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Auditory ability in malnourished child

Habilidade auditiva em criança desnutrida

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ABSTRACT

Purpose: To characterize and compare the performance of malnourished children and normal children in auditory processing. **Methods:** The sample comprised 30 children from five to ten years old, both genders, being 15 malnourished children (G1) and 15 children with adequate nutritional status, as a control group (G2). The groups were paired according to gender, age and grade level. Both groups underwent peripheral and central auditory assessment, noting that malnourished children had higher changes in the skill of sequencing score for verbal and nonverbal when compared to normal children, and the same occurred in closing skills and background figure. **Results:** Regarding the degree of auditory processing disorder, it was more severe in malnourished children. **Conclusion:** Children with malnutrition have higher frequency alterations in auditory abilities when compared to normal children, being the temporal ordering skills, auditory memory, selective attention, figure-ground and closing the most affected skills.

Keywords: Malnutrition; Hearing; Auditory perception; Auditory perceptual disorders; Hearing disorders

RESUMO

Objetivo: Caracterizar e comparar o desempenho de crianças com desnutrição e crianças eutróficas nas habilidades do processamento auditivo. **Métodos:** A amostra foi composta por 30 crianças na faixa etária de 5 a 10 anos, de ambos os gêneros, sendo 15 crianças com desnutrição, que compuseram o grupo amostral (G1) e 15 crianças com estado nutricional adequado, como grupo controle (G2). Os grupos foram pareados segundo gênero, faixa etária e escolaridade. Ambos os grupos foram submetidos à avaliação auditiva periférica e central. **Resultados:** As crianças desnutridas apresentaram maior índice de alterações na habilidade de sequencialização sonora para sons verbais e não verbais, quando comparadas com as crianças eutróficas. O mesmo ocorreu nas habilidades de fechamento e figura fundo. Quanto ao grau do distúrbio do processamento auditivo, houve maior severidade nas crianças desnutridas. **Conclusão:** Crianças com desnutrição apresentaram maior frequência de alterações nas habilidades auditivas, quando comparadas a crianças eutróficas, sendo as habilidades de ordenação temporal, memória auditiva, atenção seletiva, figura fundo e fechamento, as habilidades mais afetadas.

Descritores: Desnutrição; Audição; Percepção auditiva; Transtornos da percepção auditiva; Transtornos da audição

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INTRODUCTION

Malnutrition is a pathological condition caused by poor or inadequate calorie intake and/or proteins, presenting itself as a big issue in several countries. It is directly related to poverty, because it reflects the socioeconomic and political inequalities, unequal distribution of income, lack of access to educational resources, thus being one of the biggest factors in infant mortality in developing countries[1,2].

The risk of malnutrition is associated to the maternal mental health, unstable family structure, poor education, unemployment and poor housing conditions. Studies also reveal great difficulty in separating the economic, social and cultural causes of malnutrition[3].

Many evidences have been raised in order to demonstrate that nutritional deficiency during fetal and early life period may have deleterious effects on biochemical and morphological maturation of the organism[4]. The most severe alterations are those involving the central nervous system (CNS), because in most cases, are irreversible[4]. The earlier Protein-Energy Malnutrition (PEM) is installed, the more intense and permanent are its effects[3]. Malnourished children are less responsive, less curious and less participating in exploratory behavior than the well-nourished infants[3]. The specific nutrient deficiencies may result in decreased ability to pay attention and affect problem-solving skills[3]. There is an association between the child's alimentary insufficiency and growth, development and behavioral or academic function[3,5-7]. Depending on the duration and intensity of the nutritional deficiency, neural functions such as cognition, consciousness, emotion, learning, memory, motivation and anxiety can be affected[8,9].

Malnutrition increases the risk of various diseases due to deficiencies in the individual's immune system who, as a result of these diseases, may have their physical and intellectual development compromised[5,10].

The World Health Organization (WHO) estimates that over 20 million children are born underweight every year. About 150 million children under 5 are underweight for their age and 182 million (32.5%) have short stature.

In recent decades, the rate of malnutrition in Brazil has declined, but, as in other developing countries, it is still a significant cause of infant mortality[4].

Maranhão state, in particular, presents the most severe form of malnutrition in the country, with moderate or severe deficits of 30.6%, followed by Piauí, Ceará and Paraíba, with 22.9%, 21.1% and 19.7%, respectively[9,10]. According to statistics from the Ministry of Health, 66 cities from Maranhão are in the list of the cities with the highest number of child malnutrition and the state has the highest number of occurrences of underweight in children aged under 5 years old[11,12].

Severe malnutrition impairs the development of functions such as intelligence, memory, reading and math tests, verbal skills, problem solving ability and motor development. Children with chronic malnutrition have low scores in (expressive) vocabulary tests which points to the difficulty in organizing thoughts[5].

Considering that malnutrition causes harmful effects to the Central Nervous System (CNS) and that the auditory processing involves complex nerve connections, it reflects on how auditory information is processed by malnourished children.

The Central Auditory Nervous System (ACNS) is a complex system of neural pathways that may be affected by various developmental and pathological factors causing the Auditory Processing Disorder[13], it is considered a deficit in information processing of auditory signals without hearing changes in peripheral hearing or intellectual deficit. It is a limitation of the transmission, analysis, organization, transformation, elaboration and memory of specific information of the auditory modality[14-16]. There is a lack of studies evaluating the central auditory nervous system when associated to malnutrition, which was also reported by other authors[17,18], who conducted studies assessing the central auditory pathway of malnourished children. One of the studies[18] characterized the Long Latency Auditory Evoked Potential (LLAEP) in malnourished children and it was observed an increased latency in the group with malnutrition. The latencies of P1, N1 and P300 components were higher in the malnourished group than in the eutrophic group, which suggests a reduction in the speed of processing of acoustic information in a cortical level.

An international study[19] conducted a survey of CNS evaluations in malnourished children. The tests mentioned were: neuroimaging, electrophysiology, neuroradiology, EEG and evoked potentials. In histological studies and imaging on the developing brain, in humans and animals, both macro and microstructures were changed in the malnourished brain. The neuroradiology demonstrated cerebral atrophy and ventricular enlargement with prominence of the Sylvian fissure and basal cavity in children with Kwashiorkor. As for the findings in the electroencephalogram of malnourished children, the dominant frequency was much lower when compared to normal weight children. In the auditory evoked potential, we observed an increase in the latency of waves, suggesting a deficiency in the myelination process, with decrease of the efficiency of the synapses of the auditory system.

As given the above and the lack of national and international studies that relate malnutrition and hearing abilities, this study aimed to characterize the performance in auditory processing in children with malnutrition and compare it to normal children.

METHODS

This study was approved by the Ethics Committee from Philosophy and Sciences College, Universidade Estadual Paulista (UNESP), under protocol number 0551/2012. The participants' guardians signed an informed consent form (ICF), which all performed procedures were described.

Table 1. Distribution of subjects by age and gender groups

G1			G2		
Age group	Gender		Age group	Gender	
	Male	Female		Male	Female
5 years old	1	1	5 years old	1	1
6 years old	1	1	6 years old	1	1
7 years old	2	1	7 years old	2	1
8 years old	1	1	8 years old	1	1
9 years old	1	-	9 years old	1	-
10 years old	4	1	10 years old	4	1
	Total:	15		Total:	15

Note: G1 = sample group; G2 = Control group

The sample comprised 30 children, aged from 5 to 10 years old, both genders, being 15 children diagnosed with malnutrition, who formed the sample group (G1) and 15 children with adequate nutritional status (normal weight), control group (G2). Both diagnoses were made by a nutritionist.

It is noteworthy that in this study, the classification of nutritional status in degrees (mild, moderate and severe) was not used because the protocol used in the institution where the data were collected lacked such classification. Thus, the groups were matched according to gender, age and education (Table 1).

Children previously diagnosed with hearing loss, neurological or behavioral pathologies and genetic syndromes were excluded from the sample. This criterion was used in both groups. Children who, during the hearing evaluation, showed changes were also excluded from the sample, as shown in Figure 1.

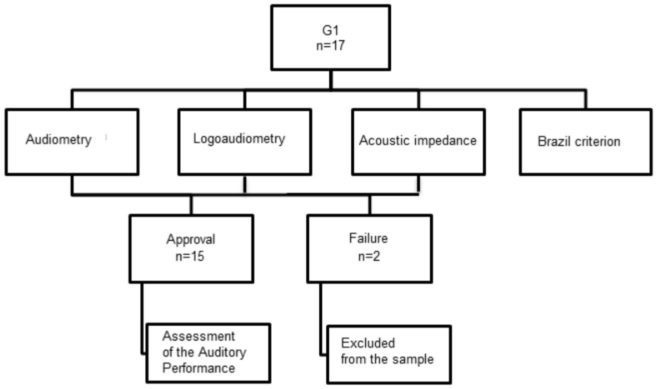

Figure 1. Representation of the selection process for the Sample Group

G2 was paired to G1 according to age, gender and education and thus subjected to peripheral and central auditory assessment, as shown in Figure 2.

Nutritional assessment

Children with malnutrition were from the Nutrition department of a public institution. The children who were part of the G2 were selected at a school and subsequently forwarded to nutritional assessment, in order to verify the possibility of belonging to this group.

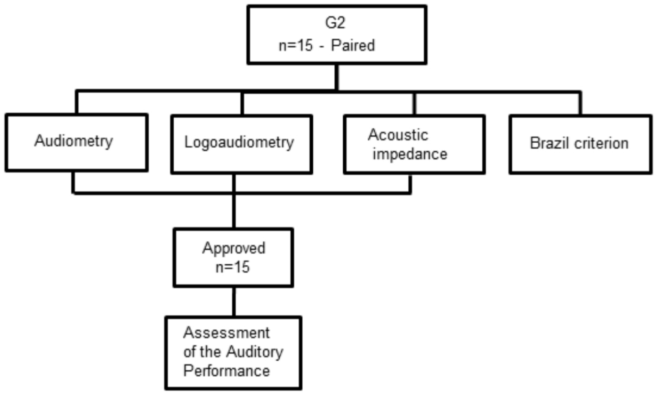

Figure 2. Representation of the selection process for the Control Group

The curves of weight for age (W/A), height for age (H/A) and body mass index for age (BMI/A) with score-z, considering the World Health Organization (WHO) - Multicenter Growth Reference Study (2007), were used as criterion to assess the nutritional status of children. The anthropometric classifications were those proposed by WHO. Assessment to determine the nutritional status was conducted by a nutritionist from the Service, in a session of approximately one hour.

Socioeconomic assessment

The criterion of Brazil's economic classification (Brazil Criterion), from the Brazilian Association of Research Companies (*Associação Brasileira de Empresas de Pesquisa* - ABEP, 2011) was used as socioeconomic characterization of the subjects. This is a socioeconomic questionnaire based on household goods and academic education, where, for each possession, there is a score and each class is defined by the sum of this score. The classes are divided into A1, A2, B1, B2, C, D and E.

Hearing assessment

The subjects from both groups participated in every stage of the study: (1) anamnesis; (2) inspection of the external auditory canal; (3) audiometry and (4) auditory processing.

The anamnesis allowed obtaining the identification data, presence or absence of hearing complaints as well as the presence of risk factors for hearing loss and symptoms related to auditory processing.

The inspection of the external auditory canal was performed in order to check its condition. Individuals with presence of cerumen were referred to ENT evaluation and subsequently underwent audiological evaluation.

With the information obtained in the interview and data on otoscopy, audiological evaluation was initiated, conducted in a soundproof booth, in three sessions of one hour each. The first session was to administer the questionnaires, interview and assessment of peripheral hearing. In the second and third sessions, the test for assessing central hearing was performed by the following procedures:

1) Pure tone audiometry: Interacoustics® AC33 audiometer calibrated according to standards 8253.1, 364.9 ISO3741 resolution was used at frequencies from 250 to 8000 Hz with frequency modulated (warble) sound stimulus[20].
2) Logoaudiometry: two tests were applied: the SRT (Speech Recognition Threshold), using a list of three-syllable and polysyllabic words as sound stimulus. The threshold has been researched by the descending method of intensity and it was obtained when the child would hit 50% of the four words given. The second test was the SDT (speech recognition percentage index), in which a list of 25 monosyllabic and 25 disyllable presented as stimuli in a fixed intensity was used (tritone average plus 40 dB HL)[20].
3) Tympanometry: a study of the tympanogram graph and ipsilateral and contralateral reflex pathways[21] was performed using imitanciometer AT235 calibrated according to standards 8253.1, 364.9 Resolution ISO3741.
4) Auditory Processing (AP): for the AP assessment, the tests described below have been applied:

Diotic tests

a) Test of verbal sound sequencing (TVSS), using as criteria analysis what Pereira and Schochat (2011) proposed[22] and considered as normal range > 2 hits in 3 attempts.
b) Test of non-verbal sound sequencing (TnVSS), also using as criteria analysis what Pereira and Schochat (2011) proposed[22] and considered as normal range > 2 hits in 3 attempts.
c) Test of localization of the sound (TLS) source in five directions using as criteria analysis what Pereira and Schochat (2011) proposed[22] and considered as normal range > 4 hits.

Monotic tests

a) Pediatric Logoaudiometry abbreviated as PSI (Pediatric Speech Intelligibility). To perform this test it was used a two-channel audiometer, CD player and CD as Pereira and Schochat (2011)[22] proposed, recording ten sentences and a child's story, used as the main stimulus and competitive message, respectively, as well as a board of figures related to the ten sentences. As a criterion of normality, the authors consider > 80% accuracy for MCI = 0; > 70% accuracy for MCI = -10 and> 60% accuracy for MCI = -15.
b) Speech Test with Noise (STN). For this test, the same test equipment mentioned above was employed and as sound stimulus, a list of 25 monosyllables as the main stimulus, and white noise as competitive message, the main stimulus/competitive message of +5 dB HL, as proposed by Pereira and Schochat (2011)[22]. As normality criterion the authors consider S/N >70% accuracy and difference between SRPI and S/N <20%.

Performance results of the test were also used to classify the severity of Central Auditory Processing Disorder (CAPD), from mild to severe, as proposed by Pereira and Schochat (2011)[22].

Dichotic tests

a) Pediatric Logoaudiometry (PSI). Equipment and procedures were identical to monotic way, the difference is the form of application of sound stimuli, which was presented simultaneously and contralaterally, with the normality criterion > 90% accuracy.
b) Dichotic digits test (DDT). To perform this test, it was necessary a two-channel audiometer, CD player, CD of sound stimulus, four lists of 20 items each, each item consisting of four selected digits from the numbers 1 to 9 representing disyllables in Portuguese (Four, five, seven, eight and nine). This test was applied in two steps: Binaural Integration and directed listening (right/left). As a criterion of normality, we used the method proposed by Pereira and Schochat (2011)[22].

The results from the audiometric assessment were recorded on audiogram and tympanogram. The results of the Auditory Processing (AP), however, were recorded in protocols proposed by Pereira and Schochat (2011)[22].

Statistical analysis

For statistical analysis, we used the statistical package IBM Statistical Package for Social Sciences (SPSS), in its 21.0version. The level of significance was 5% (0.050). The applied tests were the Likelihood Ratio Test and the Chi-square Test with Fisher's variation for proportions, in order to verify possible differences between the studied groups.

RESULTS

Analyzing the sample, it was identified a higher frequency of changes in malnourished children when compared to normal children. It was observed a high rate of children in both groups who showed no significant differences in the ability of sound source location. However, the performance of G1 when compared to G2 was lower in the skills assessed on the memory test for verbal and non-verbal sounds in sequence. The performance of the groups on the sound localization test (SLT) memory test for verbal sounds in sequence (TVSS) and memory test for non-verbal sounds in sequence (TnVSS) is detailed in Table 2.

As for DDT, it was possible to observe effective difference when comparing the two groups in the task of Binaural Integration in which G2 demonstrated superior performance than G. One hundred percent of malnourished children had difficulties in regards to the ability measured by this test. There were differences in performance between G1 and G2 in Speech Test with Noise (STN), where G1 had lower performance, not being observed, however, a significant difference (Table 3).

The values obtained in the Speech Test with noise allowed us to classify the severity of CAPD and the results showed greater severity in G1, being the mild degree the highest incidence (Table 4).

The PSI test was performed with contralateral and ipsilateral competitive message. In the contralateral PSI, there was no statistical significance between groups. However, in the ipsilateral PSI, G1 showed a higher index of changes in G2, for both ears. During the testing in ICM, there was similarity between the two groups, when the speech/noise ratio was 0 dB HL, but when performed at a speech/noise ratio -10 dB HL and -15 dB HL, there was a worse performance from G1. However, when comparing the performance between the groups, in regards to speech/noise ratio of -15 dB HL, there was no significant difference (Table 5).

The groups were also compared in regards to socioeconomic status and no significant differences were observed. When compared to gender, there was a higher index on males.

DISCUSSION

Auditory skills are extremely important in the development of language and speech of individuals. The development of these skills depends on processes that involve complex nerve pathways that can be affected by environmental, social and

Table 2. Comparative performance from groups G1 and G2 in the diotic tests

Category	Group G1				Group G2				p-value
	Normal		Altered		Normal		Altered		
	n	%	n	%	n	%	n	%	
SLT	11	73.3	4	26.7	13	86.7	2	13.3	0.358
TVSS	2	13.3	13	86.7	11	73.3	4	26.7	0.001*
TnVSS	5	33.3	10	66.7	11	73.3	4	26.7	0.026*

*Significant values (p<0.05) – Likelihood Ratio Test

Note: G1 = sample group; G2 = control group; SLT = Sound localization test; TVSS = Test of verbal sound sequencing; TnVSS = Test of non-verbal sound sequencing

Table 3. Comparative performance in TDD and TFR

Category	G1				G2				p-value
	Normal		Altered		Normal		Altered		
	n	%	n	%	n	%	n	%	
DDT - BI	0	0,0	15	100.0	10	66.7	5	33.3	0.000*
DDT-DA	5	33.33	10	66.67	11	73.3	4	26.67	0.026*
STN	6	40.0	9	60.0	11	73.33	4	26.67	0.062

*Significant values (p<0.05) – Likelihood Ratio Test

Note: G1 = sample group; G2 = control group; DDT-BI = Dichotic digits test- binaural integration); DDT-DA = Dichotic digits test- directed attention); STN = Speech Test with Noise

Table 4. Severity degree of the CAPD groups

Severity degree	G1				G2			
	RE		LE		RE		LE	
	n	%	n	%	n	%	n	%
Normal	6	40.0	6	40.0	11	73.33	11	73.33
Mild	5	33.33	5	33.33	2	13.33	2	13.33
Moderate	1	6.67	1	6.67	2	13.33	2	13.33
Severe	3	20.0	3	20.0	0	0.00	0	0.00
Total	15	100.0	15	100.0	15	100.0	15	100.0

Note: G1 = sample group; G2 = control group; CAPD = Central Auditory Processing Disorder; RE = right ear; LE = left ear

Table 5. Comparative performance between groups G1 and G2 in PSI

Test	RE									LE								
	G1				G2				p-value	G1				G2				p-value
	Normal		Altered		Normal		Altered			Normal		Altered		Normal		Altered		
PSI	n	%	n	%	n	%	n	%		n	%	n	%	n	%	n	%	
0/CCM	10	66.7	5	33.3	13	86.7	2	13.33	0.370	10	66.7	5	33.3	13	86.7	2	13.3	0.370
-40/CCM	0	0.00	15	100.0	5	33.3	10	66.7	0.152	0	0.00	15	100.0	5	33.3	10	66.7	0.152
0/ICM	9	60.0	6	40.0	12	80.0	3	20.0	0.229	9	60.0	6	40.0	12	80.0	3	20.0	0.229
-10/ICM	5	33.3	10	66.7	11	73.3	4	26.7	0.043*	6	40.0	9	60.0	11	73.3	4	26.7	0.026*
-15/ICM	4	26.7	11	73.3	9	60.0	6	40.0	0.141	5	33.3	10	66.7	9	60.0	6	40.0	0.063

*Significant values ($p<0.05$) – Likelihood Ratio Test

Note: RE = right ear; LE = left ear; G1 = sample group; G2 = control group; PSI = Pediatric Speech Inteligibility; CCM = Contralateral Competitive Message; ICM = ipsilateral competitive message

pathological factors, as described in the literature[1,2,4-6,8]

In the national and international literature there are few studies[23-25] that relate to malnutrition and development of the auditory processing skills. However, studies have also found lower performance found in children with malnutrition.

Analyzing the tests with diotic task it was identified that in the sound localization test the performance between groups was similar. Whereas the maturation process interferes with the development of listening skills, and the child is able to locate the sound source at around seven months old and the age of our sample was 5 to 10 years old, it cannot be inferred that malnutrition does not interfere with the development of this ability. One study[23] was performed in children aged 0 to 2 years of age with malnutrition, in which the central hearing was assessed by behavioral hearing assessment. The study identified changes in sound location, and may thus suggest that malnutrition could affect this ability.

In TVSS and TnVSS tests assessing memory skills for verbal and nonverbal sounds in sequence, malnourished children showed inferior performance than the eutrophic ones. Considering that the difference in performance between groups was significant, this may suggest that malnutrition may have affected the performance in the processes involved, due to the type of hearing test performed on the task, which involves complex nerve connections. In this sense, the authors reported that malnutrition can cause damage to cell structure, neurotransmitters and myelination process[4,26].

With the application of DDT in the sample and control of this study, it was possible to evaluate the performance in the ability to background figure for verbal sounds by means of dichotic tasks/Binaural Integration. Changes in this test may indicate impaired ability to background figure for verbal sounds, the physiological mechanism of selective attention and gnostic decoding process. One hundred percent of malnourished children had low performance, indicating that malnutrition may have affected the central auditory processes mentioned above.

The data found in this study agree with the study[27] performed in a group of malnourished children and in a group of healthy children, where the author applied the same test and identified significant differences in the changes in the group of children with malnutrition (67.7%), when compared to the control group (38.2%).

The dichotic listening in malnourished children was also investigated in a study[28], in regards to the role of resilience in dichotic listening tasks in adolescents at social risk. The author noted that, in dichotic digits test for the ability of binaural integration, over 85% of the vulnerable group presented alterations. The data pointed to a difficulty in transferring information from the right hemisphere to the left, which should be processed. We emphasize that the process of maturation should be taken into account when analyzing the results, due to the fact that the skills also are in development period, as mentioned in the literature[29]. Thus, given the age of the study population it was not possible in this study to relate the performance of children with possible changes in the CNS, but it was observed that nutritional factors may interfere with this process.

The tests used to assess the children in this study were also applied in a study[30], in which the auditory processing was performed in children born preterm. One of the risk factors found in this population was low birth weight, <1,500 Kg. The tests applied were SLT, TVSS, TnVSS, STN, PSI/ CCM, PSI/ ICM e DDT and the authors observed changes in 93.75% of the subjects. The physiological mechanisms that were changed were the recognition of physically distorted verbal sounds and recognition of verbal sounds in monotic (50% of children). Forty-three point seven five percent of children had alterations in temporal processing, 37.5%, of the recognition of sounds in verbal dichotic listening and 6.25% the binaural interaction mechanism. The authors also identified delay in sound localization, temporal ordination, closing and background figure, as well as in the present study.

Study of malnourished children with learning disorders assessed the central hearing through the SSW and, according to the author, 100% of malnourished children showed abnormalities in the test and the most prejudiced gnostic process was decoding[25].

The effects of malnutrition in the ABR in sensory motor stimulation and auditory processing were studied and the findings suggest that malnutrition in early life may cause serious effects on the myelination of the auditory pathway[26].

With this study, we could detect the lack of studies correlating malnutrition and development of the skills of the AP. Most research related malnutrition to poor school performance, difficulties in language development and learning. However, they mention that the group which demonstrated difficulties in written language, presented higher incidence of changes in AP than the group that did not manifest changes in written language, indicating that changes in AP may be associated with difficulty in the written language[17,26].

CONCLUSION

Malnourished children had a higher frequency of changes in hearing, when compared to eutrophic children, being the most affected skills the temporal ordering, auditory memory, selective attention, background figure and closing. Regarding the degree of auditory processing disorder, there was a greater severity in malnourished children.

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