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Associations of the Dietary Diversity Score and Food Variety Score with Serum Magnesium and Ferritin Status

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ABSTRACT

Introduction: Dietary diversity score (DDS) and Food variety score (FVS) are the appropriate measures used to evaluate the overall quality of dietary patterns. However, their associations with the serum levels of micronutrients remain unclear. The present study aimed to investigate the correlations between DDS/FVS and serum ferritin and magnesium status in the non-athlete females joining the sports clubs in Tehran, Iran.

Methods: This cross-sectional survey was conducted on 397 non-athlete women, who were members of the sports clubs in Tehran, Iran in 2013. Dietary intake was assessed using a 24-hour recall questionnaire. DDS and FVS were calculated and classified into two groups based on the guidelines of the minimum dietary diversity of women (MDD-W) and median, respectively. Serum ferritin was measured using the ELISA assay, and serum magnesium was measured using atomic absorption spectrophotometry.

Results: Mean DDS and FVS was 5.7±1.4 (range: 2-9) and 15.3±4.7 (range: 5-32), respectively. After adjustment for the confounding factors, serum magnesium in the group with high FVS was significantly higher compared to the other group (P=0.01). In the group with high FVS, serum ferritin was also higher, and the difference was considered significant (P=0.058). In addition, linear regression analysis indicated a significant association between high FVS and serum magnesium level (P=0.02). However, no significant correlations were observed between the serum levels of micronutrients and DDS.

Conclusion: According to the results, higher FVS may be associated with higher serum magnesium and ferritin levels. Further investigations are required to assess the correlations between DDS, FVS, and the status of serum micronutrients.

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Introduction

Micronutrient deficiency is considered to be a severe public health concern, which affects low-income and industrialized countries [1]. Small quantities of micronutrients, such as vitamins and minerals, play a pivotal role in normal cell growth and function [2]. According to the literature, micronutrient deficiency is remarkably involved in the etiology of chronic diseases [3].

Magnesium is an important element in the human body [4], which is involved in a wide range of biological reactions [5] and is essential to the proper functioning of various systems [4]. Magnesium deficiency is associated with several chronic diseases, including type II diabetes [6, 7], hypertension, cardiovascular diseases [7], and cancer [8, 9]. Furthermore, subclinical magnesium deficiency has been reported to be

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highly prevalent in developed and developing countries [10].
Iron deficiency is considered to be the most significant nutritional problem across the world, affecting more than two billion people [11]. Women of the reproductive age are one of the high-risk populations for iron deficiency [12], and 20% of these women experience this issue *throughout their reproductive years* [13]. According to the second National Integrated Micronutrient Survey (NIMS-II), the prevalence of anemia (low hemoglobin levels) in Iranian women ranges from 12.3% in urban areas to 14% in rural areas, while the prevalence of iron deficiency anemia (low hemoglobin, ferritin, and mean corpuscular volume) has been estimated at 6% [14]. Iron deficiency anemia leads to declined work and immune functions, as well as the increased risk of premature birth and low birth weight. Moreover, severe anemia has been associated with the increased risk of maternal and neonatal mortality [11]. Iron deficiency is also associated with other complications, including fatigue [15], attention deficit [12], depression, and low quality of life [16].
The dietary nutrients that are essential to nutritional requirements cannot be obtained from only one type of food. Therefore, regular intake of various *foods* from several *food* groups at the recommended portions is of paramount importance [17]. Since deficiencies in dietary factors are associated with the increased risk of chronic diseases and malnutrition, several dietary guidelines have been proposed regarding the consumption of various nutrients within and between different food groups [18].
Dietary diversity score (DDS) and food variety score (FVS) are proper indices in the evaluation of the overall dietary quality in various aspects [19]. Some findings have demonstrated that the total nutritional quality of a diet is enhanced by increasing the intake of healthy food groups and food items, which are measured based on the DDS and FVS, respectively [20]. In the majority of the studies in this regard, low-diversity diets, in which certain food groups are excluded, have been reported to increase the mortality rate of cancer and cardiovascular diseases [21]. In addition, dietary diversity exerts protective effects against the vascular complications associated with type II diabetes [22], thereby increasing longevity and improving the overall health status [20].
Currently, diverse diets are considered to provide adequate nutrients, thereby preventing nutritional deficiencies or over-feeding [23]. The limited intake of some foods may lead to malnutrition since essential dietary nutrients are distributed among a wide variety of foods. Lack of dietary diversity is a major challenge in developing countries due to the higher rate of poverty. A major cause of malnutrition is adherence to a monotonous diet based on starchy foods, which are often deficient in essential micronutrients [21].
Although dietary diversity has recently attracted the attention of researchers regarding chronic diseases, its association with the status of serum micronutrients has not been adequately investigated, with the exception of one study conducted on elderly adults with normal and high plasma magnesium levels, in which high DDS was reported to reduce the risk of mortality [24].
The present study aimed to assess the correlations between DDS, FVS, and serum ferritin and magnesium status in healthy women.

Materials and Methods

Subjects

This cross-sectional survey was conducted on 397 healthy, non-athlete women aged 20-50 years, who joined the sports clubs in the western municipality of Tehran, Iran in 2013. Dietary diversity and its associations with sustained attention, anthropometric measurements, body composition, and blood antioxidant status were investigated [25]. The sports clubs were selected for sampling in order to have better access to adult women and attract their cooperation in the research.
The details on the applied methods in the study have been described previously [25, 26] and are briefly described in this section. In total, 14 sports clubs were selected via *random sampling* from seven districts in the west of Tehran. Approximately 30 women who started sports activities within less than a week prior to the beginning of the study were selected randomly from each sports club.
The exclusion criteria of the study were tobacco and alcohol consumption at least once a week, diagnosis of diabetes, cardiac diseases, cancer,

and renal and liver malfunction, and pregnant and lactating women. In addition, women using medications or mineral/vitamin supplements within the past month were excluded from blood sampling. In total, 87 women were randomly selected for blood sampling and biochemical tests.

The study protocol was approved by the Ethics Committee of Tehran University of Medical Sciences, and written informed consent was obtained from the participants after explaining the objectives and procedures of the study.

Dietary Diversity Score (DDS)

In the present study, DDS was determined based on the guidelines of the minimum dietary diversity of women of reproductive age (MDD-W) [27] as proposed by the Food and Agriculture Organization of the United Nations (FAO) and USAID's Food and Nutrition Technical Assistance III Project (FANTA) in 2016. MDDW is a dichotomous indicator with the threshold of five food groups (total: 10). Accordingly, the women consuming five or more food groups are more likely to meet their micronutrient requirements compared to those consuming fewer food groups [27].

Based on the mentioned guidelines, a 24-hour recall questionnaire was completed for each participant. All the food items that were consumed by the participants based on the MDD-W guidelines were categorized into 10 food groups, including grains and potato, pulses (e.g., beans, peas, and lentils), nuts and seeds, dairy products, meat, poultry, and fish, eggs, dark green leafy vegetables, other fruits and vegetables rich in vitamin A, other vegetables, and other fruits.

The participants scored one point if they consumed a minimum of half a serving of any of the mentioned food groups. In other words, each food group had a maximum of one point out of the total DDS (=10). DDS was calculated by summing up the score of the consumed food groups by the subjects and classified into two categories of high (5≤) and low (<5).

Food Variety Score (FVS)

In the present study, FVS was calculated by the simple counting of various consumed food items during the study period (24 hours). In the counting of the food items, items such as spices, beverages, sweets, and condiments were not considered in line with the method proposed by Steyn et al. [28]. FVS was classified into two categories of high (16≤) and low (16>) based on the median of the FVS.

Physical Activity

Physical activity was assessed via interviews and using self-report physical activity questionnaires, which classified physical activity based on the metabolic equivalent task (MET). The validity of the questionnaire has been confirmed previously [29].

Anthropometric Measurements

The weight and height of the participants were measured using a SECA stadiometer without shoes and with minimum clothing at the precision of 0.1 kilogram for body weight and 0.5 centimeter for height. In addition, the body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2).

Socioeconomic Status

The socioeconomic status (SES) of the participants was determined based on the number of the household living items, including the type of the house, car, carpet, furniture, side-by-side refrigerator, computer, dishwasher, washing machine, and microwave. The principal component analysis was applied to integrate the variables into a new factor indicating the SES, which was ranked into three tertiles of low, medium, and high.

Biochemical Evaluation

Due to the limited funding of the present study, 87 women were randomly selected from the participants for biochemical evaluations. After 12-14 hours of fasting, 10 milliliters of venous blood was collected before 10:00 AM in order to measure the serum levels of ferritin and magnesium. The ELISA assay was used to measure the serum ferritin (Dia Metra S.r.l Headquarter code: DKO 039), and serum magnesium was measured using atomic absorption spectrophotometry (AA-670 Shimadzu).

Statistical Analysis

Data analysis was performed in SPSS version 16 (SPSS Inc., Chicago, IL, USA) using the Kolmogorov-Smirnov test to evaluate the normality of the data. The data with non-normal distribution were logarithmically transformed for statistical analyses. The mean and geometric mean of the data with normal distribution after log transformation were determined. Comparison of the variables between the groups with high and low scores was performed using independent t-test for continuous variables and χ2 for categorical variables. Moreover, linear regression analysis was applied to investigate the correlations between DDS, FVS, and serum levels of micronutrient. The analysis of covariance (ANCOVA) was employed to compare the mean values of the micronutrient levels in the DDS and FVS groups after adjustment for energy intake, BMI, SES, physical activity, and education level. In all the statistical analyses, P-value of less than 0.05 was considered significant.

Results

In total, 397 healthy, non-athlete women were enrolled in the study. The mean age and BMI of the participants was 34.2±8 years and 26.6±4.5 kg/m^2, respectively. According to the findings, the mean DDS was 5.7±1.4, with the minimum and maximum scores of two and nine out of 10 points, respectively. The mean FVS was estimated at 15.3±4.7, with the minimum and maximum scores of five and 32, respectively. Table 1 shows the mean age, physical activity, energy intake, BMI, SES, and dietary supplement intake of the DDS and FVS groups.

Table 1. Socio-demographic characteristics of participants (n=397)

Variables	**DDS**		**p-value**	**FVS**		**p-value**
	<5 (n=79)	**≤5 (n=318)**		**<16 items (n=218)**	**16≤ Items (n=179)**	
	Mean (SD)			**Mean (SD)**		
Age (y)	33.3 (7.5)	34.4 (8.2)	0.3	34.4 (8.2)	33.9 (7.9)	0.5
Education level (y)	11.8 (3.0)	12.7 (3.1)	0.01	12.1 (3.4)	13.1 (2.6)	0.003
BMI (kg/m^2)	29.0 (4.0)	26.0 (4.4)	<0.001	27.4 (4.5)	25.6 (4.3)	<0.001
Physical activity (Met. H/d)	32.2 (4.9)	32.4 (5.0)	0.7	30.7 (5.4)	32.8 (4.8)	0.004
Energy intake (kcal/d)	1543.6 (419.6)	1705.9 (360)	0.001	1604.1 (369.1)	1758.3 (371.1)	<0.001
BMI≥30 (kg/m^2) (%)	38	18.6	<0.001	29.4	14	<0.001
Marital status (%)						
Single	16.5	18.2	0.7	16.5	19.6	0.1
Married	74.7	75.2		74.3	76	
Widowed and Divorced	8.9	6.6		9.2	4.5	
Socio-economic status (%) *						
Low	45.6	30.2	0.005	40.8	24	0.001
Middle	35.4	33		32.1	35.2	
High	19	36.8		27.1	40.8	
Occupation (%)						
Housewife	58.2	55	0.8	54.1	57.5	0.7
Employee	27.8	29.9		30.7	27.9	
Other	13.9	15.1		15.1	14.5	
Dietary supplement intake (%)	29.1	35.2	0.3	32.1	36.3	0.3

* Based on principal component analysis method, Low: first tertile, middle: second tertile, high: third tertile
Abbreviations: FVS, Food Variety Score; DDS, Dietary Diversity Score; BMI, Body Mass Index; Met. H/d, Metabolic equivalent- Hour per day.
P< 0.05 is statistically significant.

According to the obtained results, the energy intake was higher in the groups with high DDS and FVS, while the BMI was lower in these groups. In addition, physical activity was higher in the group with high FVS (P<0.005). Significant correlations were observed between the SES, DDS, and FVS. Accordingly, the SES was higher in the groups with high DDS and FVS. Furthermore, the groups with high FVS and DDS had higher education levels.

The findings of the current research indicated no significant associations between the occupation status, marital status, and use of dietary supplements with the DDS and FVS in the women. On the other hand, comparison of the food group intakes between the DDS and FVS groups demonstrated that food group consumption was higher in the groups with high DDS and FVS. However, the obtained results were not significant in terms of grain consumption in the FVS and DDS groups, as well as dairy product and eggs consumption in the FVS group (Table 2).

Table 2. Food group consumption across dietary diversity score (DDS) and food variety score (FVS) in healthy women (n=397)

Food groups	DDS		p-value	FVS		p-value	Total
	<5 (n=79)	≤5 (n=318)		<16 items (n=218)	16≤ items (n=179)		
Grains and potato (%)	97.5	99.4	0.13	98.6	99.4	0.41	**99**
Dairy (%)	70.9	86.2	0.001	82.6	83.8	0.74	**83.1**
Dark green leafy vegetables (%)	13.9	51.3	<0.001	29.4	61.5	<0.001	**43.8**
Other vitamin A rich vegetables and fruits (%)	8.9	43.1	<0.001	27.1	47.5	<0.001	**36.3**
Other fruits (%)	35.4	81.4	<0.001	63.3	83.2	<0.001	**72.3**
Other vegetables (%)	51.9	82.4	<0.001	72	81.6	0.02	**76.3**
Meat, poultry and fish (%)	60.8	85.8	<0.001	73.9	89.4	<0.001	**80.9**
Eggs (%)	6.3	37.7	<0.001	29.8	33.5	0.42	**31.5**
Pulses (beans, peas and lentils) (%)	13.9	28.6	0.007	21.1	31.3	0.02	**25.7**
Nuts and seeds (%)	2.5	34	<0.001	15.1	43	<0.001	**27.7**

According to the information in Table 3, the serum levels of micronutrients were not associated with the DDS, and serum magnesium was significantly higher in the group with high FVS (P=0.02). After the adjustment for energy intake, BMI, SES, physical activity, and education level, the correlation of serum magnesium with FVS remained significant (P=0.01). Furthermore, a positive correlation was observed between serum ferritin and FVS (P=0.058). The results of the linear regression analysis of the DDS and FVS are presented in Table 4. The linear regression analysis indicated a significant association between high FVS and serum magnesium levels (P=0.02).

Table 3. Serum micronutrients across dietary diversity score (DDS) and food variety score (FVS) in healthy women (n=397)
*Data are shown as the geometric mean.

Micronutrients	model	DDS		p-value	FVS		p-value
		<5 (n=79)	≤5 (n=318)		<16 items (n=218)	16≤ items (n=179)	
		Mean (SD)			Mean (SD)		
Ferritin(μg/l)*	1	12.4 (0.5)	13.0 (0.2)	0.2	12.6 (0.3)	13.3 (0.2)	0.1
	2	12.5 (0.5)	13.0 (0.2)	0.4	12.5 (0.3)	13.4 (0.3)	0.058
Magnesium (mg/l)	1	4.6 (0.1)	4.4 (0.08)	0.2	4.3 (0.1)	4.6 (0.08)	0.02
	2	4.6 (0.1)	4.4 (0.07)	0.3	4.3 (0.09)	4.6 (0.1)	0.03

Model 1: Unadjusted
Model 2: Adjusted for energy intake, BMI, socio-economic status, physical activity and the years of education.

Discussion

The present study aimed to assess the correlations between DDS, FVS, and the serum levels of some micronutrients in adult women. The obtained results indicated a positive association between serum magnesium and FVS, and serum magnesium was higher in the group with high FVS even after the adjustment of the possible confounding factors. In addition, the correlation between FVS and serum ferritin was considered significant following the adjustment for the energy intake, BMI, SES, physical activity, and education level. However, no significant correlation was observed between DDS and serum micronutrients.

Few studies have investigated the correlations between DDS, FVS, and serum levels of micronutrients. For instance, Huang et al. [24] reported that the plasma levels of magnesium increased with higher DDS in elderly subjects. Moreover, the mentioned study demonstrated that the higher consumption of vegetables, eggs, and calcium was associated with the significantly higher plasma levels of magnesium. The participants with normal and high plasma magnesium and high DDS were also reported to be at the relatively lower risk of mortality compared to those with low plasma magnesium and low DDS.

In another research in this regard, Akizawa et al. [30] observed that serum magnesium level had a positive correlation with its dietary intake. Previous reports have also indicated a significant association between DDS and dietary magnesium intake [31]. In the present study, the participants with higher FVS and DDS had significantly higher consumption of fruits, vegetables, and meat compared to those with lower FVS and DDS. Additionally, the intake of dairy products was observed to be higher in the group with high DDS. These food groups are abundant sources of magnesium [5], and their consumption could result in the increased serum levels of magnesium in the participants consuming these food groups.

The findings of the current research showed no significant correlation between serum ferritin status and DDS, while serum ferritin status was significantly correlated with FVS. Similarly, Nikuyeh et al. [32] denoted no significant correlation between serum iron and dietary iron intake in students. Moreover, the findings of Broderstad et al. [33] showed no association between serum ferritin and seafood intake or vegetarian and Mediterranean dietary patterns. Several other studies have reported no association between iron consumption and DDS [21, 34]. Meanwhile, other similar studies have denoted that iron intake is associated with the consumption of whole grains, nuts, seeds, and fruits rich in vitamin C [35].

In another study conducted on women, a positive correlation was observed between iron intake and the consumption of meat, nuts, and legumes [36]. In the present study, the participants with higher FVS and DDS consumed significantly higher portions of meat, legumes, and nuts. The vegetables and fruits that were highly consumed in the groups with high DDS and FVS were abundant sources of vitamin C, which could enhance iron absorption. Therefore, it could be inferred that food variety may affect serum ferritin levels by altering the consumption of food items to the higher intake of iron-containing foods. Some of the confounding factors in the measurement of serum ferritin include food components such as tannin, phytate, polyphenols, phosphate, and carbonate, as well as conditions such as infection, inflammation, and lack of stomach acid [11]; these factors were not taken into account in the current research.

Food variety and dietary diversity are considered to be proper indicators of dietary adequacy and quality [37]. However, it has been suggested that the association of food intake from different food groups and adequacy of micronutrient intake may result from the consumption of proper amounts of foods with no correlation with the variety of food groups [38]. In addition, the simple counting of food items or food groups does not provide accurate data on dietary adequacy. In the present study, the level of consumption was not considered for FVS, while compared to DDS, FVS had a more significant association with the serum levels of micronutrients. The measurement of FVS is a rapid, simple, and inexpensive assessment technique, while it is also easy for respondents.

According to the findings of the current research, a large number of the participants had high DDS, while less than half had high FVS; approximately 80% of the participants achieved the DDS of ≥5. According to the MDD-W analysis, the women who consumed five or more food groups were more likely to meet their micronutrient requirements compared to those who consumed fewer food groups [27]. On the other hand, the mean DDS was lower in the present study compared to the research by Mirmiran et al. [39]. This discrepancy could be due to the differences in the methods of DDS calculation or type of the sample populations.

In the present study, the mean FVS was higher compared to the values reported by the previous research in this regard [19, 20]. This inconsistency could be due to the differences in the calculation methods. In the current research, the number of the consumed food items by participants within 24 hours of the study period was counted based on the FVS. The intake of beverages, sweets, spices, and condiments were not considered in the FVS calculations in the present study, while other studies did not consider spices and drinks and measured the intake of tea and coffee in the FVS calculations. Conversely, all these food items were included by other research groups in FVS calculations [19].

Lower DDS in various populations could be due to the inline differences in the SES, education level, nutritional knowledge, and food availability. Low-income families often do not have access to a wide variety of foods. Although access to sufficient food is of utmost importance, the knowledge of dietary guidelines may have more significant effects on dietary diversity [40].

One of the limitations of the present study was the use of one 24-hour recall to evaluate dietary intakes, which might have been insufficient to determine the usual dietary intakes of the individuals. Lack of dietary diversity on special days does not imply the absence of dietary variations on a daily basis [19]. Another limitation was the lack of standard methods and cutoff points for the calculation of FVS. In addition, the age range of our subjects was diverse, and the final outcomes may also reflect the age differences. However, no correlation was denoted between age and the serum levels of micronutrients. Another drawback of the current research was that the menopausal state was not considered in the participants, which might have affected the serum levels of micronutrients. Finally, similar to other cross-sectional studies, we were not able to determine the cause-and-effect relationships.

Conclusion

According to the results, high FVS is associated with increased serum magnesium and possibly ferritin status, while such association was not denoted in case of DDS. Therefore, public health awareness must be emphasized in order to promote the higher consumption of a wider variety of foods. It is recommended that further interventional studies be conducted in this regard so as to clarify the impact of increased FVS and DDS on the serum status of micronutrients.

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