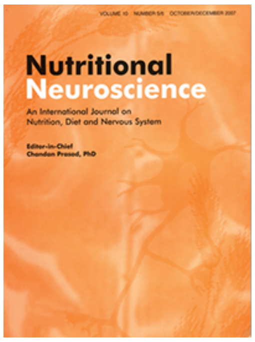

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Influence of malnutrition on the development of the central nervous system of malnourished children

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Introduction: Protein-caloric malnutrition is a public health concern in certain areas of the Brazil. It can affect growth, the auditory nervous system development and, consequently, the cognition. This study compared the Brainstem Auditory Evoked Potential (BAEP) between malnourished and eutrophic children.
Methods: A total of 111 children, aged 0–60 months, were examined: 57 were malnourished, according to the World Health Organization criteria, and 54 were normo-nourished. All the subjects underwent otorhinolaryngological evaluations and had acoustic immittance and transient evoked otoacoustic emissions within the normal range. The BAEP responses to click and tone burst stimuli were recorded at intensities of 80, 60, 40, and 30 dBNA.
Results: We observed that latencies of I, III, and V waves and interpeaks III–V at 80 dBNA with click stimuli were significantly higher in all malnourished children when compared to those in the eutrophic children, as was the I–V interval in the 0- to 24-month group. The V-wave latencies at those intensities were also significantly higher in malnourished children.
Conclusions: Malnourished children presented changes in BAEP characterized by delayed wave latency and interpeak intervals when compared to eutrophic children, suggesting alterations in both peripheral and central auditory pathways development and maturation.

Keywords: Brainstem auditory evoked potential, Children, Malnutrition

Introduction

The World Health Organization (WHO) estimates that 150 million children under five years of age worldwide suffer from malnutrition, with low weight for their age. In Brazil, child malnutrition is more prevalent in the North and Northeast regions, but is currently in a transition process, and the number of cases is declining.[1] Nevertheless, it is still one of the most frequent causes of death in children under five years of age.[2,3] It is considered a public health problem in Brazil and is associated with higher mortality, infectious diseases, impairment in psychomotor development, lower school performance, reduced height, and reduced productive capacity in adult life.[4]

Maranhão State reduced rates of malnutrition and infant mortality following the national trend, but continues to have the highest rate of malnutrition and infant mortality in Brazil[5]; of the 217 municipalities, 66 are on the high-index list of child malnutrition, and the prevalence is still more than double that observed in the country.[6]

The literature has validated the idea that adequate nutrition, especially protein, iron, choline, and polyunsaturated long-chain fatty acids, contributes to proper neuronal structure. A deficiency in one or more of these elements in the critical period of brain development due to malnutrition can lead to impaired myelination, weak synaptic junctions, and neural arborization limitation.[7] The quality of dietary proteins influences the nature and quantity of brain proteins and neurotransmitters.[8]

The brainstem auditory evoked potential (BAEP) is an electrophysiological method used to evaluate the integrity of the auditory pathway. It uses a high, non-variable intensity that allows for the identification of waves and the study of their absolute latency times and the intervals between them, thus identifying possible alterations.[9]

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In BAEP, the impulse conduction velocity is determined by axon diameter, myelination, and synaptic integrity; changes in wave latencies indicate deficiencies in one or more of these parameters.[10] It represents the synchronous neural activity of neurons in the peripheral and central auditory system. Isaac and Manfredi[11] reported that BAEP is of great importance in evaluating the maturation of auditory pathways, especially for at-risk children. The latency delay of waves is more visible in late than early BAEP components, due to the myelination process that occurs centripetally.[12]

The maturation of the central auditory nervous system takes place gradually and influences the BAEP normative values, reaching measures of wave latency and interpeak intervals compatible to those of an adult between 12 and 24 months.[13] In the present study, 111 evaluated children were allocated into a 0–24 months group or a 25–60 months group, to differentiate maturation stages of the auditory nervous system.

The integrity of the peripheral and central auditory system is extremely important for the development and acquisition of language, speech, environmental interaction, knowledge, and learning acquisition; any changes in the auditory system, either peripheral or central, should be identified and treated early. Thus, this study sought to identify, through BAEP at the brainstem level, the probable deleterious effects that child malnutrition causes on the auditory nervous system. This study will increase the knowledge base of this subject, which will enable necessary corrective and/or preventive measures, as there is a shortage of this type of research in the literature.

The aim of this study was to characterize BAEP responses to *click* and *tone burst* stimuli in malnourished and eutrophic children aged 0–60 months with complete peripheral auditory function, and to compare the two groups and evaluate neural integrity and auditory sensitivity.

Methods

This study was approved by the Research Ethics Committee of Federal University of Maranhão under Report no. 23115-011953/2009-47.

A total of 111 normo- and malnourished children of both genders, aged 0–60 months, from the Maternal Children Regional Hospital, were allocated by age to a 0–24 months group and a 25–60 months group. Two groups and two subgroups were formed per age. The sample size was calculated by comparing quantitative variables between two unpaired groups.[14] The confidence interval was 95%, and standard deviations were set at 0.20. To increase calculation confidence, the difference to be detected was set at 0.15 points (5% of the mean in question). Hence, the sample size for each group was 28 children. Considering possible losses, we added 10% to the sample for a total of 31 children per group; the general data dispersion did not reach 10%.[14] We evaluated 222 ears of 111 children, allocated as described below.

✓ *Control Group (CG)* consisting of 54 normo-nourished children.

- CG 0–24 months, n=35; 25 males and 10 females.
- CG 25–60 months, n=19; 10 males and 9 females.

✓ *Study Group (SG)* consisting of 57 malnourished children.

- SG 0–24 months, n=42; 24 males and 18 females.
- SG 25–60 months, n=15; 9 males and 6 females.

The variables studied in the SG and CG were the absolute latencies of I, III, and V waves, the latencies of intervals I–III, III–V, and IV at 80 dBNA, and the absolute latency of the V-wave at 60, 40, and 30 dBNA using a *click* stimulus. We evaluated the absolute V-wave latency using the BAEP analysis with a *tone burst* stimulus between the two groups at 80, 60, 40, and 30 dBNA at frequencies of 500, 2000, and 4000 Hz.

Inclusion criteria

Full-term children with birth weight ≥2500 g with no respiratory complaints, without hearing problems, or otitis media were included in the SG and CG. All children were in good health, as determined by Transient Evoked Otoacoustic Emissions and Distorted Product Evoked Otoacoustic Emissions, normal otorhinolaryngological evaluation, and immittance test within normality to select subjects with cochlear and middle ear function within the expected range for normality. According to the WHO (2006), the children of the SG of 25–60 months being diagnosed with late malnutrition, that is, after 25 months of life, and with previous nutritional status within normality.

Exclusion criteria

Children with syndromes, neurological diseases, acute diseases or otitis media, or external or medium ear alterations found on otorhinolaryngological examination and/or audiological examinations of otoacoustic emissions, or immitanciometry, or with risk indicators for hearing loss according to the Joint Committee on Infant Hearing (2007) were excluded from this study.[15]

Evaluation of nutritional status

The nutritional evaluation was performed by anthropometry conducted by the same researcher on the same day of the auditory evaluation. A digital pediatric scale (W300, Welmy, Santa Bárbara d'Oeste, São Paulo, Brazil) and a horizontal anthropometer were used for children in the 0–24 months groups; for children in the 25–60 months groups we used an electronic platform balance (W300, Welmy) and a mobile wall to anthropometry. We used the WHO

(2006) reference to determine nutritional status based on weight, age, and gender. The determination of the *z*-score, according to WHO (2006) reference, was performed using the WHO Anthro program.

Auditory evoked brain stem potential

The BAEP examination was an important methodological tool used to evaluate the neurophysiology of the auditory system. We used the BAEP Charter Amplifier PA 800 (AB Sciex LLC, Framingham, MA, USA) with GN Otometrics equipment (Otometrics A/S, Taastrup, Denmark) and in-the-ear phones, and a 1000 average for each record with at least one replication for each evaluated intensity. The window used in BAEP for the *click* stimulus was 12 ms, with a high pass filter of 100 Hz, a low pass of 3000 Hz, and rarefied polarity. The electrical impedance of electrodes was tested and should be less than 5 kΩ.

BAEP – *click*

Click stimuli were used in rarefaction polarity and stimulation velocity of 27.7/s. The presence of waves I, III, and V, the absolute latencies and the interpeak latencies I–III, III–V, and I–V were investigated at the intensity of 80 dBNA to determine the integrity of the auditory pathways to the brainstem.

To detect the electrophysiological threshold, stimulations were made at intensities of 60, 40, and 30 dBHL, with absolute V-wave latency recorded at the other intensities. We conducted 1000–2000 averages to obtain a mean response for each stimulus, with replication to confirm the reproducibility of the chart plot. The obtained responses were filtered to improve the signal-to-noise ratio and amplified with a gain of 100 000. Both ears were examined.

BAEP – tone burst

The *tone burst* stimulus was tested in the condensation polarity; the stimulation rate was 27.7/s. We conducted 1500–2000 averages; two stimuli were used for each intensity tested. A 25-ms window was used to confirm the reproducibility of the chart plot. The envelope used was the *blackman*; the responses obtained were filtered with a band filter of 30–1500 Hz and amplified with a gain of 100 000.

Data analysis

The descriptive analysis of wave latencies was performed as median, minimum, maximum, mean, standard deviation, and *P*-value.

We verified normal distribution of the variables with a Shapiro–Wilks test. The Student's *t*-test was used for independent samples. In the comparison of latency between groups, the non-parametric Mann–Whitney *U* test was used for the variables that rejected the normality hypothesis. Throughout the statistical analysis, a significance level of $P \leq 0.05$ was used.

Results

In the evaluation of 111 children, with 54 in the CG and 57 in the SG, the characterization of malnutrition in the SG was analyzed (Table 1) and a moderate degree of malnutrition was observed (93%).

Table 1 Distribution of children in the SG between 0 and 60 months of age, in relation to the degree of malnutrition observed

Level of malnutrition	*N*	%
Mild malnutrition	3	5
Moderate malnutrition	53	93
Serious malnutrition	1	2
Total	57	100

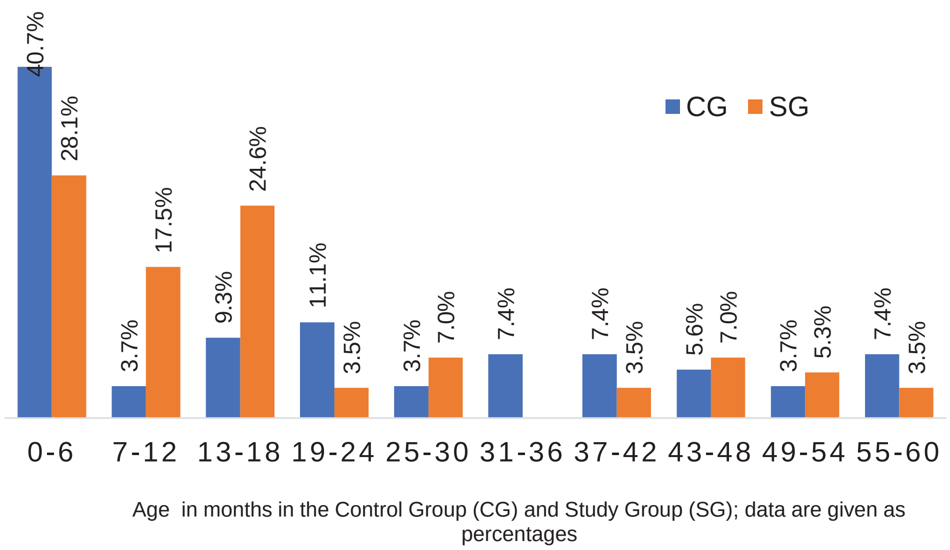

Figure 1 Distribution of children according to age in the CG and SG; data are given as percentages.

Fig. 1 shows the predominance in the 0–24 months group, with 73.7% in the SG and 64.8% in the CG.

The values of the absolute latencies of I, III, and V waves and the interpeak I–III, III–V, and I–V latencies were then evaluated for each subgroup and between the SG and CG. There was no significant difference between the right and left ears.

Tables 2 and 3 present a comparison of latencies of I, III, and V, and of interpeak I–III, III–V, and I–V waves in the BAEP using a *click* stimulus at 80 dBNA among groups of normo-nourished and malnourished children.

Table 4 shows the comparison of V-wave latencies in the BAEP with *click* stimuli at intensities of 60, 40, and 30 dBNA among groups of normo-nourished and malnourished children.

A significant difference was observed between normo-nourished and malnourished children in the 0–24 months group and the 25–60 months group in the absolute latency of waves I, III, and V, and in the interpeak intervals III–V and I–V in the 0–24 months when tested with *click* stimuli of 80 dBHL. A significant difference was also observed in between malnourished and normo-nourished children in the absolute latency of the V wave at intensities of 60, 40, and 30 dBNA.

Discussion

Studies involving nutritional status and auditive evaluation by BAEP are rare in the literature, which is a limiting factor for the discussion of our results. Despite literature limitations, the studies by Durmaz et al.,[16] Odabas et al.,[17] Vandana and Tandon,[18] and Gladstone et al.[19] detected deficient performances in malnourished children when compared with eutrophic ones.

In this study, we found a significant difference between normo-nourished and malnourished children's responses to the BAEP *click* stimulus, in the latencies

Table 2 Comparison of latency variables of waves I, III, and V (in ms), found between the groups of normo-nourished and malnourished children 0–24 and 25–60 months of age, by recording BAEP (*click*) at 80 dBNA

Group	Absolute latency at 80 dBNA							
	Wave	*N*	Mean	SD	Minimum	Maximum	Median	*P*-Value
$CG_{C\ 0–24}$	I	70	1.53	0.18	1.18	1.85	1.51	0.03*
$SG_{C\ 0–24}$	I	84	1.64	0.15	1.26	1.95	1.67	
$CG_{C\ 0–24}$	III	70	3.56	0.19	3.15	3.87	3.62	<0.001*
$SG_{C\ 0–24}$	III	84	3.71	0.19	3.18	3.96	3.76	
$CG_{C\ 0–24}$	V	70	5.52	0.19	5.11	5.88	5.53	<0.001*
$SG_{C\ 0–24}$	V	84	5.76	0.17	5.35	6.11	5.77	
$CG_{C\ 25–60}$	I	38	1.40	0.17	1.09	1.67	1.42	0.006*
$SG_{C\ 25–60}$	I	30	1.59	0.22	1.04	1.92	1.61	
$CG_{C\ 25–60}$	III	38	3.40	0.19	3.04	3.68	3.47	0.006*
$SG_{C\ 25–60}$	III	30	3.60	0.21	3.13	3.85	3.60	
$CG_{C\ 25–60}$	V	38	5.33	0.33	4.25	5.72	5.41	0.003*
$SG_{C\ 25–60}$	V	30	5.63	0.25	5.13	5.94	5.60	

Data were analyzed using the Student's *t*-Test and Mann–Whitney *U* test.
$CG_{C\ 0–24}$=Control group of normo-nourished children aged 0–24 months *click*; $CG_{C\ 25–60}$=Control group normo-nourished children aged 25–60 months *click;* $SG_{C\ 0–24}$=Study group of malnourished children aged 0–24 months *click;* $SG_{C\ 25–60}$=Study group of malnourished children aged 25–60 months *click;* SD=standard deviation, *N*=number of ears.

Table 3 Comparison of latency variables of interpeak intervals I–III, III–V, and I–V (in ms), at 80 dBNA found between groups of normo-nourished and malnourished children aged 0–24 and 25–60 months, by Student's *t*-test and Mann–Whitney *U* test

Group	Interpeak latencies at 80 dBNA							
	Interpeak	*N*	Mean	SD	Minimum	Maximum	Median	*P*-Value
$CG_{C\ 0–24}$	I–III	70	2.03	0.11	1.81	2.25	2.01	0.24
$SG_{C\ 0–24}$	I–III	84	2.06	0.09	1.84	2.23	2.07	
$CG_{C\ 0–24}$	III–V	70	1.96	0.13	1.62	2.12	2.00	0.005*
$SG_{C\ 0–24}$	III–V	84	2.07	0.16	1.89	2.95	2.05	
$CG_{C\ 0–24}$	I–V	70	3.99	0.17	3.43	4.18	4.05	<0.001*
$SG_{C\ 0–24}$	I–V	84	4.14	0.18	3.81	5.06	4.13	
$CG_{C\ 25–60}$	I–III	38	2.00	0.09	1.85	2.17	1.99	0.72
$SG_{C\ 25–60}$	I–III	30	2.01	0.15	1.73	2.20	2.02	
$CG_{C\ 25–60}$	III–V	38	1.96	0.12	1.72	2.12	1.98	0.04*
$SG_{C\ 25–60}$	III–V	30	2.03	0.08	1.80	2.17	2.02	
$CG_{C\ 25–60}$	I–V	38	3.95	0.15	3.64	4.15	4.01	0.12
$SG_{C\ 25–60}$	I–V	30	4.04	0.16	3.74	4.32	4.08	

$CG_{C\ 0–24}$=Control group of normo-nourished children aged 0–24 months *click*; $CG_{C\ 25–60}$=Control group of normo-nourished children aged 25–60 months *click;* $SG_{C\ 0–24}$=Study group of malnourished children aged 0–24 months *click;* $SG_{C\ 25–60}$=Study group of malnourished children aged 25–60 months *click;* SD=standard deviation, *N*=number of ears.

Table 4 Comparison of the variables V-wave latencies at 60, 40, and 30 dBNA (in ms) found between groups of normo-nourished and malnourished children aged 0–24 and 25–60 months, through the recording of BAEP Student's *t*-test and Mann–Whitney U test

Group	Absolute latency of V-wave							
	Intensity	*N*	Mean	SD	Minimum	Maximum	Median	***P*-Value**
$CG_{C\ 0–24}$	60dB	70	6.19	0.17	5.76	6.47	6.20	<0.001*
$SG_{C\ 0–24}$	60dB	84	6.42	0.28	6.08	7.71	6.40	
$CG_{C\ 0–24}$	40dB	70	7.02	0.29	6.41	7.46	7.11	<0.001*
$SG_{C\ 0–24}$	40dB	84	7.27	0.20	6.87	7.78	7.27	
$CG_{C\ 0–24}$	30dB	70	7.88	0.46	6.99	8.62	8.11	<0.06
$SG_{C\ 0–24}$	30dB	84	8.11	0.28	7.55	8.63	8.15	
$CG_{C\ 25–60}$	60dB	38	5.92	0.36	5.23	6.49	5.90	0.001*
$SG_{C\ 25–60}$	60dB	30	6.41	0.45	5.61	7.28	6.42	
$CG_{C\ 25–60}$	40dB	38	6.68	0.44	5.94	7.37	6.72	0.001*
$SG_{C\ 25–60}$	40dB	30	7.21	0.45	6.24	7.94	7.24	
$CG_{C\ 25–60}$	30dB	38	7.36	0.57	6.42	8.16	7.27	0.005*
$SG_{C\ 25–60}$	30dB	30	7.97	0.51	6.72	8.62	8.12	

$CG_{C\ 0–24}$=Control group of normo-nourished children aged 0–24 months *click*; $CG_{C\ 25–60}$=Control group of normo-nourished children aged 25–60 months *click;* $SG_{C\ 0–24}$=Study group of malnourished children aged 0–24 months *click;* $SG_{C\ 25–60}$=Study group of malnourished children aged 25–60 months *click;* SD=standard deviation, *N*=number of ears.

of waves I, III, and V, and in the III–V interval for both age groups studied, with increased latencies for the malnourished group. We also detected deficiencies in the I–V interval of the 0–24 months group, suggesting a deleterious effect of malnutrition on the conduction of sound stimulus in the central auditory nervous system.

Children aged 0–60 months were divided into two groups of 0–24 months and of 25–60 months due to the variations in BAEP parameters between the two age groups caused by physiological processes of maturation of neural structures and the brainstem. The auditory system undergoes its first phase of neurological maturation until the sixth month of gestation; maturation of the peripheral portion and a second phase occur with myelination throughout the central nervous system (CNS), from birth until about 18 months of age.[20,21]

The BAEP using a *tone burst* stimulus is an evaluation technique that uses a specific frequency to evaluate auditory sensitivity.[22,23] In this study, these references were used and the V-wave presence at 30 dBNA was verified in all SG and CG subjects with both *click* and *tone burst* stimuli, identifying the auditory sensitivity of the sample within normality.

There was no significant difference between the right and left ears in CG and SG participants at any frequency tested by *click* BAEP in either age group when evaluating both absolute wave latencies and interpeak intervals. Our results agreed with those obtained by other authors, who did not find significant differences between the right and left ears.[24,25]

In the absolute latencies of waves I, III, and V between the SG and CG in both age groups, there was a higher latency for malnourished children when compared with normo-nourished children. There was a significant difference between the two groups; higher latency values were observed in the malnourished group. This result suggests that malnutrition can affect the maturation of the auditory nervous system and is an important variable in the analysis of the latencies of waves I, III, and V, results which are consistent with those of Durmaz et al.,[16] who observed a significant difference in wave latency V; Odabas et al.,[17] who pointed out a significant difference in the latencies of waves I, II, III, IV, and V; Vandana and Tandon[18] who observed the prolongation of the absolute latencies of waves I, II, III, and IV; and Gladstone et al.,[19] who detected increased wave latency in the evoked auditory potential.

The results of the present study showed a difference in neural conduction from the cochlear nerve to the brainstem when malnourished and normo-nourished children were compared, by delaying the absolute latency of waves I, III, and V in both age groups of malnourished children. These results are consistent with animal models that have shown that protein-caloric or micronutrient malnutrition in the critical period of formation and myelination in the CNS affects the latency of BAEP waves.[25,26] This finding could justify the latency of BAEP wave delay observed in malnourished children in the present study, as it has been shown that myelination, synaptic junctions, and neural arborization are processes that depend on adequate nutritional intake to occur in a satisfactory way.[7]

Salamy and McKean[27] and Adelman et al.[28] observed that the maturation of wave I is the first to occur and presents values similar to those of an adult around three months of age, and that the interpeak I–V interval reduction related to chronological growth is given at the expense of wave V.

Table 3 compares the results of latency values of interpeaks I–III, III–V, and I–V with the *click* stimulus in both age groups. A significant difference in the interpeak III–V and I–V latencies was observed between CG and SG children in the 0–24 months group; the values of the largest intervals were in the SG children and there was no significant difference in the I–III interval. Considering that this age is the most important for the process of myelinization of the auditory pathways and that the most rostral part of the stem is the last to conclude myelination, the comparative results among malnourished and eutrophic children can be justified.

For the 25–60 months group, a significant difference was observed in the interpeak III–V latency between CG and SG children, with larger interpeak intervals observed in the SG; there was no significant difference in the interpeak intervals I–III or I–V. However, the means of these interpeaks were higher in malnourished than in normo-nourished children in both age groups. The absence of a significant difference observed in the I–V interval between malnourished and normo-nourished children 25–60 months may be justified by the lower deleterious effect of late malnutrition, that started after 25 months of life, in this sample on the brainstem; similar results have been reported in the literature. Durmaz et al.[16] observed a significant difference in the latency of I–V and III–V intervals between malnourished and control groups and found no difference in the interpeak I–III latency. Odabas et al.[17] detected a significant difference in latency in the III–V and I–V intervals; Vandana and Tandon[18] reported latency prolongations between interpeaks I–III and III–V when compared to CG.

Comparing the BAEP interpeak interval results between normo-nourished and malnourished children, we found a significant difference in the III–V interval between groups in both age groups, with higher latencies observed in malnourished children. There was no significant difference in the I–III interval between groups. This result could be explained by the fact that the III–V interval reflects a synchrony in the conduction of the neural stimulus in the most rostral portion of the brainstem, whereas the I–III interval reflects the conduction of sound stimulus in the most caudal portion, from the auditory nerve to the lower brainstem; the deficit of nutritional intake in the SG would cause alterations in myelination in the most rostral portion of the auditory system, leading to this result.

The interpeak I–III latency represents the activity between the auditory nerve and the lower brainstem, whereas III–V reflects the activity of neural synchronism exclusively within the brainstem, and the interpeak I–V represents the activity between the auditory nerve up to the nuclei and tracts of the brainstem.[29]

When the results detailed in Table 4 were observed, there was a significant difference between BAEP wave latencies at intensities of 60, 40, and 30 dBNA in both age groups of the CG and SG children. A higher average was observed in the SG latencies, with the exception of the 0–24 months group at the intensity of 30 dBNA, in which there was a trend to a significant difference, with higher means in the SG. These results corroborate the idea of the deleterious effects of a nutritional deficit on the physiological maturation process of the auditory nervous system. Some studies have shown that the observed changes in the BAEP of malnourished children are attributed to poor myelination of the auditory pathways.[30,31]

The results of the present study indicate that malnutrition may be a risk factor for the occurrence of hearing changes in this group of children, which would justify a preventive intervention. Delayed or altered auditory system myelinization mainly affects children from birth to two years of age, during which the maturation of the CNS and brainstem structures is observed, as detected by the continuous decrease in the latencies of waves I, III, and V and interpeak I–V, until about 18 months of age. As maturation proceeds in the cauda-rostral direction, in this age group we can see the delay of all I, III, and V waves, as well as the interpeaks III–V, and I–V, which could be explained by the myelinization deficit due to nutritional restriction occurring during the myelination critical period of the auditory nervous system. Myelination is important to establish and facilitate signal transfer between neural systems in a rapid and synchronized way.[32]

Studies that relate malnutrition and auditory changes, evaluated through Long-Latency Auditory Evoked Potentials (LLAEP), showed that cortical auditory evoked potentials are affected by malnutrition, as in Hassaan et al.,[24] who found a significant difference in the evaluation of cortical auditory potential between normo-nourished and malnourished children, with prolonged latencies of waves N1 and P2 in the SG that displayed a deficit due to malnutrition at the cortical level. Almeida and Matas[33] evaluated LLAEP in children with malnutrition and compared them with children with typical development of the same age group and identified a significant difference in the latencies of the P1, N1, and P300 components, with higher latencies observed in the SG. Caldas, Giacheti, and Capellinil[34] evaluated malnourished and normo-nourished children who underwent peripheral and central auditory evaluation and identified that, compared to eutrophic children, malnourished children presented a higher index of changes in sound sequencing abilities for verbal and nonverbal sounds and auditory processing disorders. The authors concluded that malnourished children presented changes in LLAEP, which suggested deficits in the central auditory pathway and changes in the acoustic information processing.

According to Allen[35] auditory processing includes the ability to perceive, interpret, and understand sound information even when it is presented in inappropriate conditions, such as when information is degraded or when there is background noise. Connections of the auditory pathways with the areas of memory and language are made easily and quickly, even if the clarity of the signal is reduced. Due to the significant encoding that occurs in the cochlea and brainstem, it is important to evaluate the integrity of these structures. Allen[35] observed many altered BAEPs in children referred for central auditory processing evaluation. This author suggested poor neural integrity of the auditory nerve and brainstem in some children suffering from these disorders. Abnormalities include poor replicability, the absence of waves, low V/I amplitude ratio, and latency delay. According to the author, an excellent test to assess brainstem integrity is documentation of BAEPs. The BAEPs alterations found in malnourished children in the present study may be similar to those detected in children with changes in the central auditory processing described by Allen.[35]

Due to this anatomical-functional complexity of the brainstem in auditory information processing, its impairment due to malnutrition could also generate changes in the central auditory processing of malnourished children, with immediate and future consequences in the development of the same. According to Harrison,[36] the developing central auditory system is highly plastic in newborns and young children and can be significantly influenced by auditory patterns from the peripheral system. In addition, during this early developmental period, plasticity is not only a cortical attribute, and all levels of ascending auditory pathways from the brainstem can be (re)organized by auditory stimuli. Assessing the results of this study and of the literature, we can suggest that malnutrition affects the high auditory nervous system, cortex (LLAEP), and low brainstem (BAEP). The intervention for the malnourished child should include, in addition to the nutritional component, evaluation and auditory intervention for the prevention of impairments in speech acquisition, language, and auditory processing.

We believe that it is important in the early interventional processes, whether nutritional or environmental and auditory stimulation, to direct the long-term development of the central auditory system. The symbiotic relationship between malnutrition, poverty, and low socioeconomic status is recognized in the literature as an important theme of the Millennium Development Goals and is one of the United Nations (UN) goals from 2007 to 2015.

We infer that strategies to overcome these malnutrition conditions should be implemented through public health policies such as access to health care, public assistance to raise family income, access to basic sanitation, and educational health actions regarding nutrition. In addition, preschool children should have full-time preschool access to nutritional supplementation and access to education.

Conclusions

The results of this study allowed us to conclude that:

- There was a significant difference in the absolute latencies of waves I, III, and V between malnourished and normo-nourished children evaluated by the BAEP *click* stimulus;
- Regarding latency of the interpeak intervals, there was a significant difference in the III–V interval in both age groups and in the I–V interval in the 0–24 months group;
- It was possible to identify a significant difference for all intensities and frequencies tested in the comparative evaluation of absolute V-wave latency at frequencies of 60, 40, and 30 dBNA among malnourished and normo-nourished children using the *click* stimulus;
- The V-wave was present at an intensity of 30 dBNA in all malnourished and normo-nourished children when the *tone burst* stimulus was used at frequencies of 500, 2000, and 4000 Hz.

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