Validation of the Nutrient-Rich Foods Index Estimated by 24-hour Dietary Recall Method in Chinese Mid-Eastern Adults

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Abstract

Objectives

The Nutrient-Rich Foods (NRF) Index is an important nutrient profiling model. Nutrition quality indices need to be tested and validated against the quality of the total diet and against health outcomes. A family of NRF indices was validated against the mean adequacy ratio (MAR), an overall measure of the nutrient adequacy. Besides, we examined the associations between the NRF index and obesity indicators.

Methods

A total of 656 persons aged 18-75 years from Henan province of China since 2020 were studied. All foods consumed by participants were scored using NRFn.2 (where n= 6–11) indices based on unweighted sums, means, and ratios of percent Chinese Dietary Reference Intakes (DRIs) for beneficial nutrients (n) and nutrients to limit (2). NRF index scores in this study were calculated on 100 g, 100 kcal basis. The measure of index performance was the percentage of adjusted variation in MAR (R^2). Multi-factor logistic regression models were used to examine the association between the NRF index scores and obesity indicators.

Results

The NRF9.2 index, based on 9 beneficial nutrients and 2 nutrients to limit, using the algorithm based on sums and 100 kcal, was the best predicted model, with an adjusted R^2 of 0.23 by multiple adjustments. The odds ratio (OR) for overweight (defined by BMI) in the 4th quartile (Q4) versus the 1st quartile (Q1) of the NRF9.2 index was 0.61 (95% CI=0.37, 0.98) after multiple adjustments. However, the NRF9.2 index score was not related to central obesity.

Conclusion

NRF9.2 index, using the algorithm based on sums and 100 kcal, was the best predicted model. NRF9.2 index scores were associated with BMI. These results revealed that the NRF9.2 index can be used as a validated tool to assess the overall diet quality among mid-eastern Chinese adults.

1. Introduction

An estimated 41 million people worldwide died of chronic non-communicable diseases (NCDs) in 2016, equivalent to 71% of all deaths[1]. The underlying causes of the main NCDs include genetic predispositions, modifiable risk behaviors (such as tobacco use, harmful use of alcohol, physical inactivity and unhealthy diets) and environmental risks. Dietary risks were responsible for 7.94 million deaths and 188 million disability-adjusted life years globally among adults in 2019[2]. Thus, suggestions on dietary improvements should be imperative.

Despite the amount of knowledge on the benefits of a nutritionally balanced to prevent NCDs, the prevalence of these diseases has been increasing. More and more researchers found that NCDs are associated with a high intake of energy-dense, nutrient-poor (EDNP) foods. Consuming EDNP foods may increase the risk of high energy intake, marginal micro-nutrient intake and low serum concentrations of vitamins [3]. Such unbalanced diets are modifiable risk factors for the development of obesity[4], non-alcoholic fatty liver disease[5], metabolic syndrome[6], bone health[7] and so on. Moreover, the Dietary Guidelines for Americans (DGA) since 2005 state that Americans should consume a variety of nutrient-dense foods and beverages within and among the basic food groups. Thus, more attention was paid to nutrient profiling (NP) models, which are intended to capture the nutrient density of food [8,9]. NP aims to rank foods based on their nutrient content as opposed to their energy content[10]. The Nutrient Rich Foods (NRF) Index is a crucial NP model, which takes a great quantity of beneficial nutrients and a great quantity of nutrients to limit into account. Each food is assigned a unique NRF score that reflects its total nutritional value per reference amount. Not limited to individual foods only, the NRF algorithm can be applied to food groups, meals, menus, and total diets[11]. A family of nutrient-rich foods (NRF) indices has been validated against the Healthy Eating Index (HEI)[12] and the Dutch Healthy Diet Index[13]. Diets with high NRF index score protect against central obesity[14], higher body mass index (BMI)[15] and was inversely associated with all-cause mortality[16]. The NRF index is a valid measure of diet quality in some countries.

China has achieved remarkable economic progress in recent years. Accompanied by these rapid economic changes, diet is undergoing an alarming transition: more fat and meat are consumed; EDNP foods intakes are increasing [17]. The validity of the NRF index has not yet been established in Chinese adults. Also, Drewnowski [11] proposed that the chosen models must be validated against independent measures of a healthy diet and, ideally, against health outcomes. Based on the reasons above, the objective of this study was to test several NRF indices scores for measures of a healthy diet among Chinese Mid-Eastern adults, based on Chinese Dietary Reference Intakes (DRIs)[18] and using mean adequacy ratio (MAR), an overall measure of the nutrient adequacy[19]. Percent of variation in MAR explained (adjusted R^2) was the key criterion of index performance. The indices that best predicted variation in MAR were then further characterized by calculating scores on a food group basis. We also aimed to explore the relationship between the NRF index and obesity indicators using obesity as an entry point to provide a reasonable and healthy diet for the prevention of NCDs, thereby reducing the incidence of NCDs caused by dietary factors.

2. Subjects And Methods

2.1 Study design and population

Participants for this analysis were from the cross-sectional study, which aimed to collect information on the diet, life style, and anthropometry of adults (aged 25-75 years) in 3 study sites (2 physical examination centers and 1 community) in Henan province of China since 2020. In total, 912 individuals were invited, of which 785 agreed to participate. Individuals with incomplete data (missing data on 24-h dietary recalls (n=26), on anthropometry (n=28), on covariate (n=28)) and implausible energy intake (n=47)[20] were excluded. Written informed consent was obtained from all subjects.

2.2 Dietary and covariant assessment

Data were collected by a general questionnaire and through two non-consecutive 24-h dietary recalls. To help the respondents answer accurately, 24-h dietary recalls were investigated face to face with the aid of food models. The average daily intakes of various foods and nutrients were analyzed by nutrition calculator (NCCW software), which was calculated based on the China Food Composition Tables [21]. Weight, height, waist circumference (WC) and hip circumference (HC) were measured by experienced investigators. The general questionnaire assessed age, gender, educational attainment, occupational status, smoking status, grip, family number, snap, sedentary time, physical activity, and so on.

2.3 Nutrient-rich food index scores evaluated

NRF index scores were based upon several nutrient profile models previously investigated by Drewnowski et al.[22]. The number of beneficial nutrients has ranged from 5 to 20 whereas the number of unhealthy nutrients has ranged from zero to 4. Considering the limitation of the Chinese food composition table[18], this study only included 11 encourage nutrients (protein, dietary fibre, vitamin A, C, E, B_{12}, Ca, Fe, Mg, K, Zn) and 2 limited nutrients (saturated fat, Na). Thus, only NRF6.2, NRF9.2 and NRF 11.2 indice were adopted in this study.

Three different bases of calculation were used in the NRF model: 100 g, 100 kcal, and serving size[11]. The concept of serving size is rarely used in the unit of measurement of food in China. Thus, NRF index scores in this study were calculated per 100 g, per 100 kcal of food. The daily reference intakes of nutrients were based on the recommended nutrient intake (RNI) or adequate intake (AI) of adults except for saturated fat, which was based on acceptable macro-nutrient distribution ranges (Table 1) [18]. The algorithms used to calculate the NRF index scores evaluated are listed in Table 2[23].

2.4 Assessment of nutrient adequacy

Nutrient adequacy was measured by computing MAR. To compute MAR first nutrient adequacy ratio (NAR) was calculated for the selected 10 nutrients as given in Table 3. NAR was calculated based on DRIs. MAR was calculated as described by Madden et al[19].

$$\mathrm{NAR} = \frac{\text{Actual nutrient intake of a nutrient (per day)}}{\text{Chinese daily reference intakes of the nutrient}}$$

$$\mathrm{MAR} = \frac{\sum \text{NAR(each truncated at 1)}}{\text{Number of nutrients}}$$

2.5 Assessment of basic characteristics

Anthropometric measurements were performed by trained investigators using standardized procedures. Body weight (nearest 0.1 kg) and height (nearest 0.1 cm) were measured in duplicate by using an ultrasonic weight and height instrument while the participants were barefoot and wearing light clothes only. BMI was calculated in the standard way: weight (kg) divided by square of height (m), which was classified as underweight (<18.5kg/m ^{2}), normal weight (≥18.5 and <23.9 kg/m ^{2}), overweight (≥24 and <27.9 kg/m ^{2}) and obese (≥28 kg/m ^{2}) according to the Working Group on Obesity in China (WGOC)[24].

Waist and hip circumferences were measured to the nearest 0.1 cm using a flexible metric measuring tape with the individual in a standing position. WC was measured around the abdomen at the level of the umbilicus. The hip circumference is the maximum circumference of the hip. Central obesity was defined by WC and Waist-to-hip ratio (WHR). The cut-off point of WC was recommended by WGOC: 85 cm for males and 80 cm for females [24]. WHR was calculated as WC (cm) divided by HC (cm). There is no standard for judging the cut-off point of WHR in China. Central obesity was defined according to the WHO recommendation: WHR ≥ 0.90 for males, and WHR ≥ 0.85 for females[25].

Physical activity was collected through the Chinese version of the international physical activity questionnaire (IPAQ)[26], which appeared to have acceptable reliability and validity. The moderate-vigorous physical activity (MET-h/d, MET, metabolic equivalent of task) was calculated for each individual according to Chinese Guidelines for Chinese Residents [27].

2.6 Quality control

Quality control was carried out from questionnaire design to data analysis: Firstly, the questionnaire used in the investigation was revised after pilot study and expert discussion. Secondly, all investigators must undergo unified training before the interview. Last but not the least, all data were inputted by two persons, and logical error detection and review were carried out.

2.7 Statistical analysis

Data analysis was done by using SAS statistical software, version 9.3 (SAS Institute, Cary, NC, USA), for all data analyses. A *p*-value < 0.05 was considered statistically significant.

The distribution of variables was calculated and compared according to categories of NRF9.2 score based on the Kruskal-Wallis test for continuous variables. Multiple linear regression models were used to analyze the correlation between NRF index score and MAR. The NRF index was selected according to the adjusted R^2. Potential confounders that were considered include: age, gender, smoking (yes or not), life pressure (yes or not), grip strength (normal or not), sedentary time (h/day), family number. The NRF index score in quartiles (Q1-Q4) was taken as the independent variable and the dependent variable was overweight (including obesity) or central obesity. In the basic models (model 1), the correlation analyses between the NRF index score and overweight/central obesity were carried out first by crude odds ratios

(OR) with 95% confidence interval (CI); Model 2 was adjusted for age (continuous), gender and educational level (<6, 6~12, >12 years). Model 3 was further adjusted for personal monthly income (<2000, 2000~5000, >5000 RMB), moderate-vigorous activity (Low / relatively low / relatively high / high) and nap frequency (continuous).

3. Results

3.1 Validation. All NRF indices were positively correlated (P<0.001) with MAR (Figures 1 and 2), with adjusted R^2 ranging from 0.114 to 0.232 by adjusted for age, gender, BMI, smoking, life pressure, grip strength, sedentary time and family number. NRF9.2 index using the algorithm based on sums and 100 kcal had the highest R^2 (0.232).

3.2 General characteristics of the distribution of NRF9.2 index scores. Because the NRF9.2 index using the algorithm based on sums and 100 kcal had the best ability to predict MAR, we then scored all foods consumed by participants. The mean NRF9.2 Index score of the participants was 39.93 (32.44, 47.84). We explore the distribution of NRF9.2 Index score among gender, age, central obesity (defined by WC and WHR), overweight (defined by BMI), residence, personal monthly income, educational level, occupation, marriage and family number (Table 4). The diet quality of females (NRF9.2 Index score 41.37 (33.53, 50.73)) was higher than that of males (NRF9.2 Index score 38.83 (31.83, 46.25)). The diet quality of an individual with high education (NRF9.2 Index score 43.33 (36.30, 51.78)) was higher than that of a person with low education (NRF9.2 Index score 38.26 (32.37, 45.42)).

3.3 Means of food groups and selected nutrients across quartiles of the NRF 9.2 index score. Significant and positive correlations of the NRF9.2 Index score with the majority of food groups except for meat, poultry and fish (Table 5). We also found that the higher the NRF9.2 index score, the higher intake of advantage nutrients. However, the intake of selenium, zinc, phosphorous was not significantly associated with the NRF9.2 index score (Table 6).

3.4 The association between the NRF9.2 index scores and overweight, central obesity. The odds ratio (OR) for overweight (defined by BMI) in the 4th quartile (Q4) versus the 1st quartile (Q1) of the NRF9.2 index was 0.61 (95% CI=0.37, 0.98) after multiple adjustments. However, the NRF9.2 index score was not related to central obesity, whether it was defined based on WC or WHR(Table 7).

4. Discussion

The NRF index has been proposed to predict overall diet quality in Americans, Dutch and Japanese, while it has not yet been evaluated in Chinese. In this study in Mid-Eastern Chinese adults, we observed that the optimal NRF indices was the NRF9.2 index, which is composed of nine nutrients to encourage and two nutrients to limit, using the algorithm based on sums and 100 kcal. The NRF9.2 index score was found to be related not only to the foods/food groups, but also to other essential nutrients not incorporated into the NRF9.2 index, such as thiamine, riboflavin, nicotinic acid, phosphorus, and zinc. NRF9.2 index was inversely associated with overweight (BMI, WGOC), but not with central obesity after adjustment for potential confounders. These results revealed that the NRF9.2 index can be used as a validated tool to assess the overall diet quality among Mid-Eastern Chinese adults.

Choosing the best NRF index among multiple alternatives is a scientific challenge. Of the fifteen tested scores, the prediction of the MAR was highest for the NRF9.2, with an R^2 of 0.23. In the previous study, the NRF9.3 index based on 100 kcal best predicted the HEI-2005 with an R^2 of 0.45[12] and the DHD-index with an R^2 of 0.34[13]. Compared with the above researches, the proportion of explained variance of the NRF index scores against the MAR was somewhat lower, but not to a great extent. This might be caused by the different daily reference intakes of nutrients, different study populations, differences between MAR and the HEI, the DHD-index or different nutrients included in the NRF index. Considering the less readily available added sugars data and the relatively low consumption level of added sugar in China[28], the total sugar or added sugar is not incorporated into the NRF indices. In addition, this study confirmed previous studies[22] showing that increasing the number of nutrients above 10 in a nutrient profile model provided little or no additional benefit in predicting overall diet quality. This choice was mainly based on Americans, whereas other nutrients might be more important for certain specific health outcomes or the Chinese. Nevertheless, the prediction of the MAR did not differ to a great extent between the scores and NRF index performed best in the Chinese population as well as in the US and Dutch population, a nutrient profile model for specific nationality from other parts of China and for a special purpose is expected. Regarding reference bases, serving size was rarely used in the unit of measurement of food in China, which was not adopted in the present study. Algorithms per 100 kcal, best reflected the original concept of nutrient density of foods, had higher R^2 values than those based on 100 gram which make no allowances for the fact that different foods and beverages are consumed in very different amounts [11]. The preferred algorithms were those that were based on sums, rather than a mean or ratio between the positive and negative nutrients. Compared with algorithms based on mean or ratio, those based on sums appear to be simplest, more transparent and weigh all nutrients equally [29].

In this study, the participants with higher the NRF9.2 scores had lower intakes of cereals and snacks, while with higher intakes of vegetables, fruits, beans and eggs; In terms of nutrient, the higher NRF9.2 scores, the higher intakes of vitamin B_1, vitamin B_2 and vitamin PP, the lower intakes of energy, carbohydrate and fat. Therefore, the NRF9.2 index can be used as one of the effective tools to evaluate dietary quality from the point of view, as it is consistent with the key recommendations of dietary guidelines for Chinese residents [27]. Socioeconomic factors correlated with the NRF9.2 Index were identified. Female and an individual had a higher level of education had better diet quality, which is consistent with the existing dietary indices [30]. It possibly because they have increasing nutrition knowledge [31], which was an indicator of the ability to translate nutrition knowledge into better dietary practices.

At present, multiple efforts to explore the relationship of nutrient profile models and various measures of anthropometry are underway. It is, however, not yet clear whether the NRF index is helpful in weight management. A study on 2,696 adults from the United States and the United Kingdom[32] showed that the NRF index was negatively related to BMI, consistent with our findings. While a sample of 4969, aged >55 years was carried out in the Netherlands found that the NRF9.3 index score was positively associated with BMI[33], which possibly related to underreporting of food intake in the obese subject. In terms of central obesity, Streppel et al. found that the NRF9.3 index score was positively associated with WC and waist-to-height ratio[33]. The inconsistency in the relationship of NRF9.3 and obesity indicators may be related to the following factors: (1) The characteristics of the subjects are different, including race, age, gender and health status. (2) The cut-off of obesity was quite different. (3)The method of statistical analysis is different, as some studies just explore the crude correlation, while others adjusted the possible confounding factors. (4) Some nutrients included in the NRF9.2 index were slightly different, for example added sugar was adopted in the NRF9.2 index in Aljuraiban's study[32], while total sugar was adopted in Streppel'[33] and both were abandoned in this study. Thus, the association between the NRF9.2 and obesity is therefore complex.

The present study has its limitations. Firstly, our study has a cross-sectional design, which failed to determine the exact causality of NRF9.2 index and weight gain and should be interpreted cautiously. However, we plan to conduct a follow up study to explore the cause-effect relationship. Secondly, the finding is only applicable to the mid-east Chinese, as China has a vast territory and abundant resources, and there are great cultural differences among different ethnic groups. More research needs to be carried out in different regions and ethnic groups. However, we plan to conduct multi center research to Increase the representativeness of the sample. The other limitation of this research is that it does not take into account the other beneficial nutrients or other non- nutrient substances like phytochemicals, which may be essential for the Chinese. Finally, the sample used in our analysis is not as large as that used in other cross-sectional studies. However, our analysis excluded any energy under-reporters and was carefully adjusted with potential confounders.

5. Conclusion

To our knowledge, we are the first who studied the validation of the NRF index in Chinese Mid-Eastern adults. Our findings demonstrated that the NRF9.2 index, using the algorithm based on sums and 100 kcal, was the best predicted model, with highly associated with MAR. NRF9.2 index scores were associated with BMI. These results revealed that the NRF9.2 index can be used as a validated tool to assess the overall diet quality among Chinese adults. Modifying food-selected behavior through consuming a nutrient-dense diet may be an important approach to control epidemic obesity.

Declarations

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Author contributions

All authors had full access to all of the data and take responsibility for the integrity of the data and the accuracy of the data analysis. Baihui Ma, Lijun Guo, Yongxia Kong acquired the data. Junya Zhai, Baihui Ma and Rui Liang analyzed and interpreted the data. Junya Zhai, Baihui Ma drafted the manuscript, which was critically revised for important intellectual content by all authors. Quanjun LYU and Minghua Cong were responsible for the statistical analysis and revised the manuscript. Junya Zhai supervised the study and is a guarantor.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The Committee on Human Subjects at The first affiliated hospital of Zhengzhou University approved the study design (Protocol 2020–KY-066). All subjects have signed a consent form to participate of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Authorship

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Tables

Table 1 Chinese Dietary Reference Intakes based on age and gender for calculating NRF index

Nutrients	male			female		
	18-	50-	65-	18-	50-	65-
Energy(kcal)	2250	2100	2050	1800	1750	1700
Potein	65	65	65	55	55	55
Dietary fiber (g	25	25	25	25	25	25
Vitamin A (μgRE)	800	800	800	700	700	700
Vitamin C(mg)	100	100	100	100	100	100
Vitamin E(mg α-TE)	14	14	14	14	14	14
Calcium(mg)	800	1000	1000	800	1000	1000
Iron(mg)	9	9	9	15	9	9
Potassium(mg)	2000	2000	2000	2000	2000	2000
Magnesium(mg)	330	330	320	330	330	320
Zinc(mg)	12.5	12.5	12.5	7.5	7.5	7.5
Vitamin B_{12}(μg)	2.4	2.4	2.4	2.4	2.4	2.4
Saturated fat(g)	25	23.3	22.8	20	19.4	18.9
Sodium(mg)	1500	1400	1400	1500	1400	1400

Table 2 Algorithms for the NRF Index Score

Model	Algorithm	Reference Amount	Comment
NRn[1]			
NRn_100g	$\sum_{1-n}(Nutrient_i/NVR_i)\times 100$	100 g	$Nutrient_i$:content of nutrient i in 100-kcal edible portion NRV_i= $Nutrient_i$ based on Chinese Dietary Reference Intakes
NRn_100 kcal	(NRn_100 g/ED)×100	100kcal	ED:energy density (kcal/100 g)
LIM[2]			Include saturated fat and sodium
LIM_100 g	$\sum_{1-3}(\mathrm{L}_i/\mathrm{MNVR}_i)\times 100$	100g	L_i: content of limiting nutrient i in 100-kcal edible portion; $MNRV_i$:maximum xdaily values for nutrient i
LIM_100 kcal	(LIM_100 g/ED)×100	100kcal	ED: energy density (kcal/100 g)
NRFn.3			
NRFn.3_sum_100 g	NRn_100 g- LIM_100 g	100g	Difference between sums
NRFn.3_sum_100 kcal	NRn_100kcal- LIM_100 kcal	100kcal	
NRFn.3_mean_100 g	NRn/n_100g- LIM_100g	100 g	Difference between means
NRFn.3_mean_100 kcal	NRn/n_100kcal- LIM_100 kcal	100kcal	
NRFn.3_ratio	NRn/LIM	None	NRn_100 g/LIM_100 g= NRn_100kcal/LIM_100kcal

1 NRn=subscore based on avariable number n of beneficial nutrients

2 LIM=Limited nutrient score

Table 3 Chinese Dietary Reference Intakes based on age and gender for calculating MAR

Nutrients	male			female		
	18-	50-	65-	18-	50-	65-
Energy(kcal)	2250	2100	2050	1800	1750	1700
protein(g)	65	65	65	55	55	55
Vitamin A（μgRE）	800	800	800	700	700	700
Vitamin C（mg）	100	100	100	100	100	100
calcium（mg）	800	1000	1000	800	1000	1000
Iron（mg）	9	9	9	15	9	9
Phosphorous（mg）	2000	2000	2000	2000	2000	2000
Vitamin B1（mg）	1.4	1.4	1.4	1.2	1.2	1.2
Vitamin B2（mg）	1.4	1.4	1.4	1.2	1.2	1.2
Vitamin PP（mgNE）	15	14	14	12	12	11

Table 4 General characteristics of the distribution of NRF9.2 scores

Vairable	n	The score of NRF9.2 [1]	*P* value[2]
Total	656	39.93（32.44, 47.84）	—
Gender			
Male	396	38.83 (31.83, 46.25)	0.004
Female	260	41.37 (33.53, 50.72)	
Age			
<50	99	38.42 (29.85, 47.78)	0.350
50-65	407	39.91 (32.49, 48.10)	
>65	150	41.04 (34.19, 47.04)	
Central obesity(WC)			
Yes	290	39.88(32.60, 47.96)	0.6
No	366	40.04(31.71, 47.33)	
Central obesity(WHR)			
Yes	298	39.68(32.62, 47.92)	0.9
No	358	40.49 (31.62, 47.87)	
Overweight(BMI, WGOC）			0.7
Yes	285	39.90 (32.75, 48.16)	
No	371	40.30 (31.97, 48.16)	
Residation			0.067
Urban	559	40.43(32.58, 48.06)	
Village	97	37.32 (31.55, 44.03)	
Personal monthly income			0.199
< 2000 RMB	152	38.26 (32.37, 45.42)	
2000~5000 RMB	399	39.91 (31.74, 48.20)	
>5000 RMB	105	41.77 (33.62, 48.99)	
Educational level			<0.0001
<6 years	80	38.42 (37.76, 55.66)	
6~12 years	424	38.51 (31.38, 45.39)	
>12 years	152	43.33 (36.30, 51.78)	

Vairable	n	The score of NRF9.2 [1]	*P* value[2]
Occupation			0.13
Manual	98	37.43 (31.69, 45.33)	
Professional	82	41.61 (33.45, 49.58)	
Retired	332	40.23 (33.11, 48.09)	
Others	144	39.03 (30.92, 47.21)	
Marriage			0.84
Yes	601	39.94(32.46, 47.82)	
Others	55	39.16 (32.29, 49.53)	
Family number			0.27
≤4	422	39.16(31.97, 47.50)	
>4	234	41.00 (32.49, 48.13)	

1. Values are presented as median (25th percentile, 75th percentile).
2. The general characteristics of the distribution of NRF9.2 scores was tested by Kruskal-Wallis

Table 5 Means of food groups intake across quartiles of the NRF 9.2 index score [1]

Food group	NRF9.2 index score [2]				P[3]
	Q1	Q2	Q3	Q4	
n	143	144	144	144	
NRF9.2 index score	22.04 (26.43, 31.62)	36.62 (34.79, 38.09)	43.28 (41.72, 45.18)	54.69 (50.74, 59.57)	<0.0001
Grains	463.25(318.20, 619.13)	409.25(296.88, 520.00)	373.90(271.63, 490.60)	304.75(230.00, 416.35)	<0.0001
Vegetables	75.00(32.13, 129.80)	128.00(67.55, 204.93)	166.50(92.88, 249.75)	208.50(102.75, 298.90)	<0.0001
Fruits	0(0, 172.00)	3.5(0, 230.00)	115.00(0, 299.55)	250.55(101.85, 500.00)	<0.0001
Milk and milk products	0(0, 0)	0(0, 0)	0(0, 0)	0(0, 9.38)	0.006
Beans, nuts, and seeds	0(0, 5)	0(0, 12.63)	0(0, 28.00)	4.5(0, 29.70)	<0.0001
Meat, poulty and fish	23.60(0.00, 67.15)	25.00(0.00, 68.75)	25.00(0.00, 66.87)	28.50(0.00, 82.78)	0.29
egg	20(0, 60)	30(0, 60.00)	41(0, 66.00)	60(0, 70.23)	0.004
Snacks[4]	8.00(2.00, 66.00)	5.00(2.93, 11.90)	5.00(3.00, 9.00)	4.3(2.8, 8.18)	0.057

1. Values are presented as median (25th percentile, 75th percentile).
2. Q1, 1st quartile; Q2, 2nd quartile; Q3, 3rd quartile; Q4, 4th quartile.
3. The differences of food groups intake among quartiles of the NRF 9.2 index score were tested by Kruskal-Wallis test.
4. Snacks includes cookies, fast food, sugar preserved fruits and so on

Table 6 Means of nutrients intake across quartiles of the NRF 9.2 index score [4]

Energy and nutrients	NRF9.2 index score[1]				*P*[3]
	Q1	Q2	Q3	Q4	
n	164	164	164	164	
Energy（kcal）	1560 (1257, 2021)	1470 (1211, 1794)	1380(1144, 1811)	1384 (1143, 1662)	0.001
Fat（g）	39.25(28.68, 60.48)	35.15 (24.25, 50.55)	34.10 (23.92, 46.14)	36.00 (25.58, 44.90)	0.008
Carbohydrate（g）	240.39 (193.38, 305.66)	245.67 (195.97, 286.11)	230.91 (175.54, 287.14)	215.52 (170.47, 265.60)	0.002
Vitamin B1（mg）	0.63(0.45, 0.88)	0.75 (0.51, 0.97)	0.75 (0.57, 0.96)	0.77 (0.56, 0.97)	0.018
Vitamin B2（mg）	0.56 (0.41, 0.74)	0.58 (0.46, 0.75)	0.64(0.47, 0.83)	0.72 (0.54, 0.91)	<0.0001
Vitamin PP（mg）	8.46 (5.49, 12.12)	8.96(6.10, 12.51)	8.42(6.17, 11.88)	9.73 (7.14, 13.20)	0.04
Phosphorous（mg）	702.55 (556.48, 891.28)	728.29 (606.54, 937.15)	764.80 (623.57, 955.27)	791.61 (612.51, 958.30)	0.06
Zinc（mg）	6.76 (5.36, 8.46)	7.26(5.89,8.94)	7.06(5.74, 9.11)	7.69 (6.07, 9.51)	0.095
Selenium（mg）	34.88 (25.03, 49.95)	38.48(28.33,50.81)	38.96(27.30, 51.46)	35.24 (26.10, 50.43)	0.6
MAR	0.53 (0.44, 0.63)	57.76 (48.45, 66.17)	61.90 (52.11, 69.77)	67.25 (57.40, 77.03)	<0.0001

1. Values are presented as median (25th percentile, 75th percentile).
2. Q1, 1st quartile; Q2, 2nd quartile; Q3, 3rd quartile; Q4, 4th quartile.
3. The differences of food groups intake among quartiles of the NRF 9.2 index score were tested by Kruskal-Wallis test.
4. Table 9 listed the nutrients incorporated into the NRF9.2 index.

Table 7 The association between the NRF9.2 index scores and obesity indicators

		NRF9.2 index score [1]			
		Q1	Q2	Q3	Q4
Overweight（BMI, WGOC）	Model 1[2]	1.00	0.85 (0.54, 1.33)	1.12 (0.72, 1.74)	0.85 (0.54, 1.33)
	Model 2[3]	1.00	0.87 (0.55, 1.37)	1.04 (0.66, 1.65)	0.73 (0.46, 1.17)
	Model 3[4]	1.00	0.76(0.47,1.22)	0.92 (0.57,1.48)	0.61(0.37,0.98)
Central obesity（WC）[2]	Model 1[2]	1.00	0.85 (0.52, 1.40)	1.01 (0.62, 1.65)	0.85(0.52, 1.65)
	Model 2[3]	1.00	0.85 (0.52, 1.40)	0.97 (0.59, 1.59)	0.83 (0.50, 1.37)
	Model 3[4]	1.00	0.72 (0.43, 1.22)	0.94 (0.56, 1.57)	0.78(0.46, 1.33)
Central obesity（WHR）[2]	Model 1[2]	1.00	0.72 (0.41, 1.26)	1.05 (0.62, 1.79)	0.93 (0.54, 1.59)
	Model 2[3]	1.00	0.70 (0.39, 1.25)	1.03 (0.59, 1.79)	0.93 (0.54, 1.59)
	Model 3[4]	1.00	0.60 (0.32, 1.08)	0.93 (0.52, 1.65)	0.97 (0.54, 1.74)

1. Values are presented as OR(95% confidence interval).
2. Crude model
3. Model 2 was adjusted for age (continuous), gender and educational level (<6, 6~12, >12 years) were adjusted.
4. Model 3 was further adjusted for personal monthly income (<2000, 2000~5000, >5000 RMB), moderate-vigorous activity (Low / relatively low / high / high) and nap frequency (continuous).

Figures

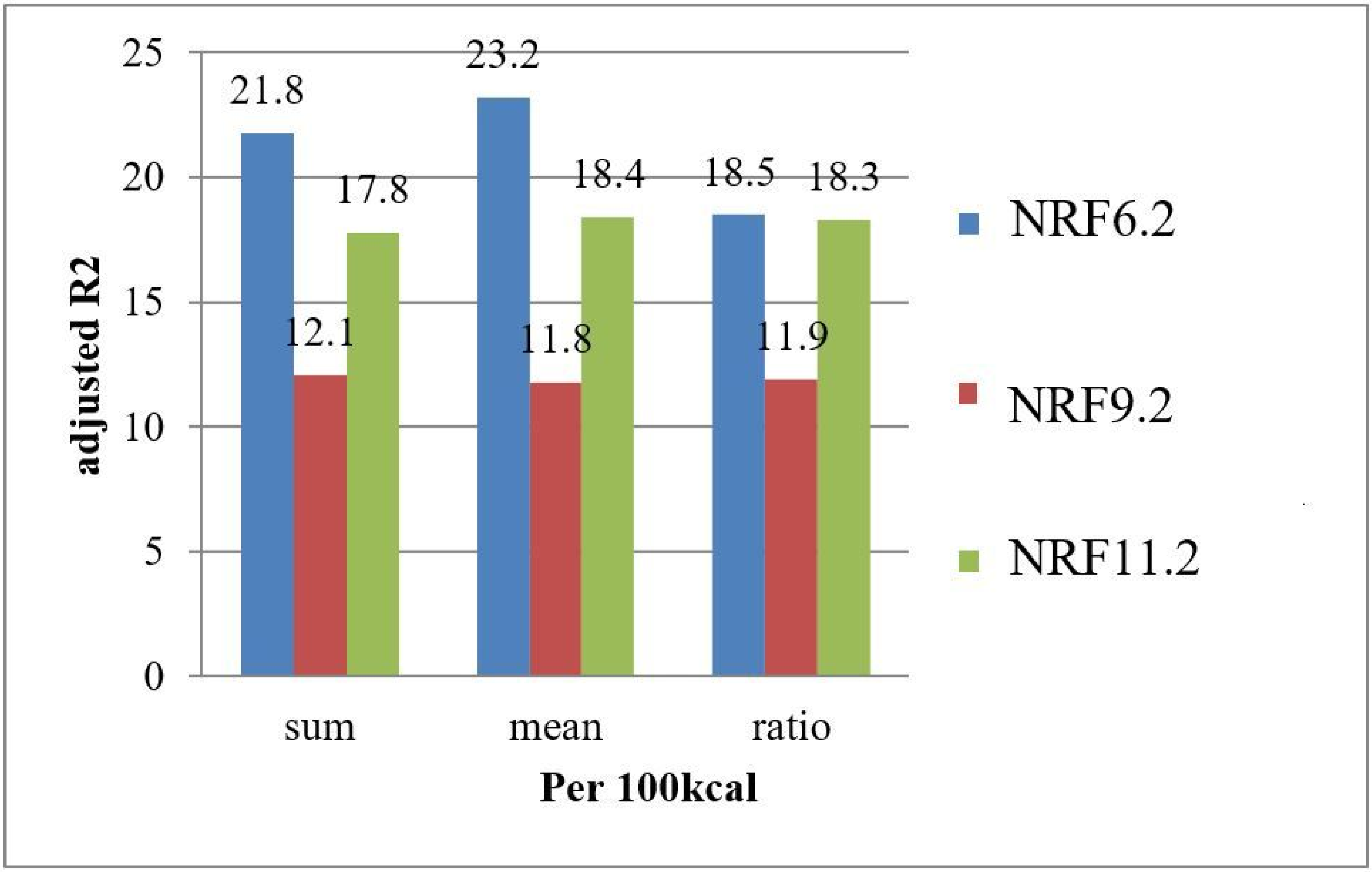

Figure 1

R2 comparison of NRFn.2 algorithms calculated per 100 kcal from regression models predicting MAR adjusted for age, gender, BMI, smoking, life pressure, grip strength, sedentary time and family number (P� 0.0001). NRF6.2 refers the 6 encourage nutrients (protein, dietary fibre, vitamin A, C, Ca, Fe,) and 2 limit nutrients (saturated fat, Na). NRF9.2 is NRF6.2 plus vitamin E, magnesium, and potassium; NRF11.2 is NRF9.2 plus vitamin B-12 and zinc.

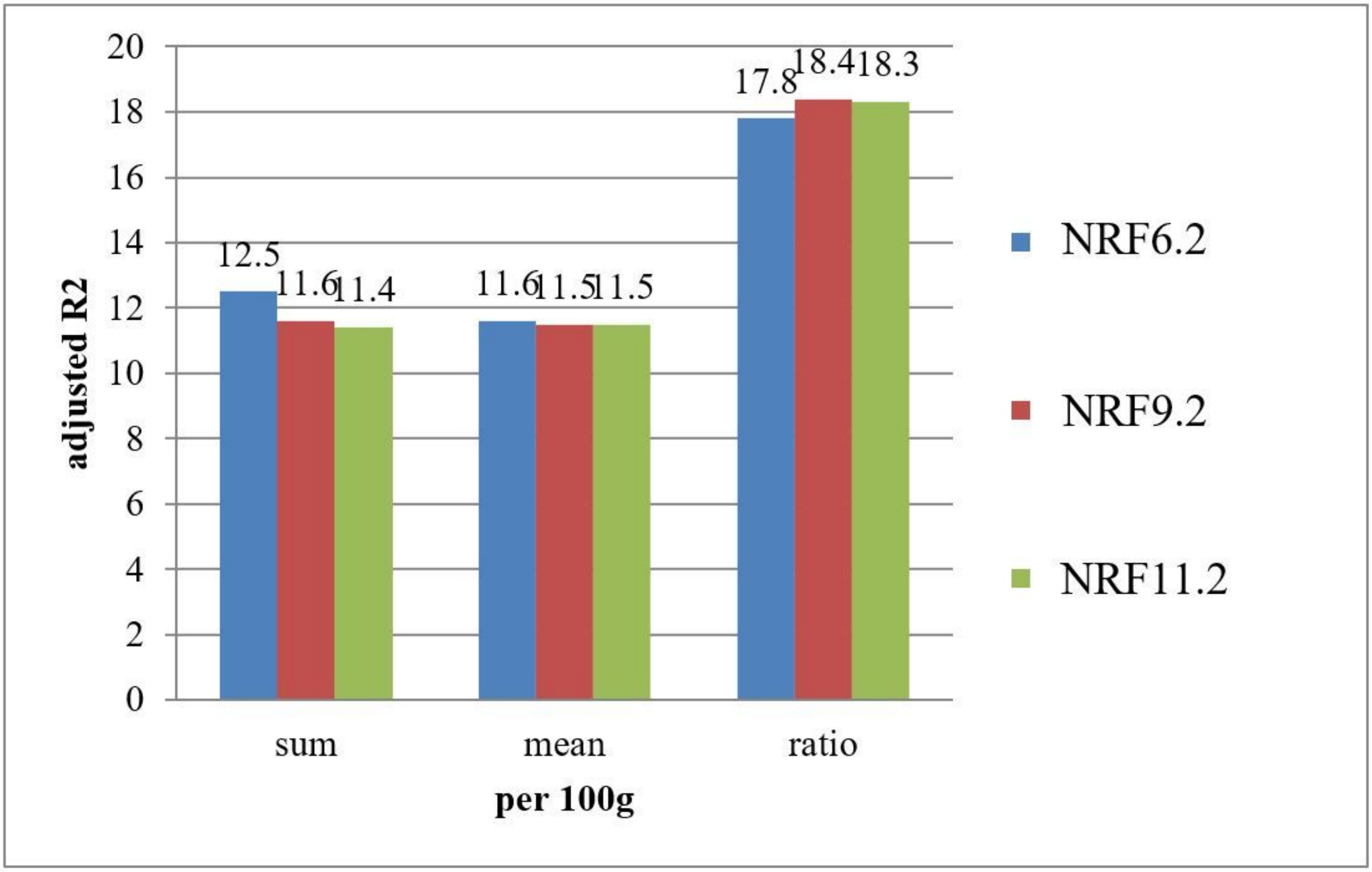

Figure 2

R2 comparison of NRFn.2 algorithms calculated per 100 gram from regression models predicting MAR adjusted for age, gender, BMI, smoking, life pressure, grip strength, sedentary time and family number (P 0.0001). NRF6.2 refers the 6 encourage nutrients (protein, dietary fibre, vitamin A, C, Ca, Fe,) and 2 limit nutrients (saturated fat, Na). NRF9.2 is NRF6.2 plus vitamin E, magnesium, and potassium; NRF11.2 is NRF9.2 plus vitamin B12 and zinc.