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Hearing and language in term and preterm children

Audição e linguagem em crianças nascidas a termo e pré-termo

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ABSTRACT

Purpose: To examine the maturation of the auditory pathway of children who were born at term and preterm, during 2 years and 6 months. Moreover, we tried to compare this maturation to the development of language skills of these children. **Methods:** It is a longitudinal and comparative study, which presents a clinical outcome related to the observation and analysis of auditory electrophysiological responses at the first month of life and 2 years and at 6 months old. The sample consisted of eight children, of both genders, being five born at term and three at preterm. Cortical Auditory Evoked Potential and the language evaluation were carried out through the Behavioral Observation Protocol. **Results:** Both term and premature babies passed through a period of maturation of the auditory pathway. In the correlation of gestation and maturation of the auditory pathway, we observed that the higher gestational age, the higher was the maturation of P1 wave. There was no correlation between language evaluation results and the maturation of the auditory pathway. **Conclusion:** Based on the results of this study, we concluded that there was maturation of the auditory pathway in the two-year period in both groups. A correlation between gestational age and maturation of P1 was observed, which shows that the higher is the gestational age, the greater is the maturity of this component. Regarding the language skills, no correlation with the maturation of this sample was noticed.

Keywords: Hearing; Evoked potentials, Auditory; Infant, Premature; Child language; Gestational age

RESUMO

Objetivo: Analisar a maturação da via auditiva de crianças nascidas a termo e pré-termo, ao longo de dois anos e seis meses e comparar a maturação auditiva com o desenvolvimento das habilidades linguísticas dessas crianças. **Métodos:** O estudo teve como desfecho clínico a observação e análise das respostas eletrofisiológicas auditivas de crianças, durante o primeiro mês de vida e aos 2 anos e 6 meses de idade. A amostra constituiu-se de oito crianças, de ambos os gêneros, sendo cinco nascidas a termo e três nascidas pré-termo. Realizou-se o Potencial Evocado Auditivo Cortical e a avaliação de linguagem, por meio do Protocolo de Observação Comportamental. **Resultados:** Tanto os bebês nascidos a termo como os prematuros passaram por um período de maturação da via auditiva. Na correlação da idade gestacional e maturação da via auditiva, observou-se que, quanto maior a idade gestacional, maior a maturação da onda P1. Não houve correlação entre os resultados da avaliação de linguagem e a maturação da via auditiva. **Conclusão:** Houve maturação da via auditiva no período de dois anos e seis meses, em ambos os grupos estudados. Observou-se correlação entre Idade Gestacional e a maturação de P1, demonstrando que, quanto maior a Idade Gestacional, maior a maturação deste componente. Quanto às habilidades de linguagem, não houve correlação com a maturação da via auditiva.

Descritores: Audição; Potenciais evocados auditivos; Prematuro; Linguagem infantil; Idade gestacional

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INTRODUCTION

Hearing is considered a prerequisite for the acquisition and development of oral language[1,2]. The exposure to auditory experiences in the first years of life allows the cortical organization, which is necessary to ensure the normal development of hearing and language[1].

The hearing thresholds within the standard of normality and the proper functioning of the central structures are essential for language development. Currently, the Cortical Auditory Evoked Potential (CAEP) has been used to evaluate the onset of cortical processing, in other words, the detection at the level of the auditory cortex[3].

The positive wave 1 (P1), negative 1 (N1), positive 2 (P2) are part of CAEP, which are called exogenous components of the Long Latency Auditory Evoked Potential (LLAEP), as they are influenced by the physical characteristics of the stimulus, such as intensity, duration and frequency[4] and they do not depend on any response of the evaluated subject[3]. CAEP emerged as a procedure that is able to measure the degree of maturation of the central auditory pathways in an objective way by analyzing the changes concerning morphology and latency values of P1-P2-N1 components, over time[4,5].

In newborns and smaller children, P1 and N1 are the predominant potentials[5,6]. On the other hand, the onset of other components would be related to the progressive maturation of central auditory pathways[5,6].

It is noteworthy that the wave P1 was established as a biomarker to evaluate the auditory maturation[7,8]. This component is a positive wave, generated by the thalamocortical circuit activity in the stimulation of sounds, being a measure that is capable of reflecting changes in central auditory nervous system (CANS), resulting from the neuronal plasticity[6].

It is also worth noting that the presence of waves in CAEP can be considered an indicator of cognitive development, especially in preterm infants, who are considered at risk for changes in auditory processing and in language[9].

Prematurity is one of the major biological risk among the factors for child development, due to the immaturity and vulnerability of the brain under development[10]. Preterm newborns are usually defined as those neonates with gestational age inferior to 37 weeks[11].

Preterm babies may experience some delay in development, which will depend on the complications and environmental stimulation received by the baby, which may reduce or increase the effects of prematurity[12].

The development of language, in all its aspects, such as vocabulary, phonology, fluency and pragmatic is related to social exchanges between children and the environment, which are mainly given by auditory experiences, in the case of oral languages. These social interactions become even more important in the case of preterm children, who require follow-ups and stimuli for the appropriate development according to their chronological age[13,14].

Most of the studies that compared the linguistic development of preterm and term children identified some delay in the development of the preterm group when compared to children born at term, particularly in relation to language development[13,14,15].

Regarding CAEP in this population, there is still the need to know more about potential features. Although some studies have already characterized, it is necessary to expand the knowledge in the pediatric population[5,9,16,17], because in the literature there are a few longitudinal studies that analyze changes in morphology and latency of waves over time.

Consequently, the motivation of this study relied on the need to investigate the correlation between the maturation of the auditory pathways and language development of children born at term and preterm, through longitudinal studies with CAEP.

The aim of this study was to analyze the maturation of the auditory pathway of children born at term and preterm and, then, compare it to the development of language skills over two years and six months.

METHODS

This is a longitudinal and comparative study, which had the observation and the analysis of electrophysiological responses from CAEP as clinical outcome, in two occasions, during the first month of life of children and when they were 2 years and 6 months. In addition, we studied the language development of the sample, by using a specific protocol. The study was part of the research project named "Infant Hearing Disability: from diagnosis to intervention," approved by the Ethics Committee of *Universidade Federal de Santa Maria*, under the number 14804714.2.0000.5346. Only subjects whose parents and/or guardians signed the Informed Consent Form (IC).

For this study, we used the medical records of 25 newborns who attended a university hospital in order to carry out the Neonatal Hearing Screening (NHS) during the first month of life, and that, at the time, were also evaluated through research and registration of CAEP, from August 2012 to November 2012. It is noteworthy that these newborns comprised the entire sample of another study in this period, which evaluated CAEP in newborns who were at most 29 days old. For the selection of the sample, we made contact with the family/guardians of 12 children born at term and preterm, of both genders, who were part of the same composition of the 2012 study. Thus, these children were again called when they were 2 years and 6 months old, for carrying out a new CAEP research. It was possible to schedule by telephone ten children to participate in this research, however, two children did not attend, even after rescheduling. The maturation of the auditory pathway was a study variable, considering the latency result of CAEP in the first evaluation (at the time of NHS, carried out from August

2012 to November 2012 - the first study) and second evaluation (carried out from the May 2015 to August 2015).

Therefore, the final sample consisted of eight children, when they were 2 years and 6 months old, of both genders, divided into two groups: Term Group: Five children born at term, three girls and two boys; Preterm Group: Three children born at preterm, two girls and one boy. Preterm newborns were considered the neonates whose gestational age was inferior to 37 weeks[11].

The following inclusion criteria were established: authorization of the mother and/or guardian for the participation in the research, by signing the Informed Consent Form; children who returned for further evaluation of CAEP and evaluation of language skills, after telephone contact; visual inspection of the external acoustic meatus without peculiarities; type A tympanometric curve and bilateral presence of Transient Otoacoustic Emissions (TOAE).

On the other hand, some exclusion criteria were defined: children who did not return for reevaluation; impossibility of communication with parents/guardians; children with middle ear disorders, observed by tympanometry; children with evident organic changes.

The procedures specified for this research were: Revaluation of Cortical Auditory Evoked Potentials and evaluation of expressive language and comprehensive.

First, the visual inspection of the external acoustic meatus was performed, for inspecting the condition of the external ear canal and tympanic membrane through the Mikatos® otoscope.

The research of TOAE and tympanometry were aimed at the exclusion of children with cochlear dysfunction and/or conductive hearing loss. For the research of the tympanometric curve, the MadsenOtoflex 100 device was used, an Otometrics® device, with 266 Hz test tone. The curves with a maximum compliance peak around 0 mmH20 (mm) whose variation did not exceed -100 mmH20 were classified as type "A". TOAEs were measured in both ears with click stimulus in the frequencies of 1000, 1500, 2000, 3000 and 4000 Hz, with an intensity of approximately 85 dB SPL. TOAEs were considered present when the signal/noise ratio was greater than or equal to 3 dB for a frequency of 1000 Hz and 6 dB for other frequencies in all the measured frequencies. The record of TOAEs was performed with the Intelligent Hearing Systems equipment (IHS), SmartTrOAE module.

For the research of CAEP, the IHS equipment was used, SmartEP module, two channels. For the electrophysiological evaluation which was performed in the first month of life, newborns remained in natural sleep in the lap of the guardians. In the evaluation performed at 2 years and 6 months, the children remained awake, sitting comfortably on the lap of the guardians, watching a video, in order to not to direct their attention to the sound stimulus. After cleaning the skin with abrasive paste, the electrodes were fixed with electrolytic conductive paste and adhesive tape, and the active (Fz) and ground (Fpz) placed on the forehead and the reference on the left mastoid (M1) and right mastoid (M2). It remained the same procedure for placing the electrodes in the two periods to preserve the standard of evaluation. The value of the impedance of the electrodes was equal to or less than 3k ohms.

CAEP were researched in a binaural form through the insertion of phones with speech stimuli frequent /ba/ and rare /g/, the intensity of 80 dB HL. Frequent stimuli equaled 80% (about 200 stimuli) of the presentations and the rare stimuli, 20% (about 40 stimuli). The stimuli were randomly presented, respecting the oddball paradigm. We used the alternating polarity and bandpass filter of 1 to 30 Hz, with window of 1020 ms. After the onset of the trancing, the latency and the amplitude of the waves (P1, N1, P2 and N2) were measured. The tracing was printed for subsequent analysis by two different professionals with experience in electrophysiology of hearing. It should be noted that the analysis of the potential was only done in the tracing of frequent stimuli.

It is noteworthy that the difference between the latencies of waves P1 and N1 of the first and second evaluation was already described as maturation of the auditory pathway.

The language evaluation was performed by the Behavioral Observation Protocol (*Protocolo de Observação Comportamental* - PROC)[18], which consists of a language evaluation and infant cognitive aspects, being a useful tool in the early detection of changes in language development in children. This instrument presents qualitative and quantitative variables, which indicates that the maximum score test is 60 points for communication skills (expressive); 40 points for spoken language comprehension; 50 points to aspects of cognitive development and 150 points in the total score. The mean score of the reference sample for 2 years[19], in each category are: communication skills - 51.44 points; verbal language comprehension - 50.70 points; aspects of cognitive development - 31.96 points and total score - 137.11 points. For the application of PROC, the interaction of the child with their family members was observed, involving pre-selected toys, during 30 minutes on average, recorded on video and analyzed later by two researchers.

It is worth pointing out that if the child had changes in the language evaluation or hearing evaluation, specialist referrals were made.

Data were arranged in Microsoft Excel spreadsheets and they were statistically analyzed by a professional of the area, being considered significant results $p < 0.05$, with a 95% confidence interval. For this analysis, non-parametric tests (Mann-Whitney test, Wilcoxon, Mann-Whitney and Spearman correlation) were used, based on the STATA 9.0 software, for crossing the following variables: gestational age versus latencies of P1 waves and N1 in the first and second evaluation; PROC analysis of the results between groups and maturation of the auditory pathway results versus PROC. Regarding the Spearman correlation test, as coefficients and correlation

values, the following correlations were established: 0 to 0.25 = very weak; 0.25 to 0.50 = weak; moderate = 0.5 to 0.75; 0.75 to 0.9 = strong; 0.9 to 1 = very strong.

RESULTS

By analyzing the latencies of P1 and N1 components to the right and left ear, considering the two moments of evaluation, we observed that in both groups there was a significant decrease in the latency over time (Table 1).

After analysis of the maturation of CAEP, which considered the difference in latency of P1 and N1 components in the two moments of evaluation, we analyzed a strong correlation between gestational age and P1 maturation in the left ear and moderate correlation in the right ear, indicating that, the greater Gestational Age, the greater the maturity of that wave (Table 2).

Given the distribution between the groups, the descriptive analysis of the presence

of the P2 and N2 waves in the second evaluation of CAEP, performed in milliseconds and that aimed to complement the maturation study of the auditory pathway, evidenced that all children presented P2 wave. Two children of the Term Group and 3 children of the Pre-Term group presented N2 wave (Table 3).

The mean analysis of the PROC results indicated that, in our sample, there was no significant difference in either group. Thus, it was decided to group the sample and analyze the correlation between the language evaluation results and the maturation of the auditory pathway, through the variation of

Table 1. Comparison of the latency between the components P1 and N1, in milliseconds, for the right ear and left ear, on 1st and 2nd evaluations, in each group: Term and Preterm

Variables	Term (n=5)				Preterm (n= 3)				p-value
	1st Evaluation		2nd Evaluation		1st Evaluation		2nd Evaluation		
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Left ear									
P1	271.60	18.89	108.00	16.73	225.33	49.81	104.67	7.57	0.011*
N1	399.20	23.65	206.00	31.53	376.67	18.90	181.33	45.88	
Right ear									
P1	266.00	20.15	111.60	18.67	226.00	47.03	104.00	12.16	0.011*
N1	399.60	10.80	217.20	46.79	363.33	28.02	187.33	47.43	

*Significant values (p<0.05) – Test of Wilcoxon

Table 2. Correlation between Gestational Age and maturation of the Cortical Auditory Evoked Potential, considering right ear and left ear (n=8)

	Right ear		Left ear	
	Gestational age x 1st P1 – 2nd P1	Gestational age x 1st N1 – 2nd N1	Gestational age x 1st P1 – 2nd P1	Gestational age x 1st N1 – 2nd N1
R	0.740	0.235	0.793	0.203
p-value	0.035*	0.416	0.018*	0.628

*Significant values (p<0.05) – Spearman Correlation Test, considering R = 0 to 0.25: very weak; 0.25 to 0.50: weak; 0.5 to 0.75: moderate; 0.75 to 0.9: strong and, 0.9 to 1: very strong

Subtitle: R = coefficient of correlation; 1st P1 = latency of the component P1 in the 1st evaluation; 2nd P1 = latency of the component P1 in the 2nd evaluation; 1st N1 = latency of the component N1 in the 1st evaluation; 2nd N1 = latency of the component N1 in the 2nd evaluation

Table 3. Descriptive analysis of the latencies of the waves P2 and N2, in milliseconds, for the studied sample: Term Group and Preterm (n=8)

	Mean	Minimum	Maximum	Standard deviation
Term Group				
P2 LE	322.40	220.00	410.00	84.25
N2 LE	296.00	276.00	316.00	28.28
P2 RE	337.00	220.00	428.00	92.48
N2 RE	364.00	276.00	468.00	96.99
Preterm Group				
P2 LE	285.3333	218.0000	402.0000	101.4364
N2 LE	389.3333	276.0000	576.0000	162.8906
P2 RE	306.6667	218.0000	454.0000	128.4731
N2 RE	404.6667	302.0000	584.0000	155.8504

Subtitle: LE = left ear; RE = right ear

Table 4. Analysis of the mean results of the Behavioral Observation Protocol: Term Group versus Preterm Group

	Expressive Communicative Skills			Verbal Language Comprehension			Aspects of the Cognitive Development			General PROC		
	P	N	D	P	N	D	P	N	D	P	N	D
Term Group (mean) n=5	46.60	51.44	-4.84	40.00	50.70	9.30	37.40	31.96	5.44	140.00	137.11	2.89
T1	60.00	51.44	18.56	40.00	50.70	9.30	50	31.96	38.04	150	137.11	62.89
T2	24.00	51.44	-22.44	40.00	50.70	9.30	10	31.96	-16.96	74	137.11	-33.11
T3	18.00	51.44	-29.44	26.00	50.70	-10.70	5	31.96	-23.96	49	137.11	-67.11
T4	49.00	51.44	6.56	40.00	50.70	9.30	42	31.96	27.04	131	137.11	39.89
T5	46.00	51.44	2.56	40.00	50.70	9.30	25	31.96	3.04	111	137.11	11.89
Preterm Group (mean) n=3	52.00	51.44	0.56	53.33	50.70	2.63	51.33	31.96	19.37	156.66	137.11	19.55
P1	24.00	51.44	-23.44	26.00	50.70	-10.70	17	31.96	-6.96	67	137.11	-44.11
P2	49.00	51.44	6.56	40.00	50.70	9.30	42	31.96	27.04	131	137.11	39.89
P3	60.00	51.44	18.56	40.00	50.70	9.30	50	31.96	38.04	150	137.11	62.89
Valor de p		0.650			0.693			0.450			0.650	

Mann-Whitney Test (p<0.05)
Subtitle: P = production; N = normative; D = deviation of the normative; PROC = Behavioral Observation Protocol (*Protocolo de Observação Comportamental*)

Table 5. Analysis of the correlation between the mean results of the Behavioral Observation Protocol and maturation of the auditory pathway (n=8)

	P1 LE		N1 LE		P1 RE		N1 RE	
	R	p-value	R	p-value	R	p-value	R	p-value
Expressive Communicative Skills	0.256	0.540	0.060	0.887	0.066	0.875	0.192	0.647
Verbal Language Comprehension	0.063	0.880	-0.125	0.766	0.063	0.881	-0.125	0.766
Aspects of the Cognitive Development	0.231	0.580	0.084	0.842	0.042	0.920	0.216	0.605
General PROC	0.256	0.540	0.060	0.887	0.066	0.875	0.192	0.647

Spearman Correlation Test (p<0.05), considering R = 0 to 0.25: very weak; 0.25 to 0.5: weak; 0.5 to 0.75: moderate; 0.75 to 0.9: strong and, 0.9 to 1: very strong
Subtitle: LE = left ear; RE = right ear; R = coefficient of correlation; PROC = Behavioral Observation Protocol (*Protocolo de Observação Comportamental*)

the latencies (1st and 2nd evaluation). It is noteworthy that there was no significant difference (Table 4 and Table 5).

DISCUSSION

Comparing the latencies of P1 and N1 waves evaluated in children, in different periods, who were up to 1 month old and when they were 2 years and 6 months old, it was observed a significant reduction in latency in both groups (Table 1). From the cortical auditory evaluation, it is inferred that both term babies, such as preterm neonates underwent a period of maturation of the auditory pathway, over these two years and six months.

The name used for the potential presented in this study was P1, N1, P2 and N2, unlike other studies in which the name used for P1 and N1 is P2 and N2. The author of a study draws attention to the subjectivity in the name of the potential in newborns, reporting that it varies in the literature, since some authors classify the potential according to the latency[17]. However, recent studies have suggested the name of P1 and N1 to the positive peak and the predominant deflection in the tracing of the infant population. It is believed that from cortical maturation, these components originate the cortical endogenous complex in adults[20].

In order to clarify the effects of maturation of CAEP components, some studies[6,21] indicate the relationship between the variable age and the reduction of latencies of P1 and N1. The reduction in latency values is related to the gradual process of myelination of the central structures and maturation of central auditory pathways, which are processes of cortical organization that are necessary for the proper development of hearing and language[1,6]. The decrease in latency had also been found in studies with another type of Auditory Evoked Potential[22,23].

In relation to gestational age and maturation of the auditory pathway, it was observed that the higher gestational age, the greater the maturation of wave P1, which was indicated by the decrease in latency of this wave (Table 2). This finding is in agreement with the study that researched, through the Brainstem Auditory Evoked Potencials, the maturation of the auditory pathway in preterm children, concluding that the higher the gestational age, the lower the latency of the waves of this potential[22].

The subjects of this study already presented the exogenous components P1 and N1 of the cortical potentials, when

evaluated with 1 month of life, results that are in agreement with other studies[9,16,17]. Regarding the evaluation carried out after two years and six months, which verified the presence of components P2 and N2 of CAEP, observing, in the descriptive analysis, the mean latencies in milliseconds, it is known that other authors, when researching CAEP in the age group from 1 year and 9 months to 2 years and 6 months old, observed P2 latencies in 332 milliseconds[21]. In the same study, children who were 2 years and 6 months presented significantly lower latencies when compared to the ones from younger age groups of 12 and 18 months. Other studies, carried out with children over 3 years old, found latencies slightly lower for P2 wave, 204 ms[6] and 289,23 ms[24] and N2, 223,33 ms[25].

According to these findings, it is possible to infer that the older the child, the lower the latency of CAEP. In other words, the maturation of the auditory pathway occurs over time, until adulthood.

Some studies indicate differences in cortical potentials between term and preterm newborns[26,27]. Such fact was not observed in this study, since the maturation of the auditory pathway was similar in both groups, which can be justified due to the fact that the development depends on the stimulation received by the child, the environment in which he/she is inserted and possible complications along his/her development[12,13,14,15].

Some authors report that, concomitant with the maturation of the auditory function, it occurs the development of speech and language skills, since the period of reception of the auditory language symbols is a prerequisite for the subsequent formulation of language[28]. After analyzing the results of PROC, no significant difference between groups with respect to the development of language (Table 4) was observed. Despite the similarity in the results, it was observed that the Group Term presented better performance only in verbal language comprehension, and for the rest of the protocol, the Preterm Group showed better scores. This relation was also observed by other authors, who reported that the evaluated preterm and term groups showed similar behavior in language development[29]. The authors believe that, possibly, this is explained due to the fact that parents receive guidance on the appropriate stimulation to language development, monitoring the evolution of preterm infants[29]. It is important to notice that in this study, children in the Preterm Group were observed over two years and six months as NHS program provides the monitoring of hearing and language of children with Risk Indicators for Hearing Loss (RIHL).

One study found, however, that the preterm children showed higher occurrence of delay in expressive language and that the expressive vocabulary was significantly lower than the one of children of the same age, born at term[30]. Other authors studied the mother-child interaction in the development of oral language of preterm newborns and they observed that the preterm children presented language performance inferior to the one expected for their chronological age, noting also that the longer the mother-child interaction and the higher the socioeconomic status of the family, the better the performance of the child in oral discourse[13]. Thus, it is noteworthy that two subjects of this research, one from the Term Group and other from the Preterm group, required specialist referral for language therapy, due to the low score obtained through the protocol. In addition, during the filming observation of the child-guardian interaction, it was possible to verify some precariousness concerning the quality of this interaction.

Although no correlation was observed between language skill and maturation of the auditory pathway (Table 5), in this study, one possible explanation would be the reduced study sample size, since other studies have shown that children who had peaks with lower latencies were more prone to present better language and cognitive scores at 3 and 4 years old[9]. However, it becomes evident the fact that this research is longitudinal, as it proposed to evaluate the maturation of the auditory pathway after two years and six months after the first evaluation and it is known the risk of sample loss in this type of study. Even with the strict control of the sample monitoring, it was not possible to complete the research with a larger number of children, since the consent of the families was low.

CONCLUSION

There was maturation of the auditory pathway in the period of two years and six months in both groups. A correlation between gestational age and maturity of P1 was observed, which demonstrates that the higher Gestational Age, the greater the maturation of this component. In relation to language skills, there was no correlation with the maturation of the auditory pathway.

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