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The diet quality index evaluates the adequacy of energy provided by dietary macronutrients

Índice de qualidade da dieta e adequação de energia fornecida por macronutrientes

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ABSTRACT

Objective

To investigate the relationship between macronutrient intake adequacy and the national diet quality index score.

Methods

The study analyzed a representative sample of 1,662 individuals from the municipality of *São Paulo* who participated in a cross-sectional study called Health Survey-*Capital* (2008/2009). Two 24-hour recalls were collected. Habitual intake was determined by the Multiple Source Method. The Brazilian index was calculated as suggested, and macronutrient adequacy was given by the World Health Organization and Food and Agriculture Organization recommendations. A generalized linear model verified the relationship between the Brazilian index and macronutrient adequacy. All analyses with a descriptive level below 0.05 were considered significant. The analyses were performed by the software Stata 12.0, survey mode.

Results

The vast majority (91%) of the population had inappropriate macronutrient intakes, and the total median Brazilian index score was 61.3 points (interquartile range=10.1). The total Brazilian index score of individuals

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with high lipid intake was worse than that of individuals with proper lipid intake (β=0,96; *p*=0,004), while those with high protein intake had a better score (β=1,10; *p*=0,003) than those with proper protein intake.

Conclusion

The revised Brazilian Healthy Eating Index assesses diet quality properly regarding high lipid intake, but it has some limitations regarding high protein intake according to the World Health Organization and Food and Agriculture Organization recommendations. New studies should investigate the possibility of adapting this index to the World Health Organization and Food and Agriculture Organization recommendations.

Keywords: Diet. Diet surveys. Macronutrients. Recommended dietary allowances.

RESUMO

Objetivo

Averiguar a relação entre adequação do consumo de macronutrientes e pontuação do índice nacional de qualidade da dieta.

Métodos

Foram analisados 1 662 indivíduos de uma amostra representativa dos residentes do município de São Paulo, pertencentes ao estudo transversal denominado Inquérito de Saúde em São Paulo (2008/2009). Foram coletados dois recordatórios de 24 horas. A ingestão habitual foi determinada pelo Multiple Source Method*. O índice foi calculado e a adequação dos macronutrientes baseou-se nas recomendações da* World Health Organization e Food and Agriculture Organization*. A relação entre índice e adequação dos macronutrientes foi verificada por meio do modelo linear generalizado. Para todas as análises, considerou-se significativo nível descritivo inferior a 0,05. As análises foram feitas no programa Stata 12.0, modo* survey*.*

Resultados

*Observou-se que 91% da população consumiram quantidades inadequadas dos macronutrientes, sendo a pontuação mediana total do índice de 61,3 pontos (*interquatile range*=10,1). A pontuação total do índice de indivíduos com consumo excessivo de lipídios apresentou-se pior em relação aos de ingestão adequada (β=0,96; p=0,004), enquanto a pontuação daqueles com consumo excessivo de proteínas apresentou-se melhor (β=1,10; p=0,003) aos de ingestão adequada desse macronutriente.*

Conclusão

O Índice de Qualidade da Dieta Revisado avalia qualidade da dieta adequadamente em relação à ingestão excessiva de lipídios e com algumas limitações em relação à de proteínas, de acordo com as recomendações da World Health Organization e Food and Agriculture Organization*. Sugerem-se novos estudos que investiguem possibilidades de adaptação desse índice às recomendações da* World Health Organization e Food and Agriculture Organization.

Palavras-chave: *Dieta. Inquéritos sobre dietas. Macronutrientes. Recomendações nutricionais.*

INTRODUCTION

Diet complexity led to the proposal of many food intake assessment methods, such as dietary indexes, which have been extensively used in the literature because of their ability to measure, in a summarized way, the main characteristics of a healthy diet, and to incorporate in the analyses the correlation between foods and nutrients[1,2]. Some of the many indexes available today are the Health Eating Index[3], Mediterranean Diet Score[4], Dietary Approaches to Stop Hypertension score[5], and in Brazil, the revised Brazilian Healthy Eating Index (BHEI), which is a version of the Healthy Eating Index (HEI-2005)[2] adapted for the Brazilian population.

In this context, the BHEI assesses the intake of many food groups, nutrients, and combinations thereof in relation to the current dietary recommendations. The BHEI assesses diet adequacy both qualitatively and quantitatively

regarding food groups, and can simultaneously assess and monitor diets at the individual and population levels[2]. Therefore, there is a gap in the literature regarding the ability of this dietary index to assess macronutrient intake adequacy.

However, the score of BHEI is based only on food group adequacy and does not directly include macronutrient intake adequacy. According to the World Health Organization (WHO) and Food and Agriculture Organization (FAO)[6], a healthy diet should get 55 to 75% of its energy from carbohydrates, 10 to 15% from proteins, and 15 to 30% from lipids.

We do not have knowledge about other studies in the literature that analyzed the ability of the BHEI to assess macronutrient intake adequacy. Hence, the present study aims to investigate the relationship between macronutrient intake adequacy and the BHEI in a representative sample of individuals from the municipality of *São Paulo* (SP).

METHODS

The study used data from a population-based cross-sectional study conducted by census sectors called *Inquérito de Saúde em São Paulo* (ISA-*Capital*, Health Survey for *São Paulo*). Trained interviewers conducted the interviews and administered the questionnaires at the participants' homes in 2008/2009[7].

The sample consisted of 560 adolescents, 585 adults, and 517 older adults, totaling 1,662 individuals. The age groups were defined as follows: adolescents aged 10 to 19 years; adults aged 20 to 59 years; and older adults aged 60 years or more[8]. Activity was assessed by a questionnaire validated in Brazil by Matsudo *et al*.[9], and level of physical activity was classified as suggested by Craig *et al*.[10]. Food intake was determined by two 24-Hour Dietary Recalls (24HR) as instructed by the manual published by Fisberg & Marchioni[7]. The software Nutrition Data System for Research analyzed nutritional value; the foods listed in this software and the conversion of cooking units into grams and milliliters are based on Brazilian publications[11,12].

The online platform Multiple Source Method estimated the habitual food and nutrient intakes[13], and the estimates were used for calculating the BHEI and BHEI component scores according to the score scale methodology proposed by Previdelli *et al*.[2]. The BHEI has twelve components: nine food groups ("total fruits", "whole fruits", "total vegetables", "dark green/orange vegetables and legumes", "total grains", "whole grains", "milk and dairy products", "meats, eggs, and legumes", and "oils"); two nutrients ("sodium" and "saturated fats"); and the last component is energy coming from Solid Fats, Added Sugar, and Alcohol (SoFAA)[1]. The maximum scores vary: five for the first six components, 10 for the next five components, and 20 for the last component. For most components, the intermediate scores are given by the proportional value of the extreme scores of each component, except for the components "sodium" and "saturated fats", whose scores have two cut-off points. The scores of these two components are calculated proportionally, considering the score intervals zero to eight and eight to ten. More details can be found elsewhere[1]. Macronutrient adequacy was based on the WHO & FAO[6] recommendations.

Descriptive data analysis used central tendency and dispersion measures. The censlope command verified the difference between the median BHEI and BHEI component scores of individuals with appropriate and inappropriate macronutrient intakes, which determines the confidence intervals between the medians[14].

Gaussian Generalized Linear Models with a logarithmic link function were constructed to measure the association between BHEI and BHEI component scores and macronutrient intake adequacy. The dependent variable was the BHEI and BHEI component scores and the independent variables were: protein, carbohydrate, and lipid intake adequacies (below the recommended

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range, within the recommended range, and above the recommended range) and age (years). The adjustment variables were sex (male and female); habitual total calorie intake/day; and education level of the household head (years). Household head was self-reported. All analyses were performed by the software Stata version 12.0 in survey mode. Modeling with the total BHEI score followed the forward stepwise procedure, selecting the most parsimonious model with the best adjustment according to assessment graphs.

The study was approved by the Research Ethics Committee of the School of Public Health of the *Universidade de São Paulo* under Protocol nº OF.COEP/050/13, nº 2001, and all participants signed an Informed Consent Form.

RESULTS

Approximately 47% of the sample was male and 53% was female. The lowest age was 12 years and the highest, 97 years. The mean education level of the household head was 8.5 years (Standard Error - SE=0.20), and the mean habitual total calorie intake was 1881.90 kcal/day (SE=25.36).

Based on the percentage distribution of energy provided by macronutrients established by the WHO & FAO[6], 91.0% of the residents of *São Paulo* city did not consume appropriate amounts of carbohydrates, lipids, and proteins. Of these, 99.5% had inadequate carbohydrate intake, with a mean intake of 35.0% (95.0% Confidence Interval - 95.0%CI=34.5-35.6) of the total energy intake. Most participants had protein and lipid intakes above the recommended range; 93.1% consumed on average 41.8% (95.0%CI=41.3-42.2) of their total calorie intake from lipids, and 97.8%, consumed on average 22.0% (95.0%CI=21.8-22.3) of their total calorie intake from proteins. Nobody in the sample had carbohydrate intake above the recommended range (Table 1).

The median general BHEI score was 61.3 points (Interquartile Range [IQR]=10.1). The score of this index indicates that diets with protein content above the recommended range and diets with lipid content within the recommended range are healthier. The BHEI did not differentiate the diet quality of individuals with macronutrient intake percentages below and within the recommended ranges, even though some BHEI components had statistically different scores for these two classifications. Diets with protein content above the recommended range contained more "meats, eggs, and legumes" and "sodium" than diets with normal protein levels. Diets with lipid content above the recommended range contained more saturated fats and less total fruits than diets with normal lipid levels (Table 2).

The relationship between the BHEI score and protein, lipid, and carbohydrate intake adequacy shows that when the mean habitual lipid intake is above the recommended range, the mean BHEI score is significantly lower (β=0.96; *p*=0.001) than when lipid intake is within the recommended range (Table 3). In other words,

Table 1. Percentage of individuals from the municipality of *São Paulo* with macronutrient intakes below, within, and above the recommended ranges as a percentage of the daily calorie intake according to the World Health Organization and Food and Agriculture Organization (WHO & FAO) recommendations. *São Paulo* (SP), Brazil, 2015.

Macronutrients	Intake adequacy					
	Below		Within		Above	
	Mean*	SE*	Mean	SE	Mean	SE
Carbohydrates	99.5	0.20	0.5	0.2[a]	-	-
Proteins	0.1	0.08	2.1	0.5[b]	97.8	0.5
Lipids	0.1	0.05	6.8	0.9[c]	93.1	0.9

Nota: *Mean percentage (%) of individuals in the population and Standard Error (SE); [a]Amount recommended by the WHO & FAO[6] is 55 to 75% kcal/day; [b]Amount recommended by the WHO & FAO[6] is 10 to 15% kcal/day; [c]Amount recommended by the WHO & FAO[6] is 15 to 30% kcal/day.

Table 2. Median score and interquartile interval of the Brazilian Healthy Eating Index (BHEI) and each of its components according to macronutrient classification as appropriate/inappropriate. *São Paulo* (SP), Brazil, 2015.

IQDR and components	Macronutrients									
	Total amount	Carbohydrates			Proteins			Lipids		
		Below*	Within*	Above*	Below	Within	Above	Below	Within	Above
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Total BHEI	61.3 (10.1)	61.3 (10.1)	65.0 (5.5)	-	36.9 (27.6)	54.8 (12.4)#	61.4 (10.1)#	63.4 (23.8)	65.9 (10.3)†	61.1 (9.9)†
Total fruits	2.7 (3.3)	2.7 (3.3)#	5.0 (2.6)#	-	1.6 (3.4)	1.9 (1.2)	2.7 (3.3)	5.0 (2.9)	4.1 (3.2)#	3.3 (3.3)#
Whole fruits	3.3 (3.3)	3.3 (3.3)	5.0 (2.0)	-	1.9 (3.2)	2.0 (3.3)	3.3 (3.3)	5.0 (3.2)	3.6 (3.4)	3.3 (0.1)
Total vegetables	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	-	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	5.0 (1.1)	5.0 (0.0)	5.0 (0.0)
Dark green/orange vegetables and legumes[1]	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	-	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)
Total grains	5.0 (0.0)	5.0 (0.0)	5.0 (0.9)	-	4.2 (0.6)†	5.0 (0.9)†	5.0 (0.0)	2.6 (2.7)	5.0 (0.2)	5.0 (0.0)
Whole grains	0.2 (0.3)	0.2 (0.3)	0.2 (1.2)	-	0.2 (2.5)	0.3 (0.2)	0.2 (0.3)	0.1 (0.3)	0.2 (0.3)	0.2 (0.3)
Milk and dairy products	5.1 (3.7)	5.1 (3.7)#	2.7 (3.6)#	-	4.9 (3.5)	5.0 (6.4)	5.1 (3.7)	1.9 (5.1)	4.8 (5.0)	5.1 (3.7)
Meats, eggs, and legumes	9.2 (1.5)	9.2 (1.5)	5.5 (6.3)	-	3.2 (0.9)†	6.1 (3.6)†	9.2 (1.4)†	4.8 (7.0)	9.2 (2.0)	9.2 (1.4)
Saturated fats	7.8 (3.0)	7.7 (3.0)†	10.0 (0.4)†	-	0 (8.8)	8.2 (4.9)	7.7 (3.0)	10.0 (0.0)†	9.5 (1.3)†	7.5 (3.1)†
SoFAA[2]	7.9 (6.9)	7.9 (6.8)	14.1 (9.2)	-	0 (5.8)	5.2 (9.8)	7.9 (6.8)	0 (18.6)	9.6 (9.8)	7.8 (6.7)
Oils	10.0 (0.0)	10 (0.0)	10 (0.0)	-	5.5 (4.5)	10 (0.0)	10 (0.0)	10 (0.0)#	10 (0.0)#	10 (0.0)
Sodium	1.6 (2.7)	1.6 (2.7)	2.4 (3.5)	-	5.5 (4.5)†	3.9 (3.3)†	1.5 (2.6)†	9.6 (7.0)†	1.5 (3.6)†	1.6 (0.8)

Note: [1]Dark green/orange vegetables and legumes; [2]Energy from solid fats, added sugar, and alcohol; *Below the recommended range; within the recommended range and above the recommended range; #Significant difference between BHEI score or each of its components between the groups named "below the recommended range", "within the recommended range", and "above the recommended range" for each study macronutrient (carbohydrates, proteins, and lipids) (<0.05); †Significant difference between BHEI score or each of its components between the groups named "below the recommended range", "within the recommended range", and "above the recommended range" for each study macronutrient (carbohydrates, proteins, and lipids) (<0.001).

IQR: Interquartile Range; IQDR: *Índice de Qualidade da Dieta Revisado*; SoFAA: Energy from Solid Fats, Added Sugar, and Alcohol.

individuals with lipid intake above the recommended range have, on average, a total score four percent lower than individuals with lipid intake within the recommended range. However, this is not valid for protein intake since the mean BHEI score of individuals with protein intake above the recommended range is significantly higher β=1.10; p=0.005) than that of individuals with protein intake within the recommended range. The values for carbohydrates were not significant.

These relationships occur regardless of sex, age group, education level of the household head, level of physical activity, and total habitual calorie intake. Diet quality also increases age (adults: β=1.04; p<0.001; older adults: β=1.11; p<0.001 in relation to adolescents) and gender, being higher in females (β=1.02; p=0.038) (Table 3). The variables education level of the household head and level of physical activity were not significantly related to the BHEI score.

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Table 3. Gaussian regression analysis with logarithmic, univariate, and multiple functions: beta and significance level between BHEI and socioeconomic and nutritional variables. *São Paulo* (SP), Brazil, 2015.

Independent variable	Categories	Coefficients and significance			
		β†	*p*†§	β‡	*p*‡§
Carbohydrate adequacy (%)	Below the RR	0.95	0.195	1.01	0.787
	Within the RR	-	-	-	-
	Above the RR	-	-	-	-
Protein adequacy (%)	Below the RR	0.84	0.337	0.84	0.392
	Within the RR	-	-	-	-
	Above the RR	1.10	0.005	1.10	0.005
Lipid adequacy (%)	Below the RR	0.98	0.839	1.04	0.686
	Within the RR	-	-	-	-
	Above the RR	0.94	<0.001	0.96	0.001
Education level of the household head (years)		0.99	0.016	0.99	0.592
Sex	Male	-	-	-	-
	Female	1.03	0.002	1.02	0.038
Age group	Adolescents	-	-	-	-
	Adults	1.05	<0.001	1.04	<0.001
	Older adults	1.13	<0.001	1.11	<0.001
Physical activity	Inadequate	-	-	-	-
	Active	0.99	0.301	1.002	0.873
Habitual calorie intake (kcal)		0.99	<0.001	0.99	0.022

Note: †Gaussian regression with univariate link log and; ‡Gaussian regression with multiple link log; βRegression coefficient; §*p*-value.
RR: Recommended Range.

DISCUSSION

The Brazilian Healthy Eating Index score classified diets with protein content above the recommended range as of better quality than those with protein content within the recommended range, and it properly assessed diets with lipid content above the recommended range, showing that these diets are worse than those with lipid content within the recommended range. Additionally, the BHEI score did not differentiate the quality of diets with protein, lipid, and carbohydrate contents below the recommended range from that of diets with macronutrient contents within the recommended ranges according to the FAO & WHO[6].

The mean Brazilian Healthy Eating Index score (61.3 points) found for the present sample was similar to that reported by Fisberg *et al.*[15], who assessed the diet quality of 3,454 individuals from the municipality of *São Paulo* and reported a mean score of 60.4 points. A higher mean score (63.7 points) was found by the Third National Health and Nutrition Examination Survey III, a study with a representative sample of the American population that used the Healthy Eating Index (HEI) to assess diet quality[16]. Navarro & Moncada[17] used a diet quality index based on HEI called *Índice de Alimentación Saludable para la población Española* and found even higher mean scores than the present score, 69.95 for men and 73.73 for women. Despite the fluctuations of the mean scores, the values are close, suggesting agreement between the adapted indexes.

One of the factors that contributes to the limited BHEI assessment of protein intake within the recommended range is the absence of negative scores for high intake of high-protein foods (like HEI-2005), such as the excessive meat intake seen in *São Paulo* and many other Brazilian municipalities[18,19]. The high intake of red meat by the population of *São Paulo* results mainly in high intake of saturated fat, and this type of fat is an important factor in the development of

cardiovascular diseases and other diseases[20]. The high intake of meats, especially processed meats, may also contribute to the high intake of sodium (low score) by people with high protein intake. This scenario may be aggravated by high intake of processed products, addition of too much salt, and use of high-sodium condiments[18, 21].

The ability of the index to capture the difference between the diet quality of individuals with lipid intake above and within the recommended ranges can be favored by the presence of moderators, such as "saturated fats" in the structure of the calculation. Furthermore, the index was capable of differentiating between the "total fruit" intake of individuals with lipid intake above the recommended range and those with lipid intake within the recommended range, even though less than 10% of the Brazilian population consumes the recommended levels of fruits, vegetables, and legumes, foods that have a protective role against chronic diseases[19,22].

Another aspect demonstrated in this study was the higher ability of the BHEI of differentiating diet quality by gender, showing that females adhere more to healthy food recommendations, corroborating Andrade *et al.*[23], who published similar findings and claimed that this specific ability is an aspect of this index that reinforces its reliability and validity. The individual's age or age group could also reflect better food choices with rising age[1], and in fact this study found that adults and older adults have healthier diets than adolescents. Other characteristics, such as education level of the household head and level of physical activity, are not significantly related to BHEI score, but are considered important variables in diet quality variability. Therefore, they are essential for the proposed analyses[1].

Some limitations of the study are the homogeneous distribution of the participants regarding the macronutrient intake adequacy in the population, with most people being classified as having inappropriate adequacy. Regardless, the relationships between the BHEI scores and macronutrient intake adequacy differed significantly. Another limitation was the use of only two 24-HR recalls, which is not enough to capture daily food intake variations. However, this study calculated the habitual food intake to remove this intrapersonal variability, hence getting closer to an individual's actual food intake[13,24].

CONCLUSION

The study results evidence that the diets of individuals from the municipality of *São Paulo* have a high inadequacy index regarding the percentage macronutrient distribution and show that this inadequacy can be partially detected by the BHEI. Therefore, the BHEI correctly assesses the diet quality of diets with lipid content above the recommended range and assesses with some limitations the diet quality of diets with protein content above the recommended range according to the WHO and FAO recommendations. BHEI does not differentiate diets with macronutrient contents below and within the recommended ranges for all macronutrients. New studies should investigate the possibility of adapting this index to the current recommendations to reduce its limitations.

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CONTRIBUTORS

A MENDES analyzed and interpreted the data and wrote the article. L GAVIOLI analyzed the data, and drafted and wrote the article. AN PREVIDELLI analyzed the data. RM FISBERG drafted the article. DML MARCHIONI supervised the study and outlined the article.

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