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Modeling Optimal Cutoffs for the Brazilian Household Food Insecurity Measurement Scale in a Nationwide Representative Sample

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Abstract

Background: This is the second part of a model-based approach to examine the suitability of the current cutoffs applied to the raw score of the Brazilian Household Food Insecurity Measurement Scale [Escala Brasileira de Insegurança Alimentar (EBIA)]. The approach allows identification of homogeneous groups who correspond to severity levels of food insecurity (FI) and, by extension, discriminant cutoffs able to accurately distinguish these groups.

Objective: This study aims to examine whether the model-based approach for identifying optimal cutoffs first implemented in a local sample is replicated in a countrywide representative sample.

Methods: Data were derived from the Brazilian National Household Sample Survey of 2013 (n = 116,543 households). Latent class factor analysis (LCFA) models from 2 to 5 classes were applied to the scale's items to identify the number of underlying FI latent classes. Next, identification of optimal cutoffs on the overall raw score was ascertained from these identified classes. Analyses were conducted in the aggregate data and by macroregions. Finally, model-based classifications (latent classes and groupings identified thereafter) were contrasted to the traditionally used classification.

Results: LCFA identified 4 homogeneous groups with a very high degree of class separation (entropy = 0.934–0.975). The following cutoffs were identified in the aggregate data: between 1 and 2 (1/2), 5 and 6 (5/6), and 10 and 11 (10/11) in households with children and/or adolescents <18 y of age (score range: 0–14), and 1/2, between 4 and 5 (4/5), and between 6 and 7 (6/7) in adult-only households (range: 0–8). With minor variations, the same cutoffs were also identified in the macroregions. Although our findings confirm, in general, the classification currently used, the limit of 1/2 (compared with 0/1) for separating the milder from the baseline category emerged consistently in all analyses.

Conclusions: Nationwide findings corroborate previous local evidence that households with an overall score of 1 are more akin to those scoring negative on all items. These results may contribute to guide experts' and policymakers' decisions on the most appropriate EBIA cutoffs. *J Nutr* 2017;147:1356–65.

Keywords: food insecurity, EBIA, surveys, psychometrics, statistical model

Introduction

Food insecurity is a global problem affecting both poor and wealthy countries (1–3). By definition, it occurs "when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life" (4). Food insecurity has many determinants, particularly those reflecting poverty and social inequalities (5–8), and is known to negatively

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Supplemental Table 1 is available from the ''Online Supporting Material'' link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.
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Abbreviations used: BIC, Bayesian information criterion; C, class; CFA, confirmatory factor analysis; EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Household Food Insecurity Measurement Scale); LCA, latent class analysis; LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey); VLMR, Vuong-Lo-Mendell-Rubin likelihood ratio.

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affect the health and well-being of individuals (9–11) as well as society as a whole (12, 13).

In the past 2 decades, a growing interest in assessing this issue in different contexts has motivated the development and consolidation of several food security experience–based scales to directly estimate the extent of food insecurity at the household level (14–16). Among many initiatives, the US Household Food Security Survey Model (17) stood out, giving rise to numerous cross-cultural adaptations (18, 19), including Brazil (20, 21). Supported by a robust psychometric history (20–26), the Brazilian Household Food Insecurity Measurement Scale [Escala Brasileira de Insegurança Alimentar (EBIA)] has been accepted in the country as a valid assessment tool for monitoring food insecurity (15, 20, 21). The EBIA has thus been used for more than a decade in many population-based studies, whether local (7, 27–31) or comprehensive nationwide (32–35) surveys.

Like the US Household Food Security Survey Model, the EBIA has several indicators describing increasing levels of intensity of food insecurity. This increasing starts with concerns about the household availability of food due to limited resources, followed by declining dietary variety and quality, and ends with restrictions on food intake, first among adults and then children (21, 36–38).

Accordingly, the classification of the EBIA typically establishes 4 categories of food security (3 that are indicative of levels of insecurity) on the basis of recommended cutoffs for households with and without children and/or adolescents <18 y of age. Drawing on well-known properties studied through the Rasch and other psychometric models, these cutoffs have also been based on expert judgment founded on theoretical considerations and usefulness for policymaking (21, 24–26). Therefore, a question worth asking is whether the cutoffs currently in use appropriately distinguish homogeneous groupings. This is an important feature to be assessed, given the objective of the EBIA to rank families with regard to food access, either to identify and monitor vulnerable groups or to assess programs aimed at combatting hunger and promoting food security in Brazil.

Reichenheim et al. (39) recently conducted a study in 1105 households from a low-income district located in the metropolitan area of the State of Rio de Janeiro (Campos Elíseos, Duque de Caxias City, Brazil). With the use of latent class factor analysis (LCFA) (40), the authors could identify 4 homogeneous groups expressing increasing levels of severity of food insecurity. Although the analyses broadly confirmed the traditionally used cutoffs, results indicated that families endorsing only 1 item would be best categorized in the first stratum usually labeled as "food security" rather than placed in the second stratum labeled as "mild food insecurity" (24, 26, 39). Furthermore, the analysis showed that the most commonly endorsed single item in this first stratum was related to "milder" issues, which referred either to worries about the availability of food in the near future or to a qualitative impairment concerning the variety of available food.

Because the study by Reichenheim et al. (39) was restricted to a specific area of a single city and because Brazil is such a culturally and economically heterogeneous country, it was deemed important to replicate findings in a nationally representative sample. Given that EBIA is being widely used in nationally representative surveys, and is recognized by public health managers as an important indicator of monitoring and evaluation of food security policies, the findings from this study may carry important implications for recommending potential modifications to the existing EBIA cutoffs.

Methods

Study sample and the assessment of household food insecurity

Data were derived from the Brazilian National Household Sample Survey [Pesquisa Nacional por Amostra de Domicílios (PNAD)] of 2013 (35, 41). PNAD is a nationally representative household survey conducted periodically by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) whose main purpose is generating information for monitoring the social and economic development of the country (41). The survey used a 3-stage, probabilistic, cluster-sampling design. The first stage comprised the selection of municipalities, followed by the selection of the census tracts in the second stage and households in the third stage. Further information on sampling design may be accessed in the official reports provided by the Brazilian Institute of Geography and Statistics (35, 41). The final sample consisted of 116,543 households, of which 58,401 included children and/or adolescents <18 y of age and 58,142 included only adults.

The PNAD-2013 used the EBIA version consisting of 14 dichotomous (yes or no) items with regard to families with children and/or adolescents <18 y of age and 8 items referring to adult-only households (26). The abbreviated items of the EBIA are presented in **Supplemental Table 1**, as well as in the third table of the Results section; the complete version can be found in Segall-Corrêa et al. (26).

Data analyses

The analyses followed the procedure outlined in Reichenheim et al. (39) and involved 2 main steps: *1*) the model-building process for the identification of possible underlying latent classes of the EBIA and *2*) assigning optimal cutoffs to the raw score of the scale by using the model-based variable containing class membership levels as a yardstick. All of the analyses were conducted on the aggregate data and by macroregions of Brazil (i.e., North, Northeast, Southeast, South, and Midwest).

Step 1: LCFA model-building process to identify homogeneous latent groups corresponding to levels of food insecurity. This stage was adapted from the modeling approach suggested by Clark et al. (40) for implementing LCFA models. Accordingly, the process starts with separately identifying the best conventional confirmatory factor analysis (CFA) and latent class analysis (LCA) models. By using these models as benchmarks, increasingly complex *f*-factor, *k*-class LCFA models are then fitted in search of the best-fitting and most meaningful solution.

Due to the consistent one-dimensional history of the scale (17, 22, 23, 36), only a conventional 1-factor CFA was implemented for later comparison with the best LCFA model. Next, conventional LCA models with *k* classes were fitted to detect the benchmark model. The simpler 1-factor CFA and the best *k*-class LCA models were then compared with the best-adjusted LCFA model to assess whether any fit and/or substantive improvement would be achieved.

In an LCFA model, classes are distinguished by their factor means (40, 42), and conditional item probabilities (i.e., information on the probability an individual in a given class will endorse a specific item) and class probabilities (i.e., the proportion of the population in a particular class) are also obtained. For model specifications and related equations, the reader is referred to Wang and Wang (43) and Clark et al. (40).

CFA, LCA, and LCFA models were fitted in Mplus 7.4 (Muthén & Muthén) (44). The robust full-information maximum likelihood estimator was used to account for the complex sampling procedure and to deal with the difference in the number of items answered by families with and without children and/or adolescents. A logit link was specified to accommodate the dichotomous characteristic of the items. The robust full-information maximum likelihood estimator enabled gathering the maximum informativeness per item to obtain model parameters by simultaneously using the complete data set composed of both family types (39, 45). However, the assessments of cutoffs were conducted separately by household type.

Model fit assessments and comparisons were based on 3 statistical parameters: *1*) the Bayesian information criterion (BIC), where lower values indicate the most parsimonious solution and better model fit (46–48); *2*) the Vuong-Lo-Mendell-Rubin likelihood ratio (VLMR) test, where a significant P value ($P < 0.05$) indicates that a k-1 class LCA/LCFA model needs refuting in favor of the *k*-class solution (49, 50); and *3*) entropy to assess how well the latent classes are distinguishable from each other (51), with values ranging from 0 to 1 and unity indicating perfect class separation (48, 52). In addition to a formal evaluation of fit, models were also checked for their interpretability on the basis of theoretical considerations, as recommended by Muthén (48) and Clark et al. (40).

Step 2: Identification of cutoffs on the overall raw score of the EBIA on the basis of identified classes (with classification agreement evaluation). First, the overall raw score of the EBIA was cross-tabulated against the classes identified in the best LCFA model. Raw scores were obtained by summing the component item scores and classes specified according to the most likely membership assignment (40). This analysis sought to *1*) identify optimal cutoffs discriminating adjacent (ordinal) severity levels of the EBIA, *2*) evaluate the proportion misclassified, and *3*) assess the degree of agreement between the model-based classification and the empirical grouping on the basis of the identified raw cutoffs (by using a quadratic-weighted κ-coefficient) (53, 54). Next, the model-based (LCFA) classification and the empirical grouping resulting thereof were compared with the classification of EBIA proposed in the previous literature. These analyses were carried out in Stata 14.2 (StataCorp) by using the svy program to allow for the complex sampling structure (55).

Results

The study sample was distributed, as follows, across macroregions: North, 7.3% (95% CI: 7.2%, 7.4%); Northeast, 26.2% (95% CI: 25.9%, 26.4%); Southeast, 43.5% (95% CI: 43.2%, 43.8%); South, 15.3% (95% CI: 15.1%, 15.5%); and Midwest, 7.7% (95% CI: 7.5%, 7.8%). Most households were in urban areas (85.8%; 95% CI: 85.1%, 86.4%) and had basic sanitation (94.9%; 95% CI: 94.5%, 95.2%). The mean ± SE number of persons in each household was 3 ± 0.007. At the US$–Brazilian real exchange rate of 1 July 2013, families had a monthly mean ± SE per capita income of $502.16 ± $4.91.

The pattern of the one-dimensional CFA for Brazil and macroregions is shown in Supplemental Table 1. As expected from previous studies (17, 22, 23, 36), factor loadings (λ_i) were >0.9 in all regions, as well as in the aggregate sample, and residuals were quite low as a result. The item severity parameter b_i showed a clear pattern of increasing severity of food insecurity. Although the order of item severity was slightly different across macroregions, the overall pattern remained consistent with theoretical expectations.

The fit statistics of the LCA and LCFA models for Brazil and macroregions are shown in **Table 1**. Examination of the LCA

TABLE 1 Fit statistics of LCA and LCFA models for the 14-item EBIA in the national sample and by macroregion: Brazil, PNAD-2013[1]

	LCA				LCFA			
	2 Classes	3 Classes	4 Classes	5 Classes	2 Classes	3 Classes	4 Classes	5 Classes
Brazil								
BIC	400,242.9	354,261.2	345,360.6	343,032.8	400,242.7	354,216.8	345,334.8	344,331.4
Δ BIC[2]	—	−11.49	−2.51	−0.67	—	−11.50	−2.51	−0.29
VLMR test,[3] *P*	—	0.000	0.000	0.000	—	0.000	0.002	0.0002
Entropy	0.976	0.974	0.961	0.961	0.976	0.974	0.961	0.953
North								
BIC	91,678.4	80,211.4	77,397.3	76,617.9	91,678.4	80,115.3	77,321.9	77,052.0
Δ BIC[2]	—	−12.51	−3.51	−1.01	—	−12.61	−3.49	−0.35
VLMR test,[3] *P*	—	0.000	0.000	0.000	—	0.000	0.494	0.608
Entropy	0.962	0.957	0.940	0.938	0.962	0.957	0.938	0.924
Northeast								
BIC	176,047.7	155,092.9	150,776.5	149,586.8	176,047.7	154,995.3	150,608.5	150,061.3
Δ BIC[2]	—	−11.90	−2.78	−0.79	—	−11.96	−2.83	−0.36
VLMR test,[3] *P*	—	0.000	0.000	0.000	—	0.000	0.064	0.097
Entropy	0.959	0.954	0.934	0.933	0.959	0.954	0.934	0.922
Southeast								
BIC	79,659.7	71,034.9	69,732.2	69,530.5	79,659.6	70,918.2	69,528.6	69,345.6
Δ BIC[2]	—	−10.83	−1.83	−0.29	—	−10.97	−1.96	−0.26
VLMR test,[3] *P*	—	0.000	0.000	0.000	—	0.488	0.675	0.159
Entropy	0.983	0.982	0.975	0.975	0.983	0.982	0.975	0.903
South								
BIC	44,548.2	39,956.9	39,203.0	39,126.3	44,548.1	39,841.8	38,988.9	38,920.5
Δ BIC[2]	—	−10.31	−1.89	−0.20	—	−10.56	−2.14	−0.18
VLMR test,[3] *P*	—	0.000	0.000	0.029	—	0.166	0.379	0.110
Entropy	0.982	0.980	0.975	0.975	0.982	0.980	0.975	0.877
Midwest								
BIC	33,697.6	30,176.2	29,773.4	29,730.1	33,697.5	30,061.7	29,576.0	29,492.1
Δ BIC[2]	—	−10.45	−1.33	−0.14	—	−10.79	−1.62	−0.28
VLMR test[3]	—	0.000	0.000	0.072	—	0.820	0.569	0.605
Entropy	0.980	0.980	0.971	0.948	0.980	0.980	0.970	0.962

[1] BIC, Bayesian information criteria; EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Household Food Insecurity Measurement Scale); LCA, latent class analysis; LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey); VLMR, Vuong-Lo-Mendell-Rubin likelihood ratio; Δ, change.

[2] Percentage of variation in BIC comparing a model that used *k* classes with another that used *k*-1 classes.

[3] *P* values comparing a model that used *k* classes with another that used *k*-1 classes.

TABLE 2 Percentage of families in each raw score of the EBIA classified according to latent class membership identified through the best LCFA 1-factor, 4-class model in the national sample and by macroregion: Brazil, PNAD-2013[1]

	Latent classes (FI)							
	Families with children and/or adolescents				Families without children and/or adolescents			
	C1	C2	C3	C4	C1	C2	C3	C4
Brazil								
Raw score								
0	71.2	0	0	0	83.4	0	0	0
1	6.98	0	0	0	4.55	0	0	0
2	0	3.51	0	0	0	2.44	0	0
3	0	3.38	0	0	0	2.39	0.02	0
4	0	3.73	0.05	0	0	2.61	0.15	0
5	0	2.32	0.34	0	0	0	1.42	0
6	0	0	1.65	0	0	0	0.92	0.01
7	0	0	1.29	0	0	0	0.15	0.66
8	0	0	1.29	0	0	0	0	1.26
9	0	0	0.74	0	—	—	—	—
10	0	0	0.59	0.01	—	—	—	—
11	0	0	0.20	0.32	—	—	—	—
12	0	0	0	0.5	—	—	—	—
13	0	0	0	0.5	—	—	—	—
14	0	0	0	1.4	—	—	—	—
Total[2]	78.2	12.9	6.2	2.7	88.0	7.4	2.7	1.9
North								
Raw score								
0	58.0	0	0	0	73.2	0	0	0
1	8.34	0	0	0	6.85	0	0	0
2	0	5.13	0	0	0	3.66	0	0
3	0	4.43	0	0	0	3.67	0	0
4	0	4.71	0.08	0	0	3.74	0.26	0
5	0	3.03	0.7	0	0	0	2.34	0
6	0	0	2.63	0	0	0	1.83	0.05
7	0	0	2.1	0	0	0	1.54	0.15
8	0	0	2.56	0.01	0	0	0	2.71
9	0	0	1.32	0.02	—	—	—	—
10	0	0	1.1	0.08	—	—	—	—
11	0	0	0.42	0.53	—	—	—	—
12	0	0	0	0.98	—	—	—	—
13	0	0	0	0.93	—	—	—	—
14	0	0	0	2.96	—	—	—	—
Total[2]	66.3	17.3	10.9	5.5	80.0	11.1	6.0	2.9
Northeast								
Raw score								
0	54.7	0	0	0	70.7	0	0	0
1	8.72	0	0	0	6.49	0	0	0
2	0	5.0	0	0	0	4.13	0	0
3	0	5.42	0.01	0	0	4.52	0.02	0
4	0	6.45	0.12	0	0	5.33	0.30	0
5	0	4.25	0.62	0	0	0	3.0	0
6	0	0.12	2.95	0	0	0	1.87	0.02
7	0	0	2.42	0	0	0	0.19	1.21
8	0	0	2.32	0	0	0	0	2.23
9	0	0	1.28	0.02	—	—	—	—
10	0	0	0.94	0.08	—	—	—	—
11	0	0	0.24	0.74	—	—	—	—
12	0	0	0	0.77	—	—	—	—
13	0	0	0	0.71	—	—	—	—
14	0	0	0	2.1	—	—	—	—
Total[2]	63.4	21.2	10.9	4.4	77.2	14.0	5.4	3.4

(Continued)

TABLE 2 *Continued*

	Latent classes (FI)							
	Families with children and/or adolescents				Families without children and/or adolescents			
	C1	C2	C3	C4	C1	C2	C3	C4
Southeast								
Raw score								
0	81.4	0	0	0	89.0	0	0	0
1	5.67	0	0	0	3.6	0	0	0
2	0	2.57	0	0	0	1.68	0	0
3	0	2.17	0	0	0	1.57	0.01	0
4	0	2.33	0.01	0	0	1.45	0.08	0
5	0	1.19	0.21	0	0	0	0.8	0
6	0	0	0.89	0	0	0	0.5	0.01
7	0	0	0.61	0	0	0	0.13	0.41
8	0	0	0.6	0	0	0	0	0.8
9	0	0	0.43	0	—	—	—	—
10	0	0	0.3	0.06	—	—	—	—
11	0	0	0.1	0.16	—	—	—	—
12	0	0	0	0.24	—	—	—	—
13	0	0	0	0.28	—	—	—	—
14	0	0	0	0.81	—	—	—	—
Total[2]	87.1	8.3	3.1	1.5	92.6	4.7	1.5	1.2
South								
Raw score								
0	81.2	0	0	0	88.25	0	0	0
1	6.57	0	0	0	3.71	0	0	0
2	0	2.45	0	0	0	1.96	0	0
3	0	2.31	0	0	0	1.55	0.02	0
4	0	2.0	0.01	0	0	1.68	0.19	0
5	0	1.03	0.17	0	0	0	0.82	0
6	0	0.14	0.47	0	0	0	0.57	0.01
7	0	0	0.61	0	0	0	0.43	0.1
8	0	0	0.68	0	0	0	0	0.72
9	0	0	0.32	0	—	—	—	—
10	0	0	0.46	0	—	—	—	—
11	0	0	0.12	0.06	—	—	—	—
12	0	0	0	0.15	—	—	—	—
13	0	0	0	0.23	—	—	—	—
14	0	0	0	0.92	—	—	—	—
Total[2]	87.9	7.9	2.8	1.4	92.0	5.2	2.0	0.8
Midwest								
Raw score								
0	78.1	0	0	0	85.3	0	0	0
1	6.35	0	0	0	4.63	0	0	0
2	0	2.86	0	0	0	2.04	0	0
3	0	2.76	0	0	0	1.83	0.03	0
4	0	2.75	0.03	0	0	2.56	0.04	0
5	0	2.13	0.17	0	0	0	1.04	0
6	0	0	1.06	0	0	0	0.74	0.02
7	0	0	0.77	0	0	0	0	0.6
8	0	0	0.6	0	0	0	0	1.13
9	0	0	0.37	0	—	—	—	—
10	0	0	0.39	0.04	—	—	—	—
11	0	0	0.15	0.13	—	—	—	—
12	0	0	0	0.27	—	—	—	—
13	0	0	0	0.21	—	—	—	—
14	0	0	0	0.85	—	—	—	—
Total[2]	84.5	10.5	3.5	1.5	89.9	6.4	1.9	1.8

[1] Values are percentages. C, class; EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Food Insecurity Measurement Scale); FI, food insecurity; LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey).
[2] Percentage of families in each class.

models comprising 2–5 classes (*k*) shows a progressive decline in BIC. The largest decreases occurred from the 2*k* to 3*k* and from the 3*k* to 4*k* models. The percentage of variation of BIC from the 4*k* to the 5*k* solution was negligible. Entropy was within reasonable bounds in all models, indicating a high degree of class separation across latent classes. The VLMR statistic consistently favored the *k* over the *k*-1 class solutions, except for the 5*k* model compared with the 4*k* model in the Midwest region. Even though these analyses provided an overall support for the 3*k* and 4*k* solutions, it was thus decided to continue exploring a 5*k* model in the next step and to analyze 5 increasingly complex 1-factor, *k*-class (*k* = 2–5) LCFA models.

The set of fit statistics showed that the best solution would largely be between the 1-factor, 3-class and the 1-factor, 4-class LCFA models (Table 1). In favor of the 3*k* solution would be the largest decrease in BIC compared with the 2*k* solution (–11.5% in Brazil; ranging from –10.6% in the South to –12.6% in the North), the highest entropy (varying from 0.954 to 0.982), and a nonsignificant VLMR *P* value when comparing the 4*k* and 3*k* models in all macroregions. Supporting the 4*k* model would be the decrease in BIC over the 3*k* solution (–2.51% in Brazil; ranging from −1.62% to −3.69% in the macroregions), high entropy values (from 0.934 to 0.975), and a significant VLMR statistic in the aggregate data, indicating a gain in information with this model at the country level. When placing theoretical considerations at the center of decision-making (48), we chose to continue with the 1-factor, 4-class LCFA solution in the ensuing analyses. This model aligns well with the categorization in 4 levels of food insecurity established since the construction of the EBIA.

Results describing the 1-factor, 4-class LCFA model are presented in **Table 2**. For Brazil at large, the estimated class probabilities (i.e., estimated percentage of families in each class according to class membership assignment) from class 1 to class 4 (C1–C4) in households with children and/or adolescents were 78.2%, 12.9%, 6.2%, and 2.7%, respectively. In adult-only households, these values changed slightly to 88.0%, 7.4%, 2.7%, and 1.9%, respectively, indicating a higher proportion of families in C1 as opposed to the other classes.

The cross-classifications of households as identified by the 4 latent classes (based on class membership assignment) and the raw scores of the EBIA at the national level and disaggregated by macroregions are also shown in Table 2. Three thresholds emerged. With regard to Brazil as a whole, cutoffs were between scores 1 and 2 (1/2), 5 and 6 (5/6), and 10 and 11 (10/11) in households with children and/or adolescents, whereas these were between scores 1 and 2 (1/2), 4 and 5 (4/5), and 6 and 7 (6/7), respectively, in adult-only households. Overall, these cutoffs were replicated in all macroregions. However, some discrepancies in the limits between the third and fourth groups in households with children and/or adolescents emerged in the South and Midwest (11/12 rather than 10/11) and in adult-only households in the South and North (7/8 rather than 6/7). Still, only 0.14% (*n* = 167) of families would be reclassified in these macroregions by using the cutoffs identified for Brazil (aggregate).

The 1-factor, 3-class LCFA model was also examined to understand and better explore the small discrepancies within the limits of C3 to C4 observed in some of the macroregions. This additional analysis involved a comparison between a 3-level classification obtained from this model (extracted by a process such as that presented in Table 2) and another classification achieved by combining the C3 and C4 categories identified through the 4*k* LCFA model. The limits identified for the 3*k* model nearly coincided with those obtained with the 4*k* model once reduced to 3 classes. The exception was the cutoff from C2 to C3, which moved from 5/6 to 7/8 in households with children and/or adolescents and from 4/5 to 5/6 in adult-only households in the 3*k* LCFA model. This would entail reclassifying 2.17% of Brazilian families from C3 to C2 (data not shown).

The item-response probabilities per latent class (C1–C4) estimated in the aggregate data are shown in **Table 3**. Noticeably, high item probabilities only emerge in the second latent class, which is

TABLE 3 Latent item profile and item-response probabilities of the EBIA according to families' latent class membership identified through the best LCFA 1-factor, 4-class model in the national sample: Brazil, PNAD-2013[1]

Item[2]	C1 (*n* = 96,921) (83.2%)	C2 (*n* = 11,830) (10.1%)	C3 (*n* = 5114) (4.4%)	C4 (*n* = 2681) (2.3%)
1. Worried (19.3)	0.052	0.857	0.934	0.967
3. Not healthy and varied diet (14.9)	0.008	0.758	0.939	0.983
4. Few foods (13.2)	0.005	0.635	0.930	0.978
2. Ran out of food (12.8)	0.005	0.633	0.867	0.963
9. C&A did not eat a healthy and varied diet (5.7)	0.000	0.275	0.731	0.969
6. AD ate less (6.9)	0.000	0.119	0.801	0.979
10. C&A ate less (3.4)	0.000	0.017	0.553	0.979
11. C&A cut meal size (3.3)	0.000	0.024	0.529	0.983
5. AD skipped meal (4.1)	0.000	0.022	0.394	0.917
7. AD felt hungry (3.6)	0.000	0.008	0.303	0.959
12. C&A skipped meal (1.8)	0.000	0.002	0.121	0.963
8. AD ate ≤1 meal/d (2.9)	0.000	0.010	0.223	0.808
13. C&A felt hungry (1.6)	0.000	0.002	0.092	0.904
14. C&A did not eat all day (1.3)	0.000	0.002	0.048	0.764

[1] Values are estimated conditional (on class membership assignment) endorsement probabilities per item; *n* values represent model-based counts encompassing clustering and sampling weights. AD, adults aged ≥18 y; C, class; C&A, children and/or adolescents <18 y of age; EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Food Insecurity Measurement Scale); LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey).
[2] Each item refers to conditions experienced during a 3-mo period before the survey application, due to a lack of resources to purchase food. Items are ordered according to their estimated scalar intensities (i.e., increasing b_i item-response theory parameters as modeled in the confirmatory factor analysis presented in Supplemental Table 1). Raw percentage endorsements are shown in parentheses.

TABLE 4 Percentages of families classified according to the EBIA model-based and traditional cutoffs, by food insecurity latent class membership identified through the best LCFA 1-factor, 4-class model in the national sample: Brazil, PNAD-2013[1]

	EBIA classification							
Latent	Using model-based cutoffs[2]				Using traditional cutoffs[3]			
classes (FI)	None	Mild	Moderate	Severe	None	Mild	Moderate	Severe
Brazil								
C1	83.16	0	0	0	77.41	5.75	0	0
C2	0	10.15	0	0	0	8.83	1.32	0
C3	0	0.28	3.93	0.18	0	0.2	3.25	0.93
C4	0	0	0.04	2.26	0	0	0.003	2.3
North								
C1	71.69	0	0	0	63.93	7.75	0	0
C2	0	14.86	0	0	0	13.4	1.47	0
C3	0	0.57	7.53	0.86	0	0.47	6.25	2.24
C4	0	0	0.08	4.41	0	0	0.02	4.47
Northeast								
C1	69.66	0	0	0	61.94	7.71	0	0
C2	0	17.9	0.06	0	0	15.5	2.47	0
C3	0	0.55	7.63	0.21	0	0.42	6.41	1.57
C4	0	0	0.06	3.93	0	0	0.01	3.98
Southeast								
C1	90.05	0	0	0	85.51	4.54	0	0
C2	0	6.31	0	0	0	5.52	0.79	0
C3	0	0.15	2.0	0.12	0	0.11	1.63	0.53
C4	0	0	0.03	1.34	0	0	0.002	1.37
South								
C1	90.09	0	0	0	85.09	5.0	0	0
C2	0	6.37	0.06	0	0	5.44	0.99	0
C3	0	0.2	1.92	0.29	0	0.1	1.5	0.81
C4	0	0	0.005	1.07	0	0	0	1.07
Midwest								
C1	87.28	0	0	0	81.81	5.47	0	0
C2	0	8.41	0	0	0	7.1	1.31	0
C3	0	0.14	2.46	0.08	0	0.11	1.92	0.65
C4	0	0	0.03	1.6	0	0	0	1.63

[1] C, class; EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Food Insecurity Measurement Scale); FI, food insecurity; LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey).
[2] Cutoffs for families with children and/or adolescents: 1/2, 5/6, and 10/11; adult-only families: 1/2, 4/5, and 6/7.
[3] Cutoffs for families with children and/or adolescents: 0/1, 5/6, and 9/10; adult-only families: 0/1, 3/4, and 5/6.

mostly represented by endorsements for items 1, 3, 4, 2, and 9, respectively. In contrast, item probabilities are low in the first class, except for items 1 and 3, which show response probabilities of 0.052 and 0.008, respectively. This profile is consistent with an interim analysis showing, for instance, that in households with children and/or adolescents attaining an overall raw score of 1, 76.8% and 9.2% of households endorsed either item 1 or item 3, respectively.

Table 4 shows the cross-classification between the specified latent classes (C1–C4) and two 4-level variables grouped according either to the model-based cutoffs (columns 2–5) or the traditionally used cutoffs (columns 6–9). The related degree of reclassification (C-error) and quadratic weighted κ-coefficients for Brazil and macroregions are shown in **Table 5**. The grouping procedure founded on the model-based approach uniformly used the cutoffs obtained for the Brazilian aggregate sample. This approach not only is justified by the low degree of misclassification obtained when applied to the macroregions, but also allows an assessment of how much would be missed overall by using a universal criterion for classifying families. In tandem, the 2 tables showed that the degree of reclassification when using the model-based cutoffs is lower than the classification traditionally proposed. The proportion in the model-based grouping never exceeds 1.5% (North), resulting in κ-coefficients close to 1 in all strata. Yet, few disagreements are noticeable in C2 (Northeast and South) or in C3 and C4 (Brazil and all the macroregions).

With regard to the traditionally used classification of the EBIA, the pattern for C2, C3, and C4 did not differ much from the pattern obtained with the model-based cutoffs, but was substantially different at the lower end (C1) for Brazil and in each of the 5 macroregions. Reclassification in C1 was 6% in the aggregate sample data and reached ∼8% in the North and Northeast regions. Consistent with this, the crude errors were higher and κ values lower than those obtained when classifying the groups via modeling.

Discussion

This study applied a latent class modeling approach to a nationally representative sample of households to determine the proper raw score cutoffs of EBIA to classify households according to their level

TABLE 5 Misclassification and agreement between the model-based cutoffs and the traditional cutoffs of the EBIA, based on food insecurity latent class membership identified through the best LCFA 1-factor, 4-class model in the national sample and by macroregion: Brazil, PNAD-2013[1]

	EBIA			
	Using model-based cutoffs[2]		Using traditional cutoffs[3]	
Country or region	C-error[4]	κ Coefficient (95% CI)[5]	C-error[4]	κ Coefficient (95% CI)[5]
Brazil	0.50	0.983 (0.981, 0.984)	8.20	0.756 (0.751, 0.761)
North	1.51	0.968 (0.964, 0.972)	11.95	0.757 (0.745, 0.770)
Northeast	0.88	0.981 (0.979, 0.983)	12.18	0.763 (0.754, 0.771)
Southeast	0.30	0.984 (0.981, 0.987)	5.98	0.730 (0.718, 0.742)
South	0.56	0.970 (0.965, 0.976)	6.90	0.694 (0.677, 0.711)
Midwest	0.25	0.989 (0.985, 0.993)	7.54	0.726 (0.709, 0.744)

[1] C-error, percentage of families misclassified (or reclassified); EBIA, Escala Brasileira de Insegurança Alimentar (Brazilian Food Insecurity Measurement Scale); LCFA, latent class factor analysis; PNAD, Pesquisa Nacional por Amostra de Domicílios (Brazilian National Household Sample Survey).
[2] Cutoffs for families with children and/or adolescents: 1/2, 5/6, and 10/11; adult-only families: 1/2, 4/5, and 6/7.
[3] Cutoffs for families with children and/or adolescents: 0/1, 5/6, and 9/10; adult-only families: 0/1, 3/4, and 5/6.
[4] Sum of off-diagonal percentages shown in Table 4.
[5] Quadratic-weighted values obtained via bootstrap (B = 1000) by using the Stata routine bootstrap (54), including clustering and sampling weights.

of severity of food insecurity. Results from the LCFA supported 4 classes, with a very high degree of separation. With regard to the group-separating cutoffs, results show that the first level should include households with ≤1 positive answer in the overall raw score of the scale. This was the most notable difference from the cutoffs currently in use, whereby households with 1 affirmative answer are considered mildly food insecure.

These findings are consistent with those found in our previous study in the State of Rio de Janeiro that applied the same methodology (39). In that local sample, the specified cutoffs were 1/2, 5/6, and 10/11 for households with children and/or adolescents and 1/2, 3/4, and 5/6 for adult-only households. Although the same cutoffs emerged in the national sample in households with children and/or adolescents, 2 of 3 cutoffs for households confined to adults were set a little higher (4/5 and 6/7). However, these cutoffs are likely equivalent because Reichenheim et al. (39) used a slightly different version of the EBIA (32), which contained 1 less adult item. Although in this version, item 4 (on having to limit one's diet to a few types of food due to money shortage) referred specifically to the children and/or adolescents living in the households, in the current study it relates generically to all household members. An ancillary analysis on the national data excluding item 4 from the adult-only scale (as in Table 2) shows the same cutoffs for adult households specified in the first study (39) (data not shown).

The present study also considered the identification of EBIA cutoffs by region to evaluate possible inconsistencies in scale functioning due to sociocultural and economic disparities. These analyses uncovered some discrepancies at the higher end of the scale (C4) in the North, South, and Midwest compared with the cutoffs identified in the other 2 regions and the national data. In principle, this could suggest the need for specific model-based cutoffs by region. However, results also indicate that the percentage of families misclassified when using the cutoffs identified for the entire country was quite small. Because this level of reclassification would be inconsequential from a quantitative perspective, pragmatically, it may be sensible to use a single set of cutoffs overall, including for regions. A common set would not only cover most of the cutoffs identified across strata but, in addition, induce a favorable conservative reclassification. This is because specifying the most severe empirical food-insecurity group with lower limits would tend to include more vulnerable families. These at-risk families would otherwise be left out of immediate assistance if more restrictive cutoffs were chosen in some macroregions.

A third grouping proposition with the use of a 3-class model might also be offered, given the fit assessments. Joining the moderate and severe levels has been accepted in some analytical circumstances throughout the EBIA's history (6, 29, 31, 56). Nevertheless, models 3k and 4k do not seem to differ substantively. In addition, consideration of a 4k model may improve sensitivity, allowing for more families to be monitored or even singled out for immediate intervention. A 4-tiered classification would enable distinguishing an extremely vulnerable population (C4) prone to overt quantitative food shortages and their negative consequences. Put into perspective, this group corresponds to 2.26% of Brazilian households (Table 4). After the PNAD-2013's expansion fraction is applied, ~1.47 million families would be projected to experience the most severe form of food insecurity in 2013.

Notably, at the opposite end of the spectrum, any latent class (LCFA) model leads to the same decision with regard to the classification of families. The cutoff of 1/2 separating C1 from C2 seems consistent and unequivocal and has now been replicated in 2 independent studies, one local and one national. Findings emphasize that families with a raw score of 1 are closer to those who score 0, which means that they should not be considered as having mild food insecurity but as having food security. As extensively discussed in the earlier study by Reichenheim et al. (39), and corroborated in the current study, either being worried that food will run out or going through some qualitative restriction with regard to the variety of available food does not necessarily imply that families are classified as insecure. However, in most cases, these less-severe items would have to be jointly endorsed to classify families as such. It is worth noting that reclassifying families from mild food insecurity to food security would mean that 5.75% of households (Table 4) would now be regarded as at very low risk of food insecurity rather than as under some level of food-related stress. Once again applying the PNAD's expansion fraction, this would entail not less than 3.74 million Brazilian households. Therefore, reclassifying families has far-reaching implications from a public health stance, because policies and actions to promote food security may now be refocused on families actually at risk of experiencing food insecurity, be it due to shortage or an outright absence of food.

In terms of the latent spectrum analogous to what experts regard as moderate and severe food insecurity, classes obtained through the model-based approach confirm the traditional cutoffs for these categories. This is a highly relevant finding that not only replicates previous findings (39) but also provides strong, nationally representative evidence to support 2 of the 3 cutoffs previously recommended for EBIA on the basis of >10 y of EBIA's qualitative and quantitative studies and numerous expert meetings (20, 21, 24–26, 31).

Indeed, the present findings broadly overlap with those found in the previous study (39). This is quite reassuring considering that the current study involving a nationally representative sample based on 116,543 households replicates this former local study. On one hand, the results reinforce the robustness of the EBIA in its ability to capture the construct of household food insecurity (21, 24, 26). On the other hand, they ratify the appropriateness of the current methodologic approach with regard to its capacity to separate homogeneous groups representing different levels of food insecurity. As shown in this study, the recommendation by Reichenheim et al. (39) to consider reclassifying the reference food security and the mild food insecurity category may be justified.

Following the guidelines proposed by Mokkink et al. (57), a critical step forward should be to assess construct validity via hypothesis testing, contrasting key correlates of food insecurity (e.g., socioeconomic and demographic indicators, infants' and children's food intake) with other classification formats proposed so far, not least the model-based classification emerging in this study. Recognizing that there is a global initiative of using only 8 general or adult items (2), another recommendation would be to apply the modeling strategy to only the 8 EBIA items answered by all households, regardless of their demographic composition. This would enable verification of how classifying households with children and/or adolescents by means of just 8 general items would compare with the current (usual) approach that encompasses specific items as well. If equivalent, opting for a smaller version of the EBIA when desirable would be warranted.

The findings first presented by Reichenheim et al. (39) and endorsed in this study show that, although the cutoffs for the classification of families into food security categories are reasonable overall, they may be refined, especially with regard to the food security category. In consideration of this new evidence, it is hoped that this finding may assist food security experts and policymakers to decide on the most appropriate EBIA cutoffs, and contribute not only to the further improvement of the scale as a tool for research and evaluation of household food insecurity programs but also to strengthening food security governance at all levels (58). Moreover, countries with similar food security experience scales should be encouraged to apply the current methodologic approach to assess the appropriateness of their classification system.

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