Research, Society and Development, v. 12, n. 7, e15712742662, 2023
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v12i7.42662

Wideband tympanometry and otoacoustic emissions in children with risk factors for hearing loss

Timpanometria de banda larga e emissões otoacústicas evocadas em crianças com e sem indicadores de risco para a deficiência auditiva

Timpanometría de banda larga y emisiones otacústicas evocadas en niños con o sin indicadores para deficiencia auditiva

Received: 07/11/2023 | Revised: 07/23/2023 | Accepted: 07/25/2023 | Published: 07/29/2023

Jéssica Raignieri
ORCID: https://orcid.org/0000-0002-4291-7592
Pontifícia Universidade Católica de São Paulo, Brazil
E-mail: jessicaraignieri@outlook.com.br
Doris Ruthy Lewis
ORCID: https://orcid.org/0000-0002-7110-147X
Pontifícia Universidade Católica de São Paulo, Brazil
E-mail: drlewis@uol.com.br
Ana Carla Oliveira Garcia
ORCID: https://orcid.org/0000-0003-4664-0073
Pontifícia Universidade Católica de São Paulo, Brazil
E-mail: anacarlagarciausa@gmail.com
Fabiana Cristina Mendonça de Araújo
ORCID: https://orcid.org/0000-0002-3778-1133
Universidade Federal do Rio Grande do Norte, Brazil
E-mail: fabiana.araujo.cm@ufrn.com
Tatiana Vieira Lira
ORCID: https://orcid.org/0009-0009-5692-2286
Pontifícia Universidade Católica de São Paulo, Brazil
E-mail: tatianavieiralira@hotmail.com
Barbara Cristina da Silva Rosa
ORCID: https://orcid.org/0000-0001-6585-1517
Universidade Federal de Sergipe, Brazil
E-mail: barbararosa@academico.ufs.br

Abstract
Introduction: Wideband tympanometry and evoked otoacoustic emissions can help audiologically monitor children birth to 3 years old, with or without risk factors for hearing loss. Objective: To study wideband tympanometry results in acoustic absorbance measures and transient evoked and distortion-product otoacoustic emission records during audiological monitoring. Method: This prospective observational study encompassed 58 children with and without risk indicators for hearing loss, with a mean age of 16.7 months. Data were obtained from the databases of four public maternity hospitals in São Paulo. Subjects were characterized as normal hearing or conductive hearing loss in the groups with and without risk factors for hearing loss. Results: Wideband absorbance at 1000 to 8000 Hz was verified to correlate the absorbance level with the transient evoked and distortion-product otoacoustic emission response levels at 1000 to 8000 Hz and wideband tympanometry. Normal hearing individuals' absorbance at 1500 Hz to 6000 Hz ranged from 0.92 to 0.98, in which the best results may be found. Conclusion: Absorbance values are higher in male and normal hearing children. Evoked otoacoustic emission levels agreed with absorbance measures – the greater the absorbance, the higher the transient evoked and distortion-product otoacoustic emission levels.
Keywords: Otoacoustic emissions, evoked; Audiological monitoring; Wideband tympanometry; Acoustic absorbance; Risk factors for hearing loss; Ear, middle; Hearing tests.

Resumo
Introdução: A Timpanometria de Banda Larga e as Emissões Otoacústicas Evocadas podem contribuir para o monitoramento audiológico de crianças recém-nascidas até três anos de idade, com e sem Indicadores de Risco para a Deficiência Auditiva (IRDA). Objetivo: estudar os resultados da Timpanometria de Banda Larga nas medidas de absorvância acústica e do registro das Emissões Otoacústicas Evocadas Transiente (EOAT) e Emissões Otoacústicas Produto de Distorção (EOAPD), durante o monitoramento audiológico. Método: Trata-se de estudo observacional, prospectivo em 58 crianças com e sem indicadores de risco para a deficiência auditiva, com idade média de 16,7 meses de vida, com informações obtidas de um banco de dados de quatro maternidades públicas de São Paulo. Os

sujeitos foram caracterizados em status auditivo normal e status auditivo alterado condutivo nos grupos com e sem indicadores de risco para a deficiência auditiva. Resultados: A Absorvância de Banda Larga nas frequências entre 1.000 a 8.000 Hz foi verificada para correlacionar o nível de absorvância e o nível de resposta das EOAT e EOAPD nas frequências de 1.000 a 8.000 Hz e a Timpanometria de banda larga. Observou-se que, na frequência de 1500 Hz a 6000 Hz, nos sujeitos com status auditivos normal, a absorvância variou entre 0,92 a 0,98, podendo estar, nessa faixa de frequência, os melhores resultados. Conclusão: os valores de absorvância são maiores no sexo masculino e em crianças com status auditivo normal. Houve concordância para os resultados de nível de Emissões Otoacústicas Evocadas e medidas de absorvância, sendo que, quanto maior a absorvância, maior o nível de EOAT e EOPD.
Palavras-chave: Emissões otoacústicas evocadas; Monitoramento audiológico; Timpanometria de banda larga; Absorvância acústica; Indicadores de risco para a deficiência auditiva; Orelha média; Testes auditivos.

Resumen
Introducción: Timpanometría de banda larga y las emisiones otacústicas evocadas pueden contribuir para la supervisión audiológica de niños recién nacidos hasta tres años de edad, con y sin indicadores de Riesgo para la Deficiencia Auditiva (IRDA). Objetivo: estudiar los resultados de la Timpanometría de Banda Larga en las mediadas de absorción acústica y del registro de las emisiones otacústicas evocadas transigente (EOAT) y emisiones otacústicas producto de distorsión (EOAPD), durante el monitoreo audiológico. Método: se trata de estudio de observación prospectivo en 58 niños con y sin indicadores de riesgo para la deficiencia auditiva, con una edad promedio de 16.7 meses de vida, con información obtenida de una base de datos de cuatro maternidades públicas de São Paulo. Se caracterizó a los sujetos en estado auditivo normal y estado auditivo alterado conductivo en grupos con y sin indicadores de riesgo para la deficiencia auditiva. Resultados: La absorción de Banda Larga en las frecuencias 1,000 a 8,000 Hz para correlacionar el nivel de absorción y el nivel de respuesta de las EOAT y EOAPD en las frecuencias de 1,000 a 8,000 Hz y la timpanometría banda larga se observó que en la frecuencia de 1500Hz a 6000Hz, en los sujetos con estatus auditivos normal, la absorción varía entre 0,92 a 0,98 pudiendo estas, en esa faja de frecuencia, los mejores resultados. Conclusión: Los valores de absorción son mayores en el sexo masculino y en niños con estatus auditivo normal. Hubo concordancia para los resultados de nivel de emisiones otacústicas evocadas y mediadas de absorción siendo que, cuanto mayor la absorción mayor el nivel de EOAT y EOPD.
Palabras clave: Emisiones otoacústicas evocadas; Monitoreo audiológico; Timpanometría de banda ancha; Absorbancia acústica; Factores de riesgo para la deficiencia auditiva; Oído medio; Pruebas auditivas.

1. Introduction

Literature data indicates that 60% of audiological changes in children are characterized by otitis media (Joint Committee on Infant Hearing, 2007). Among newborns, 67% of false-positive results in universal neonatal hearing screening (UNHS) are due to otitis media with effusion (Margolis et al., 2000).

Tympanometry is the main method to assess the middle ear, as it verifies its functioning through tympanic-ossicular chain mobility (Mishra et al., 2017). The outer and middle ears in newborns and infants have anatomical and functional differences from those of adults. The tympanic membrane is more horizontalized and has low-frequency resonance and greater resistance, which confirms the theory that newborns' and infants' tympanic-ossicular chains are driven by mass, instead of stiffness as in adults. Conventionally, tympanometry is performed with a 226-Hz pure-tone test. However, in the last decades, studies have pointed out the need for using probes with 1000-Hz pure-tone tests in infants. It must be highlighted that the predominating factor in the middle ears of adults and children above 6 months old is stiffness, while in newborns and infants, it is mass. Low-frequency pure-tone tests is more appropriate to assess stiffness, whereas probes in 1000-Hz pure-tone tests are more indicated when mass is the predominating factor (Vilela, 2017; Mishra et al., 2017).

Middle-ear resonance frequency is canceled according to the mass and stiffness in its structures. Hence, multi-frequency tympanometry assesses the resonance frequency of the middle-ear system, with a method in which the probe tone is swept by a series of frequencies (e.g., from 250 to 2000 Hz) (Vilela, 2017).

Tympanometry with 226-Hz probe tone was used to assess infants up to 6 months corrected age with conductive hearing loss. The results show that 98.1% of the children with otitis media were diagnosed as normal with the 226-Hz probe tone, resulting in a low sensitivity rate, at only 0.02%. The same study pointed out that the opposite also occurred. When the 1000-Hz probe tone was used, 99.4% of the children with otitis media had abnormal tympanometry results (0.99% sensitivity), and 87% of children with no conductive changes had normal tympanometry results (0.89% specificity) (Baldwin, 2006).

Wideband tympanometry provides acoustic absorbance results. This measure is obtained with wideband chirp or pure-tone stimuli, encompassing a wide frequency band, possibly ranging from 62 to 13000 Hz depending on the equipment. This measure also increases the possibility of studying anatomical and physiological variations in children's middle ears – which has helped this method stand out as a gold-standard examination to diagnose middle-ear affections (Margolis et al., 2000).

A study aimed to assess wideband acoustic immittance measures with 1000-Hz probe tone to predict middle-ear conditions in newborns in a hearing screening program. They selected 455 ears, and distortion-product otoacoustic emissions (DPOAE) were present in 375 and absent in the other 80. The DPOAE results were used as the gold-standard to identify sound conduction changes, thus defining them as conductive changes. The test indicated that newborns who passed the screening test (DPOAE) had a greater absorbance curve – hence, their external auditory meatus was free for sound to pass. The authors concluded that the ears that passed the hearing screening had greater sound absorption than those that failed the hearing screening (Feeney & Sanford, 2012).

Tympanograms were conducted at 226 Hz with absorbance in both normal and peak tympanic pressures in two groups of children to test whether wideband absorbance could be used to predict conductive hearing loss. Group 1 had 35 ears, with a mean age of 5.2 years, with suspected middle-ear effusion and ≥ 20 dBHL air-bone gap in pure-tone audiometry at one or more frequencies in audiometry. Group 2 (control) had 43 ears, with a mean age of 5.5 years, no history of middle-ear effusion in the previous 6 months, and audiometry and bone-conduction thresholds at ≤ 15 dBHL. The results showed that the ears with conductive hearing loss had less absorbance at 700 to 800 Hz than the normal hearing ears. The authors concluded that wideband absorbance at 700 Hz is an important predictor for a differential diagnosis in children with conductive hearing loss, as this analysis cannot be performed in conventional 226-Hz tympanometry (Keefe et al., 2012).

Research aimed to study the results of acoustic absorbance measures with wideband tympanometry in a sample of 229 newborns who passed UNHS (group I) and 11 who failed it (group II), all of them assessed before hospital discharge. The subjects were characterized as normal hearing (thresholds at ≤ 15 dBHL) and abnormal hearing (thresholds at ≥ 15 dBHL), according to the screening test results. Absorbance was analyzed with 11 frequency bands ranging from 226 to 8000 Hz, and the percentage analysis was performed between normal hearing subjects. The authors concluded that normal hearing subjects had higher absorbance values, as well as those with abnormal hearing at birth but who had normal results in follow-up after 15 days. The percentage curve can help analyze clinical data, especially concerning the frequency band from 749.15 to 2000 Hz, which can be considered the wider band to interpret absorbance results in newborns (Vilela, 2017).

Since small children have high middle-ear change rates, particularly those with risk factors for hearing loss (RFHL) and satisfactory responses in UNHS, they should be audiologically monitored from 6 to 36 months old with behavioral, electroacoustic, and electrophysiological measures.

This research considers the cross-check principle and the importance of early hearing loss diagnosis and intervention in children with and without RFHL.

2. Methodology

This quantitative, prospective, observational study was approved by the Research Ethics Committee under number 34707314.1.0000.5482. The study was conducted at the Children's Hearing Center – which belongs to the Department of Studies and Rehabilitation of Communication Disorders at the Pontifical Catholic University of São Paulo (DERDIC/PUC-SP), Brazil, and is accredited by the Ministry of Health as a Level-II Specialized Rehabilitation Center – and the laboratory of the Child Hearing research line of the Postgraduate Speech-Language-Hearing Studies Program at PUC-SP.

After the Research Ethics Committee approved the informed consent form, under number 4.07.00.00-03, it was signed by the children's parents/guardians.

Subjects

This study assessed 58 children with and without RFHL, aged 6 to 36 months old. Those with a history of RFHL at birth or failed in UNHS were referred to the Children's Hearing Center for diagnosis.

It is important to highlight that children with RFHL or who failed UNHS with OAE were submitted to automated auditory brainstem response (A-ABR) test before hospital discharge. Those without RFHL were screened with transient evoked otoacoustic emission (TEOAE) or DPOAE, and those who failed it underwent A-ABR test at the same moment.

Inclusion criteria

Children with and without RFHL who passed UNHS satisfactorily with either TEOAE or A-ABR records. An otorhinolaryngologist verified them with otoscopy before beginning the procedures. The exclusion criterion was auditory meatus agenesia. After the pure-tone audiometry assessment, the children were divided into two groups: Group 1 (G1) – normal hearing thresholds (thresholds at ≤ 15 dBHL); and Group 2 (G2) – examinations suggestive of conductive changes. Normal hearing thresholds were those whose responses were better than 20 dBnHL at 500, 1000, 2000, and 4000 Hz. When thresholds were worse than 20 dBnHL, the were assessed with bone conduction to distinguish between conductive and sensorineural hearing loss.

Data Collection Procedures

Audiological monitoring was carried out with visual reinforcement audiometry (VRA) in children 6 months to 2 years old and conditioned play audiometry (CPA) for those older than 2 years. Pure-tone audiometry was conducted at 500, 1000, 2000, and 4000 Hz with insert earphones. Those who did not accept the phones underwent the examination in free field, which characterizes a limitation of the study, as it obtained the response of the best ear. Subjects whose audiometry verified normal hearing thresholds were included in G1, whereas G2, the group with conductive changes, had the subjects with abnormal audiometry results.

Audiological monitoring was concluded with tympanometry using two single-frequency stimuli (226 and 1000 Hz) and one wideband stimulus (chirp) to verify middle-ear functioning based on the tympanogram and acoustic absorbance (Keefe et al., 2012; Aithal, Kei, Driscoll, Khan, & Swanston, 2015). The children were either asleep or awake on their parents' laps, and the first ear tested was the free one, depending on how they were positioned. Then, the OAE were recorded, first TEOAE and then DPOAE, in an acoustically treated room.

The tympanogram with 1000-Hz probe test was considered normal when the complacency peak was positive, according to Marchant et al. (1986) and Baldwin (2006).

TEOAE were evoked with non-linear click stimuli at 83 dB peSPL, with a 4-to-12-ms window. Responses were considered present when their general reproducibility was > 50%, signal-to-noise ratio of 3 dBSPL in the first two and 6 dBSPL in the last three bands, including 4000 Hz, and probe stability > 75%. Assessments were conducted at 1000, 1500, 2000, 3000, and 4000 Hz using two pieces of equipment (Al-Malky et al., 2022).

Then, the criterion DPOAE and criterion wideband tympanometry measures were recorded, presenting L1/L2 stimuli at 65/55 dBSPL with an F2/F1 ratio of 1.22, at 1000 Hz to 80000 Hz, totaling eight frequencies. The response criteria were negative noise levels at -3 and signal-to-noise ratio above 6 dB in at least 50% of these frequencies (Prieve, 2002).

VRA was conducted in an acoustically treated room with an Interacoustics audiometer, model AC-33, at 500, 1000, 2000, and 4000 Hz. It was conducted in free field or with earphones in children who accepted them. The minimum response levels were obtained with insert earphones. The normal standard was a minimum response level better than or equal to 20 dBHL at all frequencies in both free field and with insert earphones (Gorga et al., 2000).

CPA was conducted in an acoustically treated room with an Interacoustics audiometer, model AC-33, at 500, 1000, 2000, and 4000 Hz. Descending and ascending techniques were used to establish the minimum response levels at each frequency (Day et al., 2008). As with VRA, the normal standard in CPA was a minimum response level better than or equal to 20 dBHL.

Material

VRA and CPA were conducted with an Interacoustics AC 40 audiometer in an acoustically treated room, using ER-3A insert earphones when the child accepted them. If they did not accept them, the behavioral procedures were carried out in free field.

TEOAE, DPOAE, tympanometry, and wideband absorbance were carried out with Interacoustics equipment, model Titan.

3. Results

The association between absorbance and OAE in both ears at each frequency was assessed with adjusted regression models, in which absorbance was the response variables and the emission was the explanatory variable. The model was chosen depending on the results of the agreement analysis between absorbance and emission measures in both ears. When the two variables had a strong agreement, the model was adjusted considering the mean of the measures in each subject's two ears. Otherwise, the observations in both ears were considered, adopting a regression model that regards that measures in a single subject may be correlated (Neter et al., 2005).

The sample had 58 children, aged 6 to 36 months - 27 females and 31 males.

Thirty-eight (65.5%) of them had RFHL, with a prevalence of ICU stay for more than 5 days (19%), ototoxic drugs, and craniofacial anomalies (17.2%), and so on.

The absorbance verified in children with RFHL and conductive hearing loss was smaller than in the group with normal hearing and no RFHL at all frequencies, except for 8000 Hz.

After conducting conditioned visual reinforcement audiometry (VRA) and conventional tympanometry, the sample was categorized into two groups. Those whose audiometry indicated normal hearing thresholds were included in G1, while G2 had the subjects with abnormal audiometry – the group with conductive changes (Table 1).

Correlation coefficient values, shown in Table 1, are all above or equal to 0.80, thus indicating strong agreement between the absorbance measures in the two ears. The mean absorbance of each child's two ears was calculated, and the results shown in this section were obtained considering these mean values.

Table 1 – Descriptive summary of the absorbance in each hearing status category (normal hearing and conductive loss), obtained with the mean measures in both ears at 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz.

Frequency (Hz)	Hearing status	N	Mean	Standard deviation	Minimum	Median	Maximum
1000	Conductive	14	0.2333	0.0910	0.1146	0.2042	0.4494
	Normal	44	0.3883	0.1782	0.0488	0.3523	0.8208
1500	Conductive	14	0.2205	0.0985	0.0652	0.1958	0.4958
	Normal	44	0.5630	0.1989	0.1579	0.5734	0.9239
2000	Conductive	14	0.1735	0.1494	0.0003	0.1174	0.5082
	Normal	44	0.5901	0.1953	0.0461	0.6143	0.9710
3000	Conductive	14	0.2444	0.2820	0.0000	0.1463	0.9051
	Normal	44	0.5884	0.2119	0.1392	0.6227	0.9420
4000	Conductive	14	0.4195	0.2872	0.0000	0.3781	0.9680
	Normal	44	0.7197	0.1946	0.0797	0.7523	0.9866
6000	Conductive	14	0.3267	0.2715	0.0000	0.3012	0.9459
	Normal	44	0.5590	0.2612	0.0000	0.5762	0.9454
8000	Conductive	14	0.1983	0.2197	0.0006	0.1247	0.7414
	Normal	44	0.2545	0.1864	0.0000	0.2451	0.7684

Source: Authors.

An association analysis of absorbance was performed with the level of response to TEOAE in 58 children who attended audiological monitoring. Intraclass correlation values of TEOAE response levels in both ears and 95% confidence intervals of the coefficients at 1000, 1500, 2000, 3000, and 4000 Hz are shown in Table 3. These values indicate strong agreement of absorbance between the measures taken in the two ears at all frequencies.

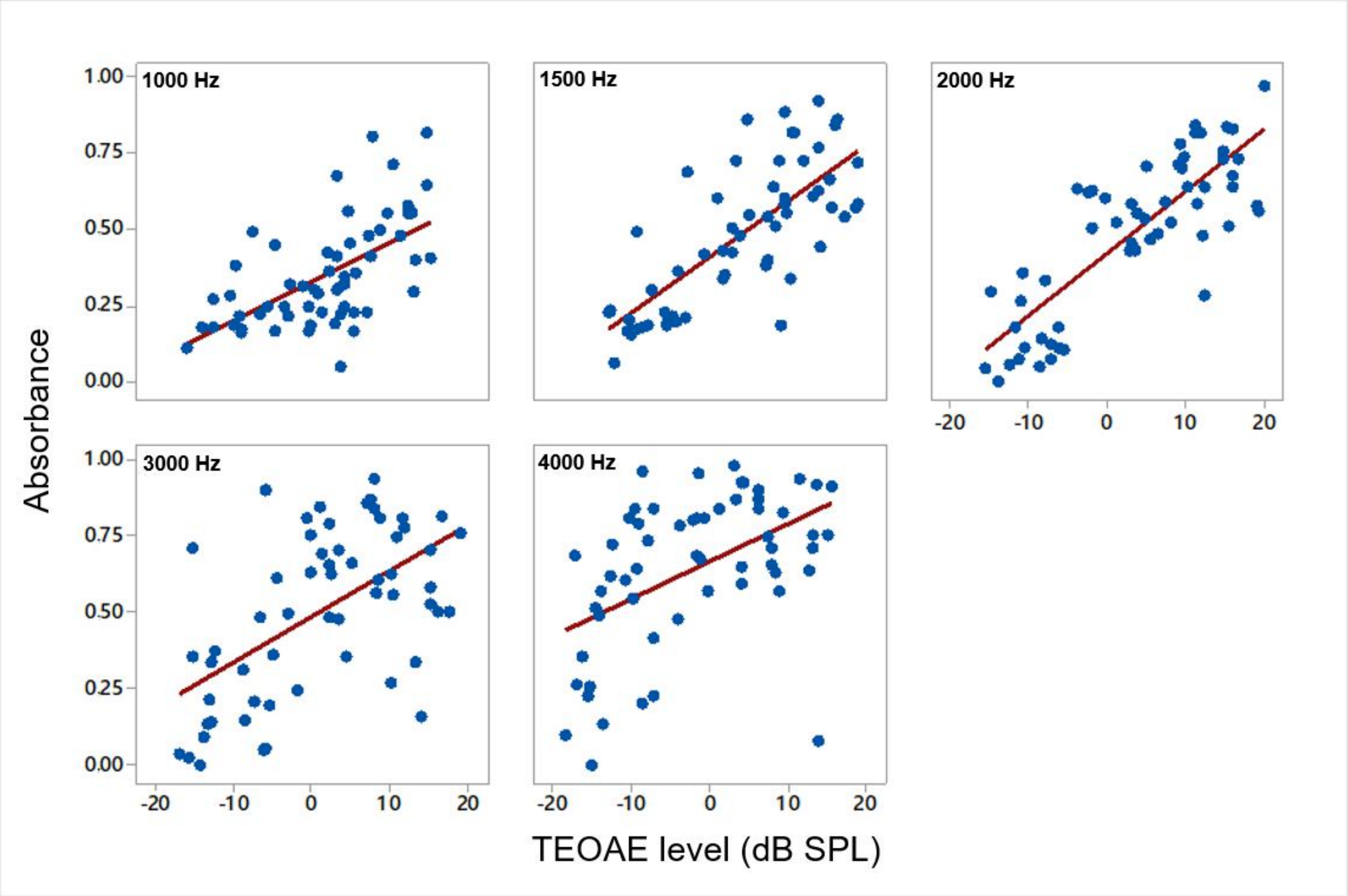
Table 2 – Association analysis of the absorbance with transient evoked otoacoustic emissions at 1000, 1500, 2000, 3000, and 4000 Hz.

Frequencies	Effect	Standard Error	p
1000 Hz	0.013	0.003	<0.001
1500 Hz	0.012	0.002	<0.001
2000 Hz	0.016	0.002	<0.001
3000 Hz	0.010	0.004	<0.001
4000 Hz	0.010	0.003	<0.001

Source: Authors.

Intraclass correlation coefficients of the DPOAE response levels in both ears and the 95% confidence intervals of the coefficients at 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz are shown in Table 4. These values indicate a strong agreement between DPOAE response levels in both ears at 1500, 4000, 6000, and 8000 Hz and a moderate agreement at the other frequencies.

Figure 1 - Dispersion diagrams of the absorbance and transient evoked otoacoustic emission levels (dB SPL) at each frequency.



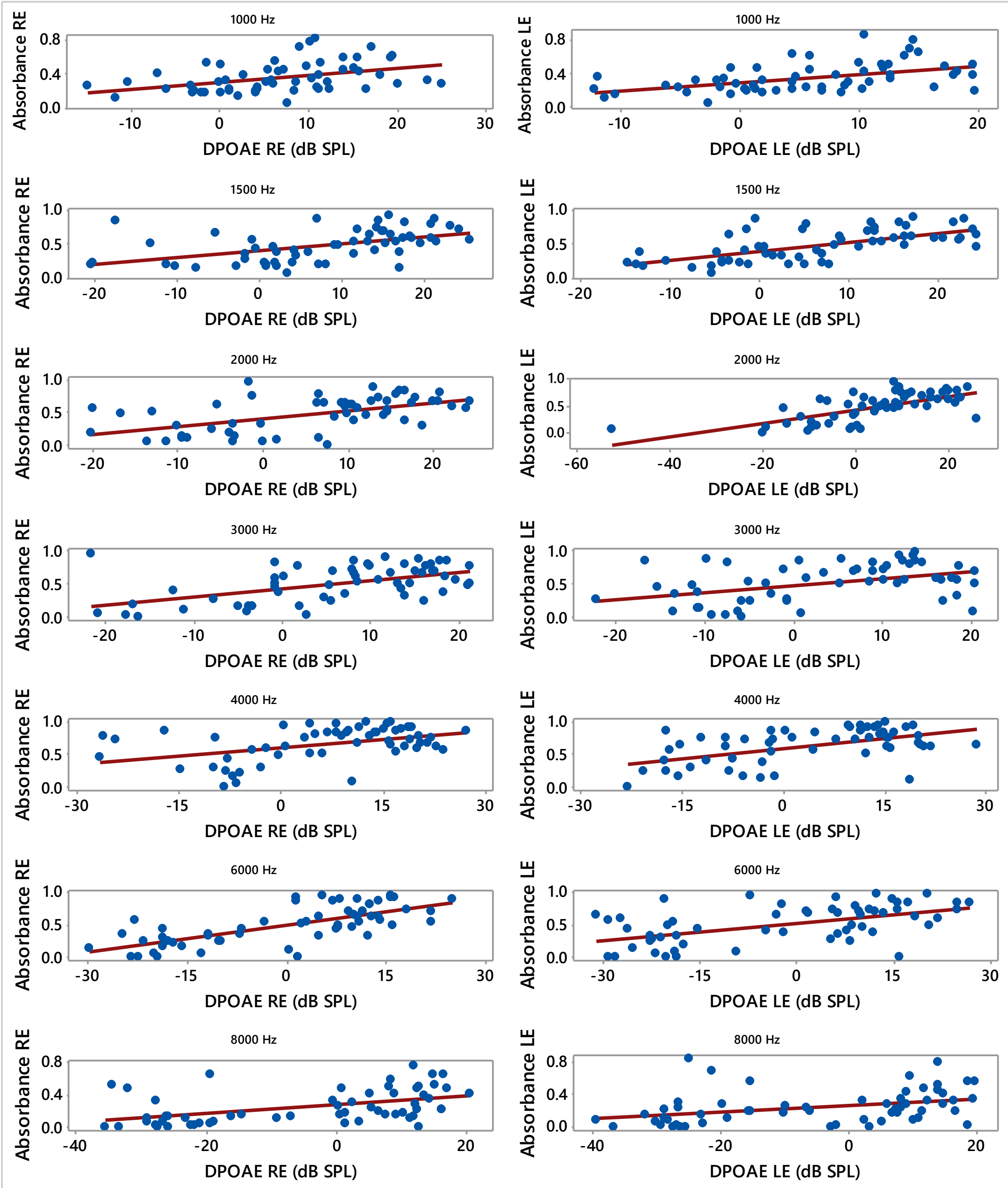
Source: Authors.

Table 3 – Association analysis of the absorbance with distortion-product otoacoustic emissions at 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz.

Frequencies	Effect	Standard Error	P
1000 Hz	0.011	0.003	< 0.001
1500 Hz	0.009	0.003	< 0.001
2000 Hz	0.010	0.002	< 0.001
3000 Hz	0.010	0.003	< 0.001
4000 Hz	0.008	0.003	< 0.001
6000 Hz	0.012	0.002	< 0.001
8000 Hz	0.005	0.001	< 0.001

Source: Authors.

Figure 2 - Dispersion diagram of absorbance and DPOAE levels in the right and left ears at 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz.



Source: Authors.

These values indicate strong agreement between DPOAE response levels measured in both ears at 1500, 4000, 6000, and 8000 Hz. There was a moderate agreement at the other frequencies.

4. Discussion

The study had a sample of 58 subjects, 27 female and 31 male children, thus ensuring a homogeneous study.

The 58 research subjects could perform free-field VRA, pointed out by Widen et al. (2000) as the gold-standard assessment. These authors obtained successful VRA performance in 95.6% of the subjects.

Russo and Santos (1994) highlighted that the sound stimuli in any type of behavioral assessment in children must be

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v12i7.42662

first presented in free field and then try to place insert earphones on them. Hence, they get acquainted with the stimuli and learn to respond to them when the sound is present. This study tried to insert the phones in the 58 children who attended audiological monitoring, but only 14 of them accepted them. As indicated by Agostinho and Azevedo (2005), besides ensuring more effective research of the minimum response levels, earphones obtain them monaurally, unlike free-field assessment, in which the best-ear response is verified.

Subjects with conductive changes in this study had smaller absorbance at all frequencies from 1000 to 8000 Hz than normal hearing ones. This agrees with discoveries in previous research, in which middle-ear dysfunctions led to significantly smaller absorbance than in normal middle ears in newborns and children (Rabinovich, 1997; Vander Werff et al., 2007; Hunter et al., 2008; Shahnaz, 2008; Sanford et al., 2009).

TEOAE are usually evoked with brief acoustic stimuli with a wide frequency range (click), enabling the stimulation of the whole cochlea. TEOAE are recorded in 98% of normal hearing individuals. Usually, the TEOAE spectrum obtained as response to click is broad, and more precise responses appear at 1000 to 4000 Hz (Shahnaz, 2008). This corroborates the present study, in which the TEOAE responses are more precise at 1000 to 4000 Hz.

Wideband absorbance represents the proportion of sound energy absorbed by the middle ear with wideband stimuli (such as click or chirp), covering a frequency range from 200 to 8000 Hz. Wideband absorbance ranges from 1.0 (meaning all energy is absorbed by the middle ear) to 0.0 (meaning the middle ear reflects all energy) (Shahnaz, 2008).

This study combined the TEOAE records and wideband absorbance values at 1000, 1500, 2000, 3000, and 4000 Hz, verifying a strong association between TEOAE response levels and absorbance measures at all frequency bands, as seen in Table 2. Every 1 dBSPL increased in TEOAE level was accompanied by a mean absorbance increase of 0.016 to 0.010 units per frequency. However, no study was found in the literature with the same results.

DPOAE records combined with wideband absorbance values at 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz revealed they were strongly associated. Some authors argue that subjects who passed DPOAE tests have greater energy absorbance than those who failed them (Shahnaz, 2008). These results are compatible with data found in the present study, as every 1dBSPL increased in the DPOAE level also increased the absorbance level by a mean of 0.005 to 0.012 units per frequency.

The sample obtained in this study is greatly important because it assesses the relationship between TEAOE and DPOAE associated with absorbance levels per frequency, showing that the results are correlated.

This study led to the conclusion that greater samples are needed to obtain more relevant comparisons.

5. Conclusion

The absorbance is greater in normal hearing children and smaller in those with conductive changes at all frequencies tested. TEOAE was accompanied by greater absorbance at all frequency bands (1000, 1500, 2000, 3000, and 4000 Hz) – every increase in 1 dBSPL also increased absorbance by 0.016 to 0.010 units per frequency. DPOAE was accompanied by greater absorbance at all frequencies (1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz) – every increase in 1 dBSPL also increased absorbance by 0.0012 to 0.005 units.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

References

Agostinho, C. V., & Azevedo, M. F. (2005). Visual reinforcement audiometry using earphones in children with 5-16 months. *Fono Atual*, 8(32), 25-31. https://pesquisa.bvsalud.org/portal/resource/pt/lil-451477

Aithal, S., Kei, J., Driscoll, C., Khan, A., & Swanston, A. (2015). Wideband absorbance outcomes in newborns: A comparison with high-frequency tympanometry, automated brainstem response, and transient evoked and distortion product otoacoustic emissions. *Ear and Hearing*, 36(5), e237-e250. 10.1097/AUD.0000000000000175

Al-Malky, G., et al. (2022). *Recommended procedure: Clinical application of otoacoustic emissions (OAEs) in children and adults*. Bathgate, England: British Society of Audiology.

Baldwin, M. (2006). Choice of probe tone and classification of trace patterns in tympanometry undertaken in early infancy. *International Journal of Audiology*, 45(7), 417-427. https://doi.org/10.1080/14992020600690951

Day, J., et al. (2008). *Visual reinforcement audiometry testing of infants: A recommended test protocol*. (Version 2.0) Newborn Hearing Screening Programme (England). https://research.manchester.ac.uk/en/publications/visual-reinforcement-audiometry-testing-of-infants-a-recommended-

Feeney, M. P., & Sanford, C. A. (2012). Application of wideband acoustic transfer functions to the assessment of the infant ear. In Kei, J., & Zhao, F. (Eds.). *Assessing Middle Ear Function in Infants* (pp. 131-161). San Diego, CA: Plural Publishing.

Gorga, M. P. et al. (2000). Identification of neonatal hearing impairment: distortion product otoacoustic emissions during the perinatal period. *Ear and Hearing*, 21(5), 400-424. https://journals.lww.com/ear-hearing/Abstract/2000/10000/Identification_of_Neonatal_Hearing_Impairment_.7.aspx

Hunter, L. L., Tubaugh, L., Jackson, A., & Propes, S. (2008). Wideband middle ear power measurement in infants and children. *Journal of the American Academy of Audiology*, 19(4), 309-324. 10.3766/jaaa.19.4.4

Jerger, J. (1970). Clinical experience with impedance audiometry. *Archives of Otolaryngology*, 92(4), 311-324. http://dx.doi.org/10.1001/ archotol.1970.04310040005002.

Joint Committee on Infant Hearing. (2019). Year 2019 Position Statement: Principles and guidelines for early hearing detection and intervention programs. *Journal of Early Hearing Detection and Intervention*, 4(2), 1-44. https://doi.org/10.15142/fptk-b748

Keefe, D. H., Sanford, C. A., Ellison, J. C., Fitzpatrick, D. F., & Gorga, M. P. (2012). Wideband Aural Acoustic Absorbance Predicts Conductive Hearing Loss in Children. *International Journal of Audiology*, 51(12), 880-891. https://doi.org/10.3109/14992027.2012.721936

Marchant, C. D., et al. (1986). Objective diagnosis of otitis media in early infancy by tympanometry and ipsilateral acoustic reflex thresholds. *The Journal of Pediatrics*, 109(4), 590-595. https://doi.org/10.1016/S0022-3476(86)80218-9

Margolis, R. H., Saly, G. L., & Hunter L. L. (2000). High-frequency hearing loss and wideband middle ear impedance in children with otitis media histories. *Ear and Hearing*, 21(3), 206-211. https://doi.org/10.1097/00003446-200006000-00003

Mishra, S. K., Dinger, Z., & Renken, L. (2017). Maturation of middle ear transmission in Children. *Hearing Research*, 344, 62-67. https://doi.org/10.1016/j.heares.2016.10.029

Prieve, B. A. (2002). Otoacoustic emissions in neonatal hearing screening. In: Robinette, M.S., Glattke, T.J. *Otoacoustic emissions: clinical applications* (2nd ed., p. 348-374). New York, NY: Thieme.

Rabinovich, K. (1997). Avaliação da audição na criança. In *Tratado de Fonoaudiologia*. (1st ed., pp. 265-283). Editora Roca.

Russo, I. E. P., & Santos, T. M. M. (1994). A avaliação audiológica de crianças de 0 a 2 anos de idade. In *Audiologia Infantil*. (4th ed). Cortez.

Sanford, C. A., et al. (2009). Sound conduction effects on DPOAE screening outcomes in newborn infants: Test performance of wideband acoustic transfer functions and 1- kHz tympanometry. *Ear and Hearing*, 30(6), 635-652. https://doi.org/10.1097%2FAUD.0b013e3181b61cdc

Shahnaz, N. (2008). Wideband reflectance in neonatal intensive care units. *Journal of the American Academy of Audiology*, 19(5), 419–429. 10.3766/jaaa.19.5.4

Vander Werff, K. R., Prieve, B. A., & Georgantas, L. M. (2007). Test-retest reliability of wideband reflectance measures in infants under screening and diagnostic test conditions. *Ear and Hearing*, 28(5), 669-681. http:// dx.doi.org/10.1097/AUD.0b013e31812f71b1.

Vilela, C. D. (2017) *Medidas de absorbância acústica por meio da timpanometria de banda larga em neonatos*. [Master's dissertation]. Pontifical Catholic University of São Paulo.

Widen, J. E., et al. (2000). Identification of neonatal hearing impairment: Hearing status at 8 to 12 months corrected age using a visual reinforcement audiometry protocol. *Earing and Hearing*, 21(5), 471-487. https://journals.lww.com/ear-hearing/Abstract/2000/10000/Identification_of_Neonatal_Hearing_Impairment_.11.aspx