Original Article

Artigo Original

Auditory processing evaluation in children born preterm

Avaliação do processamento auditivo em crianças nascidas pré-termo

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Keywords

Hearing tests
Speech perception
Auditory perception
Term birth
Infant, premature

ABSTRACT

Purpose: To verify the performance of children born preterm on auditory processing evaluation, and to correlate the data with behavioral hearing assessment carried out at 12 months of age, comparing the results to those of auditory processing evaluation of children born full-term. **Methods:** Participants were 30 children with ages between 4 and 7 years, who were divided into two groups: Group 1 (children born preterm), and Group 2 (children born full-term). The auditory processing results of Group 1 were correlated to data obtained from the behavioral auditory evaluation carried out at 12 months of age. The results were compared between groups. **Results:** Subjects in Group 1 presented at least one risk indicator for hearing loss at birth. In the behavioral auditory assessment carried out at 12 months of age, 38% of the children in Group 1 were at risk for central auditory processing deficits, and 93.75% presented auditory processing deficits on the evaluation. Significant differences were found between the groups for the temporal order test, the PSI test with ipsilateral competitive message, and the speech-in-noise test. The delay in sound localization ability was associated to temporal processing deficits. **Conclusion:** Children born preterm have worse performance in auditory processing evaluation than children born full-term. Delay in sound localization at 12 months is associated to deficits on the physiological mechanism of temporal processing in the auditory processing evaluation carried out between 4 and 7 years.

Descritores

Testes auditivos
Percepção da fala
Percepção auditiva
Prematuro
Nascimento a termo

RESUMO

Objetivo: Verificar o desempenho de crianças nascidas pré-termo na avaliação do processamento auditivo, correlacioná-lo com os dados da avaliação comportamental da audição realizada aos 12 meses, e compará-lo com os resultados da avaliação do processamento auditivo de crianças nascidas a termo. **Métodos:** Participaram 30 crianças, com idades entre 4 e 7 anos, que foram divididas em Grupo 1 (nascidas pré-termo) e Grupo 2 (nascidas a termo). Os resultados da avaliação do processamento auditivo do Grupo 1 foram correlacionados com os dados da Avaliação Comportamental da Audição realizada aos 12 meses. Foi realizada comparação dos resultados obtidos nos dois grupos. **Resultados:** Os indivíduos do Grupo 1 apresentaram pelo menos um indicador de risco para alteração auditiva ao nascimento. Em avaliação comportamental da audição, realizada aos 12 meses, 38% das crianças do Grupo 1 apresentaram risco para alteração auditiva central, e 93,75% apresentaram alteração do processamento auditivo. Houve diferença entre os grupos para os resultados dos testes de ordenação temporal, PSI com competição ipsilateral e fala com ruído. Verificou-se associação entre o atraso da habilidade de localização sonora e a alteração do mecanismo de processamento temporal. **Conclusão:** Crianças nascidas pré-termo apresentam pior desempenho do que crianças nascidas a termo na avaliação do processamento auditivo. Há associação entre o atraso da habilidade de localização sonora aos 12 meses e a alteração do mecanismo fisiológico de processamento temporal na avaliação do processamento auditivo entre 4 e 7 anos.

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Received: 2/9/2011

Accepted: 5/4/2011

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INTRODUCTION

According to the International Statistical Classification of diseases and related health problems of the World Health Organization (WHO), babies born with gestational age below 37 weeks are considered preterm[1]. The preterm baby, depending on his or her maturity, weight at birth, type and degree of those factors that acted during the intra uterine life may present a greater risk to other complications during the neonatal period[2]. Among the possible sequelae is hearing problems[3], that may be related to the peripheral auditory system and also to alterations of auditory processing.

There are prenatal, perinatal, and postnatal complications associated to hearing deficiency. Those complications characterize the indicators for the risk for hearing problems. At the Universidade Federal de São Paulo – UNIFESP, the researched indicators are: family history of hearing loss; suspected delay in hearing, speech and language development or any development delay; stay in a neonatal intensive care unit (NICU) for more than five days or prolonged stay due to the need of mechanical ventilation; use of ototoxic medication and hyperbilirubinemia/blood transfusion; congenital infections; craniofacial anomalies, including those of the auricle and external auditory meatus; syndromes that include hearing loss among their signs; postnatal infections associated to sensorineural hearing loss such as bacterial meningitis; cranial traumas that require hospitalization; chemotherapy and neurodegenerative diseases[4] .

Children considered at risk for hearing disorders must be submitted to a hearing evaluation at the beginning of their lives. They should be followed up on their hearing what would allow the monitoring of hearing ability acquisition still during the period of ideal stimulation, that is, at the critical period for language acquisition[5].

The term auditory processing refers to the perceptual processing of the auditory information at the Central Nervous System and to the neurobiological activity underlying the following abilities: sound localization and lateralization; auditory discrimination; temporal pattern recognition; temporal ordering; temporal masking; acoustic performance with competitive and with distorted acoustical signals[6,7]. The disorder of the auditory processing is due to the inefficiency or incapacity of the auditory system to process acoustical information[8].

Regarding the development of the prenatal brain and auditory system, the cerebral lobes and the lateral fissure are completely developed around the 28th week of gestation. At about 30 weeks of gestation, the auditory pathways of the brainstem are complete. Taking that into account, prematurity represents a disadvantage from both the structural and physiological points of view. Besides, it is also known that the efficiency of the auditory system continues to develop after birth and during the following years due to the neuromaturational process[7]. Auditory processing disorders may present themselves: independently[9]; associated with other developmental problems[10]; as a consequence of a neuromorphological disorder, a maturational delay of the auditory nervous system and neurological problems including neurodegenerative diseases[11].

The aim of this study was to verify the performance of children born preterm and correlate this performance with data obtained from a behavioral hearing assessment conducted at 12 months. Also, the results from the auditory processing assessment of the preterm children will be compared to that of a group of children born full term.

METHODS

This study was conducted at the clinic of the Discipline of Hearing Disorders at the Department of Speech-Language Pathology and Audiology, Universidade Federal de São Paulo (UNIFESP), during the year of 2008, with the approval of the Research Ethics Committee of UNIFESP, with the ID number 0942/08. All of the responsible adults received information referring to the research and signed a Free and Informed Consent Term (FICT).

Participants were 30 children, with ages between four and seven, from both genders, that were divided in two groups:

- Group 1 (G1): formed by 16 children born preterm, with birth weights under de 2 kg, normal peripheral hearing, that were submitted to auditory processing assessment with ages varying from 4 to 7 years. All the children in this group are followed up at the clinic of the Discipline of Hearing Disorders at UNIFESP.
- Group 2 (G2): formed by 14 children born full term, ranging in age from 4 to 7 years, enrolled at public schools in the city of São Paulo. All children presented normal peripheral hearing and did not have speech, language or hearing complaints or any risk indicators for hearing problems at birth.

Children presenting any clinical history of psychiatric and/or neurological problems were excluded from either group.

Analyses of the records of children in Group 1 were carried out. Data on the risk indicators for hearing problems at birth were collected as well as the information regarding the behavioral hearing assessment at the age of 12 months, results for the basic hearing assessment and the auditory processing assessment completed at ages ranging from four to seven. Subjects in Group 2 completed both the basic hearing assessment and the auditory processing one.

The indicators for the risk of hearing problems were researched by the Joint Committee on Infant Hearing, in 2007, and they are related to retro-cochlear problems: stay at the neonatal ICU for over five days or longer hospital stays due to need of mechanical ventilation, hyperbilirubinemia/blood transfusion, bacterial meningitis and periintraventricular bleeding, weight under 1500 grams (g) and use of ototoxic medication. These factors were selected for this study.

The behavioral assessment of hearing conducted at 12 months, was part of the clinic routine for kids in this age group[12]. This assessment included the study of these items: hearing thresholds obtained by visual reinforcement audiometry, recognition of orders, sound localization at the lateral position (right and left, upwards and downwards) and the startle response. For children at 12 months of age hearing thresholds are expected to be between 20 and 40 dB, lateral sound localization, direct downwards sound localization and indirect upwards sound

localization, recognition of level I orders and the presence of the startle response[13]. The following were considered suggestive signs of central hearing problems (auditory processing): absence of the startle response and the delay in the sound localization ability[13,14].

The basic hearing assessment that subjects from both groups completed was composed of a pure tone audiometry, speech audiometry, and impedance measures. It was considered a normal result when hearing levels were below 20 dB, a type A curve and the presence of acoustic reflexes in the contralateral mode (indicating absence of problems of the medial and external ears).

The auditory processing assessment required: a two-channel audiometer GSI-61, attached to a portable compact-disc (CD) player; CDs[8] of the recorded stimuli to be used in the tests. All the special auditory tests were conducted in a sound-proof hearing cabin. The auditory processing tests completed were:

- Sound Localization Test (S/L): assesses the sound localization ability and the physiological mechanism of binaural interaction (BI).
- Sequential Verbal Sound Memory Test (SVSM) and Sequential Non-Verbal Sound Memory Test (SNVSM): assess the auditory ability of temporal organization and the physiological mechanism of temporal processing (TP).
- Speech in White Noise Test (S/N): assesses the auditory ability of auditory closure and the physiological mechanism low redundancy monotic listening with noise competing message (LRMLN).
- PSI with contralateral competitive message (PSI/CCM): assesses the auditory figure ground ability for verbal sounds and the physiological mechanism of verbal sound recognition in a dichotic listening task (SRDL).
- PSI with ipsilateral competitive message (PSI/ICM): assesses the auditory figure ground ability for verbal sounds and the physiological mechanism of verbal sound recognition in a monotic listening task (SRML).
- Dichotic Digit Test (DDT): assesses the auditory ability of figure ground for verbal sounds and the physiological mechanism of verbal sound recognition in dichotic listening task (SRDL).

A level of significance of 0.05 (5%) was defined. All the confidence intervals constructed along this work were built with 95%statistical confidence. The statistical tests applied were Mann-Whitney to compare the quantitative results between groups; the Fischer Exact test, which allows for the calculation of the probability of the association of the analyzed characteristics; and the Two Proportion Equality test, which compares if the proportion of responses of two determined variables and/or their levels is statistically significant.

Characterization of groups regarding gender and age

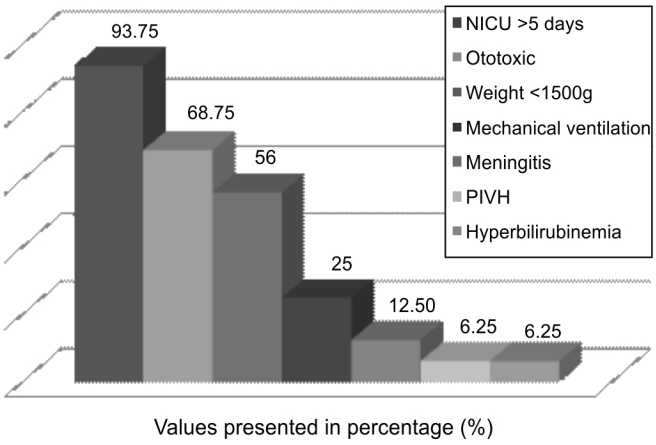
It was noted that there were no statistically significant differences regarding gender between the groups.

It was noted that subjects in Group 2 were older than those in Group 1 even though this difference was not considered significant.

RESULTS

Risk indicators of hearing problems at birth and data on the behavioral hearing assessment completed at 12 months by G1

A distribution of risk indicators present at birth for G1 was completed (Figure 1). All children born preterm presented one or more risk indicators for hearing disorders at birth. The risk indicators most often observed were: NICU stay longer than five days (93.75%), use of ototoxic medication (68.75%).



Note: PIVH = periventricular-intraventricular hemorrhage

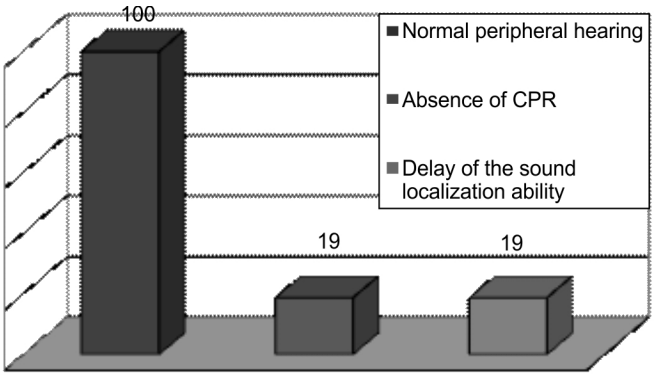
Figure 1. Risk indicators for hearing problems verified at birth in Group 1 (G1)

Data referring to the behavioral hearing assessment of subjects in G1 at 12 months were collected. Data selected from the behavioral hearing assessment were: auditory thresholds obtained by visual reinforcement audiometry, startle response and sound localization ability to localize the sound (Figure 2). Peripheral hearing was normal in 100% of the cases. From the total (n=16), 19% (n=3) presented absence of the coclehar palpebral reflex (CPR) and 19% (n=3) a delay in the sound localization ability.

Auditory processing assessment

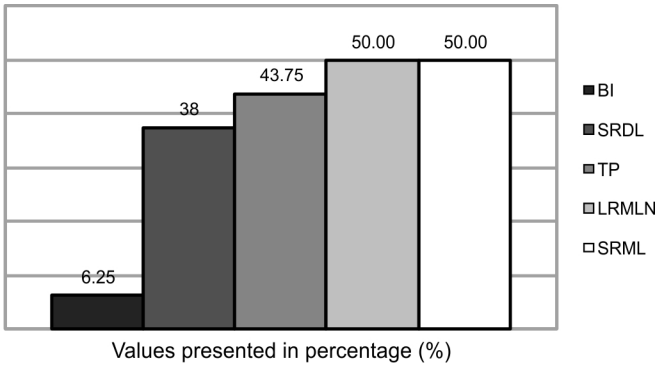
Groups were compared on descriptive and comparative measures (p-value) (Table 1).

Data obtained in the auditory processing assessment considered the physiological mechanisms tested and altered in the studied groups (Figures 3 and 4). In G1, problems were noted for 93.75% subjects. The physiological mechanisms of low redundancy monotic listening with noise sound competing message (LRMLN) and verbal sound recognition in monotic listening (SRML) were altered in 50% of subjects; 43.75% presented temporal processing alterations (TP), 37.5% had verbal sound recognition in dichotic listening (SRDL) problems and 6.25% presented difficulties in the do binaural interaction mechanism (BI). In G2, auditory processing assessment was altered in 35.71% of subjects. The physiological mechanisms of temporal processing and verbal sound recognition in monotic



Note: CPR = cochlear palpebral reflex

Figure 2. Data from the behavioral hearing assessment of children in Group 1 (G1), conducted at 12 months.



Note: BI = binaural interaction; SRDL = sound recognition in dichotic listening; TP = temporal processing; LRMLN = low redundancy monotic listening with noise competing message; SRML = verbal sound recognition in monotic listening

Figure 3. Percentage of alterations in the physiological auditory mechanisms in Group 1 (G1)

listening were altered in 7.14% of subjects; 21.4% presented alterations of the verbal sounds recognition in dichotic listening; and 28.5% of the low redundancy monotic listening with noise competing message. The physiological mechanism of binaural interaction was normal at a 100% subjects.

Correlation between the results of the auditory processing assessment and data on the hearing behavioral assessment completed at 12 months for G1

It was possible to compare between the sound localization ability (S/L) and the auditory physiological mechanisms of verbal sound recognition in dichotic listening (SRDL), verbal sound recognition in monotic listening (SRML), low redundancy monotic listening with noise competing message (LRMLN) and temporal processing (TP) (Table 2). There was a significant correlation between the altered physiological mechanism of temporal processing in the auditory processing assessment and the delay of sound localization ability at 12 months.

DISCUSSION

Characterization of G1

One or more indicators of the risk for hearing problems at birth were found for every single preterm subject. These results are similar to those found in the literature on the presence of indicators of the risk for hearing problems at birth[15-17].

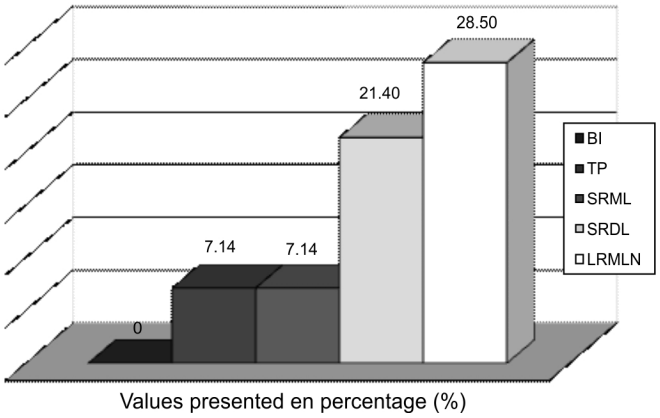
For the behavioral assessment of hearing of subjects born preterm at 12 months of age it was observed normal peripheral

Table 1. Results obtained by Groups 1 e 2 at the auditory processing tests

Grupo		Mean (%)	Median (%)	SD (%)	Q1 (%)	Q3 (%)	n	CI (%)	p-value
S/L	Group 1	92.5	100	12.4	80	100	16	6.1	0.795
	Group 2	94.3	100	9.4	85	100	14	4.9	
SVSM	Group 1	68.8	67	19.1	67	67	16	9.4	<0.001*
	Group 2	95.2	100	12.1	100	100	14	6.3	
SNVSM	Group 1	50.0	67	27.2	33	67	16	13.3	0.002*
	Group 2	83.3	100	21.7	67	100	14	11.4	
PSI/CCM (-40)	Group 1	96.3	100	4.9	90	100	30	1.8	0.054
	Group 2	98.6	100	3.6	100	100	28	1.3	
PSI/ICM (-10)	Group 1	67.8	70	18.3	60	80	32	6.3	0.022*
	Group 2	79.3	80	14.6	70	90	28	5.4	
S/N	Group 1	70.4	84	27.8	40	90	32	9.6	0.014*
	Group 2	88.7	90	9.4	86	92	28	3.5	
DDT	Group 1	69.5	73	17.5	61	79	14	9.2	0.069
	Group 2	80.7	84	9.1	73	90	18	4.2	

* Significant values (p≤0.05) – Mann-Whitney test

Note: S/L = sound localization; SVSM = sequential verbal sound memory; SNVSM = sequential non-verbal sound memory; PSI/CCM = PSI contralateral competing message; PSI/ICM = PSI ipsilateral competing message; S/N = speech in noise; DDT = dichotic digits test; SD = standard deviation; Q1 = first quartile; Q2 = second quartile; CI = confidence interval



Note: BI = binaural interaction; TP = temporal processing; SRML = verbal sound recognition in monotic listening; SRDL = sound recognition in dichotic listening; LRMLN = low redundancy monotic listening with noise competing message

Figure 4. Distribution of alterations in the physiological auditory mechanisms in Group 2 (G2)

hearing in 100% of cases. Some subjects revealed absence of the startle response and a delay in the sound localization ability. Studies conducted with children born full term and preterm concluded that for those born full term in behavioral assessment of hearing at 12 months it was expected that they presented: hearing thresholds between 20 and 40 dB, lateral sound localization, direct downwards sound localization and indirect upwards sound localization, recognition level orders and presence of startle response. It was noted that full term children presented more elaborate responses in the behavioral assessment of hearing than children born preterm, considered high risk. Not only that but it was observed as well that children tend to narrow this response gap in their first year of life[13]. A study comparing the development of healthy preterm children and those who presented postnatal problems (bleeding, severe anoxia, neurological anomalies) in their first year of life and to the development of children born full term was conducted[18]. The authors concluded that full term babies developed normally on aspects such as motor abilities, fixation to stimuli and visual and auditory attention. However preterm healthy babies presented an unstable developmental pattern during the first six months, progressing towards normality at the end of the first year. Preterm babies with postnatal complications presented a compromised pattern of development when compared to both other groups.

Auditory processing assessment

The difference between groups was noticed at the auditory processing assessment for the sequential verbal (SVM) and non verbal (SNVM) memory tests, PSI with ipsilateral competitive message (PSI/ICM) and speech in noise (S/N). For all the obtained significant results the group of subjects born full term presented better results than those born preterm. Data is in accordance to findings of other studies, indicating an inferior performance in auditory behavior and in language development in pre term born children[19-22]. Alterations in the auditory processing tests in children born pre term indicate that the abilities of temporal ordering and figure ground for verbal sounds are the most affected when compared to children born full term.

Considering the physiological mechanisms assessed on subjects born pre term, 93.75% of them (n=15) presented difficulties with at least one of the auditory physiological mechanisms. This high percentage can be related to neuromaturation, because there may be a problem with the development of the auditory pathway in children born pre term. Regarding the development of hearing, it was noted that at 12 months, 31.25% of subjects presented a sign of central disorder. Later on, with ages ranging from 4 to 7, 93.75% of subjects presented a central auditory disorder.

Regarding the prenatal brain and hearing system development, the cerebral lobes and the lateral fissure are completely formed around 28 weeks of pregnancy and with 30 weeks of pregnancy the auditory pathways from the brainstem are structurally complete. From this perspective prematurity represents a disadvantage. Besides, it is known that the efficiency of the auditory system continues to develop even after birth and the following years due to neuromaturation[7].

Table 2. Correlation between sound localization ability at 12 months and physiological mechanisms in Group 1

Sound localization		Normal		Altered		Total		p-value
		n	%	n	%	n	%	
SRDL	Normal	7	54	3	100	10	63	0.137
	Altered	6	46	0	0	6	38	
SRML	Normal	7	54	1	33	8	50	0.522
	Altered	6	46	2	67	8	50	
LRMLN	Normal	6	46	1	33	7	44	0.687
	Altered	7	54	2	67	9	56	
TP	Normal	9	69	0	0	9	56	0.029*
	Altered	4	31	3	100	7	44	

* Significant values (p≤0.05) – Spearman correlation test and Correlation test

Note: SRDL = sound recognition in dichotic listening; SRML = sound recognition in monotic listening; LRMLN = low redundancy monotic listening with noise competing message; TP = temporal processing.

Brain areas are highly vulnerable to damage due to hypoxia and periventricular lesions, such as periventricular leukomalacia, usually associated to prematurity and low birthweight[23,24]. Another very common anomaly in children born preterm is the extremely thin corpus callossum[25,26]. In a recent study, it was noted that the total area of the corpus callossum in the preterm children is 7.5% smaller then it is in for the group of children born full term[25]. It is worth remembering that the corpus callosum is an extremely vulnerable area to ischemia and hemorrhage. Also, it can suffer the influence by its proximity to the periventricular area, a common region where hemorrhages in the perinatal period. Auditory processing problems may happen due to compromising of this area[26].

Literature presents a consensus that prematurely born children and low birth weight are risks for delayed motor, cognitive and linguistic development[27,28]. The present study revealed that children born pre term presented a worse performance than children born full term in auditory processing. Therefore, it can be concluded that prematurely born children present more difficulties to process perceptually auditory information.

For G2, the auditory processing assessment was altered in 35.71% of subjects. The physiological mechanism of binaural interaction was normal in all subjects. The physiological mechanisms that revealed most difficulties were verbal sound recognition in dichotic listening and low redundancy monotic listening with noise competing message.

Another study completed auditory processing tests of sound localization, verbal and non verbal sequential sound memory with 126 children ranging in age from 3 to 5. It was identified that almost 91% of the children presented adequate sound localization ability. Regarding the sequential memory of non verbal sounds it was observed a higher percentage of altered responses independent of gender and age group[29].

A study conducted with school aged children, ranging from 5 to 10 years of age observed the children´s performance during the hearing screening and simplified auditory processing assessment. It was verified that for the sequential verbal and non-verbal sound memory tests, the mean of adequate responses was below the expected for the children in Group 1 (5 and 6 year olds) and 2 (7 and 8 years olds). Participants revealed more difficulty in memorizing sound sequences or temporal ordering then to localize the sound source [30].

Correlation between the results of the auditory processing assessment and the behavioral assessment of hearing data at 12 months for G1

There was a significant correlation between the delay of the sound localization ability at 12 months and the altered hearing physiological mechanism of temporal processing at the auditory processing assessment. It is known that sound localization is one of the first auditory processing abilities that can be measured. This ability suffers the interference of maturation that refines it with time, until it reaches the expected pattern for adult individuals.

In order for one to be able to localize sounds it is important that the hearing system can analyze the acoustical clues of time and intensity. Therefore, if an individual has a difficulty localizing sounds at 12 months of age, there is a hypothesis that he or she is having difficulties to deal with the temporal clues. Hence, this difficulty will also interfere with the ability of sound ordering. This ability was assessed in this study with the sequential memory test for verbal and non-verbal sounds that characterize the alteration of the physiological mechanism of temporal processing.

The newly born that presents risk indicators for hearing problems require follow up hearing assessments every six months until they turn 3 years of age. The knowledge of the abilities related to auditory processing of preterm children can contribute to the development of intervention programs that improve the development of these individual´s hearing and language.

It is believed that it is very important to have a speech and hearing professional following the evolution of children born preterm in their peripheral and central hearing. That is why the auditory processing assessment should be conducted from the age of 4 since most prematurely born children assessed in this study revealed the need of speech language and hearing interventions.

CONCLUSION

Premature children present a worse performance then children born full term at the auditory processing assessment, with observed differences on the sequential memory tests for verbal and non-verbal sounds, the recognition of phrases with ipsilateral competitive message test (ipsilateral PSI/ICM) and on the speech in white noise test. There was also an association between the sound localization ability at 12 months and the alteration of the physiological mechanism of temporal processing in the auditory processing assessment.

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