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Original Article
Artigo Original

Steady-state auditory evoked potential in children and adolescents

Potencial evocado auditivo de estado estável em crianças e adolescentes

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Keywords

Auditory Evoked Potential
Hearing
Hearing Loss
Child
Adolescent

ABSTRACT

Introduction: The applicability of the Steady-State Auditory Evoked Potential has grown in audiological diagnosis. **Objective**: To investigate the correlation between the electrophysiological thresholds and behavioural thresholds in individuals with normal hearing and sensorineural hearing loss. **Method**: We evaluated 25 individuals of both genders aged between 5 and 15 years divided into the following groups: 15 individuals with normal hearing and 10 individuals with moderate and moderately severe sensorineural hearing loss. The individuals were submitted to pure tone audiometry, speech audiometry, acoustic impedance and Steady-State Auditory Evoked Potential. **Results**: In the group with normal hearing, the maximum thresholds electrophysiological ranged from 19 to 27dBcgNA. In the group with moderate and moderately severe hearing loss the correlation was 0.42 to 0.74. Mean differences in electrophysiological and behavioural thresholds were between –0.3 and 12dB for the normal hearing group, –9 and 2dB in the moderate and moderately hearing loss group. **Conclusion**: In the group with normal hearing there was no correlation between the electrophysiological and behavioural thresholds, however positive correlation was found in the group with loss of moderate and moderately severe.

Descritores

Potenciais Evocados Auditivos
Audição
Perda Auditiva
Criança
Adolescente

RESUMO

Introdução: A aplicabilidade do potencial evocado auditivo de estado estável tem crescido no diagnóstico audiológico. **Objetivo**: Verificar a correlação entre os limiares eletrofisiológicos obtidos no Potencial Evocado Auditivo de Estado Estável e os limiares comportamentais obtidos na audiometria tonal liminar em crianças e adolescentes com audição normal e perda auditiva neurossensorial de grau moderado a moderadamente severo. **Métodos**: Foram avaliados 25 indivíduos de ambos os sexos com idade entre 5 e 15 anos, distribuídos nos seguintes grupos: 15 indivíduos com audição normal e 10 indivíduos com perda auditiva neurossensorial de grau moderado a moderadamente severo. Os indivíduos foram submetidos a: audiometria tonal liminar, logoaudiometria, medidas de imitância acústica (timpanometria e pesquisa dos reflexos acústicos) e ao potencial evocado auditivo de estado estável. **Resultados**: No grupo com audição normal, os limiares eletrofisiológicos máximos situaram-se entre 19 a 27 dBcgNA. No grupo com perda auditiva de grau moderado a moderadamente severo, a correlação encontrada foi de 0,42 a 0,74. As diferenças médias do limiar eletrofisiológico e o limiar comportamental situaram-se entre: –0,3 e 12 dB para o grupo de audição normal e de –9 e 2 dB no grupo com perda auditiva de grau moderado a moderadamente severo. **Conclusão:** No grupo com audição normal não houve correlação entre os limiares eletrofisiológicos e comportamentais, em contrapartida foi encontrada correlação positiva no grupo com perda de grau moderado a moderadamente severo.

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INTRODUCTION

The integrity of the hearing system is a prerequisite for the acquisition and the normal development of oral language, therefore the early diagnosis of hearing loss becomes necessary in the first months of the child's life, especially in the first six months, which are considered the critical period for the development of hearing and language.

The hearing evaluation is composed of subjective and objective procedures that help in the diagnosis of hearing loss and the characterization of the hearing loss degree and type. Among the subjective techniques, there is the pure tone audiometry, depending on the patient's response. Among the objectives procedures, it is highlighted the Brainstem Auditory Evoked Potentials (click and tone burst) and the Steady State Auditory Evoked Potential, in which the electrophysiological thresholds are registered without the patient's response.

Currently, the most used objective procedures are the electroacoustic tests, such as imitanciometry and otoacoustic emissions, and the electrophysiological, such as Auditory Evoked Potentials. These tests help in audiological diagnosis of children from different age groups. In order to supplement infant audiological diagnostic the applicability of the Steady State Auditory Evoked Potentials (ASSR) increasingly grows as a new electrophysiological method. The ease recording and objectivity in identifying the ASSR responses, using statistical analysis are important aspects of this procedure[1].

There is no sufficient scientific evidence in the literature for the use of ASSR in predicting behavioral hearing thresholds. However, studies indicate the presence of correlation between electrophysiological and behavioral thresholds, especially in individuals with hearing loss[2-12].

Because the ASSR is a relatively recent procedure in our area, more studies are necessary on the correlation of this procedure with behavioral hearing thresholds defined by pure tone audiometry, and most studies have been conducted with adult or neonatal. There are few studies in children and adolescents with have consistent responses in pure tone audiometry, allowing effective comparison of the behavioral and electrophysiological findings.

This study aimed to verify the correlation between the electrophysiological thresholds in Evoked Potential State Auditory Steady (ASSR) and behavioral thresholds in pure tone audiometry in children and adolescents with normal hearing and flat sensorineural hearing loss of moderate to moderately severe.

METHOD

This is an analytical observational cross-sectional study that was approved by the Research Ethics Committee of the Universidade Federal de São Paulo (no. 0669/11). All parents of children and adolescents were informed about the procedures to be performed and signed the Informed Consent Form before participating in the study and literate adolescents were also informed of the procedures to be performed and also signed the Consent Term.

The sample was selected from 107 volunteers met at the Audiology Department of the Universidade Federal de São Paulo that met the proposed inclusion and exclusion criteria. Those who did not complete the exam, missed, refused to participate or presented conductive hearing loss at the time of evaluation were excluded.

Inclusion criteria were age between 5 and 15 years tympanometric curve type A bilaterally[13] and consistent responses to pure tone audiometry. We excluded individuals with conductive and neurological disorders.

Thus, the sample consisted of 25 individuals of both genders aged between 5 and 15 years, distributed in:

Group 1: 15 individuals with normal hearing;

Group 2: 10 individuals with flat sensorineural hearing loss of moderate to moderately severe.

All individuals underwent anamnesis, pure tone audiometry, acoustic impedance and electrophysiological assessment of hearing (Auditory Evoked Potential Steady State). All procedures were performed by the same evaluator.

The audiological evaluation was performed in a soundproof booth with MA-41 audiometer model and the supra-aural TDH-39. The hearing thresholds test was conducted in the frequencies 250-8000 Hz and the subjects were told to raise the front hand to sound stimuli heard, even in low intensity. The auditory threshold was investigated at intervals of 10 decibels hearing level-dB HL (descending) and 5 decibels hearing level-dB HL (high). The lowest hearing intensity level was considered the threshold at which the patient responded to 50% of the sound stimulus presentations.

The degree of hearing loss was classified according to Lloyd and Kaplan[14], analyzing the average air conduction thresholds in the frequencies of 500, 1,000 and 2,000 Hz. We considered normal hearing when the average was between 0 and 25 dB HL and hearing loss of moderate to moderately severe when it was between 41 and 70 dB HL.

We considered type A tympanometric curve when the peak of maximum compliance was between +100 and –100 daPa and the volume of the middle ear, between 0.3 and 1.6 ml[13].

Auditory Evoked Potentials was carried out with the equipment Smart EP, manufactured by Intelligent Hearing Systems. The examination was performed in an acoustic and electrically treated room. The subjects were accommodated in reclining and comfortable chair and told to remain quiet, avoiding mostly muscle movements of the head and neck, avoiding myogenic artifacts. Before the start of the tests, the subjects skin was prepared with the aid of abrasive paste and the electrodes positioned so that the record was held ipsilateral to the stimulated ear, the impedance is maintained <5 kΩ. The electrodes were positioned as follows: M1, Fz and M2: (–) tested ear, (+) forehead (ground), non-tested ear. The acoustic stimuli were presented by insert earphones ER-3B, adapted in the external auditory canal (EAC) by means of disposable foam *plugs*. The test was performed in natural sleep with no sedatives. The stimulation was monaural and the stimulus presentation was mixed (multifrequency at the beginning of the examination and simple close to the threshold). The electrophysiological threshold test was held with the technical descent (10dB) and upward (5dB). The equipment maximum intensity was 117 dBNPS. Electrophysiological thresholds were obtained in dB SPL and converted to dB HL (dB cg NA) by the equipment itself. The correction values were: –26 dB for 500 Hz, –11 dB for 1000 Hz, –13 dB for 2000 Hz and –19 dB for 4000 Hz.

ASSR was detected automatically by comparing the signal amplitude and noise amplitude in the presentation rate. These responses were divided into signal and noise, using a statistical test F. The response was considered present when the ratio between signal and noise is equal to or greater to 6.13 dB, more responsive to 0.0125 microvolts, electric noise lower than 0.05 microvolts and less residual noise or equal to 0.07 microvolts. Statistical analysis was performed every 20 scans, using the maximum display of 400 scans using a 30-300 Hz filter. The criterion used to stop the examination record was the presence or absence of response to the residual noise below 0.70 microvolts (parameter suggested by the equipment user manual). In cases where the noise did not reach this limit in 400 scans, the test was restarted.

The stimulus was the *tonepipes*, 100% modulated in amplitude, with the carrier frequencies 500 to 4000 Hz in frequency modulation, the right ear, from: 79, 87, 95, 103 Hz and, in the left ear from: 77, 85, 93 and 101 Hz.

Despite the use of different transducers in this study, to behavioral thresholds (supra-aural TDH-39) and electrophysiological thresholds (ER-3B insert earphones), the correction of the thresholds for insertion phones in behavioral audiometry was not performed, since the correction factors for the frequency 0.5 kHz to 4 kHz are between 0 and 2 dB[15]. The 2dB correction has clinical validity, as the research of the thresholds is performed in 5 dB increments.

The statistical analysis of for this study was performed with descriptive statistics (mean, standard deviation, median, minimum and maximum) of the electrophysiological and behavioral thresholds, in groups, and Spearman and Pearson linear correlation test in the correlation between the electrophysiological thresholds of ASSR and behavioral audiometry.

RESULTS

The average values of the electrophysiological thresholds in the Steady State Auditory Evoked Potential (ASSR) and behavioral auditory thresholds obtained in pure tone audiometry in the frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for each ear, in the group with normal hearing, presented in Table 1.

The mean values of the differences between the values of the electrophysiological thresholds and behavioral thresholds in dBHL, by frequency and ear for the group with normal hearing are presented in Figure 1.

The correlation values obtained by the Pearson coefficient in the group with normal hearing are given in Table 2.

The average values of the electrophysiological thresholds in the Steady State Auditory Evoked Potential (ASSR) and behavioral auditory thresholds obtained in pure tone audiometry in the frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for each ear, in the group with moderate to moderately severe hearing loss, presented in Table 3.

The mean values of the differences between the values of the electrophysiological thresholds and behavioral thresholds in dBHL, by frequency and ear for the group with moderate to moderately severe hearing loss, are presented in Figure 2.

The correlation values obtained by the Pearson coefficient in the group with moderate to moderately severe flat hearing loss are given in Table 4.

DISCUSSION

The group with normal hearing showed higher electrophysiological thresholds compared to behavior. The presence of higher electrophysiological thresholds in the ASSR compared to pure tone audiometry has been described in most studies[16-19]. The presence of higher electrophysiological thresholds was

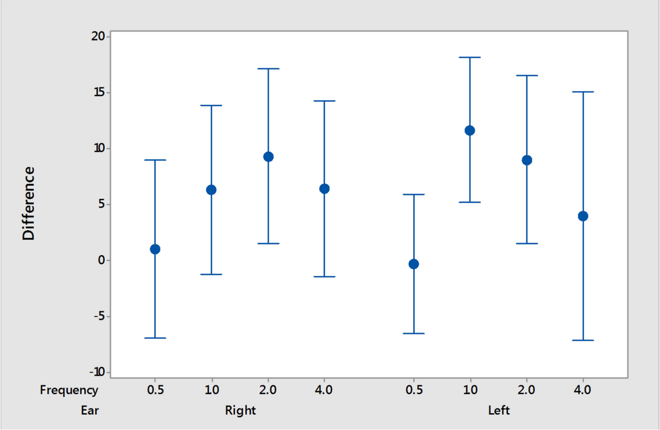

Figure 1. Graphics of average ± 1 standard deviation of the differences in dB per frequency and ear - normal hearing

Table 1. Average values of electrophysiological and behavioral thresholds in frequency of 500Hz to 4000 Hz by ear, in the group with normal hearing (G1)

Ear	Frequency (kHz)	n	Average ET	SD ET	Median ET	Average BT	SD BT	Median BT
Right	0.5	15	7.67	8.76	9	6.67	4.08	5
	1	15	12.33	7.48	9	6.00	3.87	5
	2	15	12.67	8.84	12	3.33	3.09	5
	4	15	12.73	9.41	16	6.33	4.81	5
Left	0.5	15	6.67	6.23	9	7.00	3.68	5
	1	15	16.33	6.76	19	4.67	2.97	5
	2	15	13.33	6.94	12	4.33	3.72	5
	4	15	10.67	9.15	11	6.67	5.23	5

Caption: ET = electrophysiological thresholds; BT = behavioral thresholds expected, since all studies using electrophysiological evaluation obtained electrophysiological thresholds from 10 to 15 dB higher regarding behavioral thresholds. The distance between generating sites and surface electrodes to the response capture (far field potential) is one explanation for the occurrence of this difference due to lower amplitude response that needs to be extracted from the background noise.

Electrophysiological thresholds in the group with normal hearing ranging from 6 to 16 dBcgNA at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. These findings were lower than those obtained in national studies that applied ASSR in adults and thresholds recorded around 26 dB HL[20] and between 14 and 21 dB HL[19]. Such differences may be attributed to the thresholds recording procedure. Some authors establish the minimum level of response, i.e., they interrupted the test when finding answers within the normal range. Other authors, such as in the present study investigated the electrophysiological threshold, i.e., decreasing the sound stimulus until the disappearance of the response. In fact, studies investigating minimum level of adults in response[19,20] or in newborns[21] obtained higher responses. Studies conducted using the same electrophysiological threshold detection procedure as the present study found similar data. Study with infants with normal hearing thresholds observed 6:17 dBNA[18], which coincide with those obtained in the present study.

It was observed that the mean differences in the group with normal hearing were between –0.3 and 12 dB HL. These differences agree with those obtained by population studies with normal

Table 2. Observed values of Spearman's correlation coefficient (r) between the variables electrophysiological thresholds and behavioral auditory threshold (dBNA) by frequency and ear - normal hearing group

Frequency (kHz)	Right ear		Left ear	
	r	P-value	r	P-value
0.5	0.424	0.116	0.424	0.116
1	0.189	0.500	0.189	0.500
2	0.434	0.106	0.434	0.106
4	0.422	0.116	0.422	0.116

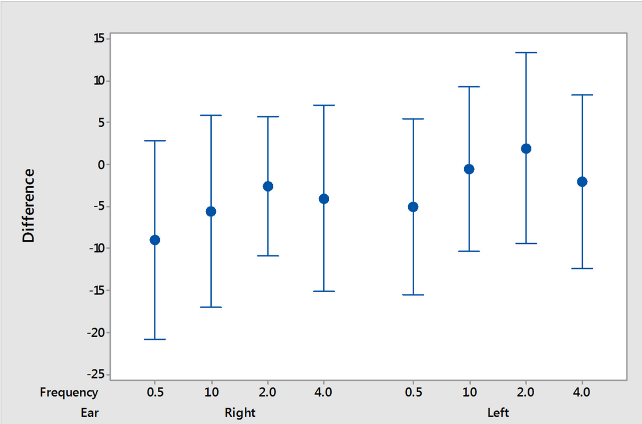

Figure 2. Graphics of average ± 1 standard deviation of the differences in dBNA per frequency and ear - moderate to severe hearing loss

Table 3. Average values of electrophysiological and behavioral thresholds in frequency of 500Hz to 4.000 Hz by ear, in the group with moderate to severe hearing loss (G2M)

Ear	Frequency (kHz)	n	Average ET	SD ET	Median ET	Average BT	SD BT	Median BT
Right	0.5	10	34.5	16.24	31.5	43.5	10.01	42.5
	1	10	50.5	16.34	51.5	56.0	9.37	57.5
	2	10	54.0	12.95	54.5	56.5	11.07	55.0
	4	10	50.0	13.29	51.0	54.0	6.99	55.0
Left	0.5	10	35.5	11.56	36.5	40.5	5.50	40.0
	1	10	50.5	13.55	49.0	51.0	7.75	47.5
	2	10	55.0	13.37	59.5	53.0	8.88	52.5
	4	10	49.5	15.10	53.5	51.5	8.83	55.0

Caption: ET = electrophysiological thresholds; BT = behavioral thresholds

Table 4. Adjusted regression lines and observed values of Spearman's correlation coefficient (r) between the variables ASSR electrophysiological thresholds (dBcgNA) and behavioral auditory threshold (dBNA) by frequency and ear - in the group with moderate to severe hearing loss

Frequency (kHz)	Right ear			Left ear		
	Adjusted line	r	P-value	Adjusted line	r	P-value
0.5	Threshold A = 28.8 + 0.425 ASSR	0.689	**0.028***	-	0.424	0.222
1	Threshold A = 34.8 + 0.42 ASSR	0.733	**0.016***	Threshold A = 30.8 + 0.399 ASSR	0.699	**0.025***
2	Threshold A = 20.9 + 0.659 ASSR	0.711	**0.009***	-	0.547	0.102
4	Threshold A = 39.4 + 0.292 ASSR	0.556	**0.095#**	Threshold A = 29.9 + 0.437 ASSR	0.747	**0.013***

*Significant values ($p<0.05$); - Pearson's correlation coefficient (r); # Tendency to significance
Caption: In adjusted lines, the variable response and threshold in the audiometry and the explanatory variable compose the ASSR threshold

hearing[1,17,19,22]. However, other studies also with normal hearing population, found major differences between the behavioral and electrophysiological thresholds[23-30].

The group with normal hearing showed no correlation between the electrophysiological and behavioral thresholds. These findings agree with most studies in national and international literature[22,30].

In the group with normal hearing, the maximum electrophysiological thresholds are between 19-27 dBcgNA. Other studies found maximum electrophysiological thresholds higher than those obtained in this study, which shows the great variability thresholds obtained in listener population[1,18,26].

In contrast, the group with hearing loss of moderate to moderately severe had higher behavioral thresholds than the electrophysiological. The presence of the best responses on ASSR in hearing loss up to moderate, where there is the involvement of outer hair cell loss, in the group with normal hearing has been explained by some authors by the recruitment phenomenon in which there is an abnormal growth of the intensity of feeling and where loud sounds are perceived normally. Thus, the presence of recruitment reflected in an abnormal increase of the amplitude response above threshold intensities, resulting in a more easily detectable response[1,7].

In this study, the electrophysiological thresholds of those with moderate to moderately severe hearing loss ranged from 34-55 dBcgNA, closer to those obtained in national work using the same equipment[19].

It was observed that the mean differences in the group with moderate to moderately severe hearing loss ranged from –9 to 2 dB HL, lower than the differences described in the international literature[1,23,27,28]. The greatest differences were found in the frequency of 0.5k Hz. This finding has been confirmed in the literature both in neurosensory and conductive losses. The highest responses at 0.5 kHz can be explained by the interference of the electrophysiological and/or environmental noise at low frequencies[1]. One of the factors responsible for the presence of the worst responses at 500 Hz due to the cochlear tonotopy, which provides greater sound dispersion, resulting in decreased response amplitude at this frequency, included in the cochlear apical part[1,25].

There was better correlation of behavioral and electrophysiological thresholds in the group with moderate to moderately severe hearing loss, ranging from 0.42 to 0.74. These findings agree with a study with subjects 15 to 18 years[9]. However, higher correlations between 0.67 and 0.93 have been found in individuals with moderate to moderately severe hearing loss[1,23].

The study data show the need for greater care in the evaluation of normal subjects, considering the ASSR as a complementary procedure in the audiological battery.

The correlation between the electrophysiological and behavioral thresholds in sensorineural moderate to moderately severe hearing loss allows its use in young children, who do not respond in pure tone audiometry, gold standard in audiology, contributing effectively to the adaptation of hearing aids in the early months of life.

CONCLUSION

There was a positive correlation between electrophysiological and behavioral thresholds only in children aged 5 to 15 years with moderate to moderately severe hearing loss.

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Author contributions

CBLL principal investigator, preparation of research, schedule development, literature review, data collection and analysis, article writing, submission and procedures of the article; MVG co-author, article writing review; MFA advisor, article writing review, approval of the final version.