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# Auditory efferent inhibitory effect in central auditory processing disorder

## Efeito inibitório da via eferente auditiva no transtorno de processamento auditivo central

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## ABSTRACT

**Purpose:** Verify and compare the occurrence and magnitude of the inhibitory effect of the efferent auditory pathway in children and adolescents with normal and auditory processing disorder, identifying a cutoff value to use in clinical settings. **Methods:** A prospective study, with a total sample of 30 children aged 7 to 14 years, half with normal auditory processing assessment (Control Group) and the other half with auditory processing disorder (Study Group). Both groups were submitted to anamnesis and evaluated using the otoacoustic emissions tests evoked by transient stimuli in the absence and presence of contralateral noise, basic audiological evaluation and auditory processing. **Results:** The study group presented a lower occurrence of the inhibitory effect of the efferent pathway when compared to the control group (p value=0.038). The mean values obtained for the control group were 0.71 in the right ear and 0.87 in the left ear and for the study group, 0.55 in the right ear and 0.41 in the left ear. The two groups showed a statistically significant difference for the left ear. **Conclusion:** There was a reduction in the inhibitory effect of the efferent pathway in children and adolescents with auditory processing disorder, suggesting a functional change in the medial olivocochlear efferent system. In this study, the cutoff value of 0.55 dB separated children with and without alteration of the efferent system with 70% sensitivity and 66.7% specificity.

**Keywords:** Hearing; Auditory pathways; Spontaneous otoacoustic emissions; Disorder of auditory perception; Efferent pathways

## RESUMO

**Objetivo:** verificar e comparar a ocorrência e magnitude do efeito inibitório da via auditiva eferente em crianças e adolescentes com processamento auditivo normal e alterado, identificando um valor de corte para uso na prática clínica. **Métodos:** estudo prospectivo, com amostra composta por 30 crianças de 7 a 14 anos, sendo 15 com avaliação de processamento auditivo normal (grupo controle) e 15 com processamento auditivo alterado (grupo estudo). Ambos os grupos foram submetidos à anamnese e avaliados por meio dos testes de emissões otoacústicas evocadas por estímulos transientes na ausência e presença de ruído contralateral, avaliação audiológica básica e de processamento auditivo. **Resultados:** houve menor ocorrência do efeito inibitório da via eferente no grupo estudo (p-valor=0,038). Os valores médios obtidos no grupo controle foram 0,71 na orelha direita e 0,87 na orelha esquerda e no grupo estudo, 0,55 na orelha direita e 0,41 na orelha esquerda. Os grupos controle e estudo diferiram de modo significativo na orelha esquerda. **Conclusão:** houve redução do efeito inibitório da via eferente em crianças e adolescentes com transtorno de processamento auditivo, sugerindo alteração funcional do sistema eferente olivococlear medial. O valor que separou as crianças com e sem alteração do sistema eferente foi de 0,55 dB na prática clínica, com 70% de sensibilidade e 66,7% de especificidade.

**Palavras-chave:** Audição; Vias auditivas; Emissões otoacústicas espontâneas; Transtorno da percepção auditiva; Vias eferentes

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## INTRODUCTION

Hearing is vital for the acquisition of oral communication. The anatomical and functional integrity of the peripheral and central auditory system added to exposure to hearing experiences in the environment are a prerequisite for normal language acquisition and development[1].

The auditory processing of acoustic information is a highly complex and redundant process because it requires several neurophysiological and cognitive mechanisms to enable its precise decoding. Hearing refers to the capacity to detect, analyze and organize such information, processes that comprise abilities to recognize, discriminate and locate sounds, as well as memorize and integrate them, involving simple and more complex non-verbal acoustic stimuli, for example, speech[2,3].

Investigating the Inhibitory Effect of Auditory Efferent Pathway (IHEAP), also called effect of suppression of otoacoustic emissions, allows obtaining information on the functioning of the medial olivocochlear (MOC) efferent system, whose function can be assessed indirectly by means of analysis of otoacoustic emissions (OAE) recorded in the presence of simultaneous noise. The efferent system is triggered by the presence of broadband noise, which reduces contraction of the outer hair cells, diminishing the OAE response[2,4].

The IHEAP plays a key role in tasks related to auditory discrimination, high frequency selectivity and speech frequency intelligibility, especially in noisy environments. Specific literature points out that, in general, individuals with learning difficulties, language disorders, stuttering, and people with difficulties in identifying in-noise speech have a decrease or absence of the efferent pathway inhibitory effect on otoacoustic emissions[2,4,5].

One of the main complaints of children with central auditory processing disorder (CAPD) is the difficulty in understanding speech in the presence of background noise, and studies indicate the negative impact that an auditory perception difficulty has on communication, learning, school performance and in the social life of these individuals[3,6].

In the literature, some studies raised the hypothesis that most of these children could present alteration of the inhibitory effect of the efferent pathway[6-10]. A clear understanding of the role and association of IHEAP with CAPD could guide and provide rehabilitation options for the treatment of this disorder[6-10].

It is hypothesized that the study of the IHEAP in children with central auditory processing disorder could contribute to more knowledge about the auditory pathway efferent function and its role in hearing in noisy environments, especially during the child development period.

The IHEAP can be another precise and reliable instrument to assist in the identification and timely intervention in the mechanisms involved in CAPD with positive impacts on the hearing health and social life of this population. In the literature, a study suggests to include the evaluation of the inhibitory effect of the efferent pathway in auditory processing evaluations[6]. However, in clinical practice, it is still necessary to establish reference values to enable identification of an alteration in the efferent auditory system.

Thus, the aim of the present study was to examine and compare occurrence and magnitude of the inhibitory effect of the auditory pathway on the transient-evoked otoacoustic emission (TEOAE) of children and adolescents with normal and abnormal auditory processing, establishing a cutoff value for use in clinical audiology.

## METHOD

This is a crosswise prospective study carried out in a healthcare public service and approved by the Human Subject Research Ethics Committee of the Federal University of São Paulo, process nº 940.099/16.

The individuals invited to participate in the study were from the Neuroaudiology Clinic and Child Audiology Clinic, both belonging to the University Hospital of the institution that promoted the research.

Following the ethical principles of human subject research, the mothers and/or guardians of the children read and signed the Free Informed Consent Form, according to the resolution no. 466 of Dec.12, 2012 of the National Health Council. All the literate children and adolescents read, clarified their doubts and signed the Assent Term.

The sample comprised children and adolescents assisted by the Unified Healthcare System (SUS) and from a public school, from June to December, 2016. All of them were subjected to pure tone audiometry, logoaudiometry, acoustic immittance, transient-evoked otoacoustic emissions (TEOAE) and central auditory processing (CAP) screening tests.

Eligibility criteria included: hearing thresholds for sound frequencies in the range of 250Hz to 8000Hz lower than or equal to 20 dB HL; conventional logoaudiometry comprising the speech recognition percentage index (SRPI) with results equal to or higher than 92% of correct answers and speech recognition threshold (SRT) compatible with the tritonal average of sound frequencies of 500Hz, 1000Hz and 2000Hz. Acoustic immittance measurement: tympanometry and contralateral acoustic reflex. As criterion of normality, the A tympanometry curve [11] and acoustic reflexes present in the contralateral mode and sensation level at 70 to 90 dB were considered. Subsequently, a complete CAP evaluation was carried out according to the protocol followed by institution' staff[12].

Non-eligible individuals comprised those with hearing losses, evidences of neurological, genetic and/or psychiatric disorders, or if they were already included in auditory training programs and/or speech-hearing therapy.

Thus, the sample comprised 30 children of both sexes, 15 (14 male and one female) with CAPD (study group – SG) and 15 (8 male and seven female) with typical development and normal auditory processing evaluation (control group - CG). Age ranged from seven to 14 years; the mean age in the SG was 10.1 years (+- 1.7) and median of 11 years, and in the CG the mean age was 9.9 years (+- 1.7) and median of ten years, to allow sample homogeneity in terms of age between the groups.

Pure-tone audiometry was performed in an acoustic booth using a *Madsen Orbiter*922 audiometer and TDH-39 earphones and MX-41/AR type cushions, ANSI 1969 standard. Measurements of acoustic immittance were recorded with an *Interacoustics* (model AT-235) middle ear analyzer. CAP evaluation was performed in an audiometric booth, using a *Madsen Orbiter* 922 audiometer with compact discs (CDs) containing recorded stimuli for the CAP tests and a portable CD player coupled to the audiometer to present the recorded sound stimuli. The evaluation consisted of the following hearing tests: Sound Localization Test (SLT); Verbal Sequential Memory Test (VSMT); Non-verbal Sequential Memory Test (NVSMT); Speech Test with White Noise (S/N); Dichotic Digit Test (DDT) and Random Gap Detection Test (RGDT) and Duration Pattern Recognition Test (DPRT) with flute sounds.

CAP test results were considered as *Normal* and *Altered,* according to the criteria recommended in literature(12,13). And the diagnosis of auditory processing disorder was given whenever an individual exhibited one or more tests considered as altered.

The electroacoustic assessments were part of the TEOAE and IHEAP screening tests performed with the equipment of the *ILO V6* system manufactured by *Otodynamics,* in an audiometric booth. At first, with the purpose of checking the cochlear function integrity, as the presence of response is a prerequisite for evaluation of the efferent system, and to inhibit a response it must be present, a transient-evoked otoacoustic emissions screening test (TEOAE) was carried out. At this step, the stimulus utilized was nonlinear click and intensity between 75 and 85 dB SPL. TEOAE was considered present when the signal/noise ratio was higher than or equal to 3 dB in the sound frequency bands of 2000 to 4000Hz, with reproducibility greater than or equal to 70%, and the probe stimulus stability was higher than or equal to 70%.

Then, a second procedure was carried out to investigate the IHEAP on TEOAE. For this purpose, two probes (probe 1 and probe 2) were put one into each ear. The stimuli were presented in alternating blocks of 10 seconds of linear click at 65 dB SPL (probe 1) and 10 seconds with broadband contralateral noise at 60 dB SPL (probe 2) until completing 260 series of stimuli. The IHEAP calculation was obtained from the result of the subtraction of the TEOAE response amplitude, comparing the response with and without noise, using linear clicks. The efferent pathway inhibitory effect (IHEAP) was considered present when there was a reduction of TEOAE amplitudes of at least 0.5dB sound pressure level (SPL) in the presence of contralateral noise(14).

The statistical analysis of the data was carried out using the Mann-Whitney test to compare the results of the CAP tests between the groups, and the chi-square test to measure the percentage of IHEAP presence or absence between the groups. The Receiver Operating Characteristic (ROC) was chosen for the analysis because it is a simple and robust graphical method that indicates the different cutoff points of the test, according to their sensitivity levels (axis Y) and specificity (axis X). The areas under the curve represent the instrument capacity to correctly classify healthy and ill individuals(15).

For this work, the level of significance (p-value) adopted was 0.05 (5%). The software programs used for this statistical analysis were SPSS V20, Minitab 16 and Excel Office 2010.

## RESULTS

The sample consisted of two groups of individuals aged 7 to 14 years. The SG was the group with central auditory processing disorder, mean age of 10.1 years (+- 1.7) and median of 11 years, and the CG comprised individuals with normal auditory processing, mean age of 9.9 years (+- 1.7) and median of 10 years (p-value=0.673).

The statistical analysis indicated a significant difference between the groups in almost all CAP tests, except for the sound localization test (SLT) and RGDT test. The number of CAP tests with alterations indicated statistical differences between the groups (p-value < 0.001). The SG had an average of 2.93 altered results; the CG had no altered result, confirming each group's representativeness (Table 1).

With respect to the occurrence of IHEAP in the CG and SG, the chi-square test showed that 100% of the children of

**Table 1.** Descriptive values of Central Auditory Processing tests and the number of altered test results

| CAP tests | Groups | Mean | Median | Standard Deviation | Q1 | Q3 | N | CI | P-value |
|---|---|---|---|---|---|---|---|---|---|
| SLT | SG | 97.3% | 100% | 7.0% | 100.0% | 100.0% | 15 | 3.6% | 1.000 |
| | CG | 97.3% | 100% | 7.0% | 100.0% | 100.0% | 15 | 3.6% | |
| VSMT | SG | 71.1% | 67% | 30.5% | 66.7% | 100.0% | 15 | 15.4% | 0.007* |
| | CG | 95.6% | 100% | 11.7% | 100.0% | 100.0% | 15 | 5.9% | |
| NVSMT | SG | 55.6% | 67% | 24.1% | 33.3% | 66.7% | 15 | 12.2% | <0.001* |
| | CG | 95.6% | 100% | 11.7% | 100.0% | 100.0% | 15 | 5.9% | |
| SDT | SG | 38.7% | 30% | 18.5% | 30.0% | 55.0% | 15 | 9.3% | <0.001* |
| | CG | 93.3% | 90% | 6.2% | 90.0% | 100.0% | 15 | 3.1% | |
| RGDT | SG | 16.6 | 10.5 | 20.3 | 5.5 | 20 | 15 | 10.3 | 0.105 |
| | CG | 7.2 | 7.5 | 2.7 | 4.5 | 10 | 15 | 1.4 | |
| S/N RE | SG | 78.5% | 76% | 10.8% | 72.0% | 86.0% | 15 | 5.4% | 0.003* |
| | CG | 90.1% | 88% | 6.7% | 88.0% | 96.0% | 15 | 3.4% | |
| S/N LE | SG | 80.0% | 80% | 11.8% | 74.0% | 86.0% | 15 | 6.0% | 0.009* |
| | CG | 89.1% | 88% | 6.1% | 86.0% | 94.0% | 15 | 3.1% | |
| DDT RE | SG | 86.4% | 88% | 11.2% | 75.6% | 96.3% | 15 | 5.7% | 0.001* |
| | CG | 97.8% | 100% | 3.8% | 96.3% | 100.0% | 15 | 1.9% | |
| DDT LE | GE | 82.1% | 80% | 13.0% | 72.5% | 92.5% | 15 | 6.6% | <0.001* |
| | CG | 97.8% | 100% | 4.0% | 97.5% | 100.0% | 15 | 2.0% | |
| Number of ALTERED CAP tests | SG | 2.93 | 3.00 | 1.16 | 2.00 | 4.00 | 15 | 0.59 | <0.001* |
| | CG | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15 | - x - | |

Mann-Whitney test; - x - = it was not possible to use the statistical test; *Significant statistical differences

**Subtitle:** CAP = central auditory processing; SG = study group; CG = control group; SLT = Sound localization test; VSMT = Verbal sounds memorization test; NVSMT = Non-verbal sounds memorization test; SDT = standard duration test; RGDT = random gap detection test; S/N RE = speech-to-white noise test in the right ear; S/N LE = speech-to-white noise test in the left ear; DDT RE = dichotic digit test in the right ear; DDT LE = dichotic digit test in the left ear; Q1 = 1st quartile (25%); Q3 = 3rd quartile (75%); N = number of children tested; CI = Confidence Interval the CG exhibited IHEAP in both ears. However, in the SG, this phenomenon was found in 86.7% of the children, and 13.3% of absence, indicating a statistical difference between the groups (p-value 0.038) (Figure 1).

The IHEAP results for the right ear (RE) and left ear (LE) in the groups with and without CAP alteration showed a significant difference between the groups for the LE, with mean values of TEOAE inhibition lower than in the study group when compared with the control group (Table 2).

In the analysis of the ROC curve for IHEAP on otoacoustic emissions, it was found that the area of the LE curve was of 0.773, with a statistical difference (p=0.011), which did not occur for the RE. When the ROC curve of both ears was considered, the curve area was of 0.720, with statistical significance (p=0.003) (Table 3).

The ROC curves for the left and right ears are illustrated in Figures 2 and 3, respectively. With respect to the IHEAP on the otoacoustic emissions of the LE, the ROC curve indicated that the cutoff point was 0.6dB, with sensitivity and specificity of 73%.

In the joint analysis of the ears, the ROC curve showed a cutoff point of 0.55dB. These results are illustrated in Table 4.

The analysis of the ROC curve of the right ear was impaired by the presence of more than one cutoff point, as can be seen in Table 4.

## DISCUSSION

The 30 children of this study were assigned to two different groups after the CAP evaluation, which identified as study group those who presented an alteration in most of the behavioral tests (Table 1). This was important because it revealed that the groups were definitely different in terms of how the auditory system processes acoustic information. In most studies found in literature, the selection of typical children to compose a sample is based only on the absence of CAP complaints,[7,8,10,16,17] which could lead to sampling bias. Performing a CAP evaluation in all children can be considered an important approach of the present study because it allowed to separate the individuals with and without alteration more precisely. In fact, the children of the SG exhibited altered results in the average of 2.93 tests and median of three tests, and in 25% of the cases they exhibited four or more altered test results, differing from the CG significantly. Literature also reports that the severity of CAP disorders has been directly proportional to the number of altered test results[3, 18, 19].

The groups were paired according to their age to ensure better sample homogeneity. It is worth mentioning that in the study group only one child was female. This was expected because literature reports a higher incidence of CAPD in males, at the rate

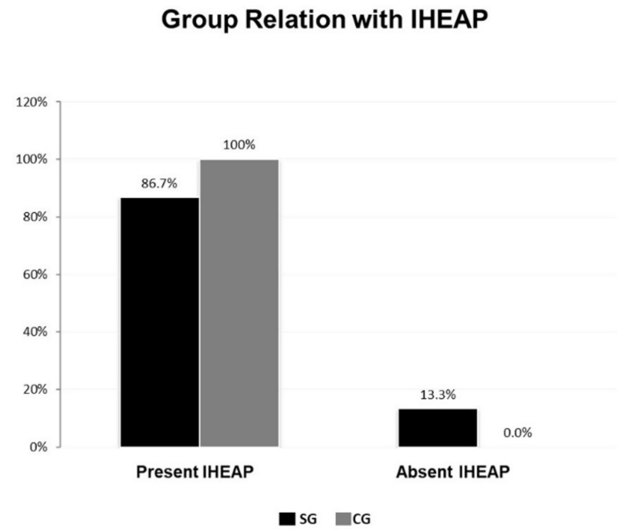


**Figure 1.** Occurrence of inhibitory effect of the efferent pathway in the control and study groups Chi-SquareTest; p-value 0.038; Significant statistical differences
**Subtitle:** SG = study group; CG = control group; IHEAP = inhibitory effect of auditory efferent pathway

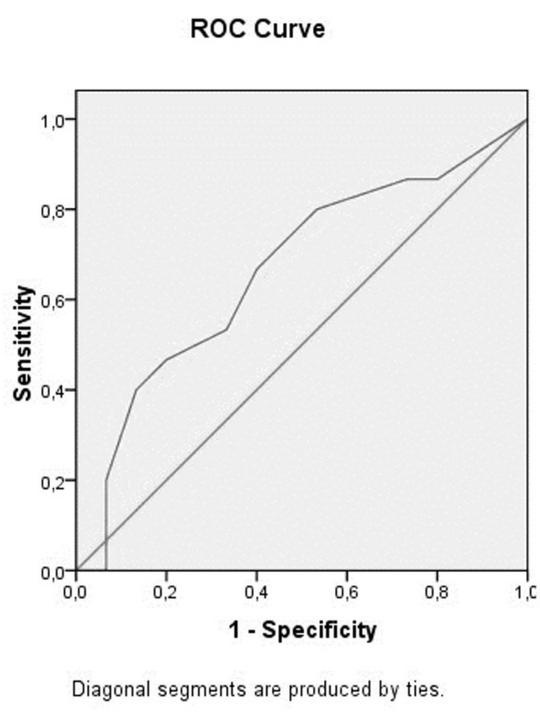


**Figure 2.** ROC curve of IHEAP of Right Ear

**Table 2.** Descriptive values for IHEAP in the right ear (RE) and left ear (LE), in the study group and control group

| Group | | Mean | Median | Standard Deviation | Q1 | Q3 | N | CI | P-value |
|---|---|---|---|---|---|---|---|---|---|
| IHEAP RE | SG | 0.55 | 0.50 | 0.32 | 0.35 | 0.70 | 15 | 0.16 | 0.122 |
| | CG | 0.71 | 0.70 | 0.32 | 0.50 | 0.90 | 15 | 0.16 | |
| IHEAP LE | SG | 0.41 | 0.30 | 0.38 | 0.15 | 0.60 | 15 | 0.19 | 0.010* |
| | CG | 0.87 | 0.80 | 0.48 | 0.50 | 1.20 | 15 | 0.24 | |

Mann-Whitney test; *Significant statistical differences
**Subtitle:** SG = study group; CG = control group; IHEAP RE = inhibitory effect of auditory efferent pathway; in the right ear; IHEAP LE = inhibitory effect of auditory efferent pathway in the left ear; Q1 = 1st quartile (25%); Q3 = 3rd quartile (75%); N = number of children tested; CI = Confidence Interval

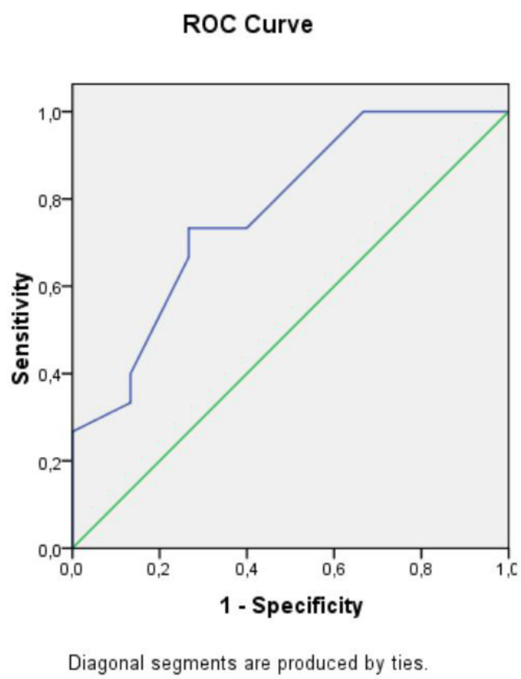


**Figure 3.** ROC Curve for IHEAP on the Left Ear

**Table 3.** ROC curve area

| IHEAP | Area | P-value | Lower threshold | Upper threshold |
|---|---|---|---|---|
| RE | 0.664 | 0.125 | 0.465 | 0.864 |
| LE | 0.773 | **0.011***  | 0.607 | 0.940 |
| RE + LE | 0.720 | **0.003*** | 0.591 | 0.849 |

*Significant statistical difference
**Subtitle:** IHEAP = inhibitory effect of auditory efferent pathway; RE = right ear; LE = left ear

of 2:1[3,19]. An explanation for the higher occurrence of CAPD in males would be the fact that the back portion of the *corpus callosum (*bundle of white mass), which is responsible for the auditory and visual transmission between the hemispheres is usually larger and bulbous in females, who can integrate auditory and visual information of both hemispheres more effectively than males[20]. Such differences, however, were not identified in other studies[21,22].

The estimated prevalence of CAPD in children, described in literature as of 2% to 10%[3], has prompted scholars to investigate the functioning of the olivocochlear efferent pathway in individuals with this disorder, since the integrity of the CAP system allows proper localization of the sound source, improves in-noise hearing, auditory sensitivity and attention, among other abilities[7,17,18,21,22, 23,24].

In this study, all subjects were subjected to CAP and IHEAP auditory evaluation. All children exhibited presence of TEOAE with non-linear click, indicating normal cochlear function. All of them were subjected to IHEAP evaluation with linear click stimulus emitted in 10-second blocks with and without noise. In literature, studies recommend to use linear click as a triggering stimulus of IHEAP on TEOAE[7,10,18] because it provides a more robust response[22]. Similar to present study, several studies used the white noise as suppression stimulus[7,10,21,24,25], obtaining better comparisons between the findings.

The SG exhibited a lower occurrence of IHEAP than the CG (Figure 1). This result is similar to those cited in literature, which reported a lower occurrence of auditory efferent suppression in children with CAPD[6]. Furthermore, studies showed that a lower occurrence of IHEAP could contribute to more difficulty in understanding in-noise speech, thus interfering in the learning process[7,19,21]. In fact, a study with children aged eight to 12 years with reading impairment identified a negative correlation between the IHEAP result and the signal-to-noise ratio that is necessary

**Table 4.** Coordinates of ROC curve, measurements of sensitivity and specificity on each point for IHEAP in the right ear, left ear and in both ears

| IHEAP RE | Sensitivity | Specificity | IHEAP LE | Sensitivity | Specificity | IHEAP BE | Sensitivity | Specificity |
|---|---|---|---|---|---|---|---|---|
| -0.8 | 100.0% | 0.0% | **-1.2** | 100.0% | 0.0% | **-1.20** | 100.0% | 0.0% |
| 0.3 | 86.7% | 20.0% | **-0.1** | 100.0% | 6.7% | **-0.10** | 100.0% | 3.3% |
| 0.4 | 86.7% | 26.7% | **0.1** | 100.0% | 13.3% | **0.05** | 100.0% | 6.7% |
| 0.5 | 80.0% | 46.7% | **0.2** | 100.0% | 26.7% | **0.15** | 100.0% | 13.3% |
| 0.6 | 66.7% | 60.0% | **0.3** | 100.0% | 33.3% | **0.25** | 93.3% | 26.7% |
| 0.7 | 53.3% | 66.7% | **0.4** | 80.0% | 53.3% | **0.35** | 83.3% | 40.0% |
| 0.8 | 46.7% | 80.0% | **0.5** | 73.3% | 60.0% | **0.45** | 76.7% | 53.3% |
| 0.9 | 40.0% | 86.7% | **0.6** | 73.3% | 73.3% | **0.55** | 70.0% | 66.7% |
| 1.0 | 20.0% | 93.3% | **0.7** | 66.7% | 73.3% | **0.65** | 60.0% | 70.0% |
| 1.1 | 13.3% | 93.3% | **0.8** | 53.3% | 80.0% | **0.75** | 50.0% | 80.0% |
| 1.3 | 0.0% | 93.3% | **0.9** | 40.0% | 86.7% | **0.85** | 40.0% | 86.7% |
| 2.4 | 0.0% | 100.0% | **1.1** | 33.3% | 86.7% | **0.95** | 30.0% | 90.0% |
| | | | **1.2** | 26.7% | 100.0% | **1.05** | 23.3% | 90.0% |
| | | | **1.4** | 20.0% | 100.0% | **1.15** | 20.0% | 96.7% |
| | | | **1.5** | 13.3% | 100.0% | **1.25** | 13.3% | 96.7% |
| | | | **1.7** | 6.7% | 100.0% | **1.35** | 10.0% | 96.7% |
| | | | **2.8** | 0.0% | 100.0% | **1.50** | 6.7% | 100.0% |
| | | | | | | **1.70** | 3.3% | 100.0% |
| | | | | | | **2.80** | 0.0% | 100.0% |
| | | | | | | **1,70** | 3,3% | 100,0% |
| | | | | | | **2,80** | 0,0% | 100,0% |

**Subtitle:** IHEAP RE = efferent pathway inhibitory effect in the right ear; IHEAP LE = efferent pathway inhibitory effect in the left ear; IHEAP BE = efferent pathway inhibitory effect in the both ears to recognize words[7]. Children with high IHEAP recognized words at a lower signal-to-noise ratio[7].

On the other hand, a recent study[16] did not identify differences between children with hearing difficulties and CAPD and children with normal development. The authors attributed the differences between their results and those in literature to different methods used in the IHEAP evaluation, the heterogeneity in CAP deficits that underlie CAPD and lack of strict measures in data treatment[16,24].

When comparing the mean values of IHEAP between the groups, it was found that the SG exhibited less reduction of the response amplitude with contralateral noise with a significant difference for the left ear (Table 2). These findings corroborate those reported in literature, indicating that children with CAPD have a decrease of the efferent inhibitory function by alteration of the medial olivocochlear system, which can affect the hearing-in-noise ability[6,8,10].

In this study, the IHEAP values found in the CG ranged from 0.2 dB to 1.8 dB with mean values of 0.71dB for the right ear and 0.87dB for the left ear (Table 2), similar to the values obtained in normal-hearing individuals (between 0.6 dB and 1.62 dB)[6,7,26]. In the SG, the IHEAP values varied from 0.1 dB to 1.4 dB, with mean values of 0.55 dB for the right ear and 0.41 dB for the left ear, which were lower than those found in the control group, with a statistically significant difference for the left ear (Table 2).

The values obtained for the children with auditory processing disorder in this study were lower than the ones described in literature for children with reading difficulty[7] and children with learning difficulty[26,27].

The IHEAP values were higher for the right ear of the SG children, similar to those found in a study with children with CAPD, showing asymmetry of the efferent system with better sensitivity in the right ear[9], as already described in literature[9]. The asymmetric suppression response between both ears might suggest that such asymmetry in normal individuals represents lateralization of the function of the outer hair cells, indicating that these cells could be more effective or responsive in the right ear[7,9], which is considered dominant because it carries the auditory information to the left hemisphere, which processes language[7,9]. Likewise, the efferent system protects more the right ear, which is dominant.

The results of the present study indicate that the inhibitory effect differed between the groups only for the left ear. This indirectly confirms the peripheral auditory asymmetry with better responses in the right ear in the study group. Some authors described the difference in IHEAP patterns between the RE and LE, describing interaural asymmetry and underlining a better sensitivity of the RE as well as a lower susceptibility to damages caused by loud noise[9,18].

In the present study, the results obtained with the ROC curve (Table 3), a technique used to establish a cutoff point for sensitivity and specificity measurements of the diagnosis test, showed that the ROC curve area was of 0.664 for the RE, 0.773 for the LE and 0.720 for both ears. It can be concluded that only in the ROC curve for suppression in the left ear and for both ears there was a statistically significant result, as the value under the curve is statistically different from 0.5.

According to Hanley & McNeil[15], a ROC curve area between 0.7 and 0.9 indicates a test result considered "good". Thus, considering the ROC curve area found in the present study for IHEAP, we can say that IHEAP is an index that is close to "good" in terms of sensitivity and specificity.

If we consider only the results for the LE, the results of the ROC curve for IHEAP allowed to identify a cutoff point of 0.6, that is, when the values for the inhibitory effect of the efferent pathway are higher than 0.6, they indicate with 73.3% of sensitivity and specificity of 73.3% that the individual possibly has normal auditory processing (Table 4). In the joint analysis of the ears, the ROC showed that the point that optimizes the sensitivity and specificity is 0.55, that is, IHEAP values higher than 0.55 diagnosed an individual as with possible normal auditory processing with 70.0% of sensitivity and 66.7% of specificity. Thus, if we consider both ears, we have values very close to the values of the ROC curve obtained for LE only (Table 4).

Thus, children with IHEAP values below 0.55 are more likely to present an altered central auditory processing. The lower this value the higher the likelihood of alteration. This fact indicates that including an IHEAP evaluation in the auditory processing screening tests is a valuable procedure[6,27]. Measures of sensitivity and specificity have been described as a useful instrument in diagnostic tests. Such information is vital for a correct diagnosis, because sensitivity and/or specificity values much lower than expected, for a valid diagnosis tool, can lead to erroneous conclusions and, possibly, inadequate interventions. In general, sensitivity and specificity values close to 80% are expected for the results to be considered a valid measurement of the performance of school-age children[28]. A limitation of this study is that it did not reach sensitivity and specificity rates higher than 80%. This fact can be associated with reduced sample size. More studies with larger sample sizes might confirm the findings.

In the present study, a lower occurrence of the inhibitory effect of the efferent system was identified in the group of children with auditory processing disorder with lower values than in the control group, in agreement with other findings in literature[6,7,21,27]. The difficulty of processing in-noise-speech signals, a common complaint of individuals with CAPD, could also be related with an alteration of the inhibitory function of the efferent system.

These results suggest to include the IHEAP evaluation, a quick, painless and safe procedure, into the protocols of auditory processing evaluations, in order to enhance clinical evaluation and make it more accurate and reliable and, consequently, ensure prompt diagnoses and interventions. The association between the results of the CAP evaluation and functioning of the efferent system also allows us to recommend the inclusion of evaluation of the efferent system into the protocol of CAP evaluation.

The discussion and importance of this topic are clear, in view of the increasing number of proposed protocols of CAP evaluation in the literature[28-30].

## CONCLUSION

In light of these findings, there was less occurrence of the inhibitory effect of the efferent pathway on otoacoustic emissions in children with central auditory processing disorder. The inhibitory effect of the efferent pathway was different between the ears, with lower performance in the left ear.

The recommended cutoff point value for the inhibitory effect of the efferent pathway is 0.55 dB. The higher this value the lesser the likelihood of occurrence of an auditory processing disorder. An inhibitory effect of the efferent pathway below 0.55 dB indicates more likelihood of occurring a central auditory processing disorder.

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