

Consequences of anemia on language development of children from a public day care center

Anemia em crianças de uma creche pública e as repercussões sobre o desenvolvimento de linguagem

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ABSTRACT

Objective: To compare language development in anemic and non-anemic children from a public day care center in Belo Horizonte, Minas Gerais, Brazil.

Methods: Cross-sectional study with evaluation of language development of anemic (cases) and non-anemic children (controls) between two and six years old. All children had a digital puncture to detect anemia (hemoglobin ≤ 11.3 g/dL). Cases were 22 anemic children and controls, 44 children selected by randomized paired sampling. The language development of each participant was observed and classified according to two main fields: communicative aspects (reception and emission) and cognitive aspects, based on the Child Behavior Observation Guide for children from zero to six years old. Performance rates were created in order to qualify children's answers.

Results: The hemoglobin values observed in case and control groups were 10.6 and 12.5g/dL, respectively. The groups did not differ regarding age, gender, breastfeeding and mother's schooling. Significant differences were observed in the language evaluation in all examined fields: levels of reception ($p=0.02$) and emission ($p<0.001$) and cognitive aspects ($p<0.001$), with worse performance of anemic children.

Conclusions: Anemic children presented worse language development when compared to non-anemic ones. In the public health context, childhood anemia should be considered as a relevant problem due to language development

alterations with possible consequences on learning abilities and future social and professional performance.

Key-words: language; anemia; child day care centers; child development.

RESUMO

Objetivo: Comparar o desenvolvimento de linguagem de crianças anêmicas e não-anêmicas de uma creche pública de Belo Horizonte.

Métodos: Estudo transversal com avaliação do desenvolvimento de linguagem de crianças anêmicas (casos) e não-anêmicas (controles) entre dois e seis anos de idade. Todas as crianças realizaram punção digital para detecção da anemia (hemoglobina $\leq 11,3$ g/dL). O Grupo Caso foi constituído por 22 crianças anêmicas e o Controle, por 44 crianças, selecionadas por amostragem aleatória pareada. O desenvolvimento de linguagem de cada um dos participantes foi observado e classificado em duas grandes áreas: aspectos comunicativos (recepção e emissão) e aspectos cognitivos da linguagem, com utilização do Roteiro de Observação de Comportamentos de crianças de zero a seis anos. Índices de desempenho foram aplicados para qualificar as respostas das crianças.

Resultados: Os valores médios de hemoglobina dos Grupos Caso e Controle foram 10,6 e 12,5g/dL, respectivamente. Os grupos não diferiram quanto às seguintes variáveis: idade, gênero, aleitamento materno e escolaridade materna. Na avaliação de linguagem, observou-se uma diferença estatística-

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mente significativa nos índices de recepção ($p=0,02$), emissão ($p<0,001$) e aspectos cognitivos da linguagem ($p<0,001$), com pior desempenho das crianças anêmicas.

Conclusões: Crianças anêmicas apresentaram pior desenvolvimento da linguagem em comparação às não-anêmicas. A anemia deve ser considerada um problema relevante de Saúde Pública também pelas possíveis alterações que pode provocar no desenvolvimento da linguagem e, consequentemente, na aprendizagem e futuro desempenho social e profissional da criança.

Palavras-chave: linguagem; anemia; creches; desenvolvimento infantil.

Introduction

Iron deficiency anemia affects approximately 2 billion people all over the world⁽¹⁾. In developing countries, nutritional anemia due to iron deprivation affects more than 50% of children aged from six months to five years, and is considered to be one of the four worldwide risk factors for abnormal child development and a serious public health problem that must be combated urgently⁽²⁾. In Brazil, the prevalence of anemia among preschool children varies from 30.2%⁽³⁾ to 68.8%^(4,5). Prevalence rates among children who attend public daycare centers have been found to be considerable⁽⁴⁻⁶⁾. A 37.5% prevalence of anemia has been observed among children from the eastern part of the city of Belo Horizonte⁽⁷⁾.

In developing countries, iron deficiency anemia is associated with low birth weight, malnutrition, unfavorable socioeconomic conditions and high morbidity^(2,8-10). Although it is infants who are at greatest risk of iron deficiency anemia resulting from rapid growth combined with exhaustion of the body's stocks of the mineral, this risk also extends to preschool and school children whose adverse living conditions and inadequate diets mean that iron deficiency is a common problem in this age group^(3,10).

Anemia leads to significant damage, with repercussions primarily affecting acquisition of motor and cognitive skills, language development, and also the learning process⁽¹¹⁻¹⁴⁾. The manifestations of iron deprivation affect several of the body's systems. Clinical diagnosis is based on observation of signs such as cutaneous-mucosal pallor, heart murmurs, tachycardia, reduced resistance to cold, reduction in certain immune functions and delayed growth, among others, and will only be established once the child is already in an advanced stage of iron deficiency. Nevertheless, among the

long-term consequences of anemia, those that affect cognitive, language, and behavior development, as well as motor coordination, have been receiving increased attention, not only because of the lower rate of suspicion that these conditions provoke, but also because of the diagnostic difficulties, the severity and the late presentation of the signs^(11,15). Furthermore, the most intense period of cerebral growth and the formation of neuronal connections coincides with the period of greatest prevalence of iron deficiency anemia⁽¹⁶⁾.

Several studies have identified a relationship between iron deficiency and delays in cognitive and psychomotor development in early childhood^(11,13-18). A large number of studies carried out during the last decade have shown the negative effects of iron deficiency on cognitive acquisition in schoolchildren and adolescents^(19,20). Anemic children over two years of age also demonstrate reduced cognitive acquisition when compared with non-anemic children, although there is an evident improvement once treatment is started⁽²¹⁾. Research that has specifically studied auditory development in anemic patients suggests that myelination of the auditory nervous system is delayed in these patients⁽¹²⁾.

Some studies have indicated that neurocognitive abnormalities may occur as a result of the cerebral repercussions of iron deficiency, even in the absence of anemia^(19,22), which is similar to results that have been obtained with animal models. In these models, iron deficiency can lead to a reduction in the activity of iron-dependent enzymes that are necessary for the synthesis, function and breakdown of neurotransmitters, directly affecting the metabolism of neurotransmission and also leading to central nervous system myelination abnormalities⁽²³⁻²⁵⁾.

No studies have been carried out with the Brazilian population evaluating the repercussions of anemia on the language development of children. Therefore, the objective of this investigation was to compare language development of anemic children with that of non-anemic children, all aged from two to six years of a public daycare center in the city of Belo Horizonte.

Methods

The present study was approved by the Research Ethics Committee at Universidade Federal de Minas Gerais (UFMG). This was a cross-sectional study that evaluated the language development of anemic and non-anemic children aged from two to six years and enrolled at a public daycare center in the city of Belo Horizonte. The daycare center

assessed is affiliated with the Belo Horizonte municipal government, is located in the eastern part of the city and is responsible for the full-time care of 139 children with low socioeconomic status.

All children at the daycare center were eligible to take part in the study. The children's parents were notified about the voluntary principle of this study, its objectives and repercussions, and also signed the consent memorandum. The parents also answered a questionnaire which requested identification data and information on the children's clinical history and development and their mothers' level of education.

Children were excluded if there was a history of prematurity, asphyxia, infection or other perinatal conditions, cognitive abnormalities, motor-based speech impediments, significant emotional disorders or neurological symptomatology or if they had not undergone otoacoustic emission tests⁽²⁶⁾. Additionally, children were excluded if, on the day of the clinical examination, they showed signs of any acute disease (fever, diarrhea, vomiting, etc.), since acute and/or chronic inflammatory processes alter hemoglobin levels. The study included 132 children enrolled at the center; the guardians of all selected children signed the aforementioned consent form.

Initially, finger prick samples were taken from the children in order to determine hemoglobin levels (Hg), using a *HemoCue*® high-precision spectrophotometer. A microcuvette was used to obtain the precise volume of blood in contact with the exact quantity of dry reagent. The microcuvette was then inserted into the *HemoCue*®, which determines hemoglobin levels in 15-45 seconds⁽²⁷⁾. Children were defined as anemic if their hemoglobin levels were below 11.3g/dL (11.0g/dL + 0.3 for the variation of the *HemoCue*® measurement), following the recommendation of the World Health Organization⁽²⁸⁾.

Later, all children underwent auditory evaluation, consisting of the following tests: transient otoacoustic emissions (TOAE) and acoustic immittance measurements. The apparatus used for these hearing tests were as follows: a Heidji otoscope, an AUDIX I 580-AX2191 TOAE machine by Biologic and a CATZA42 middle-ear analyzer by Dicton. The TOAE machine and the middle-ear analyzer were calibrated in advance. The children underwent otoscopy and then the TOAE test, where results were classed as pass or fail. These criteria were based on a signal/noise ratio ≥ 3 dB and reproducibility $\geq 50\%$ ⁽²⁹⁾. Immittance tests were carried out to obtain tympanometry and static compliance measurements⁽³⁰⁾. Tympanometric curves were interpreted with reference to published literature, and the range of tympanometric peak

pressure values considered as normal ranged from -100 to +50 Pa⁽³¹⁾. All procedures were conducted at the daycare center, in a silent room, in which sound pressure levels did not exceed 45 dBNPS, measured with a decibel meter, thereby avoiding the creation of artifacts or noise contamination.

After being tested for hemoglobin levels, the children were classified into two groups based on the presence (cases) or absence (controls) of anemia. The children were then examined by the principal investigator, who was blind to hemoglobin status. Language evaluation was carried out at the daycare center, in a room that was appropriate for observation, in individual sessions lasting approximately 40 minutes, and in the play area, when necessary, according to the criteria defined by Chiari *et al*⁽³²⁾, i.e., using the Behavior Observation Guide for children aged zero to six years. Language development was observed and classified according to two large areas: communicative aspects (reception and emission) and language cognitive aspects. Individual forms were used to record the behavior expected for each age range, marking yes or no depending on whether or not each item was present.

Although the instrument used is not a standardized test, but rather a protocol for observing behavior, performance indexes (PI) were created, expressed in percentages, in order to classify the results. We considered as cognitive performance index (CPI) those aspects rated by the author within the language cognitive aspects, and as reception performance index (RPI), and emission performance index (EPI) those aspects rated for language reception and emission, respectively. The PIs were analyzed with relation to the presence or absence of anemia for each age group.

$$Pi: \frac{Nba - Nbno \times 100}{Nba}$$

Pi: performance indexes

Nba: number of behaviors analyzed

Nbno: number of behaviors analyzed

Epi-Info version 6.04 was used for data entry, processing and analysis. The descriptive analysis consisted of frequency distribution for categorical variables involved in the language analysis and measures of central tendency and dispersion for continuous variables. The following tests were used for statistical analysis: the chi-square test and Fisher's exact test were used to assess differences between proportions; analysis of variance (ANOVA for parametric variables) and the Kruskal-Wallis test (non-parametric) were used

to compare continuous variables between the anemic and non-anemic groups.

Results

Twenty-seven (20.4%) of the 132 children initially enrolled in the study had hemoglobin levels compatible with anemia. Five of these were excluded because they had had abnormalities at birth (prematurity and perinatal complications) and/or abnormal TOAE findings. Therefore, the case group included 22 anemic children and the control group contained 44 children without anemia, selected by randomized sampling and paired for age and sex.

The distribution of the variables sex, age and hemoglobin level and those collected using the questionnaires (mothers' educational level, duration of breastfeeding and mother's perception of the child's learning) are shown in Table 1.

Otoacoustic emissions were present bilaterally in all children in both the case and control groups; 87% had type A tympanometric curves, indicating that the integrity of the peripheral auditory canal was not compromised. Table 2 and Figure 1 illustrate the results of the learning evaluation tests for children in the case and control groups.

Discussion

This study focused on language development from the perspective of speech and hearing. One difficulty encountered was the lack of a standardized and validated assessment instrument in Brazil appropriate for this study population.

Therefore, the authors decided to use the behavior observation guide for children aged zero to six years proposed by Chiari⁽³²⁾ and to create three performance indexes based on the results. The CPI illustrates the acquisition of cognitive features that impact on language development; the RPI illustrates how children receive information from the external environment and their ability to understand spoken language; and the EPI provided more information on how they articulate and connect together different structural components (syntax, phonology, and semantics) and their relationship with communicative intentions – and all three indicators are of fundamental importance to their development. The choice of this instrument was also justified by the fact that behavior observation is an evaluation technique that studies language in natural situations, prompting greater richness and variety of communicative structures, whereas formal tests demand that children perform activities that are not part of their routine⁽³³⁾. It is also worth pointing out that the instrument most often cited in the international literature for registering the negative impact of iron deficiency anemia during childhood is the Bayley scale of child development, which is an instrument used by psychologists^(11,14,21).

The children assessed in the present investigation have very similar constitutional and environmental histories. The daycare center only cares for deprived children whose parents have been means-tested. All mothers are residents of the same sociodemographic region, have a similar educational level and, from the point of view of maternal perception, their children are exposed to the same environmental factors (Table 1). All of these children showed peripheral auditory

Table 1 – Distribution of the characteristics of children and their mothers according to presence or absence of anemia

Characteristics	Anemic children	Non-anemic children	<i>p</i>
Sex			0.93
Female	12 (55%)	23 (53%)	
Male	10 (45%)	21 (47%)	
Natural breastfeeding			1.00
Yes	19 (87%)	39 (89%)	
No	03 (13%)	05 (11%)	
Learning difficulty			1.00
Yes	03 (13%)	05 (11%)	
No	19 (87%)	39 (89%)	
Hemoglobin	10.6±0.5	12.5±0.6	<0.001
Age in months	47.6±9.3	50.2±10.8	0.95
Months of breastfeeding	12.7±13.4	12.9±12.6	0.94
Mother's education level (years)	7.5±2.6	7.5±2.8	0.96

integrity and no differences in terms of sex, age, presence or duration of breastfeeding, abnormalities at birth and/or current health status. There is evidence in the literature that anemia is linked with a large number of social and economic factors, which may well affect child development in their own right⁽²¹⁾; among these, low maternal educational level is considered a risk factor for anemia^(3,9,17), as well as absent and/or reduced breastfeeding⁽¹¹⁾. Thus, the findings of this study emphasize the fact that, with relation to language problems, children with anemia may be considered vulnerable as a result of the neuromaturational physiological compromise they suffer.

Our language evaluations showed worse scores on the index of cognitive features of language in anemic children when compared with children who were not anemic. The worst performance in these tasks was observed at the ages of three, four and five years, and this difference was only not confirmed statistically in the group of children up to two years old (Table 2), which might be attributable to the small number of children tested in this age group (n=6). These findings are compatible with results found in the international literature, from studies undertaken in Israel⁽¹⁷⁾, France⁽¹⁸⁾, Chile⁽¹⁴⁾, and Costa Rica^(11,20), where cognitive development and neuropsychomotor test results were worse among anemic subjects.

The index of language reception, expressed by the RPI, when analyzed in conjunction, also differed statistically be-

tween anemic and non-anemic individuals (Table 2). Mothers of iron-deficient children, investigated using the Icelandic Parent Development Inventory, reported that their children had worse comprehension abilities⁽²²⁾. In anemic children, research using electrophysiological hearing evaluation showed slower conduction of the electrical stimulus⁽¹²⁾. In our study, although all children showed integrity of the peripheral auditory canal, their hearing abilities were not investigated, which means that the possibility of abnormalities in the processing of auditory information was not ruled out.

The anemic children assessed in our study had worse language emission indexes (Table 2, $p < 0.05$). According to dif-

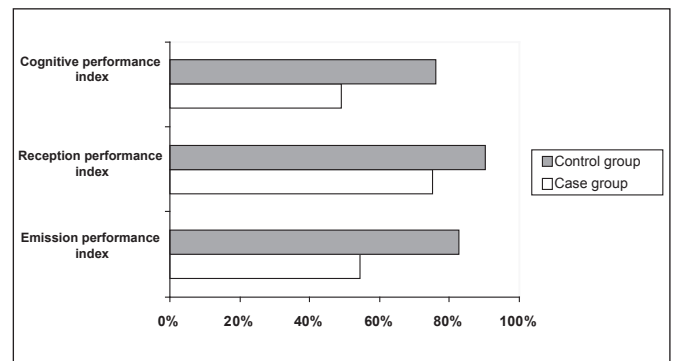


Figure 1 – Distribution of performance indexes for language cognition, reception and emission, by presence or absence of anemia.

Table 2 – Distribution of indexes of cognitive performance and language reception/emission performance according to presence or absence of anemia

Age (months)	Language features	median	Anemic minimum	maximum	median	Non-anemic minimum	maximum	p
12-24 (n=6; anemic=2)	CPI	75	75	75	79	67	87	0.62
	RPI	100	100	100	94	75	100	0.27
	EPI	86	78	93	100	86	100	0.14
24-36 (n=24; anemic=8)	CPI	33	11	78	71	44	100	0.001
	RPI	67	25	87	87	50	100	0.01
	EPI	50	8	92	83	42	100	0.003
36-48 (n=27; anemic=9)	CPI	44	37	82	70	47	88	0.002
	RPI	100	66	100	100	83	100	0.64
	EPI	56	37	87	87	62	100	0.001
48-60 (n=9; anemic=3)	CPI	69	46	77	92	69	100	0.04
	RPI	25	0	75	100	75	100	0.02
	EPI	50	40	50	80	70	90	0.01
Entire sample (n=66; anemic=22)	CPI	45	11	82	76	44	100	<0.001
	RPI	75	0	100	100	50	100	0.02
	EPI	50	8	93	83	42	100	<0.001

CPI: cognitive performance index; RPI: reception performance index; EPI: emission performance index.

ferent studies, anemic children from Costa Rica showed worse verbalization rates during interaction with their mothers⁽³⁴⁾, anemic Chilean children showed worse performance with communicative language and vocalization⁽¹⁶⁾, and Indian children with anemia presented less social interaction than non-anemic children from the same place⁽³⁵⁾. Although no studies were found in the literature specifically investigating speech and hearing, other areas demonstrate the effects of anemia on the higher cognitive processes that make language learning possible. Studies indicate that anemia acts reducing oxygenation in the brain, altering the processes of neurotransmission and myelination^(15,23-25). Furthermore, there is increased vulnerability during development in the presence of iron deficiency, which is demonstrated by abnormalities in the structure of hippocampus pyramidal cell dendrites, important components of the limbic system, which is also the seat of memory^(16,25).

The prevalence of anemia in this study was 20.4%, which is lower than the figure found in other daycare centers in the Belo Horizonte area⁽⁷⁾ and in other places in Brazil, such as Pelotas⁽³⁾, Cuiabá⁽⁴⁾, São Paulo⁽⁵⁾, and Recife⁽⁶⁾. This fact may

be explained by the fact that this daycare center receives extra financial support for dietary supplementation, which is not the case at the majority of Brazilian daycare centers. Despite the lower prevalence of anemia and the center's suitable infrastructure, the effects of anemia on language development in the children attending this daycare center were still evident, emphasizing once more the vulnerability of these children to language disorders.

It is worth pointing out that this is a comparative cross-sectional study; therefore, a causal relationship between anemia and worse language development cannot be established. Nevertheless, statistically significant differences were observed between anemic and non-anemic children in terms of language development. It is necessary to confirm these observations with prospective studies using adequate sample sizes, with control for other variables that interfere with language development. If the hypothesis is confirmed, it will further reinforce the need for developing anemia screening programs as well as interventions aimed at fortifying food with iron for children attending daycare centers.

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