British Journal of Nutrition (2024), 132, 946–955 doi:10.1017/S0007114524001375
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The concentration of hemoglobin is associated with the dietary iron availability, food insecurity and the use of oral contraceptives among women in socially vulnerable areas of a capital city in northeastern Brazil

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(Submitted 4 February 2024 – Final revision received 6 May 2024 – Accepted 17 June 2024 – First published online 17 October 2024)

Abstract

This study aimed to assess hemoglobin concentration and its association with oral contraceptive (OC) use, food insecurity (FI) and dietary iron availability (DIA) in adult women of reproductive age (20–44 years). This is a population-based cross-sectional study that analysed 505 women living in favelas and urban communities in a capital city in northeastern Brazil. Hemoglobin concentration was determined using capillary blood samples. FI and DIA were assessed using the Brazilian Food Insecurity Scale and the 24-h food recall, respectively. Association analysis was carried out using logistic regression. A directed acyclic graph (DAG) was designed to illustrate the causal paths between hemoglobin concentration and DIA. A significance level of 5 % was adopted. Low hemoglobin concentrations (11·2 g/dl: (1·79)) and a high prevalence of anaemia (64·0 %) were observed; 28·7 % used OC (28·7 %) and 76·4 % were in FI. An average energetic intake of 1495 kcal/d (482·0) and 0·46 mg/d (0·27) of DIA were also observed. In the DAG-guided multivariable analysis, it was observed that hemoglobin concentrations ≥ 12 mg/dl were directly associated with higher DIA (OR: 1·67; 95 % CI (1. 08, 2·59)) and OC use (OR: 1·67; 95 % CI (1·10, 2·55)) and inversely associated with mild FI (OR: 0·60; 95 % CI (0·37, 0·96)) or severe FI (OR: 0·37; 95 % CI: (0·18, 0·76)). Women taking OC and with a higher DIA were less likely to have low hemoglobin concentrations, while those in the context of FI were in the opposite situation.

Keywords: Diet: Poverty: Anaemia: Iron

The decrease in hemoglobin (Hb) concentration, a parameter conventionally used to determine the occurrence of anaemia, can be influenced by numerous factors, such as bleeding, nutritional deficiencies, such as Fe and folic acid, physiological situations, such as pregnancy and lactation, genetic disorders, such as thalassemia, and infectious and inflammatory processes, including those resulting from parasitic diseases[1,2]. Among the types of anaemia, iron deficiency anaemia (IDA) is the most common and affects individuals worldwide[3].

Despite efforts to reduce the prevalence of IDA, it remains high, especially in low- and middle-income countries, resulting in the most significant nutritional deficiency disease worldwide, affecting mainly children and women of reproductive age[4,5]. Globally, it is estimated that one-third of women of reproductive age have IDA[2]; in Brazil, the prevalence is approximately 25 %[6]. These scenarios highlight that IDA is a moderate public health issue that deserves special attention[2]. It is essential to emphasise that women of reproductive age in social vulnerability have less access to healthcare services, which can lead to worsening cases of anaemia and anaemic pregnancies[7].

Among the factors that increase the susceptibility of women of reproductive age to develop IDA are blood losses during the menstrual period, which contribute to the decrease in Hb concentration[4,8]. However, the use of oral contraceptives (OC) can mitigate this situation since it tends to reduce menstrual flow and blood loss[9].

Abbreviations: DIA, dietary iron availability; EF, enhancing factor; FI, food insecurity; HI, heme iron; IDA, iron deficiency anaemia; NHI, non-heme iron; OC, oral contraceptive; 24DR, 24-hour dietary recall.

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https://doi.org/10.1017/S0007114524001375 Published online by Cambridge University Press

It has also been observed that food insecurity (FI) can be a predictor for the decrease in Hb concentration, thus increasing the chance of developing IDA[10], as this context negatively affects the quality and quantity of available food for consumption, increasing the risk of inadequate Fe content in the diet[11]. In addition, FI is related to higher consumption of energy-rich and low-nutrient foods[12]. This situation requires more attention in the context of social vulnerability, as it has an even more significant impact on the overall quality of the diet, affecting the dietary iron availability (DIA), reflecting in Hb concentration and increasing the chances of developing IDA[13].

DIA corresponds to the absorbable Fe content present in the diet, which is directly related to how the mineral is found in foods, heme iron (HI) and non-heme iron (NHI), and to the influence exerted by other food constituents on its absorption[14,15]. These constituents can enhance Fe absorption, as is the case with ascorbic acid and animal tissue, or inhibit absorption, such as polyphenols, phytates and Ca[14,15].

Considering that DIA still represents a public health problem, the present study aimed to evaluate Hb concentration and its association with the use of OC, FI and DIA in adult women of reproductive age living in situations of social vulnerability in a capital city in northeastern Brazil.

Methods

Delineation, study location and ethical aspects

This is a cross-sectional, population-based study conducted between October 2020 and May 2021 in favelas and urban communities in the city of Maceió, the capital of the state of Alagoas, Northeast Brazil. According to the Brazilian Institute of Geography and Statistics[16], favelas and urban communities are places with a predominance of households with varying degrees of legal insecurity of tenure and at least one of the other criteria: absence or incomplete provision of public services; predominance of buildings, streetscapes and infrastructure that are usually self-produced or are guided by urban planning and construction parameters other than those defined by public bodies; and location in areas with restrictions on occupation defined by environmental or urban planning legislation.

This study was conducted following the guidelines established in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the Research Ethics Committee of the Federal University of Alagoas (opinion number: 4.836.765). Written informed consent was obtained from all participants.

Sample size and recruitment of participants

In Maceió, approximately 113 000 people reside in ninety-four favelas and urban communities, of which 24 614 are adult women of reproductive age[16]. For the sample calculation, performed using the StatCalc program v. 7.2.2.2, the following parameters were considered: a margin of error of 4 %, a CI of 99 % to ensure high accuracy and a prevalence of women with Hb concentration below the adequate level of 24·6 %, indicating the presence of anaemia[17]. Based on these parameters, the sample size should be a minimum of 444 women. Despite the estimate, the number of interviewees exceeded the sample since the recurrent exposure on the streets attracted more women who travelled.

The prevalence of anaemia used in the sample calculation was obtained from the IV State Health and Nutrition Survey of Pernambuco 2015/2016[17], as there is no recent estimate in the state of Alagoas or the city of Maceió. The prevalence found in Pernambuco was used due to the similarity between the target populations of the two states.

Out of the ninety-four favelas and urban communities in Maceió, forty were included in this study. The process of selecting favelas and urban communities is available in Fig. 1. The sampling design was probabilistic and of the conglomerate type, in three stages: (1) favelas and urban communities, selected by simple random sampling and proportionally in each of the seven administrative regions that were studied; (2) census tracts, whenever a favelas and urban communities had more than one census tract, one was selected by simple random sampling; and (3) streets, in each evaluated census tract, one street was randomly selected for data collection to begin.

All the houses on the selected street were visited, and when necessary, neighbouring streets were also included until the sample size for that location was completed. All households in which at least one woman between the ages of 20 and 44 years lived were included.

Pregnant women, women with a previous diagnosis of a haematological problem or a chronic disease that could affect Hb concentration and Fe metabolism, such as kidney disease, liver disease or HIV/AIDS, or those who reported having a fever at the time of the interview or the day before were not included in the study. Women who reported having any food allergies or intolerances were also not included because these conditions could influence their dietary patterns, affecting Fe intake. Additionally, women with any intellectual disability that made it difficult to understand and respond to the questionnaires, such as cognitive, memory, language, information processing and concentration disabilities, were excluded.

In households where there were multiple women within the study's age range, the one with a child under the age of 5 years was included; when this criterion did not apply, the woman responsible for acquiring and preparing food for the family was interviewed. Data were collected from only one woman per household.

Data collection

Socio-economic and health characteristics. The following information was collected: age (years), race/skin colour (white, black, brown, yellow and indigenous), lactation (yes and no) and smoking habit (yes and no). Data on family monthly per capita income were also collected to characterise the population, classifying it according to poverty cut-off points (poverty – US$ < 91·90 and above poverty US$ ≥ 91·90. Values converted from Brazilian reais to US dollars, considering the average exchange rate between October 2020 and May 2021 – R$ 5·43[18].

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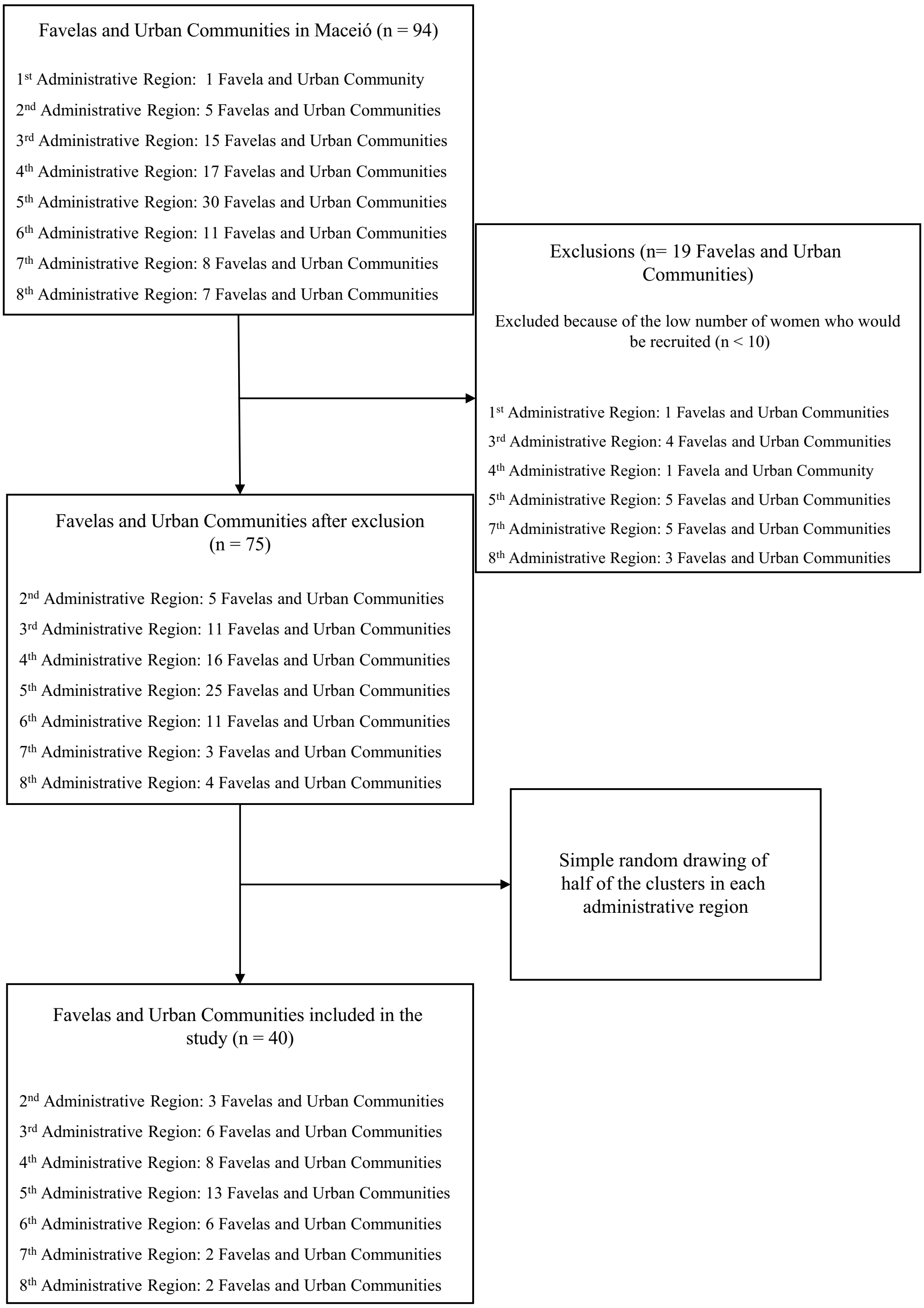

Fig. 1. A flow chart of the selection of the favelas and urban communities is included in the study.

Food insecurity. It was assessed using the Brazilian Food Insecurity Scale[19], which consists of fourteen questions (yes or no) about the experience of food inadequacy at various levels of intensity in the past 3 months. Each positive response corresponds to one point. The classification of FI was done based on the sum of points (0–14) as follows: households with individuals under 18 years old – 0: food security; 1–5: mild FI; 6–9: moderate FI; and 10–14: severe FI. Households without individuals under 18 years old – 0: FI; 1–3: mild FI; 4–5: moderate FI; and 6–8: severe FI.

Anthropometry. The weight and height of the women were measured using a digital scale (Avanutri®) and a portable stadiometer (Avanutri®). BMI was calculated and classified as underweight (BMI < 18·5 kg/m^2), normal weight (18·5–24·9 kg/m^2), overweight (25·0–29·9 kg/m^2) and obesity (≥ 30·0 kg/m^2)[2].

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Hb concentration. Capillary blood was collected by fingerstick to determine Hb concentration using a portable hemoglobinometer from HemoCueß HemoglobinPhotometer®. The analysis is based on photometric readings using ß Hb microcuvettes.

The Hb concentration was adjusted for the smoking status of the women. For those who declared themselves smokers, there was a reduction of 0·3 g/dl in Hb concentration[2]. For statistical analysis, Hb concentration values were stratified into < 12 g/dl and ≥ 12 g/dl, meaning with or without anaemia[2].

Additionally, the Hb concentration was also stratified according to the severity levels of anaemia: without anaemia (Hb ≥ 12 g/dl), mild anaemia (11 g/dl ≤ Hb < 12 g/dl), moderate anaemia (8 g/dl ≤ Hb < 11 g/dl) and severe anaemia (Hb < 8 g/dl)[2].

Dietary assessment. The assessment of dietary intake was conducted through an interview to complete the 24-h dietary recall (24DR), which covered 1 d of the week. In a subsample of 20 % of the evaluated population, the 24DR was applied two more times, up to 60 d after the first measurement, through telephone contact, to assess and correct intra-individual variability in consumption. Of the three 24DR applied in the subsample, two corresponded to weekdays and one to the weekend. The 24DR was conducted using the Automated Multiple-Pass Method[20], an approach of five consecutive steps that aims to reduce interviewee memory bias and improve data accuracy. During this assessment, whenever the woman mentioned the consumption of a preparation with multiple foods, she was asked to describe each ingredient in the preparation.

The 24DR data were analysed using the nutritional assessment and prescription system Avanutri 4·0®). To obtain the energy and nutrient values used in the study, three food composition tables were considered in the following order of priority: the Brazilian table of food composition[21], the food composition table[22] and the nutritional composition tables of foods consumed in Brazil[23].

After reviewing the dietary data, participants with implausible energy intake values were identified and excluded from the study. For this procedure, the criteria proposed by Willett[24] were adopted, which consider energy intake values between 500 and 3·500 kcal/d as plausible for women.

Next, all meals reported in the 24DR were evaluated, considering the total amount of Fe, HI, NHI, ascorbic acid and the gram quantities of meat, fish and poultry. At the end of each 24DR, the totals of all constituents were summed, obtaining data per meal and the corresponding values for the sum of meals for each day, for later assessment of DIA.

Evaluation of available iron estimation. To assess available Fe or absorbable Fe, the algorithm proposed by Monsen and Balintfy[25] was used, taking into consideration the findings of Beard et al.[26] and Lima et al.[15]. This algorithm considers only the quantities of ascorbic acid and meat, fish, and poultry as enhancing factors (EF) for the absorption of NHI. For this, the authors assume that HI corresponds to 40 % of the total Fe in meat, fish and poultry and NHI corresponds to the remaining 60 %, in addition to other dietary Fe sources. Since biochemical parameters reflecting body Fe reserves are not available, a value of 500 mg of body reserves was used[25]. In this case, the absorption percentage of HI is 25 %, while the absorption of NHI varies between 3 and 8 %, depending on the amount of ascorbic acid and meat, fish, and poultry in the meal.

The EF were summed in units: 1 unit of EF corresponds to 1 mg of ascorbic acid or, 1 g of lean cooked meat, fish and poultry, or 1·3 g in their raw form. When the sum of EF in meals was < 75 units, the calculation to estimate the percentage of absorption of NHI was performed using the equation below:

$$\text{when } \Sigma \text{ EF} < 75\text{: } \% = 3 + 8.93 \ln\left(\frac{FE + 100}{100}\right)$$

For meals without EF, the percentage of NHI absorption was considered to be 3 %, and for those with a sum of EF greater than 75 units, the absorption percentage was 8 %. The total estimated amount of Fe available was obtained by summing the absorbable FH and NHI in each meal. To estimate the daily amount of available Fe, after the calculation for each meal individually, the sum of all meals that make up the entire day was considered. This process was done individually for each 24DR.

Assessment of intra-individual variability. After applying the Monsen and Balintfy[25] algorithm to the dietary data, the usual Fe availability for each woman was assessed. The usual intake of energy content and total Fe for each participant was also evaluated. These data were estimated using the Multiple Source Method (MSM)[27].

MSM is a statistical method used to estimate usual dietary intake based on two or more consumption assessment measurements, such as 24DR data. The statistical algorithms of MSM assess the intra-individual variation in intake. This method is characterised by a two-part shrinkage technique applied to the residuals of two regression models: one for positive daily intake data and one for the probability of consumption.

Following this procedure, the usual DIA was stratified into tertiles, with the first tertile considered low, the second medium and the third high. The same procedure was carried out with energy content consumed on average, with the first tertile considered low, the second medium and the third high.

Statistical analysis

The data were entered in duplicate. Data analysis was performed using the statistical software Jamovi (version 2.3, The jamovi project). For descriptive statistics, continuous variables were presented as mean and standard deviation, complying with normality assumptions, and categorical variables as absolute and relative frequencies.

For the association analysis, logistic regression was used to estimate the OR between Hb concentration ≥ 12 mg/dl and the considered risk factors, as well as calculate their respective 95 % CI. For this analysis, a directed acyclic graph (DAG) was designed, as shown in Fig. 2, which illustrates the causal pathways between Hb concentration and DIA. The DAG was developed using the DAGitty software (http://www.dagitty.net/dags.html#). The minimal set of variables to estimate the direct effect of DIA on Hb concentration included BMI, total energy

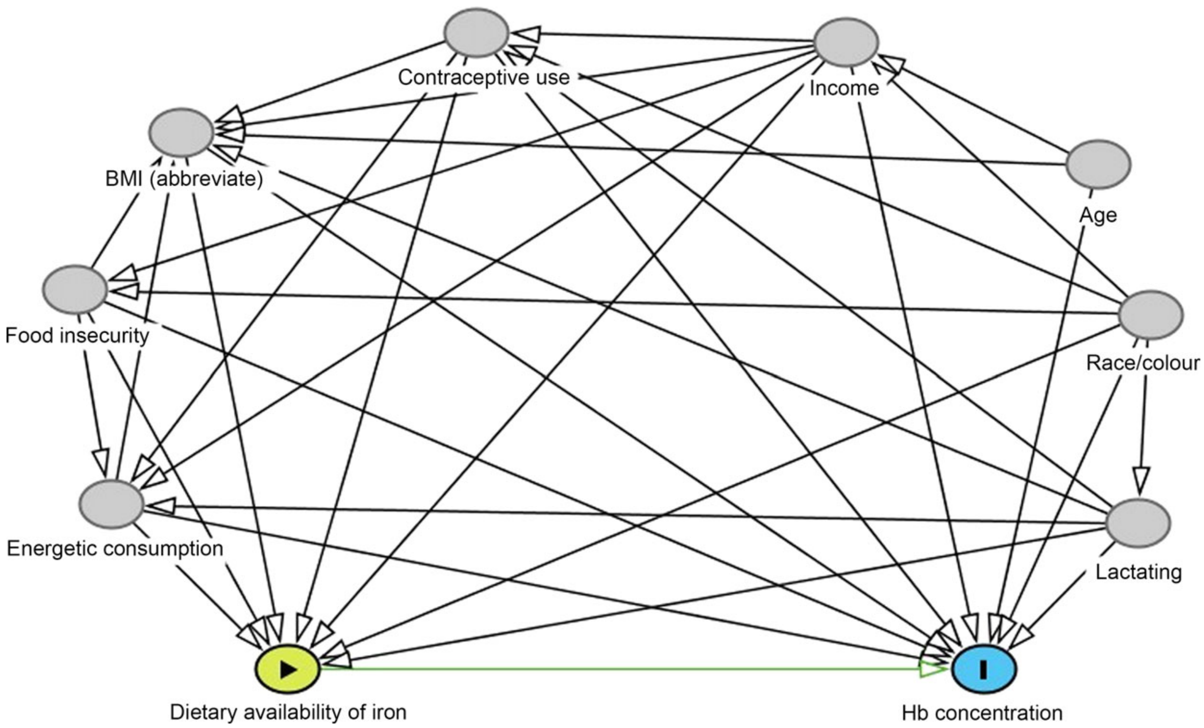

Fig. 2. Directed acyclic graph showing paths between dietary iron availability (exposure variable; circle with an arrow) and Hb concentration (outcome variable; circle with a bar). The circles indicate the variables assessed in the study, and the arrows indicate the causal relationship between these variables.

intake, use of OC, FI, income, lactation and race/skin colour. For all analyses, a significance level of 5 % was adopted.

Results

A total of 543 women were recruited and assessed. After exclusions, 505 women were included. The reasons for exclusions are presented in Fig. 3. The sociodemographic characteristics of the women included in this study are described in Table 1. The mean age of the women was 29·5 (7·3) years, 62·2 % self-identified as brown, 83·8 % were living in poverty, 76·4 % had some level of FI and 34·3 % were obese.

The means for total Fe intake and DIA were 9·07 (9·63) mg/d and 0·46 (0·27) mg/d, respectively. The mean energy intake was 1495·4 (482·0) kcal/d (Table 2). The mean Hb concentration was 11·20 (1·7) g/dl; 64·6 % of women had some level of anaemia, with 4·5 % having its severe form (Table 2).

In the multivariable analysis guided by the DAG (Table 3), it was observed that women with high DIA (OR: 1·67; 95 % CI (1·08, 2·59)), as well as those who used OC (OR: 1·67; 95 % CI: (1·10, 2·55)), had a higher chance of having a Hb concentration ≥ 12 g/dl. It was also observed that women with mild (OR: 0·60; 95 % CI: (0·37, 0·96)) or severe (OR: 0·37; 95 % CI: (0·18, 0·76)) FI had a lower chance of having a Hb concentration ≥ 12 g/dl.

Discussion

Among the study's main findings, it stands out that women with high DIA or who were using OC had a 1·5 and 1·7 times greater chance, respectively, of having an Hb concentration ≥ 12 mg/dl. Conversely, being in the context of mild or severe anaemia decreased the chance of having an Hb concentration ≥ 12 mg/dl by up to 23 % and 44 %, respectively.

It was also observed that 64·6 % of women presented some degree of anaemia, a percentage higher than that found among non-pregnant Brazilian women (22 %)[6]. This situation may be due to the low socio-economic level of the studied population, given the association between anaemia and poverty[4,28]. In this context, women with a higher wealth index have a lower likelihood of developing anaemia[7], a situation that may be related to greater ease of access to essential elements for health and well-being, such as nutrition[29].

The development of anaemia is characterised by a decrease in Hb concentration[30,31], and among the various aetiological factors that can lead to this condition, nutritional causes stand out[2]. Among the nutrients with the strongest relationship to the decrease in Hb concentration, especially in women of reproductive age, is Fe[32]. The consumption of Fe from animal-based food sources, such as red meat, shows a strong tendency for a positive correlation with Hb concentration[33–35].

It is noteworthy that socio-economic status is the primary determinant of micronutrient intake[36]. This situation suggests that the population included in this study is more likely to have low Fe intake, thus compromising DIA. This condition directly affects Hb concentration, increasing the chances of these women developing anaemia. The average Fe intake of women in situations of social vulnerability investigated in this study, 9·07 mg/d, is much lower than the recommended DRI[37] of 18 mg/d, assuming 18 % absorption. In Brazil, according to data from the Household

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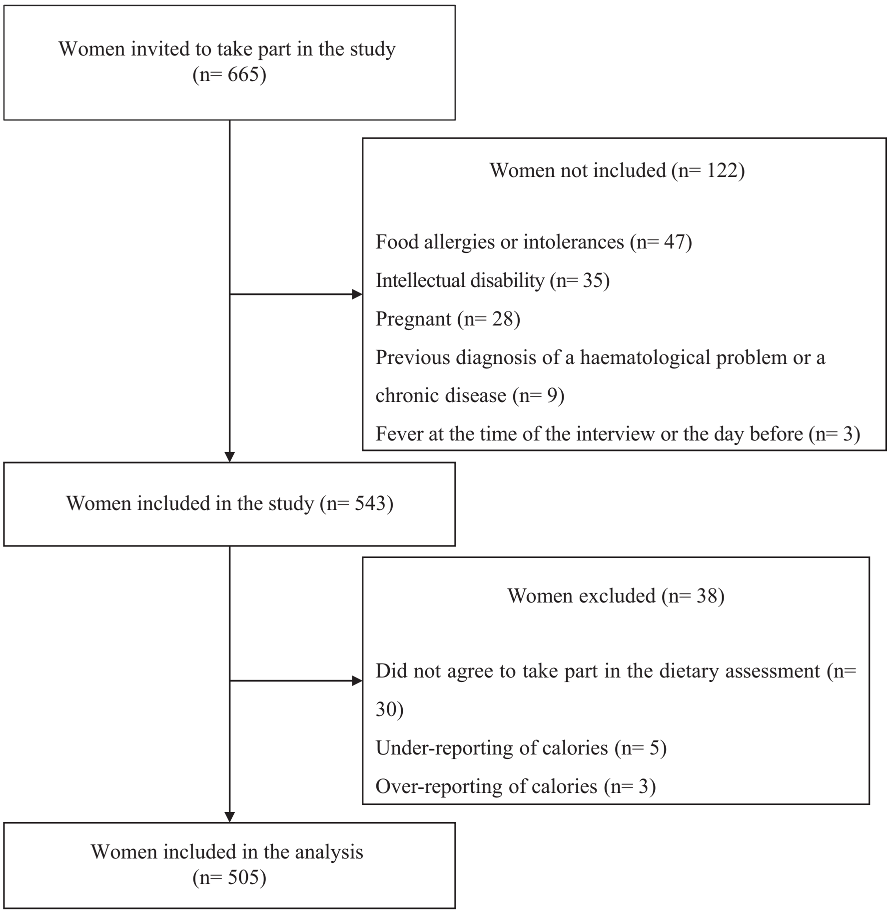

Fig. 3. Flow chart of participant selection.

Budget Survey (POF) 2017–2018, adult women (19–59 years) had an average Fe intake of 9·6 mg/d[23].

The assessment of DIA can be conducted through various methods, with the use of algorithms being the most viable approach, primarily due to its cost-effectiveness. However, it is worth noting the findings of De Carli et al.[38] and Beard et al.[26], which caution that the use of algorithms tends to underestimate the actual value of DIA. Nevertheless, these studies suggest that algorithms can still be useful tools for classifying diets in terms of Fe bioavailability levels and for monitoring their effect on the body's mineral balance. Nevertheless, in the present study, we observed that the measurement of DIA was associated with a decrease in the odds of women having Hb concentration below the median, emphasising the importance of bioavailability algorithms for a better interpretation of the role of diet in health outcomes and diseases related to Fe intake adequacy[39].

There are several other recognised risk factors for anaemia, although inadequate dietary Fe intake is listed as a proximal determinant of low Hb concentration[29]. In this context, the use of OC is noteworthy, as it tends to reduce menstrual blood loss, thereby lowering the risk of Hb concentration reduction and serving as an adjunct method in the prevention of anaemia[29,40,41]. Additionally, some manufacturers have started to include supplemental Fe in the tablets of certain OC[41]. This measure gains prominence in certain social contexts, such as social vulnerability, as these contraceptives have the potential to be an even more economically impactful solution for preventing a decrease in Hb concentration[29,34,40,41].

However, this study also found that women with mild and severe anaemia were more likely to have Hb concentrations below the median. Similarly to our findings, Bangladesh reported an association between anaemia and lower Hb levels[10]. Additionally, in Mexico, the presence of anaemia increased the likelihood of women of reproductive age having anaemia[42].

This situation may be due to the strong relationship between anaemia, especially in moderate and severe forms, and higher energy consumption of food[12], causing women in this context to have less diversified and lower-quality nutritional diets[43]. In this regard, being in a state of anaemia also favours lower consumption of vitamin C and Fe[44,45], a condition that directly affects DIA, consequently impacting the risk of low Hb concentration.

It is worth noting that factors such as anaemia and low socio-economic status are significant predictors of reduced protein intake[46,47]. Low economic power limits the acquisition of red meat for consumption[33]. In this context, refined starch consumption is observed as the main dietary source related to Fe intake (37 %), a situation resulting from the fortification of flours with this nutrient, reaffirming the importance and impact of this strategy[46].

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Table 1. Socio-economic, demographic and health characteristics of adult women of reproductive age in situations of social vulnerability. Brazil, 2020–2021 (*n* 505) (Numbers and percentages; Mean values and standard deviations)

	Total		Hb concentration < 12 mg/dl		Hb concentration ≥ 12 mg/dl		
Variables	*n*	%	*n*	%	*n*	%	*P**
Age							
Mean	29·5		29·1		30·1		0·162
SD	7·3		7·3		7·3		
Race/colour							0·094
White	56	11·1	25	9·6	31	12·7	
Black	86	17·0	48	18·4	38	15·6	
Brown	314	62·2	158	60·5	156	63·9	
Yellow	41	8·1	28	10·7	13	5·3	
Indigenous	8	1·6	2	0·8	6	2·4	
Contraceptive use							0·172
No	360	71·3	193	73·9	167	68·4	
Yes	145	28·7	68	26·1	77	31·6	
Smoking habit							< 0·001
No	436	86·3	196	75·1	240	98·4	
Yes	69	13·7	65	24·9	4	1·6	
Lactating							0·014
No	381	75·4	185	70·9	196	80·3	
Yes	124	24·6	76	29·1	48	19·7	
Poverty situation†							0·565
Out of poverty	82	16·2	40	15·3	42	17·2	
Poverty	423	83·8	221	84·7	202	82·8	
BMI‡							0·118
Low weight	10	2·0	8	3·1	2	0·8	
Normal weight	143	28·3	78	29·9	65	26·6	
Overweight	179	35·4	95	36·4	84	34·4	
Obesity	173	34·3	80	30·7	93	38·1	
Levels of food insecurity§							0·294
Food security	119	23·6	54	50·7	65	26·6	
Mild insecurity	242	47·9	125	47·9	117	48·0	
Moderate insecurity	71	14·1	39	14·9	32	13·1	
Severe insecurity	73	14·5	43	16·5	30	12·3	
Energy intake							0·788
T1	161	33·3	85	32·6	83	34·0	
T2	169	33·4	91	34·9	78	32·0	
T3	168	33·3	85	32·6	83	34·0	

* To analyse the difference between the proportions, we used the *t* test for independent samples for the continuous variable (age) and the χ^2 test for the categorical variables.
† Classified according to the cut-off points for poverty (poverty – US$ < 91·90; and out of poverty US$ ≥ 91·90. Values converted from reais to US dollars, considering the average dollar exchange rate between October 2020 and May 2021 – R$ 5·43, as proposed by the World Bank in 2022.
‡ Classified according to WHO criteria.
§ They were classified according to the Brazilian Food Insecurity Scale.

Table 2. Dietary and blood health characteristics of adult women of reproductive age and in situations of social vulnerability. Brazil, 2020–2021 (*n* 505) (Numbers and percentages; Mean values and standard deviations)

Variables	*n*	%
Dietary assessment		
Total energetic intake		
Mean	1495·39 kcal	
SD	482·0 kcal	
Dietary iron availability		
Mean	0·46 mg	
SD	0·27 mg	
Blood assessment		
Hb		
Mean	11·2 g/dl	
SD	1·7 g/dl	
Hb classification		
No anaemia	179	35·4
Mild anaemia	126	25·0
Moderate anaemia	176	34·9
Severe anaemia	24	4·8

However, foods derived from fortified flour do not contain sufficient Fe quantities in their composition to meet the high dietary needs of at-risk groups, such as women of reproductive age and preschool children[33,48]. Nevertheless, there may be an improvement in Hb concentration with fortification, provided that it is done at optimal dosages for the population[48,49].

In light of the context explored in this study, it is clear that dietary interventions focused on increasing Fe intake and improving DIA are crucial. These interventions can have a positive impact on Hb concentration, as highlighted in a systematic review with a meta-analysis conducted by Silva Neto et al.[50]. The review found that both Fe supplementation and diets enhanced with dietary Fe bioavailability have a similar beneficial effect on Hb concentration in adults with Fe deficiency or anaemia.

Consistently, when investigating the effectiveness of dietary interventions to help increase Hb concentration and thus treat anaemia in women, the important role of simultaneously increasing Fe and vitamin C intake for more effective results

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Table 3. Association between Hb concentration (≥ 12 mg/dl) and demographic and health characteristics of adult women of reproductive age and in social vulnerability. Brazil, 2020–2021 (*n* 505) (Odds ratios and 95 % confidence intervals)

	Univariable			DAG-oriented multivariable analysis		
Variables	OR	95 % CI	*P*	OR	95 % CI	*P*
Race/colour						
Other	1·00			1·00		
Black/brown	1·12	0·71, 1·77	0·611	1·13	0·70, 1·84	0·602
Use of oral contraceptive						
No	1·00			1·00		
Yes	1·61	1·08, 2·40	0·017	1·67	1·10, 2·55	0·016
Lactating						
No	1·00			1·00		
Yes	1·55	0·99, 2·40	0·054	1·50	0·94, 2·41	0·087
BMI*						
Low weight	4·26	0·52, 34·69	0·175	3·51	0·40, 30·64	0·256
Normal weight	1·00			1·00		
Overweight	0·83	0·52, 1·32	0·437	0·77	0·47, 1·26	0·303
Obesity	0·75	0·47, 1·20	0·226	0·66	0·39, 1·09	0·106
Poverty status†						
Out of poverty	1·00			1·00		
Poverty	1·14	0·71, 1·84	0·566	1·09	0·65, 2·51	0·743
Levels of food insecurity‡						
Food security	1·00			1·00		
Mild insecurity	0·67	0·43, 1·05	0·084	0·60	0·37, 0·96	0·035
Moderate insecurity	0·63	0·34, 1·17	0·146	0·61	0·32, 1·16	0·137
Severe insecurity	0·37	0·19, 0·72	0·003	0·37	0·18, 0·76	0·007
Total energy intake§						
T1	1·00			1·00		
T2	0·93	0·60, 1·46	0·766	0·90	0·56, 1·46	0·689
T3	1·11	0·70, 1·74	0·64	1·26	0·79, 2·02	0·317
Dietary Fe availability‖						
T1	1·00			1·00		
T2	1·29	0·75, 2·21	0·351	1·28	0·84, 1·96	0·238
T3	1·67	0·98, 2·86	0·059	1·67	1·08, 2·59	0·020

DAG, directed acyclic graph.
* Classified according to WHO criteria.
† Classified according to the cut-off points for poverty (poverty – US$ < 91·90; and out of poverty US$ ≥ 91·90. Values converted from reais to US dollars, considering the average dollar exchange rate between October 2020 and May 2021 – R$ 5·43, as proposed by the World Bank in 2022.
‡ They were classified according to the Brazilian Food Insecurity Scale.
§ Estimated using a 24-h dietary recall.
‖ Estimated using a 24-h dietary recall, with subsequent evaluation using an algorithm produced for this purpose.

was identified[51]. Therefore, dietary management is crucial for improving Hb concentration, with the advantage of being a well-accepted strategy by the population and without side effects.

It is important to note that in this study, despite a relatively low-energy intake, the high prevalence of obesity can be explained by other causes, such as socio-economic factors, metabolic dysregulation, poor nutritional quality and a sedentary lifestyle[52,53]. However, even considering all the methodological rigour applied, more reporting of the usual food consumption of the population evaluated may have been needed.

This study has several strengths, such as exclusively evaluating adult women of reproductive age, specifically within the context of social vulnerability, which is one of the population groups most prone to low Hb concentration and, therefore, particularly exposed to the development of anaemia. Furthermore, it is a population-based study representative of a city in the northeast of Brazil, allowing its results to be extrapolated to similar populations. Additionally, the assessments were conducted by a trained team through in-person household surveys, which enhances the robustness of the collected data.

Some limitations are also identified in this study, such as the cross-sectional design, which reduces the power of causal inference due to the absence of a temporal sequence between exposure to predictor factors and subsequent changes in Hb concentration. The use of the 24DR for dietary assessment, while commonly employed in population studies, can still lead to underestimation or overestimation of consumption. Additionally, there is a limitation associated with the use of algorithms to estimate DIA due to the tool's accuracy and precision constraints[26,38,39]. Nevertheless, the use of peripheral blood with a Hemocue device may introduce limitations in the accuracy of Hb measurement; despite providing an adequate estimate of the prevalence of anaemia in the population, the use of this method may result in excess false-negative diagnoses among individuals[54].

In conclusion, it is highlighted that there is a positive association between DIA and Hb concentration, and the use of OC may act as a preventive factor for low Hb concentration. Additionally, the presence of mild and severe anaemia increased the likelihood of women having Hb concentration below the median, indicative of more severe levels of anaemia. These conclusions emphasise the need to implement effective strategies for the prevention and control of this significant nutritional problem, particularly through nutritional education and adjustments to existing public policies aimed at combating Fe deficiency.

Acknowledgements

The authors thank all the women who participated in this study, the research team who worked hard to make this study possible and the Nutritional Recovery and Education Center (Centro de Recuperação e Educação Nutricional – CREN) of Alagoas for all logistical support.

LGRSN was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) research fellowships (grant number: 88882.330651/2019-01).

NBB is supported by a research grant from the National Council for Scientific and Technological Development – CNPq (grant number: 311401/2022-8).

T. L. F. dos S. and L. G. R. S-N.: study design, data collection, tabulation, analysis and interpretation of results, article writing, and approval of the final version; T. da R. A., E. De C., N. B. B. and G. S. B.: study design, analysis and interpretation of results, article writing, and approval of the final version; T. M. de M. T. F.: article writing and approval of the final version.

The authors declare no conflict of interest.

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