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Oral language, phonological processing, and visuospatial memory in children with a history of mild malnutrition in early childhood

Linguagem oral, processamento fonológico e memória visuoespacial em crianças com histórico de subnutrição leve na primeira infância

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ABSTRACT

Purpose: To investigate the performance of children with a history of mild malnutrition in early childhood in tasks that assess oral language, phonological processing and visuospatial memory. **Methods:** Thirty-six children participated (mean age 5.3 years; standard deviation = 0.57), with 9 children diagnosed with malnutrition between 0 and 3 years old (G1); 9 eutrophic and with language delay (G2) and; 18 eutrophic children with typical language development (G3). All were submitted to hearing screening procedures, diagnosis of current nutritional status and tests of language, phonological processing and working memory - visuospatial sketch. Statistical analysis was performed using the Test of Equality of Proportions and the Kruskal-Wallis test (α = 5%). **Results:** Differences were observed in the performance in receptive and expressive language tasks of G1 and G2 in relation to G3. Performance on working memory tasks - visuospatial sketch was significantly different between G1 and G3 and G2 and G3. There was no difference between the groups concerning expressive vocabulary, phonological aspect, phonological awareness and phonological working memory. **Conclusion:** Children with a history of mild malnutrition during the critical period of brain development may have language impairments, especially in the receptive area, and restricted performance in other cognitive skills, such as working memory - visuospatial sketch.

Keywords: Malnutrition; Child Language; Child Development; Learning Disabilities; Speech, Language and Hearing Sciences

RESUMO

Objetivo: investigar o desempenho de crianças com histórico de subnutrição de grau leve na primeira infância, em tarefas que avaliam a linguagem oral, processamento fonológico e memória visuoespacial. **Método:** participaram 36 crianças (media de idade 5,3 anos; desvio padrão = 0,57), sendo nove crianças que tiveram diagnóstico de subnutrição entre 0 e 3 anos de idade (G1); nove eutróficas e com atraso de linguagem (G2) e 18 crianças eutróficas com desenvolvimento típico de linguagem (G3). Todas foram submetidas a procedimentos de triagem auditiva, diagnóstico do estado nutricional atual e testes de linguagem, processamento fonológico e de memória operacional - esboço visuoespacial. Foi realizada análise estatística por meio do Teste de Igualdade de Proporções e Kruskal-Wallis (α = 5%). **Resultados:** foram observadas diferenças no desempenho nas tarefas de linguagem receptiva e expressiva de G1 e G2, em relação ao G3. O desempenho nas tarefas de memória de trabalho - esboço visuoespacial foi significativamente diferente entre G1 e G3 e G2 e G3. Não houve diferença entre os grupos no teste de vocabulário emissivo, aspecto fonológico, consciência fonológica e memória operacional fonológica. **Conclusão:** crianças com histórico de subnutrição de grau leve durante o período crítico de desenvolvimento cerebral podem apresentar prejuízos na linguagem, principalmente na área receptiva, e desempenho restrito em outras habilidades cognitivas, tais como memória de trabalho – esboço visuoespacial.

Palavras-chave: Desnutrição; Linguagem infantil; Desenvolvimento Infantil; Deficiências de aprendizagem; Fonoaudiologia

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INTRODUCTION

Malnutrition is a structural and functional change in body composition[1]. The physiological basis of malnutrition is the deficit in calories, resulting in adverse effects measurable in clinical outcomes[2]. When it takes place in the first years of life (particularly in the critical brain development period, which is approximately from 0 to 3 years old), malnutrition can impair development[3], causing school difficulties and less productive adulthood[4].

At the beginning of child malnutrition, when it is mild, the organism tends to protect the developing brain from nutrient deficiency through various homeostatic mechanisms, sacrificing instead the body growth rate, adapting to the less provision, and avoiding greater risks. However, if such a condition persists (if it becomes chronic), cognitive development is affected. Nutritional deficiency is more likely to impair brain development if it occurs during its critical development period – i.e., when it greatly needs nutrients for its neurodevelopment[5].

Studies have pointed out that moderate/severe malnutrition in this critical brain development period delays neurological maturation and affects myelination, synaptic plasticity, and various neurotransmission systems[6], consequently impairing auditory processing[7], academic[8] and linguistic performance[9], and cognitive capacity[10].

Hence, evidence shows that brain development can be impaired by moderate and severe malnutrition, whereas it can be preserved when the deficiency is mild[5]. Nonetheless, few studies have aimed to demonstrate which cognitive and linguistic functions are affected by this degree of malnutrition, despite the current greater prevalence of mild cases of child malnutrition.

It is greatly important to know the consequences of nutritional deficiencies on the development of language, phonological processing, and visuospatial memory because these skills are precursors of the development of school abilities. Such knowledge enables new measures to be developed and used for the partial or total recovery of cognitive capacities. Thus, the objective of this study was to investigate the performance of children with a history of mild malnutrition in early childhood in oral language, phonological processing, and visuospatial memory tasks.

METHODS

This study was approved by the Research Ethics Committee of the Clinics Hospital of the Medical School of Ribeirão Preto – University of São Paulo (HCFMRP/USP), under process no. 6498/2010 and the Municipal Department of Health (process no. 02 2014 030372 0). The parents/guardians of all children involved in the study signed an informed consent form.

Sample

This is an observational retrospective cohort study, whose sample had 36 children (20 boys and 16 girls) with a mean age of 5.3 years (standard deviation = 0.57), divided into three groups:

- G1 (n = 9): children with a history of mild malnutrition in early childhood (0 to 3 years) but currently nutritionally recovered.
- G2 (n = 9): well-nourished children with impaired language development.
- G3 (n = 18): well-nourished children with typical language development (without changes).

G1 participants were selected by analyzing medical records of a tertiary hospital and community health centers regarding children who had been diagnosed with malnutrition before 3 years old and were currently 4 years and 6 months to 6 years old. The survey found 1,097 patients/children with nutritional changes, of which 69 met the inclusion criteria in this study. Only nine children came for the application of the study instruments.

The children comprising G2 and G3 were from municipal schools and were matched with G1 children for age and sex, in the proportion of 1:1 between G1/G2 and 1:2 between G1/G3. G2 and G3 were made up according to their performance in the Language Development Assessment (LDA) – G3 children had an average performance in "total language", according to the norms in the instrument, and G2 children had a mild or severe deficit in "total language". LDA is described below.

The inclusion criteria for the three groups were as follows: being currently 4 years and 6 months to 5 years old and regularly attending school. G1 included children with a history of mild malnutrition but currently nutritionally recovered. G2 and G3 included only well-nourished children with no history of malnutrition. The following were the exclusion criteria for the three groups: a medical history of low birth weight or prematurity; diagnosis of genetic syndromes that impair cognitive function development (e.g., Down syndrome); diagnosis of autism spectrum disorder or global developmental disorder; history of neuropsychomotor developmental delay; being considered an inclusion child at school; history of speech-language-hearing therapy for language and/or speech disorders and any degree or type of hearing loss.

Instruments and Procedures

All children were individually assessed in a quiet room with the following instruments, performing the procedures described below:

- Hearing screening: the pediatric audiometer PA5 (Interacoustics of Brazil Ltda., São Paulo, SP) was used with TDH-39 earphones. The hearing screening aimed to exclude children with likely hearing loss of any degree or type. It researches air-conduction thresholds (the lowest intensity heard by the individual) with the sound-to-silence technique at 500, 1000, 2000, and 4000 Hz, which encompass human speech frequencies. A portable MT10 acoustic-immittance meter (Interacoustics of Brazil Ltda.) was used to assess the condition of the middle ear. It verified whether the child had any middle ear inflammation that might change the audiometry results.
- Anthropometric measures and nutritional status diagnosis: the Z-score was used as an indicator of the body mass index (BMI), as recommended by the World Health Organization (WHO). BMI is the person's weight in

kilograms (kg) divided by the square of their body height in meters. Malnutrition is diagnosed when the Z-score is lower than + 1 SD, whereas well-nourishment lies between – 2 SD and + 2 SD. The body weight was measured in kg on a Bal-Isopa TecLine digital scale, with 0.1 kg precision. For the procedure, children had not recently eaten anything, were wearing light clothes, were barefoot, and had just emptied their bladder. To measure their height, they stood upright, head in the vertical plane, barefoot, feet together, and their back, buttocks, and heels against the wall, on which their height was traced and verified in centimeters (cm) with a measuring tape (1-cm gradation). The health institutions' teams of physicians and nutritionists took the measures and reached the nutritional diagnoses.

- LDA[11]: this test comprises receptive and expressive language scales. The instrument assesses language content (with tasks focused on concepts of quantity, quality, spatial and temporal relationship, and sequence) and structure (with tasks on morphology and syntax). The test was applied according to the instructions in its handbook, establishing floor and ceiling scores. Based on the test score, their overall receptive and expressive language performance was classified as either average or impaired, according to the reference tables provided by the instrument. This classification was used to define G2 and G3 and later compare the language performance between the groups.
- Phonological system assessment, using part A of the ABFW Child Language Test[12], which has two tests: imitation (repeating a list with 39 words) and naming (naming 34 figures). Phonological processes (child speech reductions) were identified and classified as either expected or no longer expected for the child's age (change), according to the reference tables in the test.
- Vocabulary assessment, using part B of the ABFW Child Language Test[12], which analyzes usual word designations, no designations, and substitution processes used by the children to correctly name the words. The test has nine conceptual fields: clothing, animals, foods, means of transportation, furniture and utensils, occupations, places, shapes and colors, and toys and musical instruments. The percentage of correct answers in each semantic class was assessed.
- Phonological working memory, using two instruments. The first was the Brazilian Children's Test of Pseudoword Repetition (BCPR)[13], in which they repeated 40 meaningless words, divided into groups of 10 per number of syllables (from two to five syllables). Each correct answer scored 1 point. The second instrument was the Illinois Test of Psycholinguistic Abilities (ITPA), subtest 5[14], in which they repeated 21 forward digit sequences, ranging from two to seven digits. Each child had two attempts to repeat the sequence correctly, scoring 2 points on the first and 1 point on the second attempt. The raw answer scores were assessed, and the phonological processes verified in word repetition were considered as the test was applied.
- Working memory – visuospatial sketchpad, using the Corsi Block-Tapping Test[15] with a wooden board in which nine equal-size blocks are irregularly distributed. The examiner touched a series of blocks with the index finger, keeping it on each block for 1 second. The child should point to the blocks in the same order the examiner had touched them. Two examples were used to train the test. Each correct item scored 1 point; when the child pointed to all blocks touched by the examiner but in the wrong order, they scored 0.5 points.
- Phonological awareness: the Phonological Awareness Sequential Assessment Instrument[16] was used to assess syllabic awareness skills (tasks involving synthesis, segmentation, initial syllable identification, rhyme identification and production, word production with a syllable given, medial syllable identification, exclusion, and transposition) and phonemic awareness skills (tasks involving word production beginning with a sound given, initial and final phoneme identification, exclusion, synthesis, segmentation, and transposition). Before each task, two examples were presented to train for it. Each wrong answer scored 0 points, and each correct answer scored 1 point. The raw score was considered.

Statistical analysis

The Kruskal-Wallis test and Kruskal-Wallis multiple comparison post-test were used for the quantitative variables (significance level set at 0.05 or $\alpha = 5\%$). The two-proportion z-test was used to assess the variables described in percentages. Since three groups were involved, the significance level for this last test was decreased based on the formula: "α / number of tests" and adjusted by 1.7% ($\alpha = 0.05$; number of groups = 3; new significance level = 0.05 / 3 = 0.017).

RESULTS

The performance results in the language tasks demonstrated how even mild malnutrition can cause long-term impairments (Table 1).

In LDA overall classification (receptive and expressive language), G1 and G2 performed similarly, though both performed worse than G3. Specifically, in receptive language, G1 performed worse than G3; however, in expressive language tasks, G1 had an adequate performance, according to LDA norms, with scores similar to those of G3. Differences between G2 and G3 in expressive and receptive language were already expected, as this was the parameter used to make up the characteristics of these two groups.

No differences were found between the groups in the detailed assessments of linguistic aspects (productive vocabulary and phonology) (Tables 2 and 3). Table 2 shows which phonological processes not expected for the age were presented by one child in G1 and G3 and two in G2. The phonological processing results refer to all components in each group.

There were no differences between the groups in the working memory test-phonological loop – neither in the test using forward digit repetition nor in the one with pseudowords. On the other hand, a statistically significant difference was found between

Table 1. Standard receptive, expressive, and total language test scores in the Language Development Assessment Test (LDA)

Test	Mean	SD	p-value	Post-test (result)
Expressive language	G1: 32.66	G1: 4.5	0.04*	Difference between G2 and G3
	G2: 29.77	G2: 5.33		
	G3: 34.61	G3: 4.60		
Receptive language	G1: 32	G1: 3.12	0.003*	G1 differs from G3
	G2: 29.44	G2: 2.65		
	G3: 35.16	G3: 4.25		
Total language	G1: 166.66	G1: 24.64	0.001*	G1 differs from G3 G2 differs from G3
	G2: 149.22	G2: 3.67		
	G3: 200.22	G3: 24.20		

Kruskal-Wallis test (α = 0.05); Kruskal-Wallis multiple comparison post-test

* = difference between groups

Subtitle: G1 = children with a history of mild malnutrition in early childhood (0 to 3 years old) and currently nutritionally recovered; G2 = well-nourished children with impaired language development; G3 = well-nourished children with typical linguistic development (without changes); SD = standard deviation

Table 2. Phonological assessment results – ABFW Child Language Test

Group	Number of children with changes	Phonological processes not expected for their age	p-value
G1	1	Fricative stopping, liquid reduction, palatal backing	G1 x G2 comparison = 0.5
G2	2	Palatal backing, fricative stopping, liquid reduction, palatal fronting	G2 x G3 comparison = 0.1
G3	1	Palatal fronting, liquid reduction, syllable reduction, fricative stopping	G1 x G3 comparison = 0.6

Two-proportion z-test with a significance of 0.017 or α = 1.7% (α = 0.05; no. of groups = 3 – significance level = 0.05/3 = 0.017)

Subtitle: G1 = children with a history of mild malnutrition in early childhood (0 to 3 years old) and currently nutritionally recovered; G2 = well-nourished children with impaired language development; G3 = well-nourished children with typical linguistic development (without changes)

Table 3. Percentage of correct answers in the vocabulary (semantic) task

Test	Mean	SD	p-value	Post-test (result)
Clothing	G1: 72.22	G1: 21.08	0.1	-
	G2: 58.88	G2: 11.66		
	G3: 68.53	G3: 15.34		
Animals	G1: 85.07	G1: 16.58	0.8	-
	G2: 87.41	G2: 8.45		
	G3: 89.25	G3: 10.20		
Foods	G1: 71.46	G1: 15.75	0.4	-
	G2: 65	G2: 14.14		
	G3: 72.22	G3: 13.96		
Transportation	G1: 80.95	G1: 18.46	0.7	-
	G2: 75.74	G2: 21.31		
	G3: 80.28	G3: 9.98		
Furniture and Utensils	G1: 72.68	G1: 18.03	0.4	-
	G2: 70.44	G2: 11.38		
	G3: 76.84	G3: 7.99		
Occupations	G1: 52.22	G1: 24.88	0.2	-
	G2: 40	G2: 12.24		
	G3: 48.88	G3: 15.67		
Places	G1: 47.38	G1: 32.46	0.3	-
	G2: 36.08	G2: 24.30		
	G3: 51.82	G3: 20.73		
Colors and Shapes	G1: 81.11	G1: 26.66	0.5	-
	G2: 74.44	G2: 32.44		
	G3: 90	G3: 11.88		
Toys	G1: 64.44	G1: 33.43	0.5	-
	G2: 56.53	G2: 26.42		
	G3: 70.68	G3: 17.79		

Kruskal-Wallis test (α = 0.05); Kruskal-Wallis multiple comparison post-test, which defined the groups between which there was a difference

Subtitle: G1 = children with a history of mild malnutrition in early childhood (0 to 3 years old) and currently nutritionally recovered; G2 = well-nourished children with impaired language development; G3 = well-nourished children with typical linguistic development (without changes); SD = standard deviation

G1 and G3 and between G2 and G3 in the working memory test-visuospatial sketchpad (Table 4).

No significant difference was found in the phonological awareness test in either the syllabic score or the total score. No child scored in the phonological awareness-phonemic level (Table 4).

DISCUSSION

Nutrition and development have been studied in combination by professionals in various areas. This study approached the effects of mild malnutrition during the critical brain development period on oral language development and cognitive skills that make up phonological processing (phonological awareness and working memory) – which are all indispensable to written language development.

LDA results pointed to G1 performances similar to those of G2 (the well-nourished group with language deficit) and worse than those of G3 (the well-nourished group without language deficit) in receptive language and total scores (receptive and expressive language). This demonstrates that even mild malnutrition can affect language development. No studies analyzing linguistic development in children with a history of mild malnutrition were found.

Other variables are known to interfere with linguistic development. Hence, this study controlled some of them in sample selection, such as prematurity, low weight, and other neurodevelopmental changes (e.g., autism spectrum disorder, global developmental delay, and neuropsychomotor developmental delay).

No differences were found between the groups in linguistic aspects assessed in further detail (productive vocabulary and phonology) – i.e., children with a history of malnutrition had the same performance in these two tasks as children with typical and atypical language development.

The acquisition of the Portuguese phonological system is completed by 7 years old. Its greatest expansion occurs from 1.5 to 4 years old – hence, it is when various phonological processes appear, which must be eliminated. From 4 to 7 years old, they acquire the sounds in more complex syllable structures, thus stabilizing the phonological system[17]. To classify children as having phonological changes, they must be assessed in terms of the phonological processes they use, verifying whether these processes are expected for their age. Hence, a 4-year-old child with fricative stopping and cluster reduction is classified with a phonological change regarding the first process, which should have already been eliminated, while the second process is still expected for their age.

The phonological development is currently assessed with word repetition and/or naming tests, which verify whether these phonological processes have been eliminated – over their chronological age, children should eliminate all phonological processes until they fully master them[17]. As previously said, there were no differences between the groups in this study in the percentage of children with phonological changes – all groups had few children classified with phonological changes. Only one study[14] was found that investigated phonological acquisition in Brazilian children aged 2.1 to 6.6 years with a history of malnutrition. The authors verified that children older than 3 years were delayed in eliminating the processes (i.e., phonological changes), although they did not characterize their degree of malnutrition (mild, moderate, or severe).

Vocabulary is one of the aspects assessed in the semantic field of language in children, addressing both receptive and productive vocabulary. No difference was found between the groups in this study in vocabulary assessment performance. Only one study approached malnourished children and productive vocabulary (production of their first words) and compared the

Table 4. Mean scores in the various working memory and phonological awareness tests

Test	Mean	SD	p-value	Post-test (result)
ITPA (digits)	G1: 14	G1: 4.35	0.1	-
	G2: 11.11	G2: 5.25		
	G3: 14.94	G3: 5.83		
Pseudowords	G1: 34.11	G1: 8.35	0.4	-
	G2: 30.33	G2: 6.63		
	G3: 30.55	G3: 10.70		
Corsi Blocks	G1: 2.77	G1: 1.32	0.01	G1 differs from G3
	G2: 2.05	G2: 0.76		G2 differs from G3
	G3: 3.16	G3: 1.30		
PA syllables	G1: 8.22	G1: 5.51	0.2	-
	G2: 4.11	G2: 3.82		
	G3: 6.77	G3: 4.76		
PA phonemes	G1: 0	G1: 0	---	-
	G2: 0	G2: 0		
	G3: 0	G3: 0		
PA total	G1: 8.22	G1: 5.51	0.2	-
	G2: 4.11	G2: 3.82		
	G3: 6.77	G3: 4.76		

Kruskal-Wallis test ($\alpha = 0.05$); Kruskal-Wallis multiple comparison post-test, which defined the groups between which there was a difference

Subtitle: ITPA = Illinois Test of Psycholinguistic Abilities; PA = phonological awareness; G1 = children with a history of mild malnutrition in early childhood (0 to 3 years old) and currently nutritionally recovered; G2 = well-nourished children with impaired language development; G3 = well-nourished children with typical linguistic development (without changes); SD = standard deviation

linguistic development between children diagnosed with severe malnutrition and a control group[18]. The authors found that in the first year of life, the language scores between the groups were similar; however, after 12 months old, the children with severe malnutrition had lower scores.

When talking about oral and written language development, cognitive skills important to it must be addressed, such as the working memory-phonological loop. This skill can be assessed with forward and backward digit repetition, word repetition, and meaningless word (nonword/pseudoword) repetition tests[19]. The phonological working memory results in this study did not have a pattern of changes suggestive of associations with possible damages caused by malnutrition – i.e., the three groups performed similarly in the tests.

The phonological working memory has been studied in children of various ages with moderate or severe and usually chronic malnutrition[20]. In some studies, this skill was assessed with specific memory tests, while in others it was investigated with intellectual estimate assessment instruments[21]. All these studies pointed out that moderate or severe malnutrition was associated with difficulties in the working memory-phonological loop.

The working memory-visuospatial sketchpad can be assessed with short-term visual memory tests, such as the Corsi Block-Tapping Test, which was used in this study. No national or international study was found that assessed this cognitive skill in mildly malnourished children. However, the present study found significant differences between the groups – children with risk factors for language delay had difficulties in visual construction skills in both the malnutrition group and the language deficit group.

In phonological awareness, another phonological processing skill important to written language development, there was no difference in performance between the groups. Also, their low scores indicate that they are just beginning to develop this skill – it was not expected from the sample children to get correct answers in this test.

A national study investigated the phonological awareness skill in schoolchildren with a history of severe malnutrition and verified that they had important deficits in this skill, with consequent impairments in learning to read and write[20].

CONCLUSION

Children with a history of mild malnutrition during the critical brain development period may have signs of language impairments. Hence, they may have adequate development in some linguistic aspects (e.g., productive vocabulary and phonology) but changes on other levels (e.g., receptive language, which involves broader issues such as temporal/spatial notions, inferences, and so forth).

Concerning cognitive skills, they performed worse than the other groups in visuospatial memory but performed similarly in the phonological awareness and phonological working memory tasks. The performance in either of these cognitive-linguistic skills is predictive of their performance in learning to read and write and school achievements.

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