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The Relationship between Nutrient-Rich Foods (NRF) Index as A Measure of Diet Quality and Malnutrition in Children

Jollanar Khankan; MSc[1], Shima Jazayeri; PhD[1], Farzad Shidfar; PhD[1], Zohreh Sajadi Hezaveh; MSc[1], Agha Fatemeh Hosseini; PhD[2] & Mohammadreza Vafa; PhD[1]*.

[1] *Department of Nutrition, School of Public Health, Iran University of Medical Sciences, Tehran, Iran.*
[2] *Department of Epidemiology and Biostatistics, School of Public Health, Iran University of Medical Sciences, Tehran, Iran.*

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***Corresponding author:**
vafa.m@iums.ac.ir
Department of Nutrition, School of Public Health, Iran University of Medical Sciences, Tehran, Iran.

Postal code:1449614535
Tel: +98-21-88622755

ABSTRACT

Background: The assessment of pediatric diet quality is of high interest because food habits that develop in childhood can predict adult diet-related disease. The aim of this study was to examine the association between the Nutrient-Rich Foods (NRF) index score and weight and height status. **Methods:** This cross-sectional study was conducted in primary schools of Tehran, and the NRF9.3 algorithms were used to estimate the nutrient density of the diet of 400 girls, aged 6.5-8.4 years. Dietary data were collected using a 168-item food frequency questionnaire of foods consumed over the past month. Height and weight were measured, and height for age, body mass index (BMI) for age, and weight for age were classified using the World Health Organization's child growth standard Z-scores. Linear regression was used to examine the association between the quintiles of NRF index score and weight for age, height for age, and BMI for age**.** **Results:** Liquid oil (P < 0.001), legume (P = 0.037), meat products (P = 0.005), and fruit (P < 0.001) were consumed in higher amounts significantly in the fifth quintile, while sugar & sweet sauce (P < 0.001), snacks (P = 0.002), fats, oil and savoury sauce (P = 0.002) were consumed in lower amounts significantly. A significant relationship between the NRF9.3 index and height for age (P = 0.039) was found, however, it did not follow a trend. The NRF9.3, NR9, and LIM3 scores were unrelated to weight status in childhood. **Conclusion:** There was no significant association between the NRF9.3 index score and malnutrition in girls, except for height for age. Bias in reporting the dietary intake or defects in the NRF index formula might be the reason for this insignificant result. Prospective studies can better detect the existence of such a relationship.

Keywords: *Nutrient density; Malnutrition; Diet quality; NRF9.3 index score; Children*.

Introduction

The 2015-2020 dietary guidelines for Americans focus on variety, nutrient density, and amount to meet nutrient needs within calorie limits, and encourage to choose a variety of nutrient-dense foods across and within all food groups in recommended amounts (DeSalvo *et al.*,

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2016). In epidemiological studies, the nutrient density standard is defined as the ratio of the amount of nutrients relative to the food's energy content (Abdollahi *et al.*, Backstrand, 2003, Drewnowski, 2005).

Beneficial nutrients are almost always consumed together with significant amounts of energy. Therefore, intake of energy and vitamin and minerals are often strongly correlated. Because energy intake is actively regulated by appetite and satiety, energy requirements may be satisfied well before requirements for vitamins and minerals are met, and this may lead to malnutrition (Backstrand, 2003). Despite our extensive understanding of human nutritional requirements for maintenance of health, malnutrition continues to be one of the main causes of morbidity and mortality in low- and middle-income countries, especially in young children (Black et al., 2008). Also, many children in developing countries suffer from the effects of food insecurity resulting in deficits in energy, protein, and micronutrients such as vitamin A, iron, and zinc. These deficits are associated with low weight- and low height- for- age as well as micronutrient deficiencies (Ramakrishnan and Huffman, 2008). The assessment of pediatric diet quality is of high value because food habits and behaviors that develop in childhood can track over time and predict adult diet-related disease (Craigie *et al.*, Patterson *et al.*, 2009). Thus, an investigation into the diet quality that contributes to healthier dietary intakes in children is a public health priority.

Various diet quality models have been developed to assess the overall nutritional quality of the total diet (Drewnowski, 2005, Nicklas *et al.*, 2014). One of those models is the Nutrient-Rich Foods indices (NRF). The NRF index has been tested and validated against the quality of the total diet index such as the Healthy Eating Index (HEI) (Alkerwi, 2014, Fulgoni *et al.*, 2009). The NRF9.3 index, based on nine nutrients to encourage and three nutrients to limit and per 100 kcal, explains the highest percentage of variation from HEI, index performance declined with the inclusion of additional vitamins and minerals. Previous studies confirmed that increasing the number of nutrients over 10 in a nutrient profile model provided little or no extra benefit in predicting overall diet quality (Drewnowski and Fulgoni, 2014).

Previous studies have not investigated the relation between NRF index, obesity and stunted growth in children. Hence, this study aimed to determine the cross-sectional association between the NRF index and malnutrition in girls in Tehran.

Materials and Methods

Participants: A school-based, cross-sectional study was conducted with 400 children (girls) aged 6.5-8.4 from 12 primary schools laid in Tehran, Iran, from September 2016 to May-2017. Multi-stage cluster random sampling was used to select the study sample. Since the Z-scores of malnutrition indices are defined separately for the girls and boys, the boys were excluded in this study. Written informed consent was obtained from the children's mothers. The children selected for this study were healthy female children without any diseases who were from 6.5 to 8.5 years old, and had not received any nutritional supplements during the latter year. The exclusion criteria were having a history of any diseases affecting growth, having dead or divorced parents, having energy intake of less than 1000 or more than 4000 kcal, and also those who provided incomplete questionnaires.

All the required confirmations were obtained from the Department of Education in Tehran. Students were interviewed together with their parents at the school. The study's data has been collected by trained staff throughout two and a half months. Tehran is divided into five districts, and five regions were randomly selected from each district as follow: The northeast district: regions 1 and 4. The southeast district: region 14. The southwest district: region 19. The center district: region 7. Two primary schools were selected in each mentioned region and the parents of first grade students were invited for participation in this study. Most parents were willing to participate. A total of 400 students provided complete data and were included in the final analyses.

Assessment of dietary intake: Dietary data for each child was collected from their parents by interviewers. Diet quality was assessed using the valid and reliable food frequency questionnaire (168-item) over the past month (Asghari G *et al.*, 2012). If the child was present with an illness other than a simple cough or fever, and the mother reported the child had a poor appetite or diarrhea, the dietary data was collected in another time. The information was collected through a face-to-face interview.

Calculation of the NRF index scores: The NRF index has two components: (i) the nutrient-rich (NR) component which is based on a variable number of beneficial nutrients and (ii) the limiting nutrients (LIM) component. The NRF9.3 score is based on the sum of the percentage of reference daily values (DVs) for nine beneficial nutrients protein, dietary fiber, vitamin A, vitamin C, vitamin E, calcium, magnesium, iron and potassium minus the sum of the percentage of maximum DVs for three nutrients to limit saturated fat, total sugar, i.e. mono- and disaccharides, and sodium (Fulgoni *et al.*, 2009) (**Table 1**). This index can be used as follows: Firstly, all foods consumed by each subject are scored using the NRF9.3 algorithms based on Drewnowski's method (Drewnowski, 2009), and this resulted in a NRF9.3 score (per 100 kcal) for every food item, i.e., a NRF9.3 food score. The recommended daily allowances as set by the Institute of Medicine (IOM) of the National Academies (Dietary Reference Intake (DRI)) were used as reference DVs (Institute of Medicine, 2005, Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds, 2000, Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, 1998, Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, 1998, 2001) (**Table 2**). The percentage of reference DV for each nutrient is capped at 100% DV to avoid overvaluing of food items that provide very large amounts of a single nutrient. Secondly, the NRF9.3 food scores were converted to individual NRF9.3 index scores by multiplying the amount of calorie consumed of each food item, in 100-kcal units, by the NRF9.3 food scores and then summing these scores for each subject. Thirdly, the NRF9.3 index scores were divided by the number of 100-kcal units of the participant' total energy intake to provide a 'weighted average' diet quality score. Higher NRF9.3 index scores indicated higher nutrient density per 100 calories, and thus, the participants with a high NRF9.3 index score were considered to have a healthier dietary pattern than those with a low NRF9.3 index score.

Assessment of anthropometric measures and Demographic data: The researchers collected anthropometric data during the interview at school using validated, standardized methods. Weight measurements of parents and children were recorded to the nearest 0.5 kg using a SECA 761 medically approved flat mechanical scales. Height was recorded to the nearest millimeter using a Leicester portable height stick. Children were classified into body **m**ass index (BMI) categories using the World Health Organization's child growth standards Z-scores. Measured parent BMI was classified according to the World Health Organization (WHO) classifications as normal weight (< 25 kg/m^2), overweight (≥ 25 and <30 kg/m^2) or obese (≥ 30 kg/m^2)(WHO, 2000).

Information on physical activity (PA), screen time, sleeping hours, parent's birthday date, parent's education, family dimension, geographical region were obtained from the parent questionnaire. Child's PA was measured from the physical activity questionnaire Baecke (Baecke Jos, 1982, Moghaddam *et al.*, 2012). Child's screen time was derived from the time (in hours) spent during weekdays in (1) TV watching and (2) playing non-active video games or using the computer.

Parent's education was used as a proxy of family socioeconomic status and was recoded into four categories. The four education categories were 1: primary school, category 2: guidance school, category 3: high school, category 4: diploma, and category 5: college/university or above. Information provided by the parents were about the child's usual bedtime, an estimate of how long they stay awake during the night and also the usual wakeup time. Also, the parents were asked about the duration of any naps during the day.

Ethical considerations: This study was approved by the Ethics Committee of Iran, University of Medical Sciences with the ethics code of IR.IUMS.REC.1395.9321680001.

Data analysis: The normality of the data was assessed using the Kolmogorov-Smirnov test. The baseline characteristics of the participants were compared between quintiles of the NRF9.3 index score using analysis of variance for continuous variables and the chi square test for categorical variables. Independent sample *t-tests* was used for normally-distributed data to compare the NRF index in different weight and height status. Linear regression analysis was used to study the association between the NRF9.3, NR9 and LIM3 index scores and malnutrition indicators like weight-, height- and BMI- for age. The multiple regression models were adjusted for liquid oil, legume, meat products, fruit, sugar, sweet sauce, snacks, fats, oil, and savory sauce intake. All statistical analyses were carried out using the Statistical Package for the Social Sciences version 22 (IBM, SPSS Inc., Chicago, USA). Two-sided P-values < 0.05 were considered statistically significant.

Results

Demographic Characteristics: **Table 2** shows the distribution of demographic characteristics by the NRF9.3 index quintiles. The mean age of children was 7.25 ± 0.65 years. No significant difference was observed between children's age, sleep hours, screen time, physical activity, and parents' BMI in different quintiles of NRF index (P > 0.05). According to WHO's child growth standard Z-scores regarding BMI-for-age, 12.25% of our participants were overweight and obese (49 students), 34.50% were underweight (138 students), and 53.25% were normal (213 students). The mean weight was 25.50 ± 6.26 kg, and the mean height was 122.51 ± 7.08 cm. The mean of NRF9.3 index for the whole sample was 64.69 ± 30.98 (**Table 2**). The mean of total calories consumed was 1,411.95 ± 407.82 kcal.

Table 3 shows the difference in food items consumed among quintiles of the NRF9.3 index score. Participant in the highest quintile of the NRF9.3 index score consumed remarkably more liquid oil (P < 0.001), legume (P = 0.037), meat products (P = 0.005), fruit (P < 0.001), less sugar & sweet sauce (P < 0.001), snacks (P = 0.002), fats, oil and savory sauce (P = 0.002) comparing to those in the lowest quintile.

NRF9.3 index and anthropometric measures: In linear regression analysis, the NRF9.3 index score was positively associated with height-for-age after adjustment for confounding factors (from β = -0.03 (-0.17, 0.88, 95% CI) in the first quintile to β = 0.09 (0.27, 1.12, 95% CI) in the fifth quintile, P = 0.039). Whereas, the NR9 index score tended to increase height but it was not significant (P = 0.056). There was not a significant association between NRF9.3, NR9 and LIM3 index scores and weight- and BMI-for-age (**Table 4**). The mean of the NRF9.3 index for normal weight and overweight and obese was 64.00 ± 33.06 and 66.46 ± 25.28, respectively. There was no significant difference in the mean of the NRF9.3 index for overweight and obese children compared to normal weight (P = 0.47). Furthermore, the mean of the NRF9.3 index for normal and stunted children was 64.61 ± 31.16 and 71.54± 10.06, respectively. There was no significant difference in the mean of the NRF9.3 index for stunted children compared to the normal height (P = 0.619).

Table 1. Recommended and maximum DVs for selected nutrients

Nutrients	RDV[a]	MDV[b]
Protein (g)	19	
Dietary fiber (g)	25	
Vitamin A (RE)	400	
Vitamin E (mg)	7	
Vitamin C (mg)	25	
Calcium (mg)	1000	
Magnesium (mg)	130	
Iron (mg)	10	
Potassium (mg)	3.8	
Saturated fat (g)		10% (kcal)(Kennedy *et al.*, 1996)
Total sugar (g)		10% (kcal)(McGuire 2015)
Sodium (mg)		1.2

[a]"RDV, recommended DV; [b]:MDV, maximum DV.

Table 2. Mean (± SD) of indices score and demographic characteristics of participants according to quintiles of the NRF9.3 index

Indices and characteristics	All (n = 400)					*P* value
	Q1	Q2	Q3	Q4	Q5	
NRF9.3 index score [a]	39.52 ± 7.19	51.74 ± 2.38	60.38 ± 2.67	70.53 ± 3.75	101.30 ± 50.48	< 0.001
NR9 index score [b]	93.81 ± 25.18	94.56 ± 28.78	90.85 ± 30.04	98.29 ± 64.00	82.68 ± 22.28	0.098
LIM3 index score [c]	27.87 ± 4.80	27.25 ± 6.59	27.47 ± 4.04	27.33 ± 5.32	26.36 ± 5.93	0.495
Age (months)	86.54 ± 7.94	86.56 ± 7.74	87.93 ± 7.76	87.99 ± 7.83	85.99 ± 7.59	0.526
Child's height (cm)	121.36 ± 6.39	122.41 ± 7.12	123.47 ± 7.13	122.16 ± 8.80	123.49 ± 6.98	0.298
Child's weight (kg)	24.35 ± 5.55	26.10 ± 7.20	25.53 ± 5.76	25.17 ± 5.69	26.37 ± 6.88	0.271
Total energy (kcal)	2075.46 ± 357.01	1491.27 ± 319.58	1392.65 ± 256.18	1428.99 ± 341.16	1250.20 ± 257.16	0.062
Father's BMI (kg/m2)[d]	26.84 ± 3.69	28.16 ± 4.49	27.99 ± 4.73	27.26 ± 4.77	27.10 ± 4.06	0.239
Mother's BMI (kg/m2)	27.74 ± 4.88	27.89 ± 4.77	27.79 ± 4.34	28.53 ± 5.02	28.37 ± 4.43	0.751
Physical activity scores	2.66 ± 0.31	2.74 ± 0.30	2.70 ± 0.30	2.64 ± 0.32	2.69 ± 0.35	0.327
Sleep hours (h /day)	9.48 ± 1.04	9.35 ± 1.31	9.21 ± 1.15	9.33 ± 1.19	9.38 ± 1.22	0.721
Screen time (h /day)	2.63 ± 1.48	2.54 ± 1.85	2.36 ± 1.32	2.46 ± 1.67	2.34 ± 1.47	0.755

[a]:*Nutrient rich food;* [b]*: Nutrient rich,* [c] *: Nutrients to limit,* [d] *: Body mass index*

Table 3. Mean (± SD) of daily food intake from participants according to quintiles of the NRF9.3 index

Food items (g)	All (n=400)					P value
	Q1	Q2	Q3	Q4	Q5	
Egg	17.04 ± 20.33	17.89 ± 23.93	12.45 ± 15.55	17.52 ± 17.90	18.33 ± 18.02	0.301
Fish	4.27 ± 9.77	4.96 ± 10.41	3.63 ± 8.84	4.25 ± 11.15	5.80 ± 15.11	0.785
Liquid oil	5.41 ± 5.83	7.32 ± 7.32	6.43 ± 6.43	11.01 ± 11.01	11.08 ± 11.08	< 0.001
Bread & Cereals	405.92 ± 1126.14	298.46 ± 98.35	278.29 ± 98.05	266.33 ± 101.38	242.54 ± 92.54	0.296
Biscuits & cake	50.97 ± 38.32	36.83 ± 29.24	35.14 ± 28.67	29.94 ± 26.11	25.65 ± 20.76	< 0.001
Legumes	13.06 ± 18.64	16.61 ± 23.51	17.11 ± 28.06	25.32 ± 32.24	21.55 ± 28.13	0.037*
Meat products	1.34 ± 4.93	1.71 ± 6.21	1.11 ± 3.36	1.30 ± 4.39	4.34 ± 9.98	0.005
Meat & poultry	32.73 ± 34.23	35.08 ± 38.50	31.71 ± 32.57	31.23 ± 34.32	31.13 ± 27.68	0.943
Milk, milk products	238.53 ± 148.16	276.56 ± 176.24	280.93 ± 219.21	271.43 ± 172.64	250.58 ± 172.71	0.509
Fats, oil and savoury sauces	10.32 ± 15.16	9.12 ± 10.37	7.65 ± 9.00	7.02 ± 7.18	4.17 ± 5.63	0.002
Vegetables	76.42 ± 57.70	80.07 ± 53.59	89.01 ± 65.34	90.33 ± 66.25	91.69 ± 60.46	0.405
Fruit	162.31 ± 121.57	191.98 ± 110.43	224.92 ± 179.82	265.14 ± 118.06	311.52 ± 153.77	< 0.001
Nut & seeds	10.16 ± 16.47	8.70 ± 15.18	9.15 ± 11.79	10.14 ± 17.59	7.59 ± 8.56	0.771
Sugar & sweet sauces	76.73 ± 115.00	43.73 ± 62.38	31.90 ± 39.77	34.14 ± 53.85	24.79 ± 44.72	< 0.001
Snacks	22.19 ± 57.55	9.62 ± 32.91	5.32 ± 13.07	7.78 ± 22.98	2.69 ± 12.09	0.002
Tea & coffee	83.04 ± 79.39	86.97 ± 66.18	83.43 ± 71.18	76.87 ± 80.34	71.42 ± 73.97	0.698

Table 4. The relationship between quintiles of NRF index scores and malnutrition indicators.

NRF and its components	All (n = 400)					P value	
NRF9.3 index score	***Q1***	***Q2***	***Q3***	***Q4***	***Q5***	*Crude*	Adjusted
Height for age (z-score)	-0.03 (-0.17, 0.88)	0.42 (0.01, 0.96)	0.71 (0.11, 1.10)	-0.02 (-0.20, 1.17)	0.09 (0.27, 1.12)	0.029*	0.039
Weight for age (z-score)	0.85 (0.14 , 1.18)	0.33 (0.51, 1.18)	0.82 (0.37, 1.23)	0.91 (0.27, 1.20)	1.02 (0.60, 1.36)	0.136	0.196
BMI for age (z-score)	1.04 (0.27, 1.36)	0.89 (0.65, 1.27)	0.91 (0.40, 1.21)	0.98 (0.50, 1.20)	1.00 (0.60, 1.26)	0.307	0.391
NR9 index score	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*		
Height for age (z-score)	0.75 (0.14, 1.12)	0.46 (0.19, 0.98)	0.39 (-0.06, 0.99)	0.61 (-0.06, 0.87)	0.22 (-0.18, 1.26)	0.121	0.056
Weight for age (z-score)	1.01 (0.51, 1.34)	0.82 (0.44, 1.15)	0.95 (0.39, 1.20)	0.78 (0.25, 1.09)	1.06 (0.29, 1.41)	0.682	0.864
BMI for age (z-score)	0.99 (0.57, 1.27)	0.82 (0.42, 1.16)	0.86 (0.56, 1.17)	0.80 (0.36, 1.15)	1.11 (0.51, 1.47)	0.795	0.708
LIM3 index score	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*		
Height for age (z-score)	0.59 (0.04, 1.06)	0.66 (0.00, 1.19)	0.74 (0.11, 1.03)	0.65 (-0.09, 1.07)	0.38 (-0.04, 0.95)	0.757	0.241
Weight for age (z-score)	1.08 (0.44, 1.35)	0.79 (0.44, 1.21)	0.81 (0.41, 1.19)	0.84 (0.23, 1.25)	0.89 (0.35, 1.23)	0.819	0.744
BMI for age (z-score)	0.97 (0.54, 1.34)	0.83 (0.57, 1.25)	0.88 (0.45, 1.18)	0.77 (0.37, 1.17)	1.02 (0.48, 1.30)	0.879	0.305

Data presented as β (95%CI)

P value adjusted: Adjusted for Liquid oil, legume, meat products, fruit, sugar & sweet sauce, snacks, fats, oil and savoury sauce intake.

NRF: Nutrient Rich Food, NR9: 9 Beneficial Nutrients, LIM3: 3 Nutrients to Limit, BMI: Body Mass Index

Discussion

This study was the first study that examined the association between the NRF9.3 index and malnutrition in children. The girls with a high NRF9.3 index score had a significantly higher height as compared to those with low NRF9.3. However, no significant association between BMI-for-age, and weight-for-age, and NRF index was found. This means that the participants were more chronically malnourished than severely malnourished.

It was found that the NRF index scores were not associated with weight and BMI-for-age status, after adjustment for Liquid oil, legume, meat products, fruit, sugar & sweet sauce, snacks, fats, oil, and savory sauce intake. The result is similar to that of Zhao W., et al., in China who found no association between dietary diversity scores (DDS) and overweight and obesity in children aged 6-7 years (Zhao *et al.*, 2017). Mehran, M. et al. also found that BMI and waist circumference (WC) were not found to be predicated by Diet Quality Index-International (DQI-I) (Asghari *et al.*, 2012). However, there are studies with different findings. In Ireland, Perry, C.P. et al. found that the dietary quality score (DQS) was associated with obesity in nine year old children (Perry et al.). Jennings et al. (Jennings *et al.*, 2011) and Okubo, H., et al. (Okubo *et al.*, 2015) found that the Diet Quality Index (DQI) was inversely associated with weight status.

Lack of association with weight status may be the result of underreporting of specific foods, especially by the obese participants. Besides, energy intake is the most important variable related to weight and BMI, while this study assessed diet quality which is mostly related to height, and was found to be significantly related to the NRF index in this study. There are also several methodological issues concerning nutrient quality models like the NRF index. The NRF9.3 index was selected for the current study as it explains most of the variation in HEI. However, some nutrients included in the NRF9.3 index may be less important for weight management. Also, the total sugar was included in the NRF9.3 index, as data for added sugar was not available, so this can affect the LIM3 and consequently the NRF9.3 index scores. When using total sugar, the intake of milk and milk products were counted substantially in the LIM3 index score (~14%), while the contribution of sugar and sweets is ~10%. By exchanging total sugar with added sugar, it was expected that sugar and sweets will contribute more to the LIM3 index, and this may have affected the results of this study (Streppel *et al.*, 2012).

One of the strength of this study that is worth mentioning is that during the interview and filling out the questionnaires, the interviewers showed some kitchen utensils to mothers such as spoon, glass, bowl, etc. and asked them to report the amount of each item's intake using those utensils as the scale, so an exact dietary report was recorded. Another strength of this study is that mothers were individually interviewed to avoid under- and over-reporting of food intake which happens in group interviews. The present study has its limitations, too. Firstly, this was a cross-sectional study that only baseline data on food intake and anthropometric measures were available, and inferring causality in studies with such design is impossible. Secondly, data on sodium intake, as added salt during cooking or hidden in some food items such as cake was not taken into account. Thirdly, preparation and cooking methods of foods can affect their content of nutrients, which was not possible to be investigated in this study. Information bias due to using the FFQ questionnaire might have occurred too since it depends on self-reported information.

Conclusions

The participant with a high NRF9.3 index score had a higher height-for-age as compared to those with a low score, while the NRF index score was not associated with BMI for age and weight for age which represents the prevalence of chronic malnutrition in the participants. Therefore, the association between diet quality and malnutrition is complex. More investigations are recommended such as examination of the relationship between NRF index score and other diseases or in other ranges of age in future researches so that the government and policymakers be able to prevent adulthood diseases which cost the government a fortune, by investing in children's health.

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Authors' contributions

Khankan J and Vafa M designed the research, Sajadi Hezaveh Z conducted the research, Shidfar F and Jazayeri S provided essential materials, Hosseini AF performed statistical analysis, Sajadi Hezaveh Z and Khankan J wrote the manuscrip, and Vafa M had primary responsibility for final content. All authors have read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflict of interest**.**

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