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Prevalence of iron-deficiency anaemia in Brazilian children under 5 years of age: a systematic review and meta-analysis

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Abstract

Fe-deficiency anaemia is considered an important public health problem both in wealthier countries and in those of medium and low income, especially in children under 5 years of age. The shortage of studies with national representativity in medium-income countries, such as Brazil, prevents the knowledge of the current situation and its associated factors. We conducted a systematic review and meta-analysis to estimate the pooled prevalence of Fe-deficiency anaemia in Brazilian children under 5 years of age and determined the factors involved in the variability of the estimates of prevalence. We collected fifty-seven studies from the databases MEDLINE, LILACS and Web of Science, along with the reference lists of included articles. We contacted authors for unpublished data. We did not restrict publication timespan and language. This systematic review and meta-analysis was reported according to the guidelines by PRISMA. The pooled prevalence of anaemia in Brazil was 40·2 (95 % CI 36·0, 44·8) %. The age range of the child and the period of data collection were associated with the anaemia prevalence. The pooled prevalence of anaemia was higher in children under 24 months of age (53·5 *v.* 30·7 %; $P < 0·001$) and in studies with data collected before 2004 (51·8 *v.* 32·6 %; $P = 0·001$). The efforts made by the Brazilian government were successful in the reduction of anaemia in children under 5 years of age in Brazil in the evaluated period. However, prevalence remains beyond acceptable levels for this population group.

Key words: **Anaemia: Iron: Children: Malnutrition: Meta-analyses: Brazil**

Anaemia is defined as the condition in which the content of Hb in the blood is below the ideal in individuals within the same reference population[1]. In addition to genetic factors, many causes can lead to anaemia such as malaria and others parasitic infections, current infectious disease and the deficiency of some nutrients such as Fe, Zn, vitamin B_{12} and proteins, especially in developing regions[2]. Besides this, poor socio-demographic conditions are some of the risk factors for anaemia well described in the literature[3,4]. According to WHO, it is estimated that Fe deficiency is the main cause of anaemia[1].

Therefore, the prevalence of anaemia is used as a proxy indicator to estimate Fe deficiency at the population level[4].This nutritional deficiency, which is present all over the world, is recognised as one of the most relevant, especially due to the vulnerability to which the groups of children under 5 years of age, pregnant women and women in reproductive age are subjected[5,6].

The damaging effects of anaemia are associated with severe harm to cognitive and motor development of children, academic performance and higher susceptibility to infections. Thus, this deficiency is considered an important public health problem both in wealthier countries and medium- and low-income nations[7,8].

The global prevalence of anaemia in children under 5 years of age decreased from 47 to 43 % from 1995 to 2011 and was different among regions, being higher in Central, Western and Eastern Africa, as well as in South Asia[1,9]. In these countries, the prevalence of anaemia in children under 5 years of age was at least 55 % in 2011, which is five times higher than in wealthier countries. Despite the global tendency of decline described by Stevens *et al.*, from 1995 to 2011, the prevalence stagnated in

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high-income countries in this period, and in South Africa, it increased from 30 to 46 %[9].

More recently, the WHO published an analysis about anaemia in the world, which showed that preschool-aged children are the most affected, with an estimated prevalence of 41·7 %[10].

Brazil is a medium-income country that is going through a nutritional transition characterised by the existence of a double load of diseases, with expressive increase in obesity, a still relevant prevalence of child malnutrition, and persistence of anaemia as an important public health problem in the maternal–infant group[11,12]. The only national investigation that evaluated anaemia in the maternal–infant population revealed prevalence of 20·9 % in children under 5 years of age in 2006 and 2007, being considered a moderate public health problem in Brazil[13]. Local studies show great differences in the prevalence of anaemia according to regions, sample size and place of execution, with the classification varying from moderate[2,14,15] to severe[16,17] magnitude in the country.

Due to the shortage of studies with national representativity which reveals the current situation of Fe-deficiency anaemia and its associated factors in Brazil, the present study had the objective of conducting a systematic review and meta-analysis in order to estimate the national group prevalence of Fe-deficiency anaemia in children under 5 years of age. It also proposes to determine the factors involved in the variability of the estimate of anaemia prevalence in Brazil.

Two systematic reviews and meta-analysis previously published reported a pooled prevalence of anaemia in Brazilian children according different settings[18,19]. In the more recent paper was evaluated data published through to 22 May 2019. In the studies of Vieira and Ferreira (2010)[19] and Ferreira *et al.* (2020)[18] included thirty-five and thirty-seven studies, respectively. However, to our knowledge, no systematic review and meta-analysis evaluated anaemia prevalence in Brazilian children under 5 years of age stratified by geographic region and age group.

Methods

Protocol and registration

This systematic review and meta-analysis were reported according to the guidelines by Preferred Reporting Items for Systematic Reviews and Meta-Analyses[20]. The protocol of the present study was submitted to International Prospective Register of Systematic Reviews (PROSPERO), being registered under number CRD42017075431.

Data source and search strategy

To identify the studies that evaluated anaemia prevalence in Brazilian children under 5 years of age, the databases MEDLINE, LILACS and Web of Science were reviewed in April of 2020 to search for articles without date or language restrictions. In the literature search, terms of the outcome were combined with each of the terms for the age group and local/population of study, as described below.

MEDLINE: ((((((((((anemia) OR anaemia) OR iron deficiency anemia) OR iron deficiency anaemia) OR hemoglobin) OR haemoglobin) OR human hemoglobin) OR human haemoglobin) OR hemoglobin levels) OR haemoglobin levels)) AND (((((children) OR newborns) OR infants) OR preschoolers) OR preschool children)) AND ((brazil) OR brazilian) [All Fields];

LILACS: (((((‘ANEMIA’) or ‘ANAEMIA’) or ‘ANEMIA/IRON DEFICIENCY’) or ‘ANAEMIA-IRON-DEFICIENCY’) or ‘HEMOGLOBIN’) or ‘HAEMOGLOBIN’ [Palavras] and ((((‘CHILDREN’) or ‘NEWBORNS’) or ‘INFANTS’) or ‘PRESCHOOLERS’) or ‘PRESCHOOL CHILDREN’ [Palavras] and (‘BRAZIL’) or ‘BRAZILIAN’ [Words];

Web of Science: TS=((((((((((anemia) OR anaemia) OR iron deficiency anemia) OR iron deficiency anaemia) OR hemoglobin) OR haemoglobin) OR human hemoglobin) OR human haemoglobin) OR hemoglobin levels) OR haemoglobin levels)) AND TS=((((((children) OR newborns) OR infants) OR preschoolers) OR preschool children)) AND TS=(((brazil) OR brazilian) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=All years;

Furthermore, the reference list of the chosen articles was researched to identify studies that were not found in the database search. We also searched grey literature through thesis and dissertations databases and contacted renowned professionals in the field to obtain references of published or unpublished works that could be part of the present study.

Two independent researchers, using the same search strategy, performed the bibliographic search. The searches were compared, and discrepancies were resolved by a third reviewer.

Eligibility criteria

The included studies evaluated anaemia, Fe deficiency or Fe-deficiency anaemia in children under the age of 5 years, and they should have been developed in Brazil mandatorily. The excluded studies were the ones that did not investigate these outcomes; evaluated other types of anaemia unrelated to Fe consumption; involved children above 5 years of age; did not present sample calculation or presented convenience sampling; used method anaemia testing without digital or venous puncturing and registrations from reviews and editorials.

Selection of studies

Two reviewers selected the studies independently. After excluding duplicates, titles and abstracts were analysed to exclude the studies that were obviously irrelevant to this review. The complete texts from the remaining studies were evaluated, and the eligible studies for this review were identified. Discrepancies were resolved by a third reviewer.

Data extraction

Using a standardised protocol, two reviewers extracted data from the included studies independently, and the forms were compared. From the selected articles, the following information was extracted, besides anaemia prevalence: name of the authors, year of publication, complete title of the work, period of data collection, place of study (geographic space defined between urban or rural or that occurred in both simultaneously; city and state; location of the child in the moment of data collection – health services, schools or day care and residence

visits), type of study (cross-sectional, cohort, case control or intervention), sex of target population (male and female), sample calculation (description of the calculations, expected sample, collected sample and loss percentage when it occurred), age range of target population (in months), method of Hb testing (portable haemoglobinometer and automated blood cells counter) and cut-off points for definition of anaemia (value and reference).

A few studies did not provide the 95 % CI of anaemia prevalence. Therefore, they were calculated from sample size and number of events in the sample through formulas on the open software Microsoft Office Excel (version 365)®.

Data analysis

The geolocation of the studies was performed on QGIS® software (desktop version 2·18·20), and the coordinates in decimal degrees of each municipality were used. For the classification of anaemia magnitude as a public health problem, prevalence values proposed by the WHO[11] were used, such as < 5·0 %, it is not considered a problem; 5·0 to 19·9 %, mild problem; 20·0 to 39·9 %, moderate problem and ≥ 40·0 %, severe problem.

The statistical analyses were conducted using Stata® software version 14.0 (StataCorp). The estimates of group prevalence of anaemia in Brazil by region and age range were determined from estimates of prevalence from the studies included in this review.

Initially, the studies were combined using fixed effects models, and the heterogeneity was evaluated using Q and I^2-test. In the case of the Q-test statistically significant or $I^2 > 50$ %, which means heterogeneity between studies, the estimates were grouped using random effects models[21].

Once the significant heterogeneity in the studies was identified, the next step was to perform bivariate analyses to test the individual association of each variable (methodological variables) with the estimate of group prevalence of Fe-deficiency anaemia on a national level using meta-regression analysis[21]. This analytical strategy evaluated which variables affected the results. The evaluated methodological variables were sample size, age range, sample origin, area of influence, year of data collection and methods of Hb testing.

Afterwards, random effects model was used to evaluate sources of variability in the estimate of group prevalence of Fe deficiency anaemia on a national level. All of the co-variables associated with the prevalence rates of anaemia in the bivariate analyses, considering a P value < 0·20[22], were included in the final multi-variate meta-regression model. For these analyses, a significance level of 5 % was established.

Assessment of the methodological quality of included studies

We used a checklist adapted from Hoy *et al.*[23] to assess the methodological quality of the included studies. It is composed of nine questions that evaluate sampling, response rate, data collection, the instrument used in the study and the statistical reporting. Each question had a range score from '0' to '1', which corresponded to 'low risk of bias' and 'high risk of bias', respectively. The total score ranged from 0 to 9, which each tertile corresponded from low (0–3) to moderate (4–6) and high risk of bias (7–9).

Results

The search in the electronic databases and reverse search resulted in a total of 2871 studies. After excluding duplicates and reading titles and abstracts, 154 studies remained to read their contents in full. At the end of this last stage, fifty-seven articles remained, which comprised the qualitative analysis of this review. The reasons for exclusions from the studies can be seen in the study selection flow chart (Fig. 1).

The chosen studies involved children aged between 0 and 84 months, but for this review, only those who had age stratification were maintained, allowing data to be obtained for children under 59 months of age. As for the method of identifying blood Hb rates, most studies used portable haemoglobinometers (n 42) (data not presented in table).

Among the fifty-seven studies, fifty-one were cross-sectional[2–4,13–17,24–66], while the others were longitudinal[67–72]. All geographic regions of Brazil (North, Northeast, Midwest, South and Southeast) were considered. Most of the studies were developed in the Northeast region of Brazil[2,4,16,25–28,33,35,40,45,47–51,53,64–66,72,73], followed by the Southeast region[14,24,30–32,34,37–39,41,43,54,55,58,63,68,70], South[3,15,56,57,59,61,67,71], North[36,42,44,46] and Midwest[29]. Five studies were of the multi-centre type[13,17,60,62,69] and covered all Brazilian regions. The data collected came from residences[2–4,13,16,17,26,28,33–36,38,39,42,47–50,53,57,59,65–68], public day-care centres[14,15,24,25,29–31,37,41,45,51,52,54–56,60,64,70] and health services[27,32,40,43,44,46,58,60,62,63,69,71,72] and almost all works[2–4,13–17,24–62,64–67,69–72] used the WHO criteria[11] of determination of anaemia (Table 1).

To determine the pooled prevalence of anaemia in Brazilian children under 5 years of age, most studies contributed more than one prevalence estimate. This stratification was performed due to the child's age affecting the behaviour of the prevalence of anaemia in this group.

The pooled prevalence of anaemia in children under 5 years of age in Brazil was 40·2 (95 % CI 36·0, 44·8) %, being 53·5 (95 % CI 49·6, 57·6) % in those under 24 months old and 30·7 (95 % CI 27·7, 34·0) % in those between 24 and 59 months of age. When stratified by regions, it was possible to verify higher estimate of group prevalence of anaemia in the Midwest (45·6 (95 % CI 22·0, 94·7) %) and Northeast regions (42·9 (95 % CI 35·2, 52·3) %), whereas lower prevalence was observed in the Southeast (36·9 (95 % CI 29·5, 46·1) %).

In the analysis of bivariate meta-regression, only sample size, age range of the child and year of data collection were associated with the prevalence rates of anaemia ($P < 0·20$) and included in the multi-variate analysis. In the final multi-variate meta-regression model, the only variables that remained associated with the prevalence rates were age range and period of data collection. The estimate of group prevalence was higher in children under 24 months old (53·5 *v.* 30·7 %; $P < 0·001$) and in studies with data collected until 2004 (51·8 *v.* 32·6 %; $P = 0·001$) (Table 2).

Further analysis considering the age group stratified by collection period showed a reduction in the prevalence of anaemia

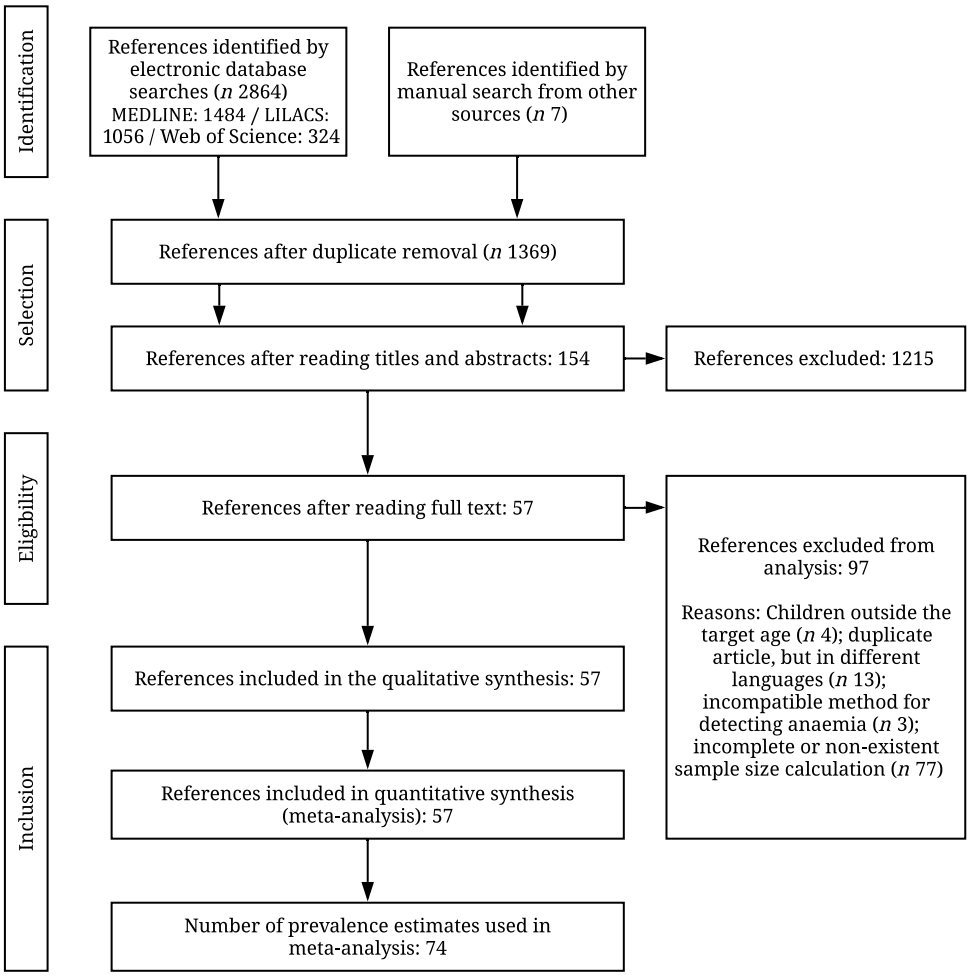

Fig. 1. Research and selection flow chart of studies that are part of this systematic review and meta-analysis.

in children under 2 years from 61·2 (95 % CI 57·4, 65·2) % to 43·9 (95 % CI 36·5, 57·8) % and in children aged 2–5 years, from 35·3 (95 % CI 31·3, 39·9) % to 27·3 (95 % CI 23·2, 32·0) %, but remaining a serious and moderate public health problem, respectively (data not shown in table).

Discussion

This review presents a broad analysis of studies conducted in Brazil, published from 1985 to 2018, that evaluated the prevalence of Fe-deficiency anaemia in children under the age of 5 and its associated factors. After meta-analysis, Fe-deficiency anaemia in Brazil was characterised as a severe public health problem and was associated with the child age range and the period of data collection of the studies.

Estimated prevalence of iron-deficiency anaemia

The estimated prevalence of anaemia in children under 5 years of age in Brazil in the North, Northeast, Midwest and South regions was classified as a severe public health problem (≥40 %). Only the Southeast, the wealthiest region of the country, had the estimate prevalence classified as a moderate public health problem (38·7 %). Therefore, anaemia is a health condition that still requires attention from the Brazilian health system through the promotion of new strategies for control and monitoring of the effectiveness of the existing public policies.

Regarding the regional aspects, it is important to highlight that, although the estimate of anaemia prevalence in the Midwest has been distinguished as the highest among the regions of the country, this result should be interpreted carefully. Considering that the Midwest region contributed with only four estimates of prevalence in the meta-analysis, we cannot discard the possibility of lower precision in the group estimate due to the low number of estimates available for this region.

Factors associated with anaemia in under 5-year-old children in the meta-analysis

Age of the child <24 months. The age of the child is the main risk factor for anaemia as shown in 47·3 % (*n* 26) of the studies in this review, being one of the variables that remained associated with the final meta-regression model. From these studies, eighteen identified higher prevalence in the age range of ≤24 months.

The group prevalence of anaemia in children under 24 months of age was classified as a severe public health

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Table 1. Description of the studies included in the present meta-analysis of the prevalence of anaemia in children under 5 years of age in Brazil (Percentages and 95 % confidence intervals)

Author	Age (months) and sample size	Study design	Setting	Criteria for anaemia status	Stratification of prevalence	Prevalence of anaemia (%)	95 % CI	Quality grade (risk)
Dricot d'Ans *et al.*[33]	0 to 59 *n* 1446	Cross-sectional	Residences in Paraíba state, northeast Brazil	WHO reference values[11]	–	19·3	17·3, 21·5	Low
Brunken[68]	4 to 59 *n* 1015	Case control	Residences in São Paulo city, southeast Brazil	WHO[11] and Brault-Dubuc *et al.*[74] reference values	Total sample Control group Intervention group	48·2 52·1 42·8	45·1, 51·3 48·1, 56·2 38·2, 47·5	Low
Neuman *et al.*[3]	0 to 35 *n* 476	Cross-sectional	Residences in Criciúma city, south Brazil	WHO reference values[11]	6–35 months <6 months 6–11 months 12–17 months 18–23 months 24–35 months	54·0 34,8 56·3 78·9 55·2 33·8	49·0, 58·9 25·9, 46·2 44,8, 67·3 68·5, 86·6 42·3, 64·8 26·6, 41·8	Low
Silva *et al.*[61]	0 to 36 *n* 557	Cross-sectional	Public day-cares in Porto Alegre city, south Brazil	WHO reference values[11]	Total sample 0–11 months 12–23 months 24–36 months	47·8 48·0 65·6 38·2	43·6, 51·9 30·0, 66·5 58·5, 72·0 33·2, 43·4	Low
Brunken *et al.*[29]	0 to 36 *n* 271	Cross-sectional	Public day-cares in Cuiabá city, Midwest Brazil	WHO reference values[11]	0–23 months 24–36 months	81·8 45·3	74·4, 87·5 37·3, 53·6	Low
Oliveira *et al.*[49]	0 to 59 *n* 1287	Cross-sectional	Residences in Paraíba state, northeast Brazil	WHO reference values[11]	–	36·4	33·7, 39·1	Low
Assis *et al.*[26]	0 to 60 *n* 603	Cross-sectional	Residences in Salvador city, northeast Brazil	WHO reference values[11]	Total sample 0–5 months 6–11 months 12–23 months 24–35 months 36–59 months	46·3 50·0 64·5 64·2 44·3 28·3	42·3, 50·3 37·3, 62·7 53·3, 74·3 55·9, 71·8 35·8, 53·1 22·7, 34·7	Low
Assis *et al.*[27]	0 to 11 *n* 553	Cross-sectional	Health services in Salvador city, north-east Brazil	WHO reference values[11]	Total sample 0–6 months 7–11 months	62·8 58·0 72·6	58·6, 66·7 53·0, 62·9 65·7, 78·6	Low
Almeida *et al.*[24]	6 to 84 *n* 659	Cross-sectional	Public day-cares in Vitória city, southeast Brazil	WHO reference values[11]	Total sample 6–23 months 24–35 months 36–47 months 48–59 months	27·0 65·2 34,8 22·1 16·3	23·1, 31·4 50·8, 77·3 25·8, 45·1 16·1, 29·5 11·3, 22·8	Low
Levy-Costa & Monteiro[38]	0 to 59 *n* 1280	Cross-sectional	Residences in São Paulo city, southeast Brazil	WHO reference values[11]	Total sample 6–11 months 12–23 months 24–35 months 36–47 months 48–59 months	45·2 71·7 63·5 48·6 29·5 22·2	41·2, 49·3 63·5, 78·8 57·5, 69·2 37·6, 59·8 10·6, 41·9 13·7, 33·9	Low
Santos *et al.*[57]	0 to 71 *n* 261	Cross-sectional	Residences in Pelotas city, south Brazil	WHO reference values[11]	Total sample 0–11 months 12–23 months 24–35 months 36–47 months 48–59 months	57·5 81·1 75·5 60·3 41·5 40·4	51·4, 63·3 65·8, 90·5 61·9, 85·4 47·5, 71·9 30·4, 59·7 28·2, 53·9	Low

Table 1. (*Continued*)

Author	Age (months) and sample size	Study design	Setting	Criteria for anaemia status	Stratification of prevalence	Prevalence of anaemia (%)	95 % CI	Quality grade (risk)
Matta *et al.*[41]	0 to 59 *n* 409	Cross-sectional	Public day-cares in Rio de Janeiro city, south-east Brazil	WHO reference values[11]	Total sample <24 months ≥24 months	47·3 70·0 40·3	44·0, 50·6 63·3, 75·8 36·7, 44·1	Low
Neves *et al.*[44]	6 to 24 *n* 410	Cross-sectional	Health services in Belém city, north Brazil	WHO reference values[11]	–	66·6	61·9, 71·0	Low
Pedraza[50]	12 *n* 610	Cross-sectional	Residences in Northeast Brazil region	WHO reference values[11]	–	78·9	75·4, 81·9	Low
Spinelli *et al.*[62]	6 to 12 *n* 2715	Cross-sectional	Health services distributed throughout all Brazilian regions	WHO reference values[11]	Total sample South Southeast Midwest Northeast North	65·4 59·7 70·4 60·2 65·9 65·3	63·6, 67·2 55·3, 63·9 67·5, 73·1 55·6, 64·6 60·3, 71·1 60·9, 69·5	Low
Bueno *et al.*[30]	6 to 75 *n* 83	Cross-sectional	Public day-cares in São Paulo city, southeast Brazil	WHO reference values[11]	–	83·1	73·7, 89·7	Low
Netto *et al.*[43]	18 to 24 *n* 101	Cross-sectional	Health services in Viçosa city, southeast Brazil	WHO reference values[11]	–	30·7	21·7, 39·2	Low
Torres *et al.*[63]	3 to 6 *n* 242	Cross-sectional	Health services in São Paulo city, southeast Brazil	Brault-Dubuc *et al.*[74] reference values	Total sample 3 months 4 months 5 months 6 months	18·2 11·8 10·2 8·3 37·5	13·8, 23·5 4·7, 26·6 5·5, 18·3 3·3, 20·0 27·2, 49·1	Low
Assunção *et al.*[67]	0 to 71 *n* 453	Case control	Residences in Pelotas city, south Brazil	WHO reference values[11]	Total sample 0–11 months 12–23 months 24–35 months 36–47 months 48–59 months	32·3 36·1 32·8 41·7 30·9 22·0	27·7, 37·3 26·0, 47·7 22·1, 45·6 31·0, 53·2 21·9, 41·6 14·4, 32·1	Low
Duarte *et al.*[34]	0 to 23 *n* 254	Cross-sectional	Residences in Itupeva city, southeast Brazil	WHO reference values[11]	Total sample 0–5 months 6–11 months 12–23 months	41·7 32·8 56·7 39·5	35·8, 47·9 23·0, 44·5 44·1, 68·4 31·4, 48·3	Low
Konstantyner *et al.*[37]	6 to 24 *n* 212	Cross-sectional	Public day-cares in São Paulo city, southeast Brazil	WHO reference values[11]	Total sample 6–14 months 15–23 months	51·9 63·7 43·0	44·9, 58·8 53·5, 72·9 34·5, 51·9	Low
Muniz *et al.*[42]	0 to 59 *n* 677	Cross-sectional	Residences in Assis Brasil and Acrelândia cities, north Brazil	WHO reference values[11]	Total sample Assis Brasil Acrelândia	30·6 36·3 28·3	27·2, 34·2 28·7, 41·8 24·5, 32·5	Low
Oliveira *et al.*[48]	6 to 59 *n* 746	Cross-sectional	Residences in Pernambuco state, northeast Brazil	WHO reference values[11]	Total sample 6–11 months 12–23 months 24–35 months 36–47 months 48–59 months	40·6 68·5 59·1 43·4 23·3 25·5	37·2, 44·2 60·0, 75·8 52·6, 65·2 35·7, 51·6 16·8, 31·6 18·2, 34·3	Low
Vieira *et al.*[64]	6 to 59 *n* 153	Cross-sectional	Public day-cares in Recife city, northeast Brazil	WHO reference values[11]	–	55·6	47·3, 63·5	Low

Table 1. (*Continued*)

Author	Age (months) and sample size	Study design	Setting	Criteria for anaemia status	Stratification of prevalence	Prevalence of anaemia (%)	95 % CI	Quality grade (risk)
Camillo *et al.*[31]	6 to 72 *n* 160	Cross-sectional	Public day-cares in Guaxupé city, south-east Brazil	WHO reference values[11]	Total sample 6–35 months 36–59 months	21·3 44·6 1·2	15·6, 28·2 33·8, 55·9 0·2, 6·3	Low
Pinheiro *et al.*[53]	6 to 59 *n* 116	Cross-sectional	Residences in Campina Grande city, northeast Brazil	WHO reference values[11]	–	31·7	23·6, 41·2	Low
Rocha *et al.*[54]	7 to 74 *n* 312	Cross-sectional	Public day-cares in Belo Horizonte city, south-east Brazil	WHO reference values[11]	Total sample <24 months 24–47 months 48–59 months	30·8 71·4 26·1 21·3	25·9, 36·1 56·4, 82·3 20·2, 33·1 14·2, 30·6	Low
Brazil[13]	6 to 59 3455	Cross-sectional	Residences distributed throughout all Brazilian regions	WHO reference values[11]	North Northeast Midwest Southeast South	24·1 19·2 19·5 19·7 17·5	22·7, 25·5 18·0, 20·6 18·2, 20·8 18·4, 21·0 16·3, 18·8	Low
Coutinho[70]	24 to 59 *n* 110	Case control	Public day-cares in Bady Bassitt city, southeast Brazil	WHO reference values[11]	–	20·2	13·5, 29·2	Moderate
Bortolini & Vitolo[71]	12 to 16 and 36 to 48 *n* 397 and 354	Cohort	Health services in São Leopoldo city, south Brazil	WHO reference values[11]	12–16 months 36–48 months	63·7 38·1	58·9, 68·3 33·2, 43·3	Low
Oliveira *et al.*[47]	0 to 59 *n* 501 and 448	Cross-sectional	Residences in São João do Tigre and Gameleira cities, northeast Brazil	WHO reference values[11]	Total sample Gameleira São João do Tigre	41·9 46·3 37·1	38·8, 45·1 42·0, 50·7 32·8, 41·6	Low
Vieira *et al.*[66]	6 to 60 *n* 666	Cross-sectional	Residences in Alagoas state, northeast Brazil	WHO reference values[11]	Total sample 6–11 months 12–23 months 24–35 months 36–47 months 48–59 months	45·0 75·2 62·1 40·4 16·9 18·5	41·3, 48·8 66·7, 82·2 54·9, 68·8 32·9, 48·4 11·4, 24·5 11·9, 27·6	Low
Rodrigues *et al.*[56]	6 to 24 *n* 256	Cross-sectional	Public day-cares in Cascavel city, south Brazil	WHO reference values[11]	–	29·7	24·4, 35·6	Low
Gondim *et al.*[35]	6 to 59 *n* 1108	Cross-sectional	Residences in Paraíba state, northeast Brazil	WHO reference values[11]	–	36·5	33·7, 39·3	Low
Leal *et al.*[4]	6 to 59 *n* 717	Cross-sectional	Residences in Pernambuco state, northeast Brazil	WHO reference values[11]	Total (1997) Urban (1997) Rural (1997) Total (2006) Urban (2006) Rural (2006)	40·9 37·8 51·4 33·0 31·5 37·0	37·4, 44·5 33·6, 42·1 45·0, 57·7 30·1, 36·1 28·2, 35·1 31·3, 43·0	Low
Arcanjo *et al.*[25]	12 to 24 *n* 72	Cross-sectional	Public day-cares in Sobral city, northeast Brazil	WHO reference values[11]	–	75·6	68·7, 81·3	Low

Table 1. (*Continued*)

Author	Age (months) and sample size	Study design	Setting	Criteria for anaemia status	Stratification of prevalence	Prevalence of anaemia (%)	95 % CI	Quality grade (risk)
Frota[16]	6 to 59 *n* 978	Cross-sectional	Residences in Maranhão state, northeast Brazil	WHO reference values[11]	Total sample 6–11 months 12–23 months 24–35 months 36–47 months 48–59 months Urban Rural	51·6 78·4 57·9 47·4 42·9 32·1 53·1 49·0	47·8, 54·0 70·9, 84·4 52·1, 63·7 41·1, 53·8 36·1, 49·9 25·0, 40·3 49·2, 56·9 43·7, 54·3	Low
Granado *et al.*[36]	0 to 23 *n* 224	Cross-sectional	Residences in Acrelândia city, north Brazil	WHO reference values[11]	2003 2007	47·5 39·7	39·0, 56·1 32·7, 47·0	Low
Leite *et al.*[17]	7 to 59 *n* 5397	Cross-sectional	Residences throughout all Brazilian regions	WHO reference values[11]	Total sample Northeast South and Southeast Midwest North 6–11 months 12–23 months 24–35 months 36–47 months 48–59 months	51·0 41·1 48·0 51·5 66·4 80·2 68·2 48·8 39·4 32·9	49·7, 52·4 38·6, 44·2 44·5, 51·5 48·6, 54·4 64·4, 68·3 77·1, 83·1 65·5, 70·8 46·0, 51·7 36·7, 42·1 30·2, 35·7	Low
Silla *et al.*[59]	18 to 84 *n* 1433	Cross-sectional	Residences in Rio Grande do Sul state, south Brazil	WHO reference values[11]	Total sample 12–23 months 24–35 months 36–47 months 48–59 months	45·4 43·3 38·1 30·5 28·7	43·3, 47·5 37·0, 49·9 34·6, 41·8 27·1, 34·2 25·2, 32·4	Low
Oliveira *et al.*[14]	6 to 72 *n* 327	Cross-sectional	Public day-cares in Belo Horizonte city, south-east Brazil	WHO reference values[11]	Total sample 6–23 months 24–47 months 48–59 months	38·5 56·1 37·5 20·3	33·4, 43·9 45·3, 66·3 30·7, 44·9 12·5, 31·2	
Paula *et al.*[2]	6 to 59 *n* 945	Cross-sectional	Residences in Pernambuco state, northeast Brazil	WHO reference values[11]	–	35·0	32·1, 38·1	
Pedraza & Sales[52]	12 to 72 *n* 53	Cross-sectional	Public day-cares in João Pessoa and Campina Grande cities, north-east Brazil	WHO reference values[11]	–	34·0	22·7, 47·4	
Saraiva *et al.*[58]	12 to 59 *n* 692	Cross-sectional	Health services in Vitória city, southeast Brazil	WHO reference values[11]	–	15·7	13·9, 19·5	
Lisbôa *et al.*[39]	0 to 59 *n* 725	Cross-sectional	Residences in Minas Gerais state, south-east Brazil	WHO reference values[11]	Total sample < 5 months 6 to 23 months 24 to 59 months	37·4 42·3 43·0 31·6	33·9, 41·0 33·3, 51·9 36·7, 49·5 27·2, 36·4	
Cardoso *et al.*[69]	6 to 8 *n* 462	Case control	Health services in Rio Branco (north), Olinda (northeast), Goiânia (midwest) and Porto Alergre (south) cities.	WHO reference values[11]	–	18·9	16·6, 21·5	Low

Table 1. (*Continued*)

Author	Age (months) and sample size	Study design	Setting	Criteria for anaemia status	Stratification of prevalence	Prevalence of anaemia (%)	95 % CI	Quality grade (risk)
Oliveira *et al.*[46]	11 to 14 *n* 150	Cross-sectional	Health services in Rio Branco city, north Brazil	WHO reference values[11]	–	22·7	16·7, 30·0	Low
Pedraza[51]	9 to 59 *n* 271	Cross-sectional	Public day-cares in Campina Grande city, northeast Brazil	WHO reference values[11]	–	17·0	14·8, 19·4	Low
Zuffo *et al.*[15]	6 to 36 *n* 334	Cross-sectional	Public day-cares in Colombo city, south Brazil	WHO reference values[11]	Total sample < 24 months ≥ 24 months	34·7 39·9 26·0	29·8, 40·0 33·3, 46·9 19·1, 34·4	Low
Novaes *et al.*[45]	0 to 59 *n* 677	Cross-sectional	Public day-cares in Vitória da Conquista city, northeast Brazil	WHO reference values[11]	Total sample < 36 months ≥ 36 months	10·2 15·3 9·7	8·1, 12·7 10·9, 21·2 7·3, 12·6	Low
Silva[60]	11 to 15 *n* 520	Cross-sectional	Health services in Rio Branco (north), Olinda (northeast), Goiânia (midwest) and Porto Alegre (south) cities	WHO reference values[11]	–	23·1	19·7, 26·9	Low
Magalhães *et al.*[40]	6 to 23 *n* 366	Cross-sectional	Health services in Vitória da Conquista city, north Brazil	WHO reference values[11]	Total sample 6 to 11 months 12 to 23 months	26·8 36·5 18·6	22·5, 31·5 29·6, 44·1 13·8, 24·6	Low
Rocha *et al.*[55]	24 to 48 *n* 306	Cross-sectional	Public day-cares in Taubaté city, south-east Brazil	WHO reference values[11]	–	19·2	15·3, 24·1	Low
Rodrigues *et al.*[72]	12 to 31 *n* 778	Cohort	Health services in São Luís city, northeast Brazil	WHO reference values[11]	–	47·4	43·9, 50·9	Low
Vieira *et al.*[65]	6 to 60 *n* 666	Cross-sectional	Residences in Alagoas state, northeast Brazil	WHO reference values[11]	2005 6 to 12 months 13 to 24 months 25 to 36 months 37 to 48 months 49 to 59 months 2015 6 to 12 months 13 to 24 months 25 to 36 months 37 to 48 months 49 to 59 months	45·1 75·2 62·1 40·4 16·9 18·5 27·4 47·9 37·2 21·5 21·9 14·2	41·3, 48·9 66·7, 82·2 54·9, 68·8 32·8, 48·2 11·4, 24·5 11·9, 27·6 24·2, 30·5 38·2, 57·8 30·8, 44·1 16·0, 28·2 16·2, 28·9 9·6, 20·6	Low
Azevedo *et al.*[28]	6 to 59 *n* 646	Cross-sectional	Residences in Pernambuco state, northeast Brazil	WHO reference values[11]	–	60·8	57·0, 64·5	Low
Carneiro *et al.*[32]	6 to 59 *n* 519	Cross-sectional	Health services in Rio de Janeiro city, southeast Brazil	WHO reference values[11]	–	13·7	11·0, 16·9	Low

Table 2. Association of methodological covariates with anaemia prevalence estimates in children under 5 years in Brazil (Pooled prevalence estimates and 95 % confidence intervals)

Variables	*n*	Pooled prevalence estimate	95 % CI	Bivariate model *P*	Multi-variable model *P*
Sample size					
<500	57	43·1	39·4, 47·2	0·065	0·124
500–1000	8	37·6	27·3, 51·7		
>1000	9	30·2	20·3, 45·1		
Age range					
<24 months	42	53·5	49·6, 57·6	<0·001	<0·001
24–59 months	25	30·7	27·7, 34·0		
Sample origin					
Households	37	39·7	33·5, 47·0	0·831	–
Daycares	21	40·3	33·0, 49·3		
Health services	16				
Region					
North	6	40·8	25·9, 64·4	0·641	–
Northeast	20	42·9	35·2, 52·3		
Midwest	4	45·6	22·0, 94·7		
Southeast	23	36·9	29·5, 46·1		
South	17	40·8	32·4, 51·3		
Setting					
Urban	52	42·1	38·1, 46·5	0·321	–
Rural	2	54·1	38·8, 42·1		
Urban and rural	20	35·8	27·2, 47·0		
Data collection period*					
Until 2004	34	51·8	47·5, 56·4	<0·001	0·001
Since 2005	37	32·4	27·0, 38·8		
Hb determination method†					
Laboratory test	10	35·3	26·3, 47·4	0·358	–
Portable haemoglobinometer	63	41·3	36·7, 46·5		

* In three estimates the year of data collection was not presented.
† In one estimate the Hb determination method was not presented.

problem. In children over this age range, prevalence was lower, but anaemia still represented a problem of moderate severity, which should be a reason for concern for administrators and health professionals in the elaboration of their priority programmes.

The WHO affirms that children under 60 months of age, especially those under 24 months, are considered a risk group for Fe deficiency anaemia[1]. This is due to the high need for Fe in this age range arising from a fast growth and development, combined with the insufficient intake of this mineral.

Furthermore, a few factors could interfere with Fe absorbency, such as the discontinuance of exclusive breast-feeding, associated with complementary feeding characterized by a monotonous diet, usually with low amounts and/or bioavailability of Fe, insufficient in vitamin C and excessive in Ca[13,31,32,35–37]. To encourage breast-feeding and adequate and healthy complementary feeding, in 2013, the Brazilian Ministry of Health established the programme Brazilian Breastfeeding and Feeding Strategy[38]. However, so far, the impact of this action on anaemia prevalence in the country has not been measured.

Another relevant aspects in Brazil are frequent morbidity, such as acute infections, diarrhoea, and intestinal parasitosis, which have a multiplicative effect on the development of anaemia in children, especially in the age range ≤ 24 months[39–41].

Years of data collection starting in 2005. Starting in 2005, we observed the lowest estimate of group prevalence of anaemia in children under 5 years of age when compared with the prevalence in previous years. The period in question coincides with two important public policies for control of Fe-deficiency anaemia in Brazil: the requirement of 'Fortification of wheat and maize flour with Fe and folic acid'[75] and the establishment of the 'National Program of Iron Supplementation'[76]. However, there are very few and contradictory results of studies that evaluate the effectiveness of these intervention strategies[45,46].

The fortification of wheat and maize flour was established by Resolution RDC number 344, from 13 December 2002[75], and determined the mandatory addition of 4·2 mg of Fe and 150 µg of folic acid in wheat and maize flour, and its effective implementation occurred in April 2005[76]. The objective of this action was to reduce the prevalence of anaemia and to prevent the occurrence of neural tube defects during gestation.

Few works investigated the effectiveness of flour fortification in Brazil. In a time series study conducted in Pelotas – RS[77], with a probability sample of children from 0 to 5 years old, analysed anaemia prevalence before and 12 and 24 months after the fortification, but did not observe significant effects on average Hb levels of the pre-schoolers. On the other hand, a literature review that included national and international articles[48] demonstrated that food fortification is one of the best processes to prevent nutritional deficiency of Fe all over the world.

Another measure was National Program of Iron Supplementation, established by the Brazilian Ministry of Health through Ordinance number 730 from 13 May 2005[76].

Its objective was to prevent and control anaemia through the prophylactic administration of ferrous sulphate in children between 6 and 24 months of age and ferrous sulphate and folic acid in pregnant women and up until the 3rd month post-partum and/or post-miscarriage.

Age v. year of collection of data

Due to the year of data collection and age range remaining in the final meta-regression model, additional analyses were performed stratifying the grouped prevalence of anaemia by age group and year of collection. There was a 1·4 times reduction in the combined prevalence of anaemia in children under 2 years and 1·3 times in children aged 2–5 years after 2004. Despite efforts by the Ministry of Health of the In Brazil, anaemia remains a serious public health problem in children under 2 years of age and moderate in children between 2 and 5 years old.

The prevalence of anaemia in Brazilian children under the age of 5 persists as a serious public health problem, indicating that efforts to combat this nutritional deficiency have not been sufficient to reduce it to acceptable levels. The factors associated with this high prevalence show the multi-causal nature and the role of social inequalities as determining factors for this disease, since a factor classically associated with age remains decisive in the onset of anaemia. Moreover, the programmes and policies developed by the public power were also associated, since studies conducted after policies of food fortification and promotion of food security were effective in reducing anaemia, but not enough to reduce its adequacy.

Furthermore, the current study, because it has no timespan restriction of the collected studies and has strong inclusion criteria in its meta-analysis, ensures that the estimated prevalence of anaemia found is as faithful as possible to the Brazilian reality and provides support for the development of new strategies, programmes and policies to combat anaemia. A limitation of the current study is the limited number of papers published in the Midwest region of Brazil, which may cause alterations or slightly biased results for this specific region.

Conclusions

The efforts made by Brazilian government were successful in the reduction of anaemia in children under 5 years of age in Brazil in the evaluated period. However, prevalence remains beyond acceptable levels for this population group.

It is concluded that Fe-deficiency anaemia remains as an important public health problem in children under 5 years of age in every region of Brazil, except in the Southeast, where it was classified as moderate. The highest prevalence of anaemia occurred in children under 24 months old and in studies with data collected before 2005. Furthermore, a continuous evaluation of the effectiveness of existing programmes is necessary to address its status.

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