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RESEARCH ARTICLE

Development and evaluation of Diet Quality Index for Brazilians based on the updated version of the 2024 Food Pyramid: Nutrition focus House Budget Survey, 2017-18

Desarrollo y evaluación del índice de calidad de la dieta para brasileños basado en la versión actualizada de la Pirámide Alimenticia de 2024: Encuesta de presupuesto interno con enfoque nutricional, 2017-18

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KEYWORDS

Dietary Guidelines
Diet
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Cross-sectional studies

ABSTRACT

Introduction: In 2024 the Brazilian Food Pyramid was updated based on 7 food groups that meet the current dietary recommendations and appeared to be useful to help population achieve healthy eating behaviours. As many epidemiologic studies use dietary indexes, the current study developed and evaluated the psychometric properties of a dietary index to measure adherence to the updated food pyramid groups recommendations on healthy food choices.

Methods: Dietary intake data from the mean of two 24-hour dietary recalls in the Nutrition Focus House Budget Survey, 2017-18 was used for this purpose. Variability among individuals were assessed via distribution of dietary intakes. Mean dietary scores were compared among population subgroups. Pearson's correlations were used to verify the relationship between each component, overall scores and total energy intake. Finally, multidimensionality was checked with principal components analysis based on the 9 components of the index.

Results: Mean Brazilian index score was 65.65/100 (95% CI, 65.55, 65.80) among Brazilians ≥ 10yo. Adolescents (64.36) and males' adults (63.94) had the lowest and female adults (66.84) had the highest total score. Sodium showed the strongest negative correlation with fruits and vegetables (r = -0.52), while total score the strongest positive correlation with fatty acids (r= 0.52). Energy intake showed a stronger positive correlation for grains (r = 0.71) and a negative for fruits and vegetables (r = -0.21). Principal components analysis revealed at least 4 dimensions (60% total variance).

Conclusions: The Brazilian Healthy Eating Index, 2024 showed good psychometric properties supporting the 2024 updated food pyramid recommendation.

PALABRAS CLAVE

Pautas dietéticas

Dieta

Alimentación y nutrición

Estudios transversales

RESUMEN

Introducción: En 2024, la Pirámide Alimenticia Brasileña fue actualizada basándose en 7 grupos de alimentos que cumplen con las recomendaciones dietéticas actuales y parecen ser útiles para ayudar a la población a lograr conductas alimentarias saludables. Como muchos estudios epidemiológicos utilizan índices dietéticos, el estudio actual desarrolló y evaluó las propiedades psicométricas de un índice dietético para medir la adherencia a las recomendaciones actualizadas de los grupos de la pirámide alimenticia sobre la elección de alimentos saludables.

Metodología: Para este propósito se utilizaron datos de ingesta dietética de la media de dos recordatorios dietéticos de 24 horas en Encuesta sobre el presupuesto de la Cámara de Enfoque en Nutrición, 2017-18. La variabilidad entre los individuos se evaluó mediante la distribución de la ingesta dietética. Se compararon las puntuaciones dietéticas medias entre subgrupos de población. Se utilizaron correlaciones de Pearson para verificar la relación entre cada componente, las puntuaciones generales y la ingesta total de energía. Finalmente, se comprobó la multidimensionalidad con un análisis de componentes principales basado en los 9 componentes del índice.

Resultados: La puntuación media del índice brasileño fue 65,65/100 (IC del 95 %, 65,55, 65,80) entre los brasileños ≥ 10 años. Los adolescentes (64,36) y los hombres adultos (63,94) tuvieron la puntuación total más baja y las mujeres adultas (66,84) la puntuación total más alta. El sodio mostró la correlación negativa más fuerte con las frutas y verduras (r=-0,52), mientras que la puntuación total la correlación positiva más fuerte con los ácidos grasos (r=0,52). La ingesta de energía mostró una correlación positiva más fuerte para los cereales (r=0,71) y negativa para las frutas y verduras (r=-0,21). El análisis de componentes principales reveló al menos 4 dimensiones (60% de varianza total).

Conclusión: El Índice Brasileño de Alimentación Saludable de 2024 mostró buenas propiedades psicométricas que respaldan la recomendación de la pirámide alimentaria actualizada de 2024.

KEY MESSAGES

1. The food pyramid reflects the dietary recommendations of a target population.
2. The psychometric properties of diet quality indices should be assessed.
3. Variability and correlations between dietary components reflect good psychometrics.
4. It is recommended to configure the weights of different components when targeting specific groups.

CITATION

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INTRODUCTION

There is clear evidence demonstrating the relationship between suboptimal dietary patterns and leading risk factors for morbidity and mortality in Brazil and worldwide. Therefore, healthy eating is important to promote health from earlier to later in life. Healthy eating is a dietary pattern favouring all type of food choices, not stigmatizing into "good" or "bad, promoting the complete physical, social and emotional well-being[1]. Many epidemiological studies have examine the associations between health outcomes and single foods or nutrients, but they are consumed in combinations which can induce interactions and synergies between dietary components[2]. Dietary pattern analysis is known to be a more appropriate approach in investigating health-related outcomes rather than focusing on single foods or nutrient[3].

Developing *a priori* dietary index is one approach to assess dietary patterns, i.e., pre-defined algorithm to quantify food and nutrient intake relative to national and international nutritional recommendations[4]we critically evaluate a priori–defined dietary indices commonly applied in epidemiological studies of CVD risk and mortality. A systematic literature search identified 59 observational studies that applied a priori–defined diet quality indices to CVD risk factors and/or CVD incidence and/or CVD mortality. Among 31 different indices, these scores were categorized as follows: 1. Indices can be used to measure diet quality in populations, monitoring over time or dietary changes in trials. Furthermore, in epidemiological studies an index can be used to investigate the associations with health and diet. Also, confounder factors can be controlled by using diet index score[5]. Several indexes have been developed, and a well-known example is the "American" Healthy Eating Index (HEI), which has passed through several updates to align to the US dietary guidelines[2]. This index has been associated with health outcomes and as monitoring tool in North America populations[5]. More recently, the Global Diet Quality Score (GDQS)[6] have been developed known as an "easy-to-be-used" tool and with an 25-item metric for nutrient adequacy and diet related diseases, more specifically for chronic non-communicable diseases. The GDQS have been correlated with the intake of "ultra-processed" foods and adequacy of some nutrients with the Brazilian population[7]. However, these indexes have limitations to be used in the Brazilian context. First, the "American" HEI is based on the US dietary guidelines and the diet is culturally different from Brazil. Second, the GDQS is a metric to focus on monitoring chronic non-communicable diseases not comprehending the overall concept of health. For instance, nutrition and diet-related health are driven by multiple factors and are embedded in social determinants of health and structural factors. These include poverty, lack of access to quality education and employment, poor quality housing, unfavourable work and neighborhood conditions, transportation issues, environmental racism, neighborhood violence, and the clustering of disadvantaged groups[8,9].

In 2024, Philippi et al.[10] updated an iconographic with seven food groups targeting overall health of the Brazilian population. Furthermore, this iconographic focused on the population health disparities that has been associated with factors at an individual level[8], e.g., food (in) security, which is the (lack) consistent, dependable access to sufficient food for an active and healthy life[11]. This factor can influence eating habits, and dietary preference and are themselves influenced by social and structural factors that contribute to diet-related disparities[8]. Therefore, addressing multiple intersecting factors that influence dietary patterns and their contribution to diet related health disparities is essential for developing effective tools to monitoring diet and health disparities. To date, two Brazilian indices have been developed, both based on an iconographic that was endorsed by the 2006 Brazilian Food Guide[12]. The first dietary quality index consisted of five criteria: < 30% of energy from total fats, < 10% of energy from saturated fats, < 300mg/day of cholesterol, ≤ 2400mg/day of sodium, and ≥ 5 servings of fruits and vegetables. For each criterion, scores ranged from 0 to 10 depending on adherence to recommendation. The score of (total and saturated) fats, cholesterol, and sodium was inversely related to the total diet score[12]. The second index was an updated version of the previous one and consisted of 12 components. The score, ranging from zero (low quality) to 96 (high quality) was based on the (American) HEI 2005 version cut-off values.

Psychometric properties of an index measuring adherence to given set of dietary recommendations should be verified before the use in epidemiological, intervention and surveillance studies. Certainly, assessing adherence to recommendations in an iconographic based on food groups (also known as the Food Pyramid) with a validated index may reduce the risk for inconsistent research findings that may impact policy decision-making and lead to confusing messages to the public. Several dimensions of validity should be applicable to validate the index and include: (i) construct validity, i.e., extent to which a given index varies according to other variables known to be associated to diet quality; and (ii) reliability, i.e., extent to which all components of an index are internally consistent[13]correlation studies the relationship between one variable and another, not the differences, and it is not recommended as a method for assessing the comparability between methods. In 1983 Altman and Bland (B&A). The aim of this study was to develop and evaluate the construct validity and reliability in terms of internal consistency of a metric based on the updated Food Pyramid groups.

METHODS

Study design and participants

Data from the 2017-18 Nutrition focus House Budget Survey was used to conduct the analyses. The House Budget Survey is a nationally representative survey of individuals ≥ 10yo living in private dwelling from the 26 Brazilian states plus the Federal

District. Individuals from the military forces, penitentiaries, shelters, orphanages, hospitals and other institutionalized venues were excluded. Data were collected between August 11th of 2017 to August 11th of 2018. Pregnant and lactating women were excluded (less than 4% of all participants in the Nutrition focus House Budget Survey (n=707)). Analyses were based on the public use microdata files obtained from the Brazilian Geography and Statistics Institute. Secondary analyses of data from the Nutrition-focus House Budget Survey do not require additional ethics approval.

Dietary assessment

The 24h-recall was the method of choice to assess dietary intake of the population and followed the Automated Multiple Pass Method. The average of two non-consecutive dietary recalls were taken to estimate each individual dietary intake[13]. From the total sample of the Brazilian – House Budget Survey, 2017-18 (n = 178,431), 25% of the respondents completed the 1st 24h-recall (n = 46,164) and 22% the second (n = 38,854) via computer-assisted interviews by a trained personal. The Global Diet software was used to translate all the information related to foods, beverages, food preparations, amounts, methods of preparations, added items and meal occasions and venues. Reported dietary intakes measured via 24-hour recall were 1st classified according to the food categories used to calculate the group components of the dietary metric and were then summed per respondent for each 24h recall available. The nutrients used to calculate the metric, i.e., saturated, mono-unsaturated (MONO) and poli-unsaturated (POLI) fats, free sugar, and sodium, expressed in grams were deemed as reference amounts (RA). Free sugars are monosaccharides and disaccharides added to foods, sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates, and sugars from foods extracts and artificial flavourings, alcoholic drinks[14].

RA reflect food typically consumed in one sitting and are developed and maintained mainly for nutrition labelling purposes. Nutrient intakes were computed using the Brazilian Food Composition Table. The Brazilian Geography and Statistic Institute provided the data from the RAs and estimation of the free sugars components were based on previous study methodology[15].

Brazilian Dietary Index

Details on assignment of scores and alignment with the updated 2024 Pyramid food groups are provided in Table 1. Briefly, the index comprises 9 components named: (i) fruits and vegetables, (ii) (whole) grains, (iii) dairy, (iv) meats and eggs, (v) beans, (vi) fatty acids ratio (MONO + POLI/SAT), (vii) saturated fats, (viii) free sugars and (ix) sodium. Each component relates to key recommendations identified in the food pyramid groups. Scoring standards were taken directly from targets proposed in the pyramid groups for nutrients components or derived from the guidelines based on consumption data and expert judgment. Table 1 presented a list of the metric components, scores and standard scores. Fruits and vegetables (FV) and grains, with preference for whole grains should be the key component indicator for diet quality and healthy dietary patterns[16]. For example, FV and (whole) grains received the same points, but reference amount for each food differs based on their energy, fibre and grams[10]. Importantly, whole grains should be always given the preference, but we should not exclude other sources of grains to attend the context of each individual, not stigmatizing foods into "bad" and "good"[16]. A maximum score of 5 or 10 was given to components related to particular recommendation or closely linked recommendations. Them, all the 9 components were summed, and index has a maximum score of 100 and reflects adherence to healthy food choices of the 2024 Food Pyramid.

Table 1. Brazilian Healthy Eating Index, 2024. Nutrition Focused Brazilian House Budget Survey, 2017-18.

Food Groups	Maximum points	Standard for maximum score	Standard for minimum score
Fruits and Vegetables	20	≥ 2.0 cup eq/1000 kcal	No fruits and vegetables
(Whole) grains†	20	≥ 128 grams eq/1000 kcal	No grains
Dairy	10	≥ 1.3 cup eq/1000 kcal	No dairy
Meat and Eggs	5	≥ 56 grams eq/1000 kcal	No meat and eggs
Beans	5	≥ 1.4 cup/1000 kcal	No beans
Fatty Acids ratio	10	(MUFA + PUFA)/SFA ≥ 2.5	(MUFA + PUFA)/SFA ≤ 1.2
Sodium	10	≤1.1g /1000kcal	≥ 2.0g/1000 kcal
Free sugars	10	≤ 6.5% of energy	≥ 26% of energy
Saturated fats	10	≤ 8% of energy	≥ 16% of energy
Total score	100	---	---

MUFA: Mono-unsaturated fats; PUFA: Poli-unsaturated fats; SFA: Saturated fats. †Preference for whole grains, such as brown rice, whole grain pasta, quinoa.

Statistical analysis

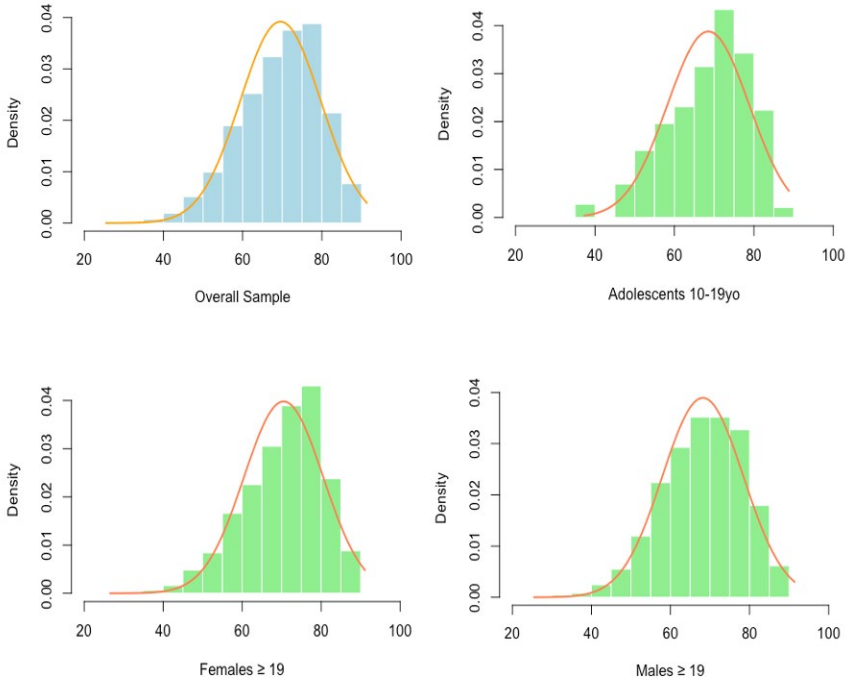
Six tasks were taken to evaluate the construct validity and reliability (internal consistency) of the dietary metric as predefined analyses of previous healthy eating indexes[17,18]. The variability among individuals were assessed via distributions of usual dietary intakes for each components estimated using the National Cancer Institute multivariate Markov Chain Monte Carlo method[19]. Stratification by age and sex were conducted due within-individual random dietary intake variations that differ across life stages[20]. A scoring algorithm was applied to the estimated usual intakes among pseudo-individuals to estimate total and components scores. The mean and percentiles of total dietary metric and components were estimated for total and sub samples. Mean dietary components and total scores for subgroups (age, sex, race and food security status) with expected differences in diet quality were estimated using the ratio method[21]. The hypothesis was tested with the U.S Healthy Eating Index, 2020 score[2] due to all the scores are intended to reflect overall diet quality. The relationship between the indexes were examined using Pearson correlation as well as linear regression with a restricted to account for potential non-linearity. Quantiles were selected a priori based on common placement to ensure enough data within each interval[22]. Association between energy intake and dietary metric scores was assessed using univariate linear regression and Pearson correlation. The last task for construct validity was the principal component analysis that was used to assess multidimensionality of the metric based on the 9 components of the index and based on usual dietary intake. The eigenvalues and eigenvectors of the principal component analysis solution were assessed to confirm multidimensionality (variance of scores not explained by only one of its components). The association between component scores was also checked with Pearson correlation. Sampling weights were used to generalize results to the Brazilian population. Analyses were performed in R Studio Version 2023.06.1+524 (Posit Software, PBC).

RESULTS

Participants variability

Distribution of the total and components scores from the Brazilian metric based on usual dietary intake in Brazilians ≥ 10yo are shown in Figure 1. The mean total score of the Brazilian index was of 65.65 (95%CI 65.55, 65.80) with a range from 40.11 (percentile 1) and 85.15 (percentile 99). Adolescents (64.36) and male adults (63.94) had the lowest total score and female adults (66.84) the highest. "Ceiling effects", i.e., greater proportion of individuals receiving maximum score, were observed for grains, meats and eggs, beans, and free sugars.

Figure 1. Estimated distribution of total dietary scores based on usual dietary intakes in Brazilians ≥ 10yo from the 2017-18 Nutrition Focus House Budget Survey, Brazil (n = 16,254).



Differences between components and total scores and subgroups

Mean differences of components scores from the Brazilian index with population subgroups are presented on Figure 2. Overall females vs. males and food secure vs. insecure presented better diet quality for fruits and vegetables and dairy. Adolescents vs. adults did not show significant differences between components.

Correlations between metrics and total energy intake

Table 2 depicts Pearson correlations between energy intake, components and total scores of the Brazilian metric. Sodium showed the strongest negative correlation with energy (r= -0.52). Total scores showed the strongest positive correlation for fruits and vegetables (r = 0.71) and negative correlation for energy intake (r = - 0.21). In contrast, saturated fats were positively correlated with fatty acids (r = 0.52). There was a strong positive correlation between the Brazilian and the US index (r = 0.75) (data not shown).

Principal components analysis of dietary components of the Brazilian Healthy Index

Scores from the first four principal components analysis (PCA) (i.e., linear combinations) of the Brazilian dietary metric components accounted for 60% of the total variance. Fatty acids, saturated

Figure 2. Brazilian Healthy Eating Index – 2024 radar plots across the population subgroups, Nutrition focus House Budget Survey, 2017-18. *Each component score is plotted as mean of its maximum points on 9 different axes. The outer edge of the radar represents 20, 10 or 5 depending on the component, while the center represents 0 of the maximum score of any component. Food security is the lack of consistent, dependable access to sufficient food for an active and healthy life.*

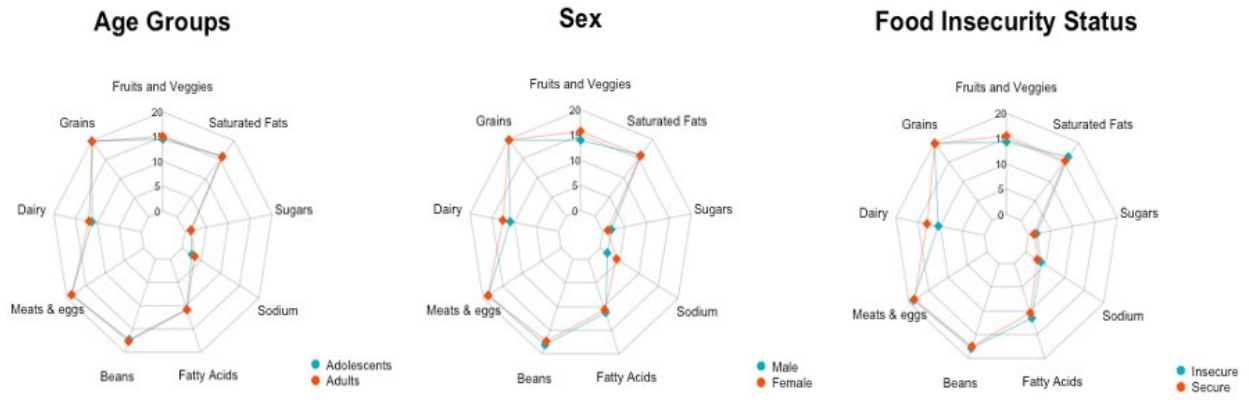


Table 2. Pearson correlations between BHEI, 2024 components scores and energy intake of Brazilians ≥ 10yo from the Nutrition focus House Budget Survey, 2017-18

	1	2	3	4	5	6	7	8	9	10	11
1	1.00	-0.03***	-0.02***	0.08***	-0.11***	0.05***	-0.03***	-0.52***	-0.09***	-0.11***	-0.21***
2		1.00	-0.01	0.08***	0.01	0.06***	-0.02***	0.03***	-0.32***	0.08***	0.71***
3			1.00	0.01*	0.03***	0.09***	0.01	-0.07***	-0.01**	0.10***	0.16***
4				1.00	-0.05***	-0.07***	-0.41***	-0.09***	-0.18***	-0.26***	0.23***
5					1.00	0.09***	0.07***	-0.01*	0.05***	0.03***	0.13***
6						1.00	0.13***	-0.11***	0.02**	0.12***	0.24***
7							1.00	0.02**	0.16***	0.52***	0.33***
8								1.00	0.09***	0.07***	0.31***
9									1.00	0.01*	0.00
10										1.00	0.43***
11											1.00

*1 = Energy, 2 = Fruits and vegetables; 3 = Grains, 4 = Dairy, 5 = Meats and eggs, 6 = Beans, 7 = Fatty acids ratio, 8 = Sodium, 9 = Free sugars, 10 = Satured Fats, and 11= Total Score. *p-value < 0.05; **p-value < 0.01; ***p-value < 0.001*

fats and dairy were the 3 components the most to the 1st principal component accounting for the largest proportion of the total variance (21%). The other 4 PCAs explained further information on total scores patterns of the Brazilians consisting with the multidimensional nature of dietary intake. For example, fruits and vegetables, and free sugars presented the most variance for the 2nd PCA (15%); for the 3rd were grains and beans (13%) and the 4th grains and meat (11%) (Table 3).

DISCUSSION

The Brazilian Healthy Eating Index, 2024 was evaluated for construct validity and reliability to assess adherence to recommendation of the updated Food Pyramid, 2024[10] on healthy food choices. The index showed sufficient variation across Brazilians with significant differences in population subgroups: sex and food insecurity status; had a strong correlation with the American Healthy Eating Index-2020 and captured several dimensions of diet quality. There was consistency between components correlations, e.g., grains and beans were positively correlated.

Table 3. Principal components analysis of components scores of Brazilian Healthy Eating Index, 2024 among Brazilians ≥ 10yo. Nutrition focus House Budget Survey, 2017-2018.

	PC1	PC2	PC3	PC4
Fruits and Vegetables	-0.09	-0.62	0.31	-0.19
Grains	0.06	0.21	-0.44	0.36
Dairy	-0.49	-0.11	-0.11	0.01
Meats	0.13	-0.05	-0.31	-0.85
Beans	0.19	-0.30	-0.46	-0.13
Fatty acids	0.59	-0.09	0.08	0.08
Sodium	0.09	0.19	0.57	-0.25
Sugar	0.26	0.58	-0.20	-0.04
Saturated Fats	0.51	-0.29	0.16	0.16
% variance	21.46	15.19	13.06	10.97
% cumulative	21.46	36.65	49.70	60.67

The total diet score demonstrated variability among Brazilians ≥10yo and by subgroups: adolescents, females ≥18yo and males ≥18yo. However, distributions of grains and meats and eggs were skewed for maximum scores and free sugars for minimum scores. In the case of meats and eggs and grains most individuals were meeting the recommendations, but in the case of free sugars were consuming above the recommendations (free sugars were reversed scored). Even though, variability of total Brazilian healthy eating index, 2024 scores was adequate to demonstrate differences in diet quality according to sex and food insecurity status[2]. Further studies are needed to verify how other populations meet the recommendations of the updated 2024 food pyramid to be understood as good quality.

The strong correlation between the Brazilian healthy eating index, 2024 and the US Healthy Eating Index, 2020 reflected adherence to the 2020-2025 Dietary Guidelines for Americans[2]. Construct validity was supported taking into account that both indices reflect adherence to sets of recommendations that are based on similar body of evidence[10]. In addition, variability among individuals for the Brazilian index showed similar variability with the US index demonstrating construct validity, i.e., 21.56 in percentile 1 and 66.89 in percentile 99.

The nine components of the Brazilian index were weighted differently to capture adequate proportions based on the food pyramid recommendations, similarly to American HEI, 2020[2] and the 2019 Canadian Food Guide[23]. Most of the components were significantly correlated, indicating overlap of dietary behaviours, leading to indirectly providing more weight to that dietary behaviour[24]. The components free sugars (r= 0.16) and dairy (r = -0.41) were correlated with fatty acids, which can be explained by the fact that preparations or industrialized foods have both sugars and fats, and reduced consumption of dairy products or consumption low-fat dairies are linked to fatty acids. The effect of additional health and diet-relations should be investigated in future studies. Maybe weighting of the components can be change according to specific recommendations, e.g., specific population group (children vs. adults vs. older adults) or presence of disease or any other healthy condition that requires stricter cut-offs points. Nevertheless, modifying scoring standards may or may not reflect adherence to specific recommendations to the Food Pyramid as per the original purpose of the Brazilian index[10]. Further, females and food secure households, i.e., adequate access to food, showed a relatively better diet quality corroborating to other studies[25,26]. Taken together, results suggest that intake of specific dietary components, i.e., fruits and vegetables, milk and dairy and sodium components, may be particularly sensitive to sex and food insecurity differences[5,27,28].

The strengths of the present study were the use of population-based data consistent to the aim of the of the index and several metrics to evaluate psychometric properties of the Brazilian index. However, limitations should be noticed. First dietary assessment methods are prone to random and systematic errors that can reflect on the quality of the estimates of diet. The estimated mean of the two 24h-recalls are prone to these errors as compared to food frequency questionnaires[29]. Second, changes over the time of the diet could not be assessed due to the cross-sectional design study. Third, evaluation among individuals with specific health conditions or other subgroups children and older people, could not be assessed. Fourth, Brazilian healthy eating index, 2024 was not assessed for health and diet health disparities. Lastly, the developing of a diet quality index based on the pyramid based on the Brazilian population might not allow for comparability to other countries and cultures.

CONCLUSIONS

The Brazilian Healthy Eating Index, 2024 showed good psychometric properties that reflects to the recommendations of healthy eating to the 2024 updated food pyramid. Future research of Brazilian Healthy Eating Index, 2024 can be used as monitoring tool in public health research or as a tool for assessing a Brazilian dietary pattern and studying nutrition or diet health disparities.

AUTHORS' CONTRIBUTIONS

ACBL and STP was involved in the conception and design of the study and interpretation of analysis. ACBL conducted statistical analysis and wrote the first draft of this manuscript. STP was involved in the adaption of the food pyramid to the Brazilian context, to its dietary recommendations and to critically review this manuscript. All authors approved the final version of this manuscript.

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The authors declare that there has been no funding to carry out this study.

CONFLICTS OF INTEREST

The authors state that there are no conflicts of interest when writing the manuscript.

DATA AVAILABILITY

This study was a secondary analysis of the Brazilian House Budget Survey – 2017-18 data. All information was de-identified and vetted by a trained member of the Brazilian Geography Statistics Institute prior to their publicly released. Data can be found: https://www.ibge.gov.br/estatisticas/sociais/saude/24786-pesquisa-de-orcamentos-familiares-2.html?=&t=microdados

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