscript was to compare micronutrient intake between MS patients and subjects without MS and finding the relationship between the micronutrient intake and MS.

Materials and Methods

Subjects

A total of 3800 men and women, aged between 35 and 65 years, were recruited from an urban population using a stratified-cluster method. Exclusion criteria included pregnancy and lactation, individuals with established CVD or diabetes, and individuals taking dietary supplements. Extreme outliers (individuals with values below the 3rd centile or above the 97th centile) for one or more variables were also excluded, as well as those individuals who reported a total daily energy intake in the range 800–4200 kcal.[14] Smoking habit was classified into two categories: current smoker or nonsmoker. Each of subjects provided written, informed consent before the study, which was approved by the Ethics Committee of Mashhad University of Medical Sciences.

Anthropometric assessment

Body weight and height were measured while subjects wore light clothing and no shoes. Body mass index (BMI) was calculated as weight (kg) divided by height (m²). Waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest during the minimal respiration. Resting blood pressure was taken three times by a trained technician using a standardized protocol. The mean value of the two last measurements was used to express the systolic and diastolic blood pressure. The average of three recorded measurements was used in all data analyses.

Biochemical assessment

Blood samples were collected in the tubes, processed, stored, and transported to the laboratory on the ice. Fasting plasma glucose, total cholesterol and its subsets, triglyceride, uric acid and high sensitive C-reactive protein (Hs-CRP) were measured enzymatically using the automated analyzers.

Metabolic syndrome

The diagnosis of MS was based on the definition of the International Diabetes Federation: the presence of three or more of the following components defined MS: fasting plasma glucose ≥110 mg/dl (6.1 mmol/l); systolic or diastolic blood pressure ≥130 or ≥85 mmHg; High-density lipoprotein (HDL) cholesterol <50mg/dl (1.29 mmol/l) for women or <40mg/dl (1.04 mmol/l) for men; triglyceride ≥150 mg/dl (1.79 mmol/l); and waist circumference ≥80 cm for women or ≥94 cm for men.[15]

Dietary assessment

Dietary information was collected using a 24-h recall questionnaire, administered by a trained dietary interviewer in a face-to-face interview, to recall and describe every item of food and beverage consumed over the 24 h period.[1] Individual nutritional intakes were assessed using Dietplan6 software (Forest field Software Ltd., UK). The variables selected for the purpose of this study were total energy intake, crude, and energy adjusted intake of the micronutrients.

Micronutrients were reported as a percentage of the RDA as well.[1]

Assessment of physical activity level

Physical activity levels were assessed using the James and Schofield human energy requirements equations.[16] Physical activity level was calculated as the total energy expenditure as a ratio of the Basal Metabolic Rate over the 24 h period. The questions on physical activity were based on the James and Schofield equations that were selected from those used in the Scottish Heart Health Study/MONItoring of trends and determinants in CArdiovascular disease (MONICA) questionnaire. Questions were divided into time spent on activities during work (including housework), during the nonwork time, and in bed (resting in bed and sleep).

Statistical analysis

Statistical analysis was performed using the SPSS version 16.0 (SPSS, Chicago, IL). Nutrient intake was expressed in gram, milligram, and microgram and as percentages of total energy. It also adjusted for total energy intake through the residual method as an alternative to using nutrient densities to control for confounding by

total energy intake and to remove extraneous variation due to total energy intake, regression analyzes was used to compute residuals of nutrient intake by removing the variation caused by total energy intake. In this procedure, the nutrient intakes of the individuals in a group are regressed on their total energy intakes. The residuals from the regression represent the differences between each individual's actual intake and the intake predicted by their total energy intake.[17-19] Energy-adjusted nutrient intakes were calculated as the residuals from the regression model, with absolute nutrient intake as the dependent variable, and total energy intake as the independent variable.[17] We used parametric tests for normally distributed data and nonparametric test for nonnormally distributed data. Logistic regression was used to calculate the odds ratios (ORs) and their 95% confidence interval (CIs) for MS, with individuals in the lowest quintile category of micronutrients as the reference category.[17] ORs were adjusted for sex, age, smoking, physical activity level, total energy, BMI, and past medical history. To assess trends across quintile categories, we assigned the median intake of each quintile category

to individuals with intakes in the category and then included this quintile median variable as a continuous factor in logistic regression models. The *P* for trend was the resulting *P* value of the associated logistic regression coefficient.[17] Categorical variables were compared by Chi-square. Statistical significance was defined as a two tailed *P* value < 0.05.

Results

The initial sample consisted of 3800 potential participants aged between 35 and 65 years. From this sample, 170 individuals were excluded from the analyzes, including 51 individuals whose total energy intake was outside of the credible range (800-4200 kcal/day), 73 further individuals were excluded as extreme outliers, and 46 individuals were excluded due to incomplete data. These exclusions resulted in a final sample of 3630 participants (34% men; *n* = 1231, 66% women; *n* = 2399), with a mean age of 49.25 ± 7.9 years of subjects with MS and 47.97 ± 7.6 years of subjects without MS [Table 1].

Table 1: Demographic, anthropometric, and clinical characteristics of subjects with and without MS						
Characteristic	Men		*P* value	Women		*P* value
	MS+ (*n*=521)	MS− (*n*=714)		MS+ (*n*=1178)	MS− (*n*=1222)	
Age	49.1±7.6	48.95±8.01	0.69	48.7±8.06	46.9±7.3	<0.001
Education level (%)						
<1 year	40 (7)	49 (6.8)	0.66	259 (21.9)	243 (19.9)	0.41
1-8 years	218 (41.8)	288 (40.3)	0.53	604 (51.4)	609 (49.9)	0.35
>8 years	263 (50.4)	377 (52.9)	0.45	315 (26.7)	370 (30.2)	0.21
Current cigarette smoking (%)						
Yes	139 (28)	209 (24)	0.31	250 (21)	178 (14)	<0.001
No	382 (71)	505 (75)	0.31	927 (78)	1044 (85)	<0.001
Physical activity level (%)						
Sedimentary	415 (80)	416 (58.2)	<0.001	904 (76)	702 (58)	<0.001
Low active	73 (14)	164 (23.2)	<0.001	216 (18)	397 (33)	<0.001
Active	21 (4.1)	88 (12.4)	<0.001	47 (3)	108 (9)	<0.001
Very active	10 (1.9)	44 (6.2)	<0.001	10 (0.8)	15 (1.2)	<0.001
Weight (kg)	83.4±11	72.7±30.01	<0.001	72.6±11.4	72.02±18.2	0.90
Waist circumference (cm)	101.8±6.9	89.5±10.8	<0.001	100.2±10.7	91.9±12.6	<0.001
BMI (kg/m²)	28.8±3.3	25.5±3.2	<0.001	30.1±4.3	29.9±79	0.81
Systolic blood pressure (mmHg)	128.9±17.1	118.8±15.5	<0.001	128.9±20.3	114.5±14.8	<0.001
Diastolic blood pressure (mmHg)	85.2±10.5	78.4±10.2	<0.001	83.3±12.1	74.9±9.9	<0.001
Blood glucose (mg/dl)	87.92±22.7	81.13±15.27	<0.001	88.17±23.9	79.4±4.7	<0.001
Cholesterol (mg/dl)	190.6±37.8	184.5±37.9	0.005	200.6±38.7	190.6±37.3	<0.001
HDL-C (mg/dl)	34.96±6.4	40.39±8.66	<0.001	40.66±7.33	47.3±10.2	<0.001
LDL-C (mg/dl)	118.4±32.7	119.7±31.8	0.51	126.39±34.7	123.5±32.1	0.04
TG (mg/dl)	179 (IQR 144-236)	109 (IQR 79-150)	<0.001	166 (IQR 119-210)	97 (IQR 73-125)	<0.001
Uric acid (mg/dl)	5.62±1.3	5.17±1.2	<0.001	4.61±2.3	3.9±1.02	<0.001
Hs-CRP (mg/L)	1.4 (IQR 1.01-2.7)	1.3 (0.79-2.3)	<0.001	2.06 (IQR 1.19-3.8)	1.3 (IQR 0.86-2.6)	<0.001

Values are expressed as a mean±SD for normally distribution data and median with inter-quartile range of nonnormally distributed data; The Student *t*-test is used for comparison of normally distributed data and Mann-Whitney test for comparison of non-normally distribution data between men with and without MS and women with and without MS; MS: Metabolic syndrome, HDL-C: High-density lipoprotein cholesterol, LDL-C: Low-density lipoprotein cholesterol, TG: Triglyceride, Hs-CRP: High sensitive C-reactive protein, MS+: With metabolic syndrome, MS−: Without metabolic syndrome, IQR: Inter quartile range, BMI: Body mass index

Comparison of anthropometric and clinical parameters between MS patients and subjects without MS

Patients with MS were not significantly heavier ($P > 0.05$), but did have a higher mean waist circumference ($P < 0.001$), blood pressure ($P < 0.001$), blood glucose levels ($P < 0.001$), serum uric acid ($P < 0.001$), serum Hs-CRP and triglyceride ($P < 0.001$). Serum HDL cholesterol level ($P < 0.001$) was lower in MS versus the subjects without MS. The mean value of Low-density lipoprotein cholesterol (LDL-C) was not significantly different between the two groups ($P > 0.05$) [Table 1].

Comparison of the crude intake and energy-adjusted intake of nutrients between the MS patients and subjects without MS

Tables 2 and 3 show the mean ± standard error of mean of the crude intake and energy adjusted intake of the micronutrient intake.

Table 2: Daily intake of the vitamins of subjects with and without MS

Nutrients	Men		P value	Women		P value
	MS+ (*n*=518)	MS− (*n*=713)		MS+ (*n*=1177)	MS− (*n*=1222)	
Retinol						
Crude intake (g)	791.4±163.9	434.4±85.2	0.03	337.3±43.6	502.1±73.8	0.05
Total energy adjusted (g)	689.7±163.8	380.3±85.3	0.09	373.01±43.7	525.9±73.4	0.07
RDA (%)	76.6±18.2	42.25±9.4	0.09	53.27±6.2	75.12±10.4	0.07
Vitamin D						
Crude intake (g)	1.55±0.09	1.39±0.05	0.14	1.09±0.04	1.14±0.04	0.41
Total energy adjusted (g)	2.05±0.09	1.98±0.85	0.53	1.85±0.04	1.88±0.04	0.63
RDA (%)	31.6±1.4	31.14±0.9	0.79	29.45±0.85	31.83±0.84	0.61
Vitamin E						
Crude intake (g)	16.6±0.37	14.8±0.3	<0.001	13.8±0.22	14.7±0.21	0.01
Total energy adjusted (g)	13.6±0.33	13.06±0.25	0.17	14.3±0.18	14.8±0.18	0.04
RDA (%)	90.9±2.2	87.08±1.7	0.17	95.64±1.2	99.15±1.2	0.04
Vitamin C						
Crude intake (g)	97.4±3.9	84.62±3.1	0.01	84.2±2.4	80.43±2.1	0.23
Total energy adjusted (g)	85.4±3. 8	78.7±3.08	0.17	89.6±2.03	84.4±2.03	0.09
RDA (%)	94.9±4.2	87.5±3.4	0.17	119.5±3.1	112.6±2.7	0.09
Thiamin						
Crude intake (g)	1.46±0.02	1.34±0.02	0.004	1.17±0.01	1.16±0.01	0.64
Total energy adjusted (g)	1.53±0.02	1.54±0.02	0.61	1.62±0.01	1.57±1.01	0.02
RDA (%)	127.7±1.8	129.04±1.6	0.60	147.3±1.1	143.4±1.1	0.02
Riboflavin						
Crude intake (g)	1.44±0.04	1.28±0.03	0.05	1.14±0.01	1.19±0.02	0.07
Total energy adjusted (g)	1.86±0.04	1.81±0.02	0.28	1.85±0.01	1.88±0.02	0.25
RDA (%)	143.6±3.5	139.3±2.1	0.30	168.6±1.5	171.7±2.1	0.24
Niacin						
Crude intake (g)	17.1±0.34	15.36±0.27	<0.001	12.63±0.18	12.68±0.18	0.83
Total energy adjusted (g)	14.0±0.27	13.5±0.21	0.20	13.35±0.13	13.08±0.14	0.17
RDA (%)	87.9±1.7	85.2±1.3	0.21	95.8±0.9	93.9±1.02	0.17
Vitamin B12						
Crude intake (g)	4.74±0.53	3.45±0.31	0.02	2.98±0.15	3.53±0.27	0.08
Total energy adjusted (g)	2.69±0.52	1.69±0.31	0.08	1.76±0.15	2.23±0.27	0.12
RDA (%)	190.3±22.3	148.6±13.1	0.10	151.3±6.4	171.2±11.4	0.13
Vitamin B6						
Crude intake (g)	1.45±0.02	1.32±0.02	<0.001	1.20±0.01	1.18±0.01	0.43
Total energy adjusted (g)	1.84±0.02	1.80±0.01	0.23	1.88±0.01	1.84±0.01	0.14
RDA (%)	122.7±1.4	120.4±1.1	0.26	125.7±0.8	122.8±0.8	0.13
Folate						
Crude intake (g)	262.2±6.9	251.08±8.3	0.33	219.03±3.9	219.06±4.3	0.46
Total energy adjusted (g)	228.2±6.5	233.6±8.1	0.62	232.3±3.6	228.5±3.9	0.48
RDA (%)	57.06±1.6	58.4±2.03	0.60	58.08±0.9	57.13±0.9	0.48

Values are expressed as a mean±SE; The Student t-test is used for normally distribution data and Mann–Whitney test for nonnormally distributed data. Nutrient intakes were adjusted for total energy intake by the residual method of linear regression. MS: Metabolic syndrome, MS+: With metabolic syndrome, MS−: Without metabolic syndrome; Nutrient intakes are reported as a percentage of the RDA: Recommended dietary allowance

Table 3: Daily intake of the minerals of subjects with and without MS

Nutrients	Men		P value	Women		P value
	MS+ (*n*=518)	MS− (*n*=713)		MS+ (*n*=1177)	MS− (*n*=1222)	
Calcium						
Crude intake (g)	912.8±16.8	820.1±14.3	<0.001	724.4±10.1	725.6±10.4	0.93
Total energy adjusted (g)	763.4±13.09	740.8±10.7	0.17	775.5±8.1	760.2±7.9	0.17
RDA (%)	69.4±1.9	67.3±0.9	0.18	70.5±0.7	69.1±0.7	0.17
Magnesium						
Crude intake (g)	249.8±4.4	233.8±4.1	0.003	210.3±2.9	210.4±2.9	0.99
Total energy adjusted (g)	200.4±3.3	204.9±3.1	0.33	219.8±2.1	215.01±2.1	0.11
RDA (%)	63.9±1.05	64.3±0.9	0.32	88.3±0.5	87.3±0.8	0.11
Copper						
Crude intake (g)	1.53±0.08	1.26±0.04	0.003	1.09±0.02	1.20±0.04	0.03
Total energy adjusted (g)	1.75±0.08	1.60±0.03	0.11	1.65±0.02	1.74±0.04	0.08
RDA (%)	195.3±9.6	178.8±4.2	0.11	183.8±2.6	193.4±4.8	0.08
Zinc						
Crude intake (g)	9.08±0.1	8.4±0.1	0.001	7.15±0.09	7.15±0.09	0.99
Total energy adjusted (g)	7.02±0.1	7.07±0.1	0.76	7.15±0.06	6.98±0.06	0.07
RDA (%)	63.9±1.05	64.3±0.9	0.76	89.4±0.8	87.3±0.6	0.07
Selenium						
Crude intake (g)	39.1±1.2	37.09±0.96	0.17	29.9±0.63	31.3±0.65	0.13
Total energy adjusted (g)	32.9±1.2	33.6±0.9	0.63	31.8±0.5	32.5±0.5	0.38
RDA (%)	59.8±2.1	61.1±1.6	0.64	57.8±1.02	59.1±1.08	0.38
Iron						
Crude intake (g)	11.3±0.24	10.6±0.22	0.04	9.22±0.14	9.34±0.15	0.55
Total energy adjusted (g)	10.07±0.2	10.3±0.18	0.32	10.6±0.1	10.5±0.1	0.55
RDA (%)	125.9±2.5	129.3±2.3	0.32	76.9±1.3	76.9±1.2	0.55

Values are expressed as a mean±SE. The Student t-test is used for normally distribution data and Mann–Whitney test for nonnormally distributed data. Nutrient intakes were adjusted for total energy intake by the residual method of linear regression. MS: Metabolic syndrome, MS+: with metabolic syndrome, MS−: without metabolic syndrome. Nutrient intakes are reported as a percentage of the RDA: Recommended dietary allowance

The mean value of crude intake of some micronutrients; calcium ($P < 0.001$), Mg ($P < 0.01$), vitamin E ($P < 0.001$), vitamin C ($P < 0.01$) in men with MS was higher than men without MS ($P < 0.001$). However, we found no difference in energy-adjusted intake of nutrient intake between two groups ($P > 0.05$). In women the crude intake of retinol ($P < 0.05$), vitamin E ($P < 0.01$) was higher in women without MS. Furthermore, we observed a significant difference in energy-adjusted intake of vitamin E ($P < 0.05$), B2 ($P < 0.01$) and B12 ($P < 0.05$) between two groups of women [Tables 2 and 3].

OR (95% CI) of MS across quintiles of micronutrient intake

After adjusting for cofounders including sex, age, physical activity level, and current smoking, past medical history, BMI, and energy intake, we found no association between micronutrient intake and MS [Tables 4 and 5].

Discussion

In the present study, we have assessed the dietary intake of antioxidant vitamins (A, C, E) and other vitamins such as; D, B1, B2, B6, B12, niacin, folate and minerals including; calcium, Mg, Zc, copper, iron, selenium. Ultimately, we found no significant difference between the intake of these nutrients in subjects with and without MS.

Several components of the MS are known to be associated with increased oxidative stress.[20,21] Dietary antioxidant intake has been suggested to ameliorate oxidative effects.[1] In the study of Kleshchina and Eliseev, assessment of nutrition in girls with MS revealed a low intake of vitamin E.[22] In the present study, we found that the mean intake of vitamin E was lower in women with MS, but after adjusting for cofounders (sex, age, energy intake, smoking, physical activity level, past medical history, and BMI), we did not observe any relationship between vitamin E intake and MS. Ford *et al*.[23] and Bruscato *et al*.[24] have also shown that there was no association between the presence of MS and intake of vitamins C, E, and A. Puchau *et al*. suggested that dietary TAC is negatively associated with some features of the MS in healthy young adults.[4] This inconsistency may be the result from the fact that our target group is different. Moreover, we considered a control group in our study. Furthermore, our sample size was larger. Lastly our study made different adjustments for confounding variables.

Table 4: ORs of MS across quintiles of energy-adjusted vitamin intake

Nutrients	Quintiles of intake					
	Q1	Q2	Q3	Q4	Q5	*P* value
Retinol						
Median intake (g/d)	36.09	96.07	183.4	268.2	396.9	-
OR	1	0.95 (0.7-1.1)	0.86 (0.6-1.1)	0.80 (0.6-1)	0.87 (0.6-1.1)	0.21
Vitamin D						
Median intake (g/d)	0.95	1.25	1.52	1.97	2.9	-
OR	1	1.39 (1.1-1.7)	1.13 (0.9-1.4)	1.24 (1-1.5)	1.15 (0.9-1.4)	0.53
Vitamin E						
Median intake (g/d)	5.63	10.6	14.17	17.14	22.76	-
OR	1	0.96 (0.7-1.1)	0.86 (0.6-1)	1.06 (0.8-1.3)	0.90 (0.7-1.1)	0.70
Vitamin C						
Median intake (g/d)	11.35	36.70	61.52	107.8	186.28	-
OR	1	1.007 (0.8-1.2)	0.89 (0.7-1.1)	1.02 (0.8-1.2)	1.08 (0.8-1.3)	0.45
Thiamin						
Median intake (g/d)	1.03	1.32	1.52	1.75	2.17	-
OR	1	0.84 (0.6-1)	0.99 (0.7-1.2)	1.08 (0.8-1.3)	0.95 (0.7-1.2)	0.24
Riboflavin						
Median intake (g/d)	1.23	1.50	1.73	2.001	2.47	-
OR	1	0.95 (0.7-1.1)	1.005 (0.8-1.2)	1.09 (0.8-1.3)	1.001 (0.8-1.2)	0.57
Niacin						
Median intake (g/d)	7.88	10.83	10.83-12.97	15.07	19.2	-
OR	1	1.13 (0.9-1.4)	1.02 (0.8-1.2)	1.22 (0.9-1.5)	1.21 (0.9-1.5)	0. 59
Vitamin B12						
Median intake (g/d)	1.03	1.95	2.67	3.54	5.24	-
OR	1	1.11 (0.8-1.3)	1.007 (0.8-1.2)	0.94 (0.7-1.1)	1.14 (0.9-1.4)	0.66
Vitamin B6						
Median intake (g/d)	1.32	1.61	1.81	2.03	2.41	-
OR	1	1.02 (0.8-1.2)	0.98 (0.7-1.2)	1.10 (0.8-1.3)	1.20 (0.9-1.5)	0.41
Folate						
Median intake (g/d)	119.3	161.8	201.1	252.15	362.7	-
OR	1	1.02 (0.8-1.2)	1.06 (0.8-1.3)	1.1 (0.8-1.3)	1.23 (1-1.5)	0.38

Data are expressed as median intake, range of intake and OR (95% CI) and adjusted for sex, age, physical activity level, smoking, past medical history, energy intake, and BMI; ORs: Odds ratios, MS: Metabolic syndrome, CI: Confidence interval, BMI: Body mass index

We found no association between vitamin D and calcium intake and MS. Some studies, have suggested that optimization of vitamin D status through sun exposure and increased intake of vitamin D rich diet may reduce the risk of type 2 diabetes and may improve cardiometabolic profile.[25] Several studies have reported an antiobesity effect of dietary calcium, and that dietary calcium may play a role in stimulating lipolysis, thermogenesis, and adipocyte apoptosis.[26,27] Other studies have reported that MS is not associated with overall intake of dietary calcium and vitamin D, but with the type of food ingested.[28,29]

In the present study, we found no relationship between vitamin B1, B2, B6, B12, and folate and MS. Alcázar-Leyva and Alvarado-Vásquez have previously suggested that, the administration of thiamine pyrophosphate to diabetics leads to an improvement in glucose tolerance, but may also provide additional protection to endothelial cells, reducing the risk of vascular damage, to which the

diabetic patient is highly susceptible through inducing nitric oxide synthesis.[30] Thiamine acts as a coenzyme for enzymes (transketolase, pyruvate dehydrogenase, and alpha-ketoglutarate dehydrogenase complexes), which contribute in intracellular glucose metabolism. Hence, glucose intolerance and diabetes might be the result of a thiamine-deficient state.[1,31] This difference between our results and other reports could be due to differences in the type of study and individuals that had been investigated. Jeon *et al.*[32] found that the dietary intake of thiamin in obese individuals is higher than subjects without MS, while Bruscato *et al.*[24] found no association between thiamin intake and risk of MS as we have now found.

Chen *et al.*[33] suggested that, N-5, 10-methylenetetrahydrofolate reductase, C677T gene polymorphism may contribute to insulin resistance in Han Chinese with MS, this being associated with increasing Hs-CRP and decreasing vitamin B12 and

Table 5: ORs of MS across quintiles of energy-adjusted mineral intake

Nutrients	Quintiles of intake					
	Q1	Q2	Q3	Q4	Q5	*P* value
Calcium						
Median intake (g/d)	430.5	603.3	736.8	887.9	1130.1	-
OR	1	1.04 (0.8-1.2)	1.08 (0.8-1.2)	1.12 (0.9-1.4)	1.17 (0.9-1.4)	0.1
Magnesium						
Median intake (g/d)	132.6	172.4	202.6	235.4	304.07	-
OR	1	1.29 (1.03-1.6)	1.22 (0.9-1.5)	1.38 (1.1-1.7)	1.21 (0.9-1.5)	0.83
Zinc						
Median intake (g/d)	4.24	5.82	6.84	8.08	10.07	-
OR	1	1.06 (0.8-1.3)	1.37 (1.09-1.7)	1.19 (0.9-1.4)	1.2 (0.97-1.5)	0.050
Copper						
Median intake (g/d)	1.14	1.37	1.53	1.71	2.05	-
OR	1	1.25 (1-1.5)	1.33 (1.06-1.6)	1.16 (0.9-1.4)	1.15 (0.9-1.4)	0.51
Selenium						
Median intake (g/d)	13.60	21.98	28.13	35.57	57.52	-
OR	1	0.96 (0.7-1.1)	0.85 (0.6-1.04)	0.92 (0.7-1.1)	0.78 (0.6-0.9)	0.02
Iron						
Median intake (g/d)	5.71	7.91	9.84	11.9	16.01	-
OR	1	1.15 (0.9-1.4)	1.24 (0.9-1.5)	1.24 (1-1.5)	1.12 (0.9-1.4)	0.21

Data are expressed as median intake, range of intake and OR (95% CI) and adjusted for sex, age, physical activity level, smoking, past medical history, energy intake, and BMI; ORs: Odds ratios, MS: Metabolic syndrome, CI: Confidence interval, BMI: Body mass index

hence may play an important role in the development of MS-associated type 2 diabetes mellitus.

The results of our present study did not show a significant association between Mg ingestion and the MS. Experimental and clinical studies suggest that Mg intake may be inversely related to the risk of hypertension and type 2 diabetes mellitus and may decrease blood triglyceride and increase HDL cholesterol levels.[34,35] The differences between the results of the present study and previous studies may result from differences in dietary pattern of the populations studied. Furthermore, we have adjusted our statistical models for total dietary energy intake, BMI, family history, physical activity level, smoking, sex, and age.

de Oliveira *et al*. investigated the association between micronutrients intake and markers of inflammation and subclinical atherosclerosis, and their results do not provide strong support for associations between the micronutrients and markers of inflammation and subclinical atherosclerosis. In this study, dietary nonheme iron and Mg intakes were inversely associated with total homocysteine concentrations, but Zn and heme iron were positively associated with CRP, other tested micronutrient-marker associations were not significant.[2]

Cross-sectional studies considered that greater consumption of fruits, whole grains, nuts, and seeds contain micronutrients that have antioxidant properties (e.g., Vitamins C, E, β-carotene, and Zn) and play essential roles in enzymatic function (e.g., Mg and Zn) are associated with lower concentrations of inflammatory markers that increased risk of MS.[2,36] The differences between our results and previous studies may be explained by differences in sample size, population group and the method of dietary assessment; or the definitions of MS may not be appropriate for an Iranian population; and self-reported intake may be imprecise. Another reason is that dietary intake may have a greater impact in the early phase of life; or probably the gender ratio of the other studies is different from the current one.

The cross-sectional nature of this present study should be considered when interpreting our findings. The responses were based on self-recall and recall bias is a problem with any self-report survey. This may be particularly the case for individuals with obesity or for women. Although the 24 h recall methodology has been largely used in cross-sectional surveys, they could be considered limited by their lack of quantitative accuracy. In the present survey, the differences in mean intake levels of nutrients between under reporters and those who give valid records reduced by energy adjustment through the residual model. Our study includes a large sample of adults to examine the association between nutrient intake and MS. Future longitudinal studies are needed to establish the potential effect and causality of dietary intake on the MS.

Conclusion

There were inconsistent differences in micronutrient intake between the sexes. After adjusting for cofounders,

there was not any association between the MS and micronutrient intake.

Acknowledgment

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