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Cognition of Women about the Combination of Foods to Make Iron Bioavailable in the Diet: A Confirmatory Factorial Study

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Authors' contributions

This work was done in collaboration between both authors. Author HSL designed the study, performed the analysis and wrote the first draft of the manuscript. Author MEB supervised the study and analysed the data. Both authors managed the literature search writing of the final manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Objective: to validate an instrument designed to assess the knowledge of adult women about combining foods to make dietary iron more bioavailable.
Design Study: cross-sectional, Confirmatory Factor Analysis (CFA).
Place and Duration: Rio de Janeiro, Brazil, May 2018 and February 2019.
Methodology: sample: n=222 women 15 to 49 years old, not pregnant. The questionnaire was designed on Likert scale. Kaiser-Meyer-Olkin (KMO) and Doornik-Hansen tests were applied, as well as the AFC models with Promax rotation. Convergent validity (CV) and discriminant validity (DV) and reliability (Cronbach's alpha) were evaluated.
The Quality of Model Fit was Assessed by: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI). The dimensional structure of the questionnaire was reevaluated by Structural Equation Modeling (Modification Indices (MI) and Expected Parameter Changes (EPC).
Results: Initial model: total KMO 0.75 (min = 0.63, max = 0.84), Doornik-Hansen (chi2 (30) = 208.91, P = .00), eigenvalue (F1 = 2.87 and F2 = 1.98), CV not reached (F1: AVE = 0.30 and F2:

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AVE = 0.21) and DV corroborated, Conbrach alphas reached for 0.75 inhibitory items (95% CI = 0.69 to 0.81), for stimulators: 0.62 (95% CI = 0.51 to 0.70), RMSEA = 0.10 (90% CI = 0.08 to 0.11), CFI (0.70), TLI (0.65), items with MI>10 (i16I, i23E, i25E, i28E). Re-specified Model: eigenvalue (F1 = 2.44 and F2 = 1.42), CV not reached (F1: AVE= 0.29 and F2: AVE=0.20) and corroborated DVI, Conbrach alphas: for 0.75 inhibitory items (95% CI = 0.69 to 0.81); stimulators items: 0.55 (95% CI = 0.44 to 0.64), RMSEA = 0.03 (90% CI = 0.00 to 0.06), CFI (0.95), TLI (0, 94). The items did not show MI>10.

Conclusion: The reliability was achieved in both models. Validities: convergent was not achieved and the discriminant attested two-dimensionality.

Keywords: Questionnaire design; iron deficiency; biological availability; factor analysis; statistical.

1. INTRODUCTION

In developed countries, the prevalence of iron deficiency anemia varies between 2% and 8%. However, the prevalence of iron deficiency, including anemic and non-anemic individuals due to the absence of iron stores or subnormal serum ferritin values, reaches a prevalence of 20-30% of women in fertile age. One of the strategies recommended by the World Health Organization (WHO) is food and nutrition education to improve the amount of iron absorbed from the diet, improving its bioavailability. Particularly in adult women (18 years or more; 62 kg body weight), the requirement for iron (mg / day; P95) according to the 15% bioavailability; 12%; 10% and 5% is 19.6 mg; 24.5 mg, 29.5 mg and 58.8 mg respectively [1].

The proposal this study to create a questionnaire to assess women's knowledge on how to combine foods to make dietary iron bioavailable can contribute to nutritional education strategies.

2. IRON BIOAVAILABLE IN THE DIET

Dietary iron consists of heme iron (red meat, offal, fish, poultry) and non-heme iron (dark green leafy vegetables, fruits, grains, dried fruits, molasses, egg) [2]. The mixed diets provide about 90% of non-heme iron [3] and the remainder is non-heme iron from foods of animal origin (in non-vegetarian diets). The heme iron content of meat comes from hemoglobin and myoglobin and varies considerably [4].

Studies have been conducted administering single meals marked with radioisotopes or stable isotopes for individuals after a fast and showed stimulating and inhibiting effects on iron absorption.

Among the stimulators are ascorbic acid (orange, lemon, tangerine, acerola, guava, kiwi, strawberry, gojiberry, cranberry, cashew, pepper, broccoli, Brussels sprouts) and muscle tissue (meat, poultry and fish). Among the inhibitors, phytate (soy, flaxseed, barley, black beans, lentils, bean sprouts, dry peas, grains, oats, corn, peanuts, cereal bran, whole wheat flour, chickpeas, brown rice, sesame, chestnut, almonds, cocoa, nuts, soybeans, whole grains, whole flours, bran, multimixtures and legumes seeds); polyphenolic compounds (tea, coffee, cocoa, red wine, spinach, eggplant, sorghum, grain products, oregano and other spices); tannic acid (in grapes, cloves, pomegranates, apples, pears, wines), oxalic acid (in almonds, cashews, buckwheat, sesame seeds, tea, coffee, chocolate, textured soy protein, beets, tomatoes, spinach, carambola, whole grains of rice, wheat, rye, oats, barley, corn) and caffeine (in matte, green and black teas, guarana, coffee, cola-type soft drinks, energy and chocolate drinks, supplements); calcium (milk and other dairy products) [2,5,6].

Collings et al. [7] carried out a systematic review study that measured the absorption of non-heme iron in complete diets, which include different meals. There was a wide variation in the reported absorption values (0.7–22.9%). It was clear that the diet had a greater effect on absorption, when the iron level was low and the absorption was greater in the presence of one or more stimulators, but the effect of inhibitors was less clear. Regression equations allowed to predict that the absorption of non-heme iron in individuals was 10.8% with serum ferritin of 12 μg/ L and consuming a standard diet; increased to 13.9% in diets with higher bioavailability and decreased to 8.4% in diets with lower bioavailability.

Fortifying iron, commonly added to cereals and infant foods, is usually an iron salt or elemental iron and the percentage of absorption varies greatly depending on the chemical form and solubility in the gastrointestinal tract and the composition of the food consumed at the same time. The technological challenge related to the production of foods fortified with iron and food ingredients is to identify a form of iron that, when added in sufficient quantity, provides enough bioavailable iron to meet physiological needs and immunity. Inorganic iron salts are generally used to fortify food products such as fluid milks, yoghurts, powdered foods and long-life drinks. However, it is important that the iron of the fortified food be evaluated before that the new fortifier be included in foods to enrich diets with iron [8].

It is not enough that the diet is rich in iron, it is necessary to make appropriate combinations between foods to maximize the absorption of iron from the diet and reduce the risk of iron deficiency and anemia. A questionnaire that allows a diagnosis of women's knowledge about the best way to combine food to make the iron bioavailable can contribute to realize interventions as well as replications of studies to be carried out in other contexts, considering that there are few studies that use factor analysis to validate instruments in the field of nutrition and food.

Given the above, the objective of the study was to validate an instrument designed to assess the knowledge of adult women about combining foods to make dietary iron more bioavailable.

3. METHODOLOGY

This is a cross-sectional study of Confirmatory Factor Analysis (CFA) of a questionnaire to assess the cognition of women about how to combine foods to make dietary iron available. The questionnaire derived from an exploratory study [9] and has two dimensions: “stimulators of iron absorption in the diet” (S) and “inhibitors of iron absorption in the diet” (I), Table1.

Participants of the study were adult women living in two municipalities in the state of Rio de Janeiro (Rio de Janeiro and Niterói) (RJ), between May 2018 and February 2019. The calculation of the sample size took into account the prevalence of anemia of 29.4%, data obtained in research with 5,698 women aged 15 to 49 years non-pregnant [10], confidence level of 90% and error estimate of 5%. The sample was 222 adult women of fertile age.

The questionnaires were applied by a trained Nutrition student from September 2018 to January 2019. Participants informed their personal data and education levels and received instructions on how to complete the questionnaire.

The measurement evidence was based on the investigation of the psychometric properties of the questionnaire. It was presented on a Likert scale with five response options: I strongly disagree (1), disagree (2), I neither disagree nor agree (3), I agree (4) and I strongly agree (5). The construct was defined as “knowledge about the combination of foods to make the iron more bioavailable in the diet” and was operated by two dimensions: “stimulators of iron absorption in the diet” (S) and “inhibitors of iron absorption in the diet” (I).

The Kaiser-Meyer-Olkin test (KMO) verified the adequacy of the sample, using a cutoff point of 0.50 [11]. The latent structure of the questionnaire was evaluated by the Confirmatory Factor Analysis (CFA) [12] and the Doornik-Hansen test for multivariate kurtosis [13] tested the multivariate normality of the item scores, necessary for the CFA model. The factor extraction was performed using the Principal Factor Analysis (PFA) method, constrained to two factors, using the likelihood ratio (LR) estimator and Promax oblique rotation. The Kaiser Guttman criterion (factors with eigenvalue>1) and the theoretical assumptions were used to confirm or deny the two-dimensionality of the instrument. It were inferred as satisfactory items those with factorial loads (λ) greater than 0.40. Items with crossed loads, that is, similar in two or more factors in the same item or whose difference between loads was less than 0.10 [14] were rigorously evaluated in their semantics about the theoretical assumptions [12]. Variance of the error (δ) equal to or less than 0.50 was considered plausible [15]. The correlation between the factors (dimensions) low (<0.30) and positive direction indicated dimensions of different meanings; if negative, permanence of the factor; whether low / positive or low / negative, content non-discriminatory of the items [12]. The convergent validity (CV), which assesses the amount of variance captured by a common factor in relation to the amount of variation due to random measurement error [15], was assessed by the Average Variance Extracted (AVE) [16,17]. The AVE value equal to or greater than 0.50 indicates that the items share a high variance in common [18]. The discriminant validity (DV) was given by the square root of the AVE. If the DV of a factor is greater than the correlations between it and the other factors, the DV is corroborated [15]. Cronbach's alpha measured the reliability. According Pasquali [19], alpha values around 0.70 are considered satisfactory.

The Quality of Model Fit (MF) was assessed by: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI). RMSEA values below 0.06 suggest adequate adjustment, while values above 0.10 indicate inadequate adjustment and in this case the model must be re-specified. The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) vary from zero to one and values greater than 0.9 are indicative of adequate adjustment [12].

When a model is not well adjusted or may have plausible alternative dimensional structures, there is the possibility of re-exploring the dimensional structure of the questionnaire [20], using Structural Equation Modeling (SEM) [21, 22]. Then the residual item correlations (error) can also be evaluated according to conditional dependencies and, consequently, indicate possible impediments of these. For such inspection, Modification Indices (MI) and Expected Parameter Changes (EPC) were used. An MI reflects how much the model's overall chi-square decreases if a constrained parameter were freely estimated. Correlations between item measurement errors involving MI values equal to or greater than 10 were examined in more detail, as well as the magnitude of the corresponding Expected Parameter Changes (EPC) for freely estimated parameters [12]. The method used to obtain adjusted parameters was the maximum likelihood, the standard method used for SEM and the theoretical meaning of the items was also considered to assess the questionnaire construct and the number of factors.

Data analysis was performed using the STATA version 12 software [23].

Table1. The questionnaire to evaluate the knowledge of adult women on combining foods to make iron bioavailable in the diet

items	Designation
i2-S	Always give as dessert a fruit, because it contains vitamin C that helps in the absorption of iron in the body.
i5-I	Do not consume mate drink at lunch and dinner because it contains substances that impair the absorption of iron from food.
i8-I	Do not drink yogurt after lunch and dinner, because the calcium in this food competes with the iron contained in vegetables.
i9-I	Do not eat calcium-rich foods, such as milk and cheese, before or after large meals (lunch and dinner).
i11-S	Eat the vegetables together with the meat, because the iron contained in the meat helps in absorbing the iron contained in the vegetables, but don't forget to eat fruits for dessert.
i14-I	Do not lay egg on spinach because spinach contains substances that hinder the absorption of iron from the egg.
i15-I	Do not eat milk pudding as a dessert because the calcium present hinders the absorption of the iron in the meal.
i16-I	Do not drink coffee after lunch or dinner; this will hinder the absorption of iron.
i17-S	Eat green vegetables in the diet because they are rich in iron.
i18-S	Eat fruits as a dessert because they improve the absorption of dietary iron
i19-S	Eat meat, chicken, fish or egg twice a day (lunch and dinner) in order to reduce the risk of anemia.
i21-I	Do not drink milk or milk derivatives as a dessert for lunch and dinner to avoid impairing iron absorption.
i23-S	Increase consumption of fruits rich in vitamin C to improve iron absorption in meals.
i25-S	Avoid drinking tea, mate and coffee during and immediately after meals to promote iron absorption.
i28-S	Drink juices of citrus fruits like orange, acerola and lemon, because these are rich in vitamin C and help to improve the absorption of iron from food at lunch and dinner.

S: stimulators of iron absorption. I: iron absorption inhibitors Source: [9]

4. RESULTS AND DISCUSSION

The questionnaire was answered by 201 adult women in fertile age, covering 90.54% of the planned sample. The women had an average age of 31 years (SD=13.4), the most expressive schooling was incomplete 3rd grade (66.67%), followed by complete 3rd grade (26.37%) and other levels of education (6.97%).

The input matrix of the scores given by the participants showed a total KMO value of 0.75 (minimum=0.63, maximum=0.84), demonstrating the adequacy of the sample.

The value of *P* <.05 for the Doornik-Hansen test (chi^2 (30) = 208.91, *P* > chi^2=0.00) showed normality of the item scores, allowing to continue the factorial model.

In the initial model, the input matrix was subjected to CFA constrained by two factors and Promax oblique rotation and presented eigenvalues that confirmed the questionnaire's two-dimensionality (Factor1=2.87 and Factor2=1.98). The proportion of the variance explained 0.64 and 0.44 of the latency of the construct "Knowledge about food combination to make iron more bioavailable in the diet" for Factor1 and Factor2, respectively. The items allocated to Factor 1 were: i-5I, i-8I, i-9I, i-15I and i-21I, whose are characterized as inhibitors of iron absorption and the item i-25S, as stimulator.

The item i25S ("Avoid drinking tea, mate and coffee during and immediately after meals to promote iron absorption"), had an expressive factor load (λ= 0.55), but presented a high error variance (δ=0, 64), possibly because it did not present a clear semantics. This suggests that it can be removed and the model may be re-specified (Table 2). The Factor 2 allowed the inclusion of items i-18S, i-23S and i-28S, which reflect combinations of foods that favor the absorption of iron. Observing the error variances, only item i-18S showed a high error variance (δ=0, 70). In this model cross-loading was identified in two items: a) i-14I ("Do not lay egg on spinach because spinach contains substances that hinder the absorption of iron from the egg.") (F1: λ=0.27, F2: λ=0.18, δ=0.85); b) i-19S ("Eat meat, chicken, fish or egg twice a day (lunch and dinner) in order to reduce the risk of anemia.") (F1:λ=0.10, F2:λ=0.17, δ=0.94). These results indicate the removal of items from the model, being corroborated by the high error variances (Table 2).

According to the results of this model, there were possible items to be removed: i-16I "Do not drink coffee after lunch or dinner, as this will hinder the absorption of iron" (F1: λ = 0.39, δ = 0, 76), i-2S "Always give as dessert a fruit, because it contains vitamin C that helps in the absorption of iron in the body." (F2: λ = 0.38, δ = 0.81), i-11S "Eating the vegetables together with the meat, as the iron contained in the meat helps in absorbing the iron contained in the vegetables, but don't forget to eat fruits in dessert "(F2: λ = 0.21, δ = 0.94), i-17S" Eat green vegetables in the diet because they are rich in iron "(F2: λ = 0.26, δ = 0.92) .

The item i16I cannot be removed for reasons of theoretical plausibility, once the caffeine interferes with the bioavailability of iron.

Items i-2S and i-11S must remain, but it must be clarified that the fruits mentioned in the proposition are sources of vitamin C, changing the wording of both to: "Always give a fruit rich in vitamin C, which helps in the absorption of iron in the body and "Eating vegetables together with meat, as the iron contained in meat helps in absorbing the iron contained in vegetables, but don't forget to eat fruits rich in vitamin C for dessert" respectively. Similarly, item i-17S loses theoretical plausibility due to a lack of detail in the specification of leafy vegetables, for which it should be specified as being dark green. Consequently, semantic change was suggested, with the following wording: "Eat dark green vegetables because they are rich in iron" (Table 2).

In this initial model, the convergent validity was not achieved for both factors (F1:VME = 0.30 and F2:VME = 0.21) but since the correlation between the factors F1 and F2 was negative (-0.29), this allows corroborating the discriminate variance. This finding suggests the existence of two factors for the construct, that is, a two-dimensional factorial model (Table 2).

Evaluating the internal consistency of the questionnaire, Cronbach's alpha reached for inhibitory items: 0.75 (95% CI = 0.69 to 0.81) and for stimulating items 0.62 (95% CI = 0.51 to 0, 70). According to Pasquali [19], the Factor 2 that presents stimulating items did not show robust Cronbach's alpha at its lower limit. Regarding the total reliability of the questionnaire, the value reached 0.75 (95% CI = 0.70 to 0.81), considered satisfactory. Regarding the quality of the model's fit, the RMSEA with a value of 0.10

(90% CI = 0.08 to 0.11) indicated an inadequate adjustment. However, CFI (0.70) and TLI (0.65) did not reach values that corroborate an adequate adjustment, in view of the need for values greater than 0.90 (Table 2).

The MI in the initial model was less than 10, showing correlations between acceptable item measurement errors, with the exception of items i25S (39.81); i28S (16.54); covariance between the items: i16I-i25S (60.33) and i23S-i28S (13.64). Some omitted paths have been identified, since the paths are listed only if the MI is significant (P= .05), corresponding to the 3.84 chi-square. The omitted pathways between foods that stimulate the absorption of iron and those that inhibit it, which had the greatest change in the observed chi-square were those with EPC of 0.51 (i25S) and EPC of -0.29 (i28S) and those with covariance 0.55 (i16I - i25S) and -0.90 (i23S - i28S). These findings revealed the relaxed restriction correlation value, that is, the reported value for the correlation path if the parameter was not constrained to zero (Table 3).

Examining the MI (Table 3), it can be seen that the item i25S (MI = 39.81) and the covariance between it and the item i16I (MI = 60.33) greatly exceeds the value 10, recommended for adjusting the item, considering all paths omitted. Once again, it is understood that the semantics of item i25S impaired its understanding, as previously verified. It is noteworthy that the item i16I had an MI of 6.74, however, when covariant with the i25S, the MI reached a value of 60.33. It is possible to infer that the i25S does not contribute to the construct (Table 3).

The covariance between i23S ("Increase consumption of fruits rich in vitamin C to improve iron absorption in meals.") and i28S ("Drink juices of citrus fruits like orange, acerola and lemon, because these are rich in vitamin C and help to improve the absorption of iron from food at lunch and dinner.") presented MI of 13.64. These items show semantics with the same assumptions for the combination of foods, considering the bioavailability of dietary iron. The EPC of the covariance of these items, with a value of -0.90, reinforced the similarity between the semantics of the items; however, i28S points out the fruits are rich in vitamin C (Table 3).

In the re-specified model, excluding items i23S and i25S, the items were distributed in the two dimensions previously established with eigenvalues F1= 2.44 and F2= 1.42 and with a proportion of the explained variance of 0.67 and 0.39, respectively. In this model, Factor 1 shows the items: i5I, i8I, i9I, i15I, i21I and Factor 2: i2S, i18S and i28S. The item i14I presented a cross load (F1: λ = 0.24 and F2: λ = 0.23), similarly, the item i16I (F1: λ = 0.27 and F2: λ = 0.22). Regarding the error variance, these items showed extremely high values (i14I: δ = 0.85 and i16I: δ = 0.84). However, for the i16I ("Do not drink coffee after lunch or dinner; this will hinder the absorption of iron."), its permanence in the questionnaire is reaffirmed given the theoretical plausibility considering that caffeine is an iron inhibitor. The items i11S (F2: λ = 0.34, δ = 0.87) ("Eat the vegetables together with the meat, because the iron contained in the meat helps in absorbing the iron contained in the vegetables, but don't forget to eat fruits for dessert."), i17S (F2: λ = 0.25, δ = 0.92) (Eat green vegetables in the diet because they are rich in iron.) and i19S (F2: λ = 0.23, δ = 0.93) (Eat meat, chicken, fish or egg twice a day (lunch and dinner) in order to reduce the risk of anemia.") had low factor loads, high error variance. Item i11S (F2: λ = 0.34, δ = 0.87), despite the measurement evidence, must remain in the questionnaire justified by theoretical plausibility. Likewise, the i17S (F2: λ = 0.25, δ = 0.92) remains, but requires semantic changes as previously proposed. The semantics suggested in this item (Eating dark green vegetables because they are rich in iron) was reiterated. Regarding i19S, its permanence is indicated, however with semantic alteration that is, excluding the word "egg", because the egg has non-heme iron, practically not bioavailable in the body. Item i19S is worded as follows: "Eat meat, chicken and fish twice a day (lunch and dinner) in order to reduce the risk of anemia" (Table 2).

The convergent validity was not reached (F1: VME = 0.29 and F2: VME = 0.20) and the correlation between the factors was negative (-0.18), suggesting the existence of two factors for the construct; which corroborates the discriminating validity of the questionnaire (Table 2).

Assessing the internal consistency of the questionnaire, Cronbach's alpha reached for the inhibitor items: 0.75 (95% CI = 0.69 to 0.81) and for stimulators: 0.55 (95% CI = 0.44 to 0, 64). Regarding total reliability, Conbrach's alpha reached 0.70 (95% CI = 0.64 to 0.78), considered acceptable [19] (Table 2). These findings indicate the need for further confirmatory studies with similar groups (Table 2).

Table 2. Confirmatory Factor Analysis of the "Questionnaire to assess the cognition of adult women about the bioavailability of iron in the diet". Rio de Janeiro and Niterói, RJ, 2019, (n=201)

Principal Factor Analysis constrained to two factors, Promax Rotation							
Initial model (*)				Re-specified model (**)			
Factor	**Eigenvalue**	**Expl Var**	**Error var**	**Factor**	**Eigenvalue**	**Expl Var**	**Error var**
F1	2.87	0.64		F1	2.44	0.67	
F2	1.98	0.44		F2	1.42	0.39	
Item	**F1** λ	**F2** λ	δ	**Item**	**F1** λ	**F2** λ	δ
i-5I	0.58	-0.11	0.68	i-5I	0.54	-0.03	0.71
i-8I	0.67	-0.14	0.58	i-8I	0.70	-0.10	0.53
i-9I	0.70	-0.08	0.53	i-9I	0.72	-0.06	0.49
i-14I	0.27	0.18	0.85	i-14I	0.24	0.23	0.85
i-15I	0.61	-0.04	0.63	i-15I	0.64	-0.06	0.60
i-16I	0.39	0.18	0.76	i-16I	0.27	0.22	0.84
i-21I	0.68	0.02	0.52	i-21I	0.69	0.05	0.49
i-2S	0.10	0.38	0.81	i-2E	0.07	0.49	0.72
i-11S	0.06	0.21	0.94	i-11E	0.01	0.34	0.87
i-17S	0.04	0.26	0.92	i-17E	0.05	0.25	0.92
i-18S	-0.12	0.57	0.70	i-18E	-0.13	0.59	0.67
i-19S	0.10	0.17	0.94	i-19 E	0.04	0.23	0.93
i-23S	0.07	0.67	0.50	i-28E	-0.12	0.56	0.70
i-25S	0.55	0.10	0.64				
i-28S	-0.16	0.77	0.45				
Validity				**Validity**			
Convergent	AVE	F1: 0.30	F2: 0.21	Convergent	AVE	F1: 0.29	F2:0.20
Discriminant	Raiz AVE			Discriminant	Raiz AVE		
		F1: 0.55	F2: 0.45			F1: 0.53	F2:0.45
Correlation between factors				**Correlation between factors**			
	F1	**F2**			**F1**		**F2**
F1	0.95	0.57		F1	0.98		0.46
F2	-0.29	0.81		F2	-0.18		0.88
Reliability – Cronbach's alpha				**Reliability – Cronbach's alpha**			

I	S	Total	I	S	Total
0.75 CI 95% (0.69-0.81)	0.62 CI 95% (0.51-0.70)	0.75 CI 95% (0.70-0.81)	0.75 CI 95% (0.69-0.81)	0.55 CI 95% (0.44-0.64)	0.70 CI 95% (0.64-0.78)
Quality of Model Fit			**Quality of Model Fit**		
RMSEA	0,10 (CI 90%:0.08 – 0.11)		RMSEA	0,03 (CI 90 %: 0.00-0.06)	
CFI	0.70		CFI	0.95	
TLI	0.65		TLI	0.94	

Note. F: factor, S: stimulators of iron absorption, I: iron absorption inhibitors, expl var: explained variance, error var: variance of error (δ), λ: factorial loads, AVE: average variance extracted, CI: confidence interval, CV: convergent validity, Root (AVE)= DV: discriminant validity , RMSEA: Root Mean Square Error of Approximation, CFI: Comparative Fit Index, TLI: Tucker-Lewis Index.

(*) LR test: independent vs. saturated: chi2(105) = 716.74 Prob>chi2 = 0.0000; (**) LR test: independent vs. saturated: chi2(78) = 439.47Prob>chi2 = 0.0000

Table 3. Modification Indices (MI) e Expected Parameter Changes. (EPC) do "Questionnaire to assess the cognition of adult women about the bioavailability of iron in the diet". Rio de Janeiro and Niterói, RJ, 2019, (n = 201)

Initial model				Re-specified model			
Measurement	**MI**	**P>MI**	**EPC†**	**Measurement**	**MI**	**P>MI**	**EPC†**
i14I stimulators	4. 76	0.03*	0.17	i14I stimulators	5.09	0.02*	0.20
i16I stimulators	6.74	0.01*	0.21	i16I stimulators	4.53	0.03*	0.19
i25E inhibitors	39.81	0.00*	0.51	Covariance e.i5I e.i18E	4.42	0.04*	-0.17
i28E inhibitors	16.54	0.00*	-0.29	e.i8I e.i18E	5.16	0.02*	-0.19
Covariance e.i5I e.i25E	8.33	0.00*	0.21	e.i14I e.i16I e.i11E	6.99 3.88	0.01* 0.05*	0.19 0.14
e.i14I e.i16I e.i11E	6.79 4.51	0.01* 0.03*	0.18 0.15	e.i15I e.i19E	5.98	0.01*	-0.18
e.i15I e.i19E	6.74	0.01*	-0.19	e.i16I e.i19E	3.92	0.05*	0.14

	Initial model				Re-specified model		
Measurement	**MI**	**P>MI**	**EPC†**	**Measurement**	**MI**	**P>MI**	**EPC†**
e.i23E	5.39	0.02*	0.21				
e.i16I				e.i18E			
e.i25E	60.33	0.00*	0.55	e.i28E	5.56	0.02*	0.31
e.i2E							
e.i11E	7.13	0.01*	0.19				
e.i18E	6.28	0.01*	0.19				
e.i23E	7.49	0.01*	-0.29				
e.i11E							
e.i23E	6.98	0.01*	-0.25				
e.i19E							
e.i25E	8.51	0.00*	0.20				
e.i23E							
e.i28E	13.64	0.00*	-0.90				

*Note. MI: modification indices, EPC: expected parameter changes.; † standardized; *P>MI chi-square significance, degree of freedom:1*

Table 4. Final questionnaire to assess the cognition of adult women about the bioavailability of iron in the diet. Rio de Janeiro and Niterói, RJ, 2019, (n = 201)

Items/ Factor 1	Designation	Items/ Factor 2	Designation
i5I	Do not consume mate at lunch and dinner because it contains substances that hinder the absorption of iron from food	i2S**	Always give as dessert a fruit, because it contains vitamin C that helps in the absorption of iron in the body.
i8I	Do not eat yogurt after lunch and dinner because the calcium in this food competes with the iron contained in vegetables.	i11S**	Eat the vegetables together with the meat, because the iron contained in the meat helps in absorbing the iron contained in the vegetables, but don't forget to eat fruits rich in vitamin C for dessert.
i9I	Do not eat calcium-rich foods, such as milk and cheese, before or after lunch and dinner	i17S**	Eat dark green vegetables because they are rich in iron.
i15I	Do not eat milk pudding as a dessert because the calcium in this food impairs the absorption of the iron in the meal.	i18S	Eat fruits as a dessert because they improve the absorption of iron from the diet.
i16I*	Do not drink coffee after lunch or dinner, as this will disrupt iron absorption.	i19S**	Eat meat, chicken and fish twice a day (lunch and dinner) in order to reduce the risk of anemia.
i21I	Do not drink milk or milk derivatives as a dessert for lunch and dinner to avoid impairing iron absorption.	i28S	Drink juices of citrus fruits such as orange, acerola and lemon, as these are rich in vitamin C and help to improve the absorption of iron from lunch and dinner.

*Factor 1: "Inhibitor of iron absorption in the diet", Factor 2: "Stimulator of iron absorption in the diet"; I = Inhibitor, S = Stimulator; * Item maintained in the questionnaire due to theoretical plausibility (caffeine content), ** items with semantic changes*

The quality of the fit of the re-specified model showed an adequate fit given the following evidences: RMSEA = 0.03 (90% CI = 0.00 to 0.06), CFI = 0.95 and TLI = 0.94 (Table 2).

Examining the MI of the re-specified model and consequently the EPC (Table 3) it was observed that all are below 10, showing a more parsimonious model.

In view of the measurement evidence of the models that were presented, the final questionnaire included the following items: Factor 1 (inhibitors): i5I, i8I, i9I, i15I, i16I, i21I; Factor 2 (stimulators): i2S, i11S, i17S, i18S, i19S, i28S (Table 4).

This questionnaire has the merit of being a proposal to create a measuring instrument to assess women's cognition about the combination of foods necessary to better make iron available in the diet. The results of the present study credit the possibility of a two-dimensional instrument, showing one dimension with combinations of foods that stimulate iron absorption and another with inhibitory foods.

This study was based on the assumptions of Psychometry and examined some properties necessary for its validation. The first results showed a two-dimensional structure of the questionnaire. However, the study indicated the need for greater investment in its elaboration, since it is a new instrument and the convergent validity has not been reached, although the internal consistency of the items, given by the Cronbach's alpha, has not shown much distant from the requirements of measurement studies for new instruments [19, 24].

Comparing the initial model with the re-specified, both presented questionable convergent validity, however, in both, the discriminant validities were reached.

In principle, failure to achieve convergent validity in the re-specified model could discourage the use of the proposed questionnaire. However, the discriminant validity having been achieved corroborates the two-dimensionality of the instrument. The questionnaire items were created from two perspectives in opposite directions, inhibitors and stimulators of iron absorption, supported by theoretical foundations. According to Hair et al. [15], validity is the degree to which a set of measures represents a concept of interest and in the present study the concept of interest was the cognition of women about the combination of foods to make iron bioavailable in the diet.

In the initial model, the RMSEA (0.10) showed an inadequate adjustment. However, in the re-specified model, once items i23E and i25E were excluded, their value was 0.03, when the evidence requirement is below 0.06. The values for CFI and TLI were higher than 0.9, confirming the adequate quality of the adjustment of the re-specified model.

If the factorial structure will be repeated under different socio-cultural conditions, it will require more research. In applied research, the questionnaire can be used as a "mapper" [20] exploratory of cognition about combining foods to make iron bioavailable in the diet.

The contribution of this study was to present a necessary path for the validation of new measurement instruments to assess cognition on nutritional aspects, particularly the bioavailability of iron.

5. CONCLUSION

The results showed evidence of reliability and validation of the instrument. Reliability reached similar Cronbach's alpha values, both in the initial confirmatory factor analysis model and in the re-specified model, and plausible for measurement instruments.

Convergent validity was not achieved in both models, however, the discriminant validity showed two-dimensionality, which corroborates theoretical assumptions, that is, combinations of foods that inhibit and stimulate the bioavailability of iron in the diet. The re-specified model showed better quality of fit than the initial model.

Replications of new studies carried out in different configurations are recommended for their use in nutritional practice; and applied research should be encouraged to evaluate the questionnaire in other cultures, since there are few studies that use factor analysis to validate instruments in the field of nutrition.

CONSENT AND ETHICAL APPROVAL

The research project that originated the present study was “Nutry Fuzzy Orixás: “Bioavailability of nutrients on the perspective of systems based on Orixás Knowledge and Fuzzy Logical Systems", approved by the Research Ethics Committee of Hospital Pedro Ernesto of the University of the State of Rio de Janeiro, under protocol number 794/2003-CEP/HUPE.

Participants who agreed to collaborate with the research signed the Informed Consent Form.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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