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Estimation of the availability of iron in the school meals of Municipal Centers for Early Childhood Education of a capital city in northeastern Brazil

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Abstract

The final stage of Fe deficiency is Fe deficiency anaemia, with repercussions for human health, especially in children under 5 years of age. Studies conducted in Brazilian public daycare centres show high prevalence of anaemia. The present study aims to evaluate the availability of Fe in the meals of the Municipal Centers of Early Childhood Education in Maceió. The experimental design comprises selection of algorithms, menu evaluation, calculation of the estimates, comparison between the estimates obtained and the recommendations, and analysis of correlation between meal constituents, and of the concordance between the absorbable Fe estimates. Four algorithms were selected and a monthly menu consisting of 22 d. The correlation analysis showed a moderate positive correlation to animal tissue (AT) *v.* non-heme iron ($r = 0{\cdot}42$; $P = 0{\cdot}04$), and negative to AT *v.* Ca ($r = -0{\cdot}54$; $P = 0{\cdot}09$) and Ca *v.* phytates ($r = -0{\cdot}46$, $P = 0{\cdot}03$). Estimates of absorbable Fe ranged from 0·23 to 0·44 mg/d. The amount of Fe available, unlike the total amount of Fe offered, does not meet the nutritional recommendations on most school days. The Bland–Altman analysis indicated that the Monsen and Balinfty and Rickard *et al.* showed greater agreement. The results confirm the need to adopt strategies to increase the availability of Fe in school meals.

Key words: Heme iron: Non-heme iron: Availability of dietary iron: Iron-deficiency anaemia: Algorithms

Iron deficiency anaemia (IDA) is the most prevalent of all anaemias, accounting for about 50 % of cases worldwide. There are several organic repercussions of IDA, such as compromised immune system, reduced cognitive ability, reduced growth and neuropsychomotor development, decreased learning ability in schoolchildren, and increased perinatal mortality of mothers and newborns. Among the most vulnerable risk groups for developing anaemia are children under 2 years of age, pregnant women and women of childbearing age[1–3].

In Brazil, estimates show a prevalence of 10 % IDA (Hb < 11 g/dl) in children under 5 years old. The northeast region reaches a prevalence of 11·9 % IDA[4]. In Alagoas, a state located in northeastern Brazil, which has the second lowest Human Development Index among Brazilian states (0·684)[5], there was a decline in the prevalence of IDA (Hb < 11 g/dl) in children under 5 years old between 2005 and 2015, falling from 45·1 % to 27·4 %, considered a moderate magnitude public health problem[6]. In addition, it is noteworthy that there has been an improvement in socio-economic conditions in this period which, combined with the National Iron Supplementation Program (NISP), have contributed to this decline. This reduction may also be associated with the National School Feeding Program (NSFP), which focuses on food and nutritional education and the provision of adequate and healthy food[7,8].

The NSFP has also contributed to dietary management aimed at increasing the availability of Fe[7], which comprises the amount of dietary Fe available for intestinal absorption, while bioavailability presupposes the actual absorption of the mineral and its incorporation into the various parts of the body[9]. However, the two terms availability and bioavailability are often used interchangeably and will thus be used in this text.

Dietary Fe comes in two forms: heme iron (HI), present in the heme group in meat, fish, and poultry (MFP), and non-heme iron (NHI), distributed in various food sources, including MFP and plant foods, which exhibit different availabilities. Thus, dietary management should be used to increase the absorption of this

Abbreviations: ASC, ascorbic acid; AT, animal tissue; EAR, estimated average requirement; HI, heme iron; IDA, iron deficiency anaemia; NHI, non-heme iron; NSFP, National School Feeding Program; MFP, meat, fish, and poultry; SF, stimulatory factors.

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micronutrient, notably NHI, through stimulatory factors (SF), such as ascorbic acid (ASC)[10], which reduces and forms a soluble chelate with NHI. Other factors can negatively interfere with the absorption of this mineral, such as Ca, phytates, and tea polyphenols, through the formation of insoluble chelates or by competition for the same absorption site[11–13]. In addition, the absorption rate of dietary Fe is influenced by body stores and the characteristics of the diet. Therefore, care in menu design is of particular importance, especially when targeting groups at risk of nutritional Fe deficiency[14–16].

Menu planning should therefore consider the dietary factors that can positively or negatively influence Fe absorption, as a strategy that favours the increase of absorbable Fe supply[17]. Assuming such a premise, Resolution No. 06 of the Ministry of Education-ME/ National Fund for Education Development-NFED, 8 May 2020[8], recommends the inclusion of HI food sources at least 4 d a week, and the association of foods that are sources of vitamin C with the provision of NHI, in order to increase the availability of Fe in school meals.

Considering the variation in dietary Fe availability, some models have been developed in order to estimate it. Such models can contribute to the assessment of whether the nutritional needs of individuals and population groups are being met. Estimates are made from the analysis of meal constituents, in addition to the inclusion, in some algorithms, of biochemical parameters related to Fe nutritional status, such as ferritin and serum Fe[18,19].

These tools are easy to use and can contribute to clinical practice and to the evaluation of food intake and diet quality, especially when targeting groups at risk of deficiency for this mineral. In addition, each model presents specificities depending on the construction method used, such as how to estimate availability, which can be from a single meal and/or considering complete diets[18–20].

Given the lack of studies on the estimation of Fe availability in school meals at Municipal Centers for Early Childhood Education (MCECE), the present study sought to evaluate such availability at MCECE in Maceió-AL.

Methods

This study evaluates the availability of Fe, based on the performance of different algorithms, in the menus prepared by the Municipal Secretary of Education (MSE) for the meals of preschoolers regularly enrolled in the MCECE in the city of Maceió, Alagoas. This study is part of a larger project entitled ‘Effect of an iron-enhanced diet compared with a regular diet on Hb concentrations in preschool children’, conducted according to the guidelines laid down 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 (CAAE: 30523820·0·0000·5013; opinion number: 4·835·130). Written informed consent was obtained from all subjects/patients.

The study design comprised five steps: (1) selection of algorithms available in literature for estimating the availability of dietary Fe; (2) menu evaluation; (3) calculation of the available Fe estimates provided by the selected algorithms as well as efficiency of Fe absorption; (4) comparison of the estimates obtained and the Fe recommendations adopted by the NSFP; and (5) analysis of the correlation between the constituents of the meals that comprise the menu and of the agreement between the results from the selected algorithms.

Selection of algorithms

A literature review of published algorithms was performed, without language or time restriction. Searches were performed in the PUBMED, SCIELO and LILACS databases using the following keywords: iron, heme iron, NHI, availability, bioavailability and algorithm. Printed materials available on the subject were also included.

Algorithms that estimate total absorbable Fe were included. Algorithms that use biochemical markers, were made from vegetarian meals, require calculations for energetic adjustments or have a later version were excluded.

Evaluation of the menu

This evaluation was based on data made available by MSE, through food preparation technical sheets that make up the menus offered before the interruption in activities due to the COVID-19 pandemic.

The menu offered in March 2020 was used for the analysis, consisting of twenty-two school days in that month, with three meals a day (snack, lunch and dinner), totalling sixty-six analysed meals. The evaluation was carried out per meal, based on the *per capita* values established for the children in the daycare centres. To obtain the amount of Fe, the SF and inhibiting factor (IF) from the menu, the values from the technical data sheets were summed up for each meal. In the absence of information on the technical data sheets, data were obtained from food composition tables, in the following order of priority: The Brazilian Food Composition Table – BFCT[21], Food Chemical Composition Table[22], Food Composition Table: Support for Nutritional Decision[23], and nutritional information obtained from food labels. For the determination of phytate content, information available in the *PhyFoodComp* database, version 1.0 [24] was used, regarding values of inositol pentaphosphate (IP5) or inositol hexaphosphate (IP6); when in the presence of both, the sum of IP5 and IP6 was used.

HI and NHI calculations were performed according to Monsen and Balinfty[25], based on the amount of Fe in the foods from the data sheets and estimated in the tables of their chemical composition. Tea polyphenol contents, predicted in the algorithms by Singer *et al.*[26], Du *et al.*[27] and Rickard *et al.*[28], were considered absent, since the meals offered to children did not contain tea.

After checking the data from the preparation technical data sheets, the meals on the monthly menu were evaluated. This procedure was carried out considering the total amount of Fe, HI, NHI, as well as the SF and IF. For each day, all constituents were totalled, thus obtaining data per meal and values corresponding to the sum of the meals for each day, for subsequent application of the algorithms. The analyses, as well as the estimates described in the following section, were carried out using Microsoft Excel version 16.50. It was carried out independently by two people, and if there were divergences in the values obtained, a third evaluator was consulted.

Estimates of available iron and the efficiency of absorbable iron

Estimates of available or absorbable Fe were performed independently by two individuals using the four algorithms selected. A third evaluator was consulted in case of divergence between the values. For each of them, the Fe absorption efficiency was also estimated using the ratio between the estimated absorbable Fe and the total amount of Fe in the meals.

Estimates of available Fe were made for each meal. Then, the results for a given day were summed to obtain a daily estimate of absorbable Fe, followed by an estimate of the efficiency of daily Fe absorption. Finally, the mean and standard error for the amount of absorbable Fe and the estimated Fe absorption efficiency were calculated, taking into account the twenty-two results obtained with each algorithm.

Comparison between estimates and nutritional recommendations

The values adopted by NSFP were considered for the supply of school meals to full-time preschoolers, according to Resolution no. 06-ME/NFED, of 8 May 2020(8). According to NSFP, in this case, 70 % of the nutritional recommendations should be guaranteed by school meals.

Thus, since this is a menu prepared for population groups, the value of the estimated average requirement (EAR) was considered for the total daily Fe recommendation per age group, from 1 to 3 years and from 4 to 8 years of age. From this total, the amount of absorbable Fe recommended for the age groups evaluated was calculated, considering an 18 % absorption rate(29). The recommended values of absorbable Fe were compared with the estimates obtained from each algorithm to verify that the daily requirements of this mineral were met.

Statistical analysis

The analyses were performed using the software R, version 4.1.0. The association between meal constituents of interest (AT, NHI, ASC, Ca and phytates) was measured by correlation analysis, using Pearson's correlation coefficient. The estimates obtained with each of the four algorithms were described as mean and standard error. ANOVA with repeated measures was performed to compare the absorbable Fe estimates obtained with the four algorithms. The assumptions of normality and sphericity were examined using the Shapiro–Wilk and Mauchly test, respectively. Finally, Bland–Altman analysis was performed(30–33), in order to verify the agreement between the results obtained with the different algorithms. A significance level of 5 % was considered in all tests.

In the Bland–Altman analysis, the differences and the averages between the twenty-two estimates obtained with each algorithm were calculated for each pair of algorithms. Then a scatter plot was drawn with these pairs (mean × difference) in order to check the magnitude and distribution of the difference between the results obtained with the algorithms. To evaluate the magnitude, the mean of the differences (bias) and the($\bar{x}$) limits of agreement were calculated, equal to $\bar{x} \pm 1 \cdot 96s$, where s is the standard deviation(30). Subsequently, a regression analysis was performed between the means and differences in order to see if there was any systematic divergence between the results obtained with each pair of algorithms. Finally, the root mean square error between the estimates obtained with each pair of algorithms was calculated, taking into account that the smallest values indicated the best matches(32).

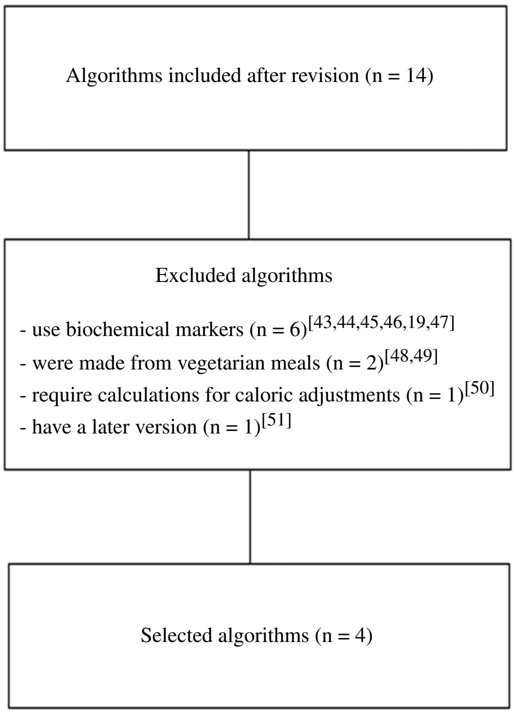

Fig. 1. Flow chart of algorithm selection.

Results

Figure 1 shows how the selection of algorithms used in the study was performed. The algorithms selected for the estimation of Fe availability were Monsen and Balinfty(25), Singer *et al.*(26), Du *et al.*(27) and Rickard *et al.*(28). When necessary, body Fe that stores levels of 250 mg were considered, assuming a mean serum ferritin concentration of 30 µg/l(34,35).

The algorithm of Monsen and Balinfty(25) considers the following variables: total amount of Fe, HI, NHI and the stimulating factors ASC and MFP. To determine the amount of HI, the authors considered 40 % of the total Fe in MFP, with an absorption percentage of 23 %. Singer *et al.*(26), in addition to the SF animal tissue (AT) and ASC, included tea as IF for Fe absorption. In this algorithm, meals are classified according to the amount of MFP protein (g), instead of the amount of MFP (g), and the HI corresponds to 40 % of the total Fe in MFP. The percentage of absorption varies according to the quality of the meal. Du *et al.*(27), in turn, considered ASC, food of animal origin, vegetables and fruits as SF, and as IF, rice, beans and tea, with HI corresponding to 40 % of the total Fe of food of animal origin, with a bioavailability of 23 %. And Rickard *et al.*(28) considered ASC and

Table 1. Description of the main constituents present in the menu*

	Snack		Lunch		Dinner		Daily total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TI (mg/d)	0·14	0·08	3·20	1·66	1·27	0·78	4·62	1·88
HI (mg/d)	0·00	0·00	0·33	0·40	0·12	0·24	0·46	0·46
NHI (mg/d)	0·14	0·08	2·87	1·40	1·15	0·60	4·16	1·59
AT (g/d)	0·00	0·00	47·73	6·85	20·45	20·52	68·18	21·47
ASC (mg/d)	15·97	18·11	39·58	21·65	27·65	67·20	83·19	66·39
Ca (mg/d)	6·14	3·21	52·02	19·47	64·96	78·12	123·12	73·79
Phytates (mg/d)	0·00	0·00	104·44	52·11	40·01	39·37	144·45	60·70

TI, total iron; HI, heme iron; NHI, non-heme iron; AT, animal tissue; ASC, ascorbic acid.
* Mean ± standard deviation.

Table 2. Correlation matrix between constituents present in the meals of the monthly menu of the MCECE of Maceió-AL, in March 2020

	ASC	Ca	Phytates	NHI
AT	$r = -0·19$ $P = 0·39$	$r = -0·53$ $P = 0·009$	$r = 0·28$ $P = 0·19$	$r = 0·42$ $P = 0·04$
ASC		$r = 0·13$ $P = 0·55$	$r = -0·09$ $P = 0·66$	$r = -0·01$ $P = 0·97$
Ca			$r = -0·45$ $P = 0·03$	$r = -0·14$ $P = 0·52$
Phytates				$r = 0·03$ $P = 0·89$

MCECE, Municipal Centers for Early Childhood Education; ASC, ascorbic acid; NHI, non-heme iron; AT, animal tissue.

MFP as SF, and phytate, tea polyphenols, Ca and the NHI content of the meal as IF. The authors assumed availability of 25 % of HI. To calculate the daily Fe bioavailability with the four algorithms, the amounts of Fe bioavailability from each of the meals of the day were added altogether.

Twenty-two school days' worth of menu offerings, with three meals a day, snack, lunch and dinner, totalling sixty-six meals, were evaluated. AT (beef, fish or poultry) was present in lunches every day and in fifteen of the twenty-two dinners analysed. At snack, there was no AT. The constituents of the meals of interest are presented in Table 1.

Correlation analysis between the constituents present in each day's meals (Table 2) showed that AT *v.* NHI showed moderate positive correlation, while AT *v.* Ca and Ca *v.* phytates showed moderate negative correlation.

Table 3 shows the estimates of Fe availability, calculated with the selected algorithms, and of Fe absorption efficiency, considering the 22 d corresponding to the chosen monthly menu. Absorbable Fe estimates ranged from 0·23 mg/d, with Singer *et al.*[26], to 0·44 mg/d, with Rickard *et al.*[28]. Meanwhile, the estimated absorption efficiency ranged from 4·8 % to 9·7 % for the same algorithms.

The ANOVA with repeated measures indicated that there were significant differences between the estimates of absorbable Fe obtained by each algorithm ($P < 0·001$). Using Tukey's test, it was found that, with the exception of the comparison between Monsen and Balintfy[25] and Rickard *et al.*[28] ($P = 0·07$), the results estimated by the other algorithms show significant differences. To Singer *et al.*[26] and Du *et al.*[27] $P = 0·002$ and to the others pairs, $P < 0·001$.

Table 4 shows the number of days that the total Fe of the menu and the estimates of absorbable Fe obtained from the algorithms meet the Fe nutritional recommendations adopted by the NSFP, according to the age group being evaluated. For the 1- to 3-year age group, the estimates calculated using the Rickard *et al.*[28] and Monsen and Balintfy[25] algorithms met the EAR[34] for the most days, 12 and 10, respectively. Considering the results obtained with the four algorithms, the absorbable Fe requirements were simultaneously met on three of the 22 d analysed.

When grouping three algorithms, the combination showing the best performance was among the algorithms of Monsen and Balintfy[24], Du *et al.*[26], and Rickard *et al.*[27], which simultaneously met the EAR[29] in 5 d. When compared two by two, Monsen and Balintfy[25] and Rickard *et al.*[28] had the highest number of days meeting the EAR[29] (9 d).

As for the daily nutritional requirements for absorbable Fe for the 4–8 age group, the data in Table 4 show that the estimates obtained by the algorithms of Rickard *et al.*[28] and Monsen and Balintfy[25] met the recommendation on the greatest number of days 6 and 5, respectively. On the other hand, no estimate obtained from the Singer *et al.*[26] algorithm met the recommendation. Considering the other three algorithms, the recommendations were met concurrently on 3 d. With regard to the algorithm pairs, the best result was obtained with the combination of Monsen and Balintfy[25] and Rickard *et al.*[28], where the recommendation was simultaneously met on 5 d.

For the agreement analysis of the estimates obtained by each of the four algorithms, the Bland–Altman graphs comparing the results by algorithm pair are shown in Fig. 2. For each pair, the root mean square error and the *P*-value from the linear regression analysis between the differences in absorbable Fe estimates and their means are given.

From the results presented in Fig. 2, it can be observed that the pair Monsen and Balintfy[25] and Rickard *et al.*[28] showed the smallest average difference between their estimates. Meanwhile, the algorithms of Singer *et al.*[26] and Du *et al.*[27] had the lowest root mean square error. Furthermore, linear regression analysis indicated that only the Singer *et al.*[26] and Du *et al.*[27] pair did not show a proportion bias, suggesting that the values have a homogeneous distribution. It is worth noting that the *P*-value corresponding to the pair Monsen and Balintfy[25] and Rickard *et al.*[28] suggests that their measures are close to a homogeneous distribution, implying an agreement between the two algorithms.

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Table 3. Estimates of absorbable iron and efficiency of iron absorption from the monthly menu of the MCECE in Maceió-AL, in March 2020*

	Monsen and Balintfy[25]		Singer *et al.*[26]		Du *et al.*[27]		Rickard *et al.*[28]	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Absorbable iron (mg/d)	0·39	0·04[a]	0·23	0·03[b]	0·30	0·03[c]	0·44	0·04[a]
Absorption efficiency (%)	8·2	0·30	4·8	0·20	6·5	0·41	9·7	0·44

MCECE, Municipal Centers for Early Childhood Education.
* Mean ± standard error.
a,b,cDifferent letters indicate statistically significant differences using Tukey's test ($P < 0·05$).

Table 4. Number of days of compliance with the recommendations of total iron and of absorbable iron according to each algorithm in the 22 d of monthly menu from March 2020 at the CMEI in Maceió-Alagoas

				Number of days†			
	70 % of the EAR of iron	Number of days*	70 % of the EAR of absorbable iron‡	Monsen and Balintfy[25]	Singer *et al.*[26]	Rickard *et al.*[28]	Du *et al.*[27]
EAR (1–3 years)	2·10	20	0·38‡	10	3	12	5
EAR (4–8 years)	2·87	17	0·52‡	5	0	6	3

EAR, estimated average requirement[29].
* Number of days of compliance with the recommendations of total Fe.
† Number of days of compliance with the recommendations of absorbable Fe according to each algorithm.
‡ Values obtained assuming an 18 % Fe absorption.

For the other cases, the *P*-values obtained in the linear regression indicate that there is a proportion bias, that is, the disagreement increases or decreases as the estimates vary. Considering the regression line as shown in Fig. 2, it can be seen that for the pairs Monsen and Balintfy[25] and Singer *et al.*[26], Monsen and Balintfy[25] and Rickard *et al.*[28], Monsen and Balintfy[25] and Du *et al.*[27], and Rickard *et al.*[28] and Du *et al.*[27], disagreement is greater for higher estimates of absorbable Fe, whereas for Singer *et al.*[26] and Rickard *et al.*[28], disagreement decreases with higher estimates of absorbable Fe.

Discussion

The amount of Fe available in school meals estimated from the 22 d of the menu analysed does not meet, on most days, the nutritional recommendations adopted by the NSFP. Although the reference used here, Resolution nº 06-ME/NFED, of 8 May 2020[8], was published at a later date than the analysed monthly menu, the previous resolution[7] also adopted the dietary reference intakes[29] as a standard assuming, however, the RDA and not the EAR as an intake level, which was a mistake in the previous resolution that was corrected in the current one. In addition, some strategies that could contribute to the increased availability of this mineral, especially considering the dietary factors that stimulate its absorption, were not observed.

The days that met the nutritional recommendations for absorbable Fe, considering the results obtained with the four algorithms, for example, were those that had the highest amount of total Fe, with appreciable amounts of HI and ASC. On the other hand, those who did not meet the nutritional recommendations for absorbable Fe, also considering the results obtained with the four algorithms, had especially low levels of total Fe and high levels of phytates. The amount of other SF and IF varied between the different days analysed.

The analysis of the constituents of the meals, in turn, consists of another evaluation strategy of the elaborated menus, which allows the study of correlation between SF and IF. As expected, the findings of the present study show a moderate positive correlation between AT and NHI, given that AT such as MFP is a source of Fe. It is also worth noting that the concomitant supply of NHI from other dietary sources with AT is a recommended practice, given the stimulatory effect on NHI absorption exerted by the AT itself[36].

It was also found that AT *v.* Ca and Ca *v.* phytates showed a moderate negative correlation. In the study by Reddy, Hurrell and Cook[37], the authors observed a strong negative correlation between AT and Ca, as well as a significant low correlation between phytates and Ca. Considering the inhibitory effect of divalent metals such as Ca on the absorption of dietary Fe, even of HI[38–40], the correlation between AT and Ca observed here deserves to be highlighted as a positive aspect of the proposed menu. Ca may compete for the same absorption site and thus reduce Fe availability[11–13]. For this reason, offering foods with higher amounts of Fe separated from those rich in Ca in the same meal can contribute to increasing the bioavailability of these minerals.

In addition, no correlation was observed between ASC and NHI. However, a strong positive correlation between ASC and NHI is easily achievable through improvements in menu design, such as the inclusion of ASC sources in meals with higher Fe content. Such an approach would be opportune and could meet the recommendations of Resolution No. 06 ME/NFED mentioned above. The ASC is an important promoter of the bioavailability

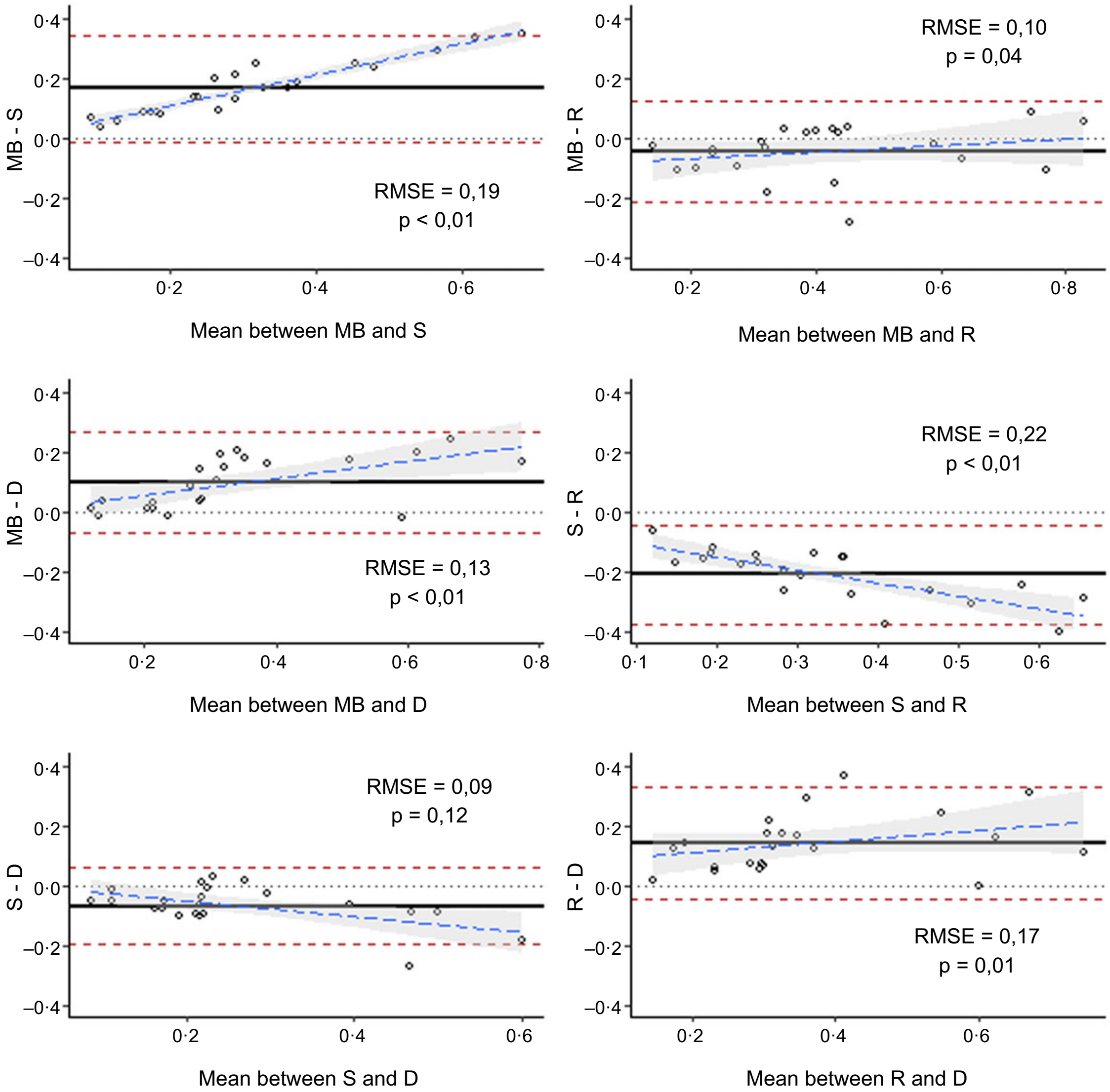

Fig. 2. Graphical representation of the agreement between estimates of dietary Fe availability obtained by the indicated algorithms. MB, Monsen and Balintfy[25]; S, Singer *et al.*[26]; D, Du *et al.*[27]; R, Rickard *et al.*[28] RMSE, root of the mean square error between the measurements obtained with the two algorithms. p, linear regression analysis between the differences and the means.

of dietary Fe, increasing Fe absorption even in the presence of foods containing IF, such as phytates and polyphenols[41].

At the local level, the analysis of the menu offered at the MCECE in the city of Maceió-AL carried out in this study allows us to conclude that when menu preparation takes into account only the total amount of Fe, and not the amount of absorbable Fe, on most days it can be assumed that the recommendations for this mineral have been met. Considering the current nutritional recommendations adopted by the NSFP[8], based on the EAR[29], this result is similar to that found by Zuffo *et al.*[42], in a study carried out in MCECE of Colombo, in the state of Paraná. However, the authors of that study concluded that the total Fe supply was inadequate since it was below the recommendations adopted by the NSFP at the time[7], based on the RDA[29], rather than on the EAR.

However, when checking the amount of absorbable Fe in the menu, the values found on most days did not meet the daily nutritional Fe recommendations for children attending the MCECE of Maceió, across both age groups considered. Thus, the result of the present study contributes to the discussion and highlights the need to evaluate dietary Fe availability, especially for vulnerable population groups, since the total amount of the mineral in the diet, even when apparently sufficient, may not ensure that the nutritional needs of the target population are met. Therefore, the overall quality of the diet needs to be observed in order to increase the percentage of mineral absorption.

The estimates of dietary Fe availability obtained by the four algorithms employed here showed that the pair of Monsen and Balintfy[25] and Rickard *et al.*[28] provided the closest results, which simultaneously met the nutritional recommendations for available Fe on a greater number of days. When estimating Fe absorption efficiency, it was observed that this same pair of algorithms showed the highest percentages, 8·2 % and 9·7 %, respectively.

The Bland–Altman analysis confirmed that the algorithm pairs of Singer *et al.*[26] and Du *et al.*[27], and of Monsen and Balintfy[25] and Rickard *et al.*[28] showed the highest agreement between their results when comparing the estimates obtained with the four algorithms used. Interestingly, although Monsen and Balintfy[25] and Rickard *et al.*[28] use as factors stimulating NHI absorption the presence of ASC and MFP, only Rickard *et al.*[28] included inhibitory factors in the analyses, a fact that did not compromise the agreement between such algorithms in the present study.

Conclusion

The amount of Fe available in school meals estimated in this study, unlike the total amount of Fe offered, does not meet the nutritional recommendations adopted by the NSFP on most school days. In addition, the analysis of menu constituents confirmed the need to adopt strategies to associate the consumption of NHI and ASC, as well as to increase the amount of HI and reduce the presence of IF in meals with a higher intake of Fe-source foods.

The present study thus emphasises the caution needed in menu planning with regard to estimating dietary Fe availability and the consequent importance of using algorithms as a tool for evaluating the quality of diets.

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All authors collected and analysed data, drafted the manuscript, critically reviewed the manuscript, and read and approved the final version of the manuscript.

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