Peripheral auditory maturation: analysis of the amplitudes of the distortion product otoacoustic emissions in preterm and term neonates

Maturação auditiva periférica: análise das amplitudes das emissões otoacústicas produto de distorção em neonatos pré-termo e a termo

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ABSTRACT

Purpose: To compare preterm and term neonates in relation to the presence and amplitude of Distortion Product Otoacoustic Emissions (DPOAEs), as well as to characterize them regarding risk indicators for hearing loss. **Methods:** Study realized by the analysis of the DPOAEs (frequencies of 2000, 3000, 4000, 6000 and 8000 Hz) and risk indicators for hearing loss. The neonates were grouped according to the gestational age. The results were analyzed by ANOVA, Kruskal-Wallis and Chi-square tests (5%). **Results:** The sample consisted of 109 neonates (218 ears) in homogenous distribution related to gender and preterm/term classification. A high risk for hearing loss was observed in 40.4% of the infants. From the risk indicators for hearing loss, the most common were the duration of the stay in incubators and intensive care units (ICU) longer than five days. The DPOAEs were present in 209 ears (95.9%). The absence of responses to DPOEAs was significantly more frequent in groups with lower gestational age. It was observed an increase of the amplitudes of the DPOEAs with the increase of the gestational age, except for the frequency of 8000 Hz in the left ear. There were no differences between ears and genders regarding the presence and amplitude of the DPOAEs. **Conclusion:** There are differences between preterm and term groups in relation to the presence and amplitude of the DPOAEs: higher probability of failure in the groups with lower gestational age and (nonlinear) increase of the amplitudes with the increase of the gestational age. The findings suggest the phenomenon of maturation of the peripheral auditory system.

Keywords: Hearing; Neonatal screening; Infant, premature; Hair cells, auditory; Hearing disorders; Early diagnosis; Diagnostic techniques, otological; Speech, language and hearing sciences

RESUMO

Objetivo: Comparar neonatos prematuros e a termo quanto à presença e amplitude das Emissões Otoacústicas Produto de Distorção (EOAPD), bem como caracterizá-los em relação aos indicadores de risco para perda auditiva. **Métodos:** Estudo realizado por análise das EOAPD (frequências de 2000, 3000, 4000, 6000 e 8000 Hz) e dos indicadores de risco para perda auditiva. Os neonatos foram agrupados segundo a idade gestacional. Os resultados foram analisados empregando-se testes ANOVA, Kruskal-Wallis e Qui-quadrado (5%). **Resultados:** A amostra constituiu-se de 109 neonatos (218 orelhas), com distribuição homogênea quanto ao gênero e a classificação a termo/pré-termo. Foi observado alto risco para perda auditiva em 40,4% dos lactentes. Dos indicadores de risco para deficiência auditiva, os mais frequentes foram a permanência em incubadora e internação em UTI superiores a cinco dias. As EOAPD mostraram-se presentes em 209 orelhas (95,9%). A ausência de respostas às EOAPD foi significativamente mais recorrente nos grupos com menor idade gestacional. Verificou-se aumento das amplitudes das EOAPD de acordo com o aumento da idade gestacional, exceto para a frequência de 8000 Hz na orelha esquerda. Não foi observada diferença entre orelhas e gêneros quanto à presença e amplitude das EOAPD. **Conclusão:** Há diferença entre os grupos pré-termo e a termo, quanto à presença e amplitude das EOAPD: maior probabilidade de falha nos grupos com menor idade gestacional e aumento (não linear) das amplitudes, conforme a idade gestacional torna-se maior. Os achados sugerem o fenômeno de maturação do sistema auditivo periférico.

Descritores: Audição; Triagem neonatal; Prematuro; Células ciliadas auditivas; Transtornos da audição; Diagnóstico precoce; Técnicas de diagnóstico otológico; Fonoaudiologia

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INTRODUCTION

The importance of hearing and the losses that hearing impairments can cause for the proper acquisition and development of speech and language, as well as for the full social, emotional, psychological and cognitive growth of the child are known and largely discussed in the literature. The Neonatal Hearing Screening (NHS) is essential for the early diagnosis and intervention of hearing loss. The selection of Evoked Otoacoustic Emissions (EOAEs) as a method of hearing evaluation of the neonatal population is justified by the fact that it is an objective, quick, painless, low-cost examination, which enables individual evaluation of the cochleae. Although they evaluate the inner ear, the EOAEs are influenced by the conditions of the external and middle ear, by environmental and/or physiological noises of the assessed children. It is worth noting that the research of the EOAEs enables only the evaluation of the cochlear function being, therefore, of utmost importance its association to other examinations in order to better understand the function of the auditory system[1,2].

The hearing alterations occur in approximately one to three in 1000 neonates without risk indicators for hearing impairment. Considering the newborns from the intensive care units (ICU), they occur in 2% to 4%[3,4]. In Brazil, this prevalence ranges from 1.8% to 6.3% among very low birth weight infants[5-7].

The risk indicators for hearing loss include the family history of congenital hearing loss; neurodegenerative disorders; cranial trauma; exchange transfusion due to hyperbilirubinemia; intrauterine congenital infections such as syphilis, toxoplasmosis, rubella, cytomegalovirus, HIV; post natal bacterial or viral infections as cytomegalovirus, herpes, measles, chickenpox and meningitis; birth weight lower than 1500 g; ototoxicity; syndromes associated with conductive or sensorineural hearing loss; chemotherapy; extracorporeal ventilation; assisted ventilation; severe perinatal anoxia; Apgar zero to four in the first minute, or zero to six in the fifth minute; craniofacial anomalies; maternal alcoholism and/or use of psychotropic drugs during pregnancy; ventricular hemorrhage; duration of the stay in incubators longer than seven days; neonatal convulsions; child born small for gestational age; duration of the stay in the ICU longer than five days[8-10]. As the number of coexisting risk indicators for hearing loss increases, the greater the likelihood of sensorineural hearing loss[11].

It is worth noting that approximately 50% of the hearing losses are identified in children without risk indicators for this deficiency[8], which suggests the need to test all newborns by the Universal Neonatal Hearing Screening (UNHS)[11,12]. In many countries, there are growing efforts to improve the quality, universalization of the NHS and drafting of relevant legislation[13,14].

The NHS can be performed by means of Evoked Otoacoustic Emissions, Brainstem Auditory Evoked Potential (ABR) and observation of the auditory behavior. The research of OAE suppression aggregates information on the efferent auditory system[15]. The methods have characteristics that complement each other to achieve the early diagnosis of hearing loss[12].

The NHS programs have been successfully conducted in about 55 countries, being the EOAEs the main method of analysis. In case of failure, the most common measure is to retest, and if the result does not change, the research of ABR[13].

The EOAEs are sounds produced by the outer hair cells (OHCs) of the cochlea in response to acoustic stimuli presented through the external auditory canal (EAC). The transient otoacoustic emissions (TOAEs) and distortion product otoacoustic emissions (DPOAEs) are the most used in audiology. The DPOAEs are obtained in response to the auditory stimulation by means of two simultaneous pure tones (f1/f2). The generated response is nonlinear (ratio 2f1-f2) and indicates the cochlear state in the tested region[16]. Thus, the DPOAEs have the advantage of frequency specificity, which enables to separately evaluate different regions of the cochlea[16,17].

Studies indicate a correlation between the results of TOAEs and DPOAEs. However, it is noteworthy that the DPOAEs are less sensitive to environmental or physiological noise, which suggests that the DPOAEs are more appropriate to reduce the "failure" rate in the NHS of infants in maternities, with particular applicability in the ICU, environment that usually concentrates high environmental noise[17].

The NHS in NICUs has been increasingly common since the advances in Neonatology enable the survival of newborns with increasingly lower gestational ages. However, prematurity involves various risks, with higher rates of morbidity and mortality among preterm neonates compared to term neonates[18].

The preterm neonates show peculiarities in the auditory system that need to be further studied[17,19-21]. Some researches indicate immaturity of the cochlear amplifier until the period of term birth, possibly originated in the OHCs and/or efferent regulation of the same[22]. It is also verified an increase in the magnitude of the suppression of the TOAEs with the increase of the chronological age, whether among premature neonates[15] or those born at term[23]. The contribution of the immaturity of the middle ear in this process[22] is also highlighted.

The literature indicates differences between the auditory function of preterm and term infants, both measured by DPOAEs[20,22,24-26] as by TOAEs[21], regarding the presence of OAEs[25,26] and amplitude of the responses[19,21,22,24,26] as well as the presence and threshold of suppression of the OAEs[22,23].

In order to better understand the auditory characteristics of the preterm neonates, a research conducted the analysis of the DPOAEs in preterm neonates, with the hypothesis that the gestational age (GA) would influence the amplitude of the DPOAEs, which would indicate the existence of peripheral auditory maturation during prematurity[27].

It is believed that the comparative analysis of the DPOAEs

in preterm and term neonates is useful to check if the GA influences the occurrence and amplitude of the responses during the examination. The findings of this study will enable to analyze the existence of a possible peripheral auditory maturation in the neonatal period. Practically, this research will enable considerations regarding the best moment for NHS through the DPOAEs, besides improving the criteria for the interpretation of the results of the OAEs.

Thus, the purpose of this study was to compare preterm and term neonates regarding the presence and amplitude of DPOAEs, as well as to characterize them in relation to the risk indicators for hearing loss.

METHODS

This study was approved by the Research Ethics Committee of the Universidade Federal de Minas Gerais (UFMG), opinion no. 0210.0.203.000-10.

It is an observational cross-sectional study, in a public maternity of reference for high-risk pregnancy, in the city of Belo Horizonte, through the analysis of the results of the examination of distortion product otoacoustic emissions and medical records regarding risk indicators for hearing loss.

The data related to the evaluations of 109 neonates were collected from July 2011 to December 2011. For preterm neonates, the criterion for inclusion in the research was: gestational age below 37 weeks, from NICU of public maternity of reference for high-risk pregnancy. The term neonates were randomly selected, group with the same quantity of neonates as in the preterm group, inclusion criteria: gestational age from 37 weeks, be evaluated in the first aid station of Speech Therapy and present no risk of hearing loss (low risk). The term neonates that presented a risk indicator for hearing loss were excluded, and also the preterm neonates with unstable clinical status, using mechanical ventilation or conditions that could interfere/hinder the execution of the DPOAEs.

Preterm neonates were considered those born before 37 weeks of gestation and term neonates, those born between the 37th and 41st week of gestation. The reference for the gestational age was the last menstrual period of the mother[18].

The risk indicators for hearing loss considered in this study were those routinely adopted by the Service in which the data were collected: family history of congenital hearing loss; duration of the stay in the ICU longer than five days; use of mechanical ventilation; exposure to ototoxic drugs; duration of the stay in the incubator longer than five days; birth weight lower than 1500 g; ventricular hemorrhage; neonates small for the gestational age; HIV positive; intrauterine infections caused by the TORCHS group; syndromes associated with hearing loss; craniofacial anomalies; hyperbilirubinemia associated with exchange transfusion and meningitis. It is noteworthy that the risk indicators for hearing loss used for this service are based on those proposed by the literature[8-10].

The parents and/or guardians have agreed with the inclusion of the data of anamnesis and examinations in this study by signing the Free and Cleared Term of Consent.

The evaluated neonates were grouped according to the gestational age: 28 to 30 weeks (P1), 31 to 33 weeks (P2), 34 to 36 weeks (P3) and 37 to 42 weeks (T). The age at the time of evaluation was up to 90 days.

The evaluated neonates were submitted to the DPOAE research in both ears during natural sleep or in the absence of conditions that could compromise the result. The test was conducted in a quiet environment.

The information about the risk indicators for hearing loss and the duration of the stay and the gestational age were collected from neonate records.

The equipment used for the examinations were: otoacoustic emissions analyzer of the brand Otodynamics®, model ILO 292 USB, coupled to a notebook. In the DPOAE examination the frequencies of 2 kHz, 3 kHz, 4 kHz, 6 kHz and 8 kHz (reference F2) were analyzed with stimulation intensity L1=65 dB and L2=55 dB, f2/f1 = 1, 22.

Otoacoustic emissions with response amplitude greater than or equal to -5 dB and signal/noise relationship greater than or equal to 6 dB were considered present. To consider the DPOAEs present, the response records should be observed in at least three of the tested frequencies.

The analysis of the data was done with resources of statistical processing of the software EPIINFO, version 3.5.3 from January 2011. The frequency distributions were constructed and the averages, standard deviations and percentages were calculated for each variable included. The required statistical comparisons were organized in contingency tables of the R x C (rows x columns) type and in tables according to the ANOVA or Kruskal-Wallis H test, as indicated for each situation. The Chi-square test was used for categorical variables for the comparison of the proportions only between two categories in each variable. The significance level of 5% was considered for all analyses.

RESULTS

The sample consisted of 109 neonates, 56 female and 53 male (218 ears). Of these, 51% were born at term (n=55) and 49% preterm (n=54), with gestational age between 28 and 42 weeks. The average age at the time of evaluation was 26 days.

The distribution of the assessed neonates was homogeneous regarding gender and term/preterm classification. Specifically in the preterm group, the sample was distributed in P1: 6% (n=7), P2: 21% (n=23) and P3: 22% (n=24).

According to the risk indicators for hearing loss used in this study, 40.4% (n=44) of the sample was classified with high risk for hearing loss and 59.6% (n=65) with low risk. Among the risk indicators for hearing loss, the most frequent were the duration of the stay in the incubator and in the ICU longer than

five days, followed by the use of mechanical ventilation and exposure to ototoxic medication (Table 1).

The occurrence of a single risk indicator for hearing loss occurred in 11.9% (n=13) of the neonates. The combination of two risk indicators for hearing loss in the same neonate was observed in 11.9% (n=13), and the coexistence of three or more risk indicators for hearing loss in 16.5% (n=18) of the evaluated neonates.

In relation to size at birth, 108 neonates (99.08%) were adequate and one of them small for the gestational age.

The DPOAEs were present in 209 ears (95.9%), result similarly distributed regarding the sides and genres evaluated. The absence of responses in the DPOAEs occurred in nine ears (4.1%), all of the preterm group, with the following distribution: three in the group P1, five in group P2 and one in the group P3. Therefore, a statistical difference between the term and preterm groups regarding the presence of DPOAEs (Table 2) was observed.

Regarding the amplitude of the DPOAEs, there was no difference between the groups in relation to gender and evaluated ear. However, statistical differences were found when comparing the term and preterm groups in relation to the average amplitude of the DPOAEs. An increase of the amplitudes of the DPOAEs was verified at all frequencies according to the increase of the gestational age (Figures 1 and 2), except for the frequency of 8 kHz in the left ear (OE). The average amplitude of the DPOAEs per ear was recorded considering the frequencies of 2 kHz, 3 kHz, 4 kHz, 6 kHz and 8 kHz (Tables 3 and 4).

Table 1. Distribution of risk indicators for hearing loss among preterm neonates

Risk indicators for hearing loss	n	%
Duration of the stay in incubator longer than five days	37	34.04
Duration of the stay in the intensive care unit (ICU) longer than five days	37	34.04
Use of mechanical ventilation	17	15.64
Use of ototoxic medication	17	15.64
Birth weight lower than 1500 g	15	13.80
Family history of congenital hearing loss	9	8.28
Ventricular hemorrhage	7	6.44
Neonate small for the gestational age	1	0.92
HIV positive	1	0.92
Intrauterine infections caused by the TORCHS group	1	0.92
Syndromes associated with hearing loss	0	0.00
Craniofacial anomalies	0	0.00
Hyperbilirubinemia associated with exchange transfusion	0	0.00
Meningitis	0	0.00

Note: n = number of occurrences of risk indicators for hearing loss among preterm neonates, ICU = Intensive Care Unit, TORCHS = Toxoplasmosis, Rubella, Cytomegalovirus, Herpes and Syphilis

Table 2. Distortion product otoacoustic emissions versus gestational age

DPOAE RE/GA	**P1: 28-30 weeks**	**P2: 31-33 weeks**	**P3: 34-36 weeks**	**T: 37- 42 weeks**	**Total**
*None	n=2 50.0%	n=2 50.0%	n=0 0.0%	n=0 0.0%	n=4 100.0%
*Present	n=5 4.8%	n=21 20.0%	n=24 22.9%	n=55 52.4%	n=105 100.0%
*Total	n=7 100.0%	n=23 100.0%	n=24 100.0%	n=55 100.0%	n=109 100.0%
DPOAE LE/GA	**P1: 28-30 weeks**	**P2: 31-33 weeks**	**P3: 34-36 weeks**	**T: 37- 42 weeks**	**Total**
** none	n=1 20.0%	n=3 60.0%	n=1 20.0%	n=0 0.0%	n=5 100.0%
** Present	n=6 5.8%	n=20 19.2%	n=23 22.1%	n=55 52.9%	n=104 100.0%
** Total	n=7 100.0%	n=23 100.0%	n=24 100.0%	n=55 100.0%	n=109 100.0%

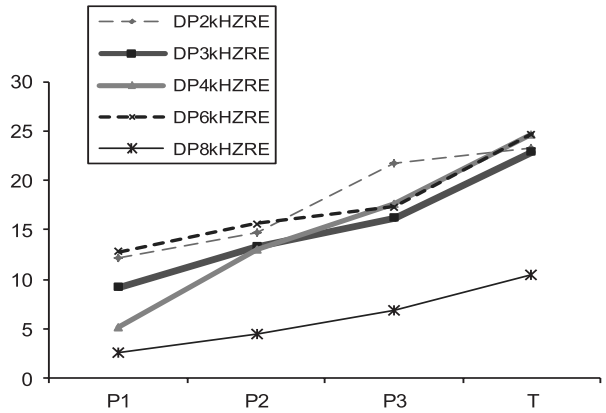
* Chi-square test (p=0.001); ** Chi-square test (p=0.048)

Note: DPOAE = Distortion product otoacoustic emissions; RE = right ear, LE = left ear, GA = gestational age; Groups of neonates according to gestational age: P1 = 28 to 30 weeks; P2 = 31 to 33 weeks; P3 = 34 to 36 weeks, T = 37 to 42 weeks

DISCUSSION

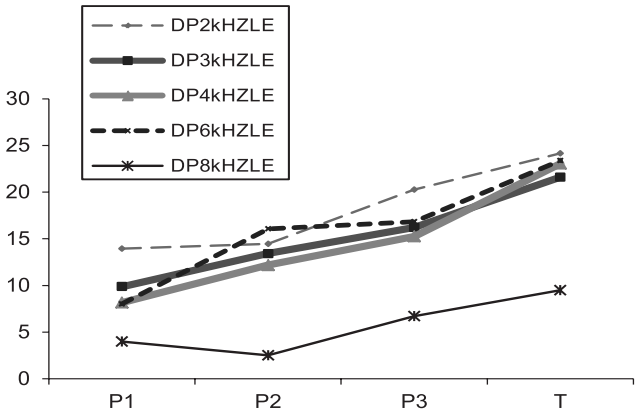
The sample of this study was homogeneous with regard to gender and number of individuals in the preterm and term groups.

Regarding risk indicators for hearing loss, it was observed that the most common were the duration of the stay in the incubator and in the ICU longer than five days, other researchers that analyzed 2986 neonates with risk indicators for hearing loss observed the occurrence of this indicator in 10.64%[11] of the sample. It is believed that the higher percentage found in the present study was caused by the collection of data in a public



Note: Groups of neonates according to gestational age: P1 = 28 to 30 weeks; P2 = 31 to 33 weeks; P3 = 34 to 36 weeks, T = 37 to 42 weeks; DP = distorction product; RE = right ear

Figure 1. Amplitude of the distortion product in the right ear



Note: Groups of neonates according to gestational age: P1 = 28 to 30 weeks; P2 = 31 to 33 weeks; P3 = 34 to 36 weeks, T = 37 to 42 weeks; DP = distorction product; LE = left ear

Figure 2. Amplitude of the distortion product in the left ear

Table 3. Distortion product otoacoustic emissions – right ear

	GA	n	Average	Standard deviation	p-value
DP 2 kHz RE	28-30	07	12.24	8.97	0.000
	31-33	23	14.75	8.15	
	34-36	24	21.67	5.94	
	37-42	55	23.31	5.60	
	Total	109	17.99	7.16	
DP 3 kHz RE	28-30	07	9.23	8.58	0.000
	31-33	23	13.35	6.80	
	34-36	24	16.30	8.51	
	37-42	55	22.93	5.99	
	Total	109	15.45	7.47	
DP 4 kHz RE	28-30	07	5.14	12.87	0.000*
	31-33	23	13.09	5.78	
	34-36	24	17.67	13.03	
	37-42	55	24.64	10.75	
	Total	109	15.13	10.61	
DP 6 kHz RE	28-30	07	12.77	8.01	0.000*
	31-33	23	15.58	9.19	
	34-36	24	17.31	12.00	
	37-42	55	24.67	6.11	
	Total	109	17.58	8.83	
DP 8 kHz RE	28-30	07	2.57	14.60	0.023
	31-33	23	4.40	10.12	
	34-36	24	6.81	10.36	
	37-42	55	10.49	7.86	
	Total	109	6.07	10.73	

Significant values ($p<0.05$) – Anova Test, * Kruskal-Wallis H Test

Note: GA = gestational age in weeks; DP = amplitude of the distortion product; RE = right ear

Table 4. Distortion product otoacoustic emissions – left ear

	GA	n	Average	Standard deviation	p-value
DP 2 kHz LE	28-30	07	13.96	6.44	0.000
	31-33	23	15.46	6.99	
	34-36	24	20.28	6.08	
	37-42	55	24.16	5.14	
	Total	109	18.47	6.16	
DP 3 kHz LE	28-30	07	9.89	5.62	0.000*
	31-33	23	13.43	7.20	
	34-36	24	16.22	10.68	
	37-42	55	21.62	5.29	
	Total	109	15.29	7.20	
DP 4 kHz LE	28-30	07	8.16	8.89	0.000*
	31-33	23	12.18	7.36	
	34-36	24	15.26	16.26	
	37-42	55	23.06	8.46	
	Total	109	19.00	10.24	
DP 6 kHz LE	28-30	07	8.03	9.31	0.000*
	31-33	23	16.07	8.24	
	34-36	24	16.84	11.23	
	37-42	55	25.39	6.11	
	Total	109	16.58	8.72	
DP 8 kHz LE	28-30	07	3.99	6.17	0.045
	31-33	23	2.53	11.78	
	34-36	24	6.73	11.09	
	37-42	55	9.50	9.29	
	Total	109	5.69	9.58	

Significant values (p<0.05) – Anova Test, * Kruskal-Wallis H Test

Note: GA = gestational age in weeks; DP = amplitude of the distortion product; LE = left ear

maternity of reference for high-risk pregnancy and most of the evaluated preterm were from the NICU. In the international literature, the most frequent risk indicator for hearing loss was the use of ototoxic drugs (33.13%)[11].

The results related to the presence of DPOAEs agree with the research in which it was observed that 97.0% of the tested ears showed present responses[16]. Another study showed similar results, with "pass" index in 1582 neonates (93.6%)[25].

The fact that there is no difference between genders when comparing the amplitude of the DPOAEs in preterm and term neonates also confirms the data of other surveys conducted by the same procedure[27] and also using TOAEs[21].

Regarding the amplitude average of the DPOAEs, whose highest values are related to frequencies of 2 kHz and 6 kHz, similar data were obtained from a study that analyzed the DPOAEs in 50 premature neonates, with results that indicated the frequencies of 2 kHz and 8 kHz as the highest amplitude[17]. In a research with 67 preterm and term neonates exposed to ototoxic medication and control group, the highest amplitude frequency was 6 kHz[24], in agreement with the present study.

Regarding the response level, the amplitudes ranged between 2.53 dB and 25.39 dB. In the analysis of the medians of the response level per frequency, other researchers have found values between 6.0 and 16.3 dBNPS[1]. The differences observed between the studies are possibly due to the methodology employed. In the present study, preterm and term neonates with and without risk of hearing loss were evaluated, and the other study included only newborns with low risk of hearing loss. Furthermore, only the neonates with previous record of present TOAEs were analyzed. In addition this research analyzed the amplitude average of the DPOAEs and the referred study addressed the medians.

The analysis of the amplitudes of the DPOAEs, which showed differences between the preterm and term groups, whereby the amplitude increased in a nonlinear way with the increase of the gestational age except for the frequency of 8 kHz in the left ear, confirms the trends observed in another study, in which the amplitude of the DPOAEs became progressively higher with the increase of the age, from the period of 31/33 weeks to the period equivalent to birth at term (37 to 40 weeks)[20]. The amplitude of the DPOAEs was lower in preterm neonates compared to that obtained in term neonates in a research about the exposure to ototoxicity[24]. Some authors that observed a gradual increase in the amplitude of the DPOAEs with the increase of the conception age until the 35th week of life[26] have also agreed with the findings above. Other researchers who used TOAEs in the analysis of preterm and term neonates[21] as well as the DPOAEs with exclusive evaluation of preterm neonates[27] also observed

the increase of the amplitude of the otoacoustic emissions with the increase of the gestational age. This fact presented itself as a trend, but was not statistically proven[21,27]. Once more, the methodological choices can justify the differences between these studies and the findings of this research.

The occurrence of maturation of the peripheral auditory system is also strengthened by studies on the TOAE suppression. A research on the effect of the suppression of the TOAEs in preterm infants with risk of hearing loss observed a trend of increase of the magnitude of suppression with the increase of the chronological age[15]. In another study with the same evaluation, but comparing term and preterm neonates, it was concluded that the magnitude of suppression significantly increases with the increase of the gestational age[23].

Thus, several studies point out, to a greater or lesser extent, to the trend of increase of amplitude with increase of the gestational age. Thus, the literature suggests maturation of the functions of the peripheral auditory system. However, the authors do not agree about the structures involved in the maturation process and period of occurrence. Some highlight the maturation of the inner ear as the main responsible for the increase of the amplitude of the OAEs[21,24,26,27]. Others emphasize the anatomical and functional maturation of the outer and middle ears, cochlear and medial olivocochlear system, synergistically contributing for this increase[20].

There are also controversies about the duration of the maturation process of the auditory system. Some authors state that it occurs until the period of birth at term[26,27]. Others point out the occurrence of maturation also in the postnatal period[20,21,24]. There are studies that highlight the maturation of the medial efferent system[15-23] and suggest its occurrence until around the 32nd week of gestational age[15].

It is believed that, although the DPOAEs originate in mechanisms of the inner ear, they are also influenced by the outer and middle ear as well as being mediated by efferent pathways of the medial olivocochlear system. Thus, the increase of amplitude may result of the maturation of all mentioned structures and, therefore, it becomes complex to individually analyze the contribution of each structure in the increase of the amplitude of the DPOAEs.

CONCLUSION

The most frequent risk indicators for hearing loss were the duration of the stay in the incubator and in the ICU longer than five days.

The gestational age was correlated with the presence and magnitude of responses in the auditory evaluation through DPOAEs. Therefore, it is suggested to consider it in clinical practice with regard to the moment for examination.

The findings related to the presence and amplitude of the DPOAEs suggest the occurrence of maturation of the peripheral auditory system.

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