Original Article

https://doi.org/10.1590/2317-6431-2017-1945

Audiology Communication Research
ISSN 2317-6431

Auditory steady-state response and behavioral evaluation in children between 6 to 48 monhts of age

Resposta auditiva de estado estável e avaliação comportamental em crianças de 6 a 48 meses

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ABSTRACT

Purpose: The objective of the following study was to verify how the thresholds obtained by ASSR can estimate the thresholds obtained by the VRA in children with normal hearing and hearing loss of different degrees. **Methods:** Were evaluated 41 children of both sex (28 boys and 13 girls), on ages between 18 and 48 months. The thresholds were obtained with ASSR with multiple and simultaneous stimulation on frequencies of 500, 1000, 2000 and 4000Hz. The thresholds were obtained with VRA on each ear separately on frequencies of 500, 1000, 2000 and 4000Hz. Were evaluated 82 ears, 20 with normal hearing and 62 with hearing loss. The correlation between the thresholds was calculated. **Results:** The findings of this study demonstrate that the thresholds didn't have a statistic relevant relation with variables of age and sex. Considering the mean, the eletrophysiological thresholds were higher than the behavioral. These findings suggest ASSR can determinate hearing thresholds objectively and with a high correlation with psychoacoustic thresholds obtained by the behavioral method. **Conclusion:** We recommend, however that another Brazilian studies be made, so it can be established a minimum criteria necessary for the planning and application of pattern protocols, contributing with diagnostic validation of ASSR technique.

Keywords: Hearing; Hearing loss; Audiometry evoked responses; Audiometry pure-tone; Child

RESUMO

Objetivo: Verificar como os limiares obtidos pelas respostas auditivas de estado estável (RAEE) podem estimar os limiares obtidos pela audiometria com reforço visual (VRA), em crianças com audição normal e perda auditiva de diversos graus. **Métodos:** Foram avaliadas 41 crianças de ambos os sexos (28 crianças do sexo masculino e 13 do sexo feminino), com faixa etária de 18 a 48 meses. Foram pesquisadas as frequências de 500, 1000, 2000 e 4000 Hz, em ambos os métodos de avaliação, e avaliadas as orelhas separadamente, totalizando 82 orelhas, sendo 20 com audição normal e 62 com perda auditiva. Os limiares foram analisados para calcular suas correlações e outras variáveis. **Resultados:** Os limiares não variaram significativamente, nem com a idade, nem com o sexo. Em média, foram observados limiares eletrofisiológicos maiores que os limiares comportamentais. **Conclusão:** A técnica da RAEE possibilita a determinação dos limiares auditivos objetivamente, com uma considerável correlação com os limiares psicoacústicos, concordando com a literatura. Recomenda-se, entretanto, a realização de novos estudos brasileiros, que visem ao estabelecimento de critérios mínimos necessários para o planejamento e aplicação de protocolos, com fins de padronização, contribuindo com a validação diagnóstica.

Palavras-chave: Audição; Perda auditiva; Audiometria de resposta evocada; Audiometria de tons puros; Criança

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Conflict of interests: No.
Authors' contribution: DGP: data collection and article writing; OGL: orientation during the research progress and article writing.
Funding: None.
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Received: December 08, 2017; **Accepted:** May 17, 2018

INTRODUCTION

Hearing loss may have negative impact on individuals' cognitive, social and emotional development[1]. The signs of hearing loss in very young children are subtle and difficult to be detected. The need to develop screening programs able to detect hearing loss as early as possible resulted from hearing loss identification in approximately 2-year-old children, when parents notice that their child does not speak[2].

The visual reinforcement audiometry (VRA) technique by Lidén and Kankkunen[3] may be used as viable method in the auditory assessment of babies who reached the chronological/development age of 5 or 6 months and show cervical control. The VRA is the gold standard technique used in the behavioral assessment of auditory sensitivity in young children (between 6 and 30 months old)[4].

Sometimes, when children do not accept the headphones in the clinical practice, it is necessary performing free-field tests. Thus, it becomes difficult detecting unilateral hearing losses, as well as defining the asymmetric bilateral hearing loss degree, since responses from the healthiest ear are recorded[5].

Moreover, VRA is not viable to assess hard-to-test populations or populations presenting compromised cognitive development, since it may generate unreliable results[6]. Another issue reported in the literature refers to the fact that the conditioning necessary to apply the technique to assess children younger than 1 year old is more difficult to be accomplished; thus, responses may not be reliable[6-8].

In these cases, it is essential using objective, electrophysiological techniques because they are able to provide important additional information, even after reliable behavioral responses are recorded.

Auditory Steady-State Response (ASSR) is a new technique aimed at identifying electrophysiological thresholds through specific frequencies (500 to 4000 Hz) in an objective way; thus, it does not require conditioning the patient. The technique allows making a reliable, complete and considerably rapid assessment, which is essential to help making interventions as soon as the hearing loss is diagnosed during childhood[9,10].

Therefore, the aim of the present study was to investigate if the auditory thresholds obtained by the Auditory Steady-State Response (ASSR) can estimate the auditory thresholds obtained by the Visual Reinforcement Audiometry (VRA), in children with normal hearing and hearing loss, thus investigating the clinical applicability of ASSR in children`s audiological evaluation.

METHODS

Transversal, descriptive, diagnostic-validation study.

The sample comprised 6-to-48-month-old boys and girls showing normal hearing level and hearing loss, whose parents or legal guardians agreed to spontaneously participate in the study. Children diagnosed with auditory neuropathy were excluded from the study.

Data were collected through the application of subjective and objective audiological procedures in behavioral and electrophysiological assessments, respectively.

The subjective audiological assessment consisted of visual reinforcement audiometry using an *Interacoustics* audiometer, model 227. The tonal audiometry was performed in an acoustic booth equipped with supra-aural TDH-39 headphones; frequencies 500, 1000, 2000 and 4000Hz were assessed. The herein used stimuli - modulated pure tone ("warble") - were presented to the children through descending and ascending techniques. Minimal hearing level up to 15 dB HL was considered normal[11].

The CHATR EP 200/Otometrics equipment was used to apply the ASSR protocol. Before the examination started, it was necessary cleaning patients' skin with abrasive paste and 70% alcohol. Next, disposable electrodes were fixed, which were positioned as Fpz (active electrode), M1 (reference) and M2 (ground). The electrode impedance was kept below 5 KΩ, whereas the impedance balance between electrodes did not exceed 2 KΩ.

The stimuli used in the current study consisted of modulated pure tones, which were bilaterally and simultaneously presented to the patients. Frequencies 500, 1000, 2000 and 4000 Hz were simultaneously (both ears) and individually (each ear) assessed by applying 8 100% amplitude-modulated and 20% frequency-modulated stimuli (4 in each ear) at modulation frequencies 97, 81, 95, 88 Hz to the right ear, and at 92, 77, 84 and 85 Hz to the left ear.

The stimuli were presented to the children through ER-3A insert earphones. The initial intensity was 50dB SPL, and it decreased in 10 dB steps until children's response was no longer observed in the automatic equipment protocol (Child Asleep Test).

Data were analyzed through descriptive and inferential statistics. Graphs of individual profiles were generated by taking into consideration all the thresholds of the two methods in order to provide a general view between the corresponding ASSR and VRA thresholds. The descriptive analysis (mean, standard deviation, minimum, median, maximum and percentiles) applied to the absolute thresholds found through ASSR and VRA, as well as the difference between the two methods, was calculated for each frequency. Data were presented through tables and graphs.

Scatterplots were generated in order to investigate the association between the two methods. The inferential analysis took into consideration the simple linear regression model in order to study the association between the VRA and ASSR techniques

It is worth emphasizing that the electrophysiological thresholds recorded in dB SPL were converted into dB HL, according to the ANSI S3-6 standard "Specification for Audiometers"; and according to ISO 389.2 "The insert earphone calibration standard", by applying -6; -0; -3 and -6dB corrections to 0.5; 1; 2 and 4kHz tones, respectively. It was done in order to compare the electrophysiological results to visual reinforcement audiometry results, which were recorded in dB HL.

The research was approved by the Human Research Ethics Committee of the Health Sciences Center (CCS - Centro de Ciências da Saúde) at UFPE, under CAAE (Certificate of Presentation for Ethical Condideration) n. 25622913.4.0000.5208, according to National Health Council Resolution 196/96.

RESULTS

Ten (10) children showing normal hearing and 31 children showing hearing loss of the 41 children selected to participate in the current were assessed - 13 girls (32%) and 28 boys (68%). All 41 children allowed performing VRA using TDH-39 supra-aural headphones, fact that enabled individually assessing both ears. Eighty-two (82) ears were assessed, in total: 20 were normal and 62 showed different hearing loss degrees. Children's age ranged from 18 to 48 months, and the mean age was 39.7 months (Table 1).

Regarding the thresholds obtained in the two evaluation methods, the majority of the thresholds in ASSR were higher than those found in VRA, except for 3 individuals: individual 4 (OD, 4KHz), individual 20 (EO, 4KHz) and individual 26 OE, 4KHz). The individual profiles of the thresholds obtained in both evaluation methods for each frequency (0.5, 1, 2 and 4 KHz) are shown in Figure 1.

Concerning the electrophysiological thresholds and the behavioral thresholds, some negative values were found between the mean difference in the thresholds obtained by the two methods of evaluation, indicating electrophysiological thresholds better than those of the VRA, in some circumstances. The bias confidence intervals ranged from 2 dB (4 kHz) to 26 dB (1 kHz). The mean (bias) difference between electrophysiological thresholds and behavioral thresholds is shown in Table 2.

Figure 2 shows the simple linear regression graphs correlating the thresholds collected through VRA and ASSR at frequencies 0.5, 1.0, 2.0 and 4.0 kHz. It is possible seeing linear relation between the thresholds of the two techniques through the inclination of the longer line towards high frequencies, fact that shows discrete approximation between the ASSR and VRA thresholds.

It is possible seeing that the model was mathematically well-applicable, since it provided highly-significant data such as the R^2 value. All the frequencies showed statistically significant association between the audiometry and ASSR thresholds.

DISCUSSION

The aim of the current study was to assess how electrophysiological thresholds obtained through ASSR can estimate behavioral thresholds obtained through VRA in 6-to-48-month-old children. Thus, the ASSR findings concerning all 41 selected children were compared to those of conditioned audiometry (82 ears, in total), since TDH39 headphones were used during VRA to separate the results of the ears.

The age of the herein assessed children (between 18 and 48 months old) explains the fact that they allowed using headphones to perform the VRA, since this age group is more prone to accept the use of headphones during conditioned audiometry testing[12-16].

However, the thresholds in the present study were not analyzed according to age, since there was not great age variability in the sample – most of the children were older and showed mean age 39.7 months (Table 1). Other studies addressed this relation, but they did not find statistically significant difference in age thresholds through VRA[17,18].

The variable "sex" was just subjected to descriptive analysis in the present study and it was not correlated with the herein found thresholds. The population comprised 68.3% (n = 28) boys and 32.7% (n = 13) girls (Table 1). According to the literature, there is no relation between sex and the thresholds found in the techniques[19-21].

However, female patients showed slight tendency to present better thresholds than male patients. Auditory steady-state responses tended to show lower latency and larger amplitude in female patients. The small size of the head and the shorter length of the auditory pathway would lead to lower latency and to increased neural fiber synchronization discharge[21].

Regarding the individual electrophysiological and behavioral threshold values recorded at each frequency (Figure 1), the ASSR thresholds were overall higher than the VRA ones, except for tree individuals.

This finding can be attributed to the age of the herein tested children (48 months old). It is believed that older children may show worse responses to VRA because the visual reinforcement in this age group would no longer be attractive enough to keep children actively involved until the end of the test. Overall, the 4KHz frequency is the penultimate frequency tested in each ear during the assessment; in addition, the left ear is the last to be assessed, fact that may explain the current findings[18].

It is known that there were differences between the thresholds of the two techniques, since they are distinct assessment methods and each of them presents specific features. Some aspects inherent to the assessment nature and to the herein applied methodology are directly related to the difference in findings between techniques.

Table 1. Distribution according to age (mean, standard deviation, minimum, median and máximum) and sex of the population (n=41)

Variables	Sex			Idade (meses)			
	n	M	F	Mean ± SD	Minimum	Median	Máximum
Normal hearing	10	7	3	40 ± 6	36	36	48
Hearing loss	31	21	10	40 ± 11	18	48	48
Total	41	28	13	40 ± 10	18	48	48

Subtitle: n = subject number; M = masculine; F = feminine; SD = Standard Deviation

Table 2. Descriptive statistcs of mean between ASSR thresholds and VRA's described on each frequency (n=82). Are described the values of mean, standard deviation (SD), median, mínimum, máximum and confidence interval of (CI95)

Variables (dB HL)	Freq. (KHz)	Mean	SD	Median	Mínimum	Máximum	CI95
	0.5	**12**	**4**	15.	-6	25	**4-20**
	1.0	**18**	**4**	18	10	30	**10-26**
	2.0	**14**	**4**	12	2	22	**6-22**
	4.0	**12**	**5**	15	-6	20	**2-21**

Subtitle: dB HL = hearing level decibel; Freq = frequency; KHz = Quilohertz; SD = Standard Deviation; CI95 = Confidence interval of 95%

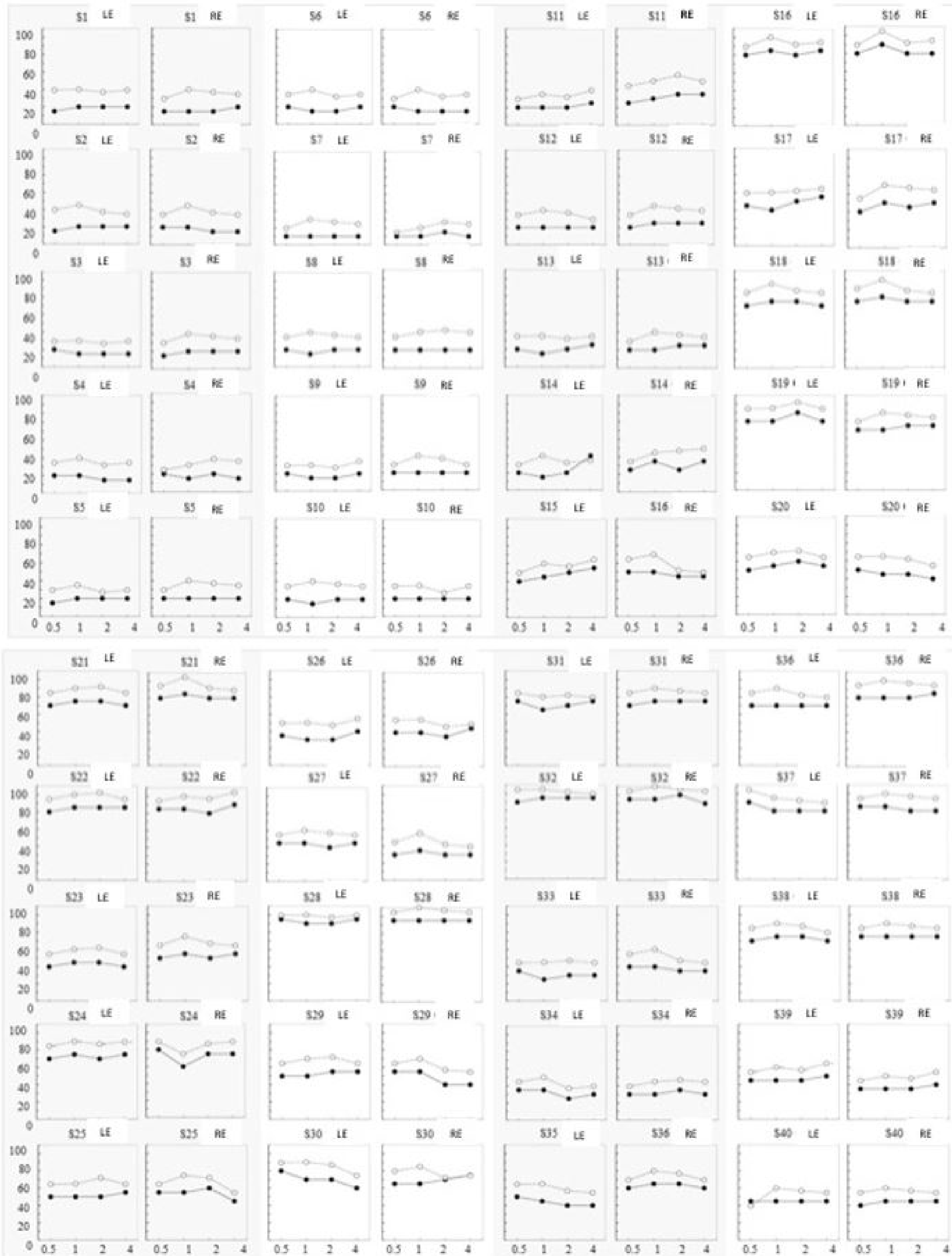

Figure 1. Individual profiles of the hearing thresholds obtained by both methods (VRA and ASSR) for each frequency (0,5, 1, 2 e 4KHz), (n=41). The hearing thresholds are represented on Y axis, while the hearing thresholds obtained by VRA and ASSR are represented on X aix. The hearing thresholds of each subject, ear and frequency of evaluation with RAEE technique are plotted with open circles The hearing thresholds of each subject, ear and frequency of evaluation with RAEE technique are plotted with closed circles
Subtitle: RE = right ear; LE = left ear; S = subject

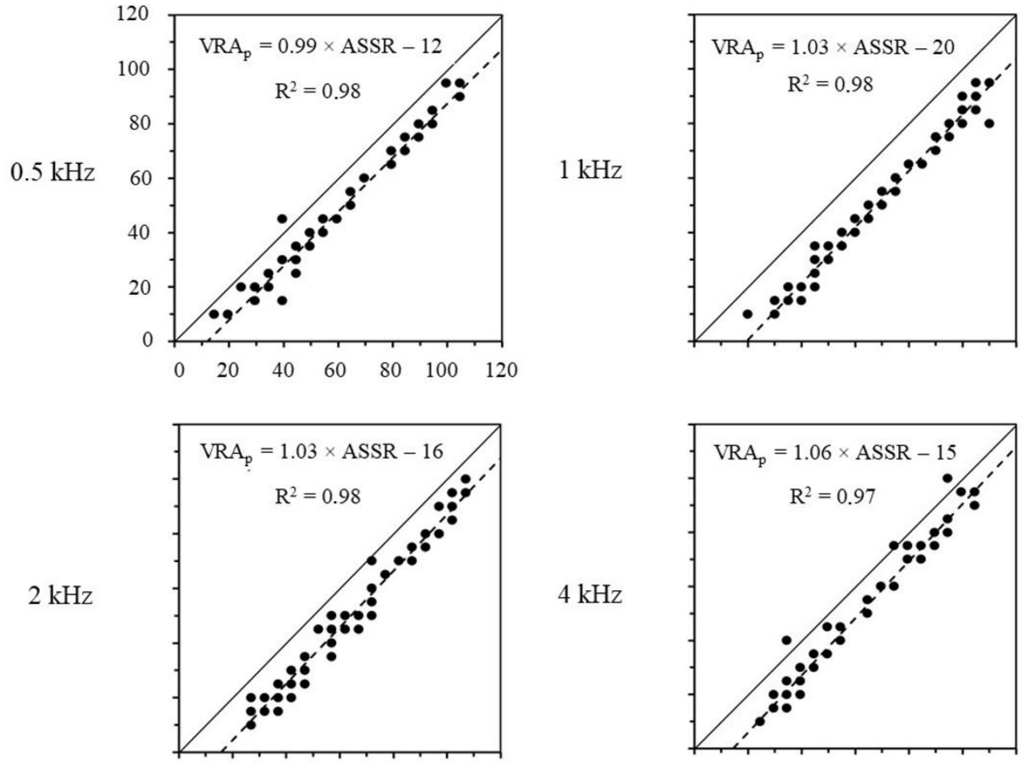

Figure 2. Linear regression grafics correlating ASSR findings with VRA's on 500, 1000, 2000 e 4000Hz frequencies. The 45° lines are represented by solid lines (—) while the regression lines are represented by dashed lines (---). Above each grafic are the linear regression equation and the correlation coeficient R2

Subtitle: ASSR = thresholds obtained by Auditory Steady State Responses; VRA = threshold prediction by auditory visual reinforcement audiometry; KHz = Quilohertz; R^2 = correlation coefficient

Generally, the electrophysiological thresholds are higher than the behavioral ones. The means of the ASSR thresholds in the present study were higher than the means of the VRA thresholds (Table 2). The explanation for these differences is inherent to the grand-averaging technique used to extract the auditory potential evoked by the noise[(22)].

In other words, the ASSR requires longer grand-averaging time, mainly in older children who have greater difficulty to cease movements and to relax. It happened in the present study, since the mean age of the herein assessed children was 39.7 months. Thus, it is possible saying that the ASSR technique clearly tends to present higher thresholds than the VRA technique, as well as that, sometimes, it shows threshold levels above the normality standard[(10,15,23)].

However, some cases in the current study showed better ASSR than VRA thresholds, and it generated negative value in the difference between the two thresholds (Table 2). These findings were also reported in other studies comparing ASSR and VRA[(10,15)].

It is necessary taking into consideration that the behavioral assessment of children may generate values higher than the true auditory thresholds, since the development of hearing and motor skills leads to more mature responses[(4,10,15)].

The mean differences between the electrophysiological and behavioral thresholds in the current study were up to 18 dB (CI from 10 to 26); there was similar difference between the thresholds found in normal individuals and in those presenting hearing loss (Table 2, Figure 2). Similar mean differences were reported in other studies. Aoyagi et al.[(24)] found differences ranging from 4 to 16 dB; Rance and Rickards[(25)] recorded differences from 10 to 15dB. The mean difference lies within the expected range, since it is below the limit (approximately 30dB) described in the literature[(21,26-30)].

Some authors[(13)], however, found differences ranging from -2 to 4dB, whereas other authors[(16)] found differences from 2 and 4dB; both differences were smaller than that found between the assessment methods used in the present study. It may have happened because the aforementioned studies were conducted with populations affected by hearing loss. Studies have shown smaller differences between tonal thresholds and ASSR when there is hearing loss; the higher the hearing loss degree, the smaller the difference[(14,25-27)].

However, it is worth noticing that, for some authors[(9,10)], the decreased threshold difference dues to the recruitment phenomenon found in individuals with sensorineural hearing loss, as well as that this phenomenon can be prevented from happening by amplifying the grand-averaging in the acquisition protocol.

The mean of the differences between ASSR and VRA at the herein studied frequencies showed discrete approximation in the high frequency values. Figure 2 shows the inclination of the longer line towards high frequencies; it is possible seeing approximation between the VRA and ASSR threshold values if one takes into consideration frequencies such as 2 and 4KHz. This result was also reported by other studies[(9,22,28)].

Higher responses were recorded at frequencies 500 Hz and 1000 Hz, on average, than at other analyzed frequencies.

This discrepancy was reported in previous studies and several factors contributed to this phenomenon[15,16,22,28].

The main reason for this type of finding may due to the intrinsic characteristic of the technique, i.e., the response to acute frequencies is clearer and closer to the threshold for physiological reasons; which is similar to what happens in the brainstem auditory evoked potential[10].

There is differentiated neural activation at 500 Hz. There is greater dispersion in the phase of the neurons responding to this frequency, which is caused by the slow sound wave change in the basilar membrane, fact that allows the wave to reach a wider region in the cochlea. It results in decreased signal-record amplitude, which was also reported for brainstem auditory evoked potentials at the specific frequency 0.5 kHz[9,16].

Other factors have been taken into consideration, namely: the electrophysiological noise at low frequencies, due to the predominance of such noise at the low ones[28]; as well as the masking effect from the environmental noise on these frequencies in studies whose data were collected in acoustically-untreated environments[9,26].

The difference and the variability of this difference or standard deviation, i.e., how much the values, found through the differences between thresholds, vary around the mean, are equally important. The standard deviations of the means of the differences ranged from 5 dB (Table 2), thus corroborating the study by Calil et al.[20], who found variation from 5.4 to 12.6 dB.

CONCLUSION

The ASSR technique allowed simultaneously and objectively estimating auditory thresholds simultaneously in both ears; the herein estimated thresholds showed above 90% correlation with psychoacoustic thresholds.

It is known that diagnostic tests are not perfect, but there is probability of correctness. Thus, it is necessary conducting further research focused on assessing the accuracy of ASSR sensitivity to varying hearing loss degrees in children, so that it can be implemented in evidence-based clinical assessments. It is also important setting minimum criteria aimed at the planning and application of protocols for standardization purposes, in order to contribute to the diagnostic validation.

REFERENCES

1. Pupo AC, Balieiro CR, Figueiredo RSL. Estudo retrospectivo de crianças e jovens com deficiência auditiva: caracterização das etiologias e quadro audiológico. Rev CEFAC. 2008;10(1):84-91. http://dx.doi.org/10.1590/S1516-18462008000100012.

2. Novaes BCAC, Versolatto-Cavanaugh MC, Figueiredo RSL, Mendes BCA. Fatores determinantes no desenvolvimento de habilidades comunicativas em crianças com deficiência auditiva. J Soc Bras Fonoaudiol. 2012;24(4):335-341. http://dx.doi.org/10.1590/S2179-64912012000400008. PMid:23306686.

3. Lidén G, Kankkunen A. Visual reinforcement audiometry. Acta Otolaryngol. 1969;67(2):281-92. http://dx.doi.org/10.3109/00016486909125453. PMid:5374646.

4. Hoshino ACH, Cruz DR, Goffi-Gomez MVS, Befi-Lopes DM, Matas CG, Fortunato-Tavares TM, Tsuji RK. Evolução audiométrica em usuários de implante coclear multicanal. Rev CEFAC. 2013;15(2):297-304. http://dx.doi.org/10.1590/S1516-18462012005000037.

5. Correa BM, Lautenschlager L, Tochetto T, Pacheco LC, Maggi CR, Gonçalves MS. Triagem auditiva: concordância entre os métodos comportamental e objetivo. Rev CEFAC. 2012;14(1):84-9. http://dx.doi.org/10.1590/S1516-18462011005000051.

6. Didoné DD, Kunst LR, Weich TM, Ourique AC, Franceschi CM, Tochetto T. Acompanhamento do desenvolvimento da função auditiva em crianças sem e com indicadores de risco para a surdez. Distúrb Comun. 2011;23(3):317-23.

7. Versolatto-Cavanaugh MC, Novaes B, Martinez MAN, Mendes B. Audiometria de reforço visual em crianças de cinco a nove meses de idade: repercussões do desenvolvimento sensório motor e características individuais. Distúrb Comun. 2009;21(2):207-17.

8. Lee CY, Jaw FS, Pan SL, Hsieh TH, Hsu CJ. Effects of age and degree of hearing loss on the agreement and correlation between sound field audiometric thresholds and tone burst auditory brainstem response thresholds in infants and young children. J Formos Med Assoc. 2008;107(11):869-75. http://dx.doi.org/10.1016/S0929-6646(08)60203-X. PMid:18971156.

9. Lins OG. Audiometria fisiológica tonal utilizando respostas de estado estável auditivas do tronco cerebral [tese]. São Paulo: Escola Paulista de Medicina, Universidade Federal de São Paulo; 2002.

10. Santos AGA. Respostas auditivas de estado estável em crianças de 6 a 48 meses com audição normal [tese]. Recife: Programa de Pós-graduação em Neuropsiquiatria e Ciências do Comportamento, Universidade Federal de Pernambuco; 2010.

11. Northern JL, Downs MP. Audição em crianças. São Paulo: Manole; 1989.

12. Organização Mundial de Saúde. Relatório do Grupo Informal de Planejamento e Programação de Prevenção de Surdez e Perda Auditiva. Genebra: OMS; 1991.

13. Luts H, Desloovere C, Kumar A, Vandermeersch E, Wouters J. Objective assessment of frequency-specific hearing thresholds in babies. Int J Pediatr Otorhinolaryngol. 2004;68(7):915-26. http://dx.doi.org/10.1016/j.ijporl.2004.02.007. PMid:15183583.

14. Attias J, Buller N, Rubel Y, Raveh E. Multiple auditory steady-state responses in children and adults with normal hearing, sensorineural hearing loss or auditory neuropathy. Ann Otol Rhinol Laryngol. 2006;115(4):268-76. http://dx.doi.org/10.1177/000348940611500404. PMid:16676823.

15. Han D, Mo L, Liu H, Chen J, Huang L. Threshold estimation in children using auditory steady-state responses to multiple simultaneous stimuli. ORL J Otorhinolaryngol Relat Spec. 2006;68(2):64-8. http://dx.doi.org/10.1159/000091091. PMid:16428896.

16. Rodrigues GRI, Lewis DR. Potenciais evocados auditivos de estado estável em crianças com perdas auditivas cocleares. Pró-Fono R. Atual. Cient. 2010;22(1):37-42. http://dx.doi.org/10.1590/S0104-56872010000100008.

17. Parry G, Hacking C, Bamford J, Day J, Parry G. Minimal response levels for visual reinforcement audiometry in infants. Int J Audiol. 2003;42(7):413-7. http://dx.doi.org/10.3109/14992020309080050. PMid:14582637.

18. Lemos ICC, Tomé T, Silva JNG, Lauris JRP, Lopes AC. Avaliação do nível mínimo de audição em lactentes de seis a 24 meses por meio do reforço visual. Rev Soc Bras Fonoaudiol. 2007;12(2):86-91. http://dx.doi.org/10.1590/S1516-80342007000200004.

19. Ferraz OB, Freitas SV, Marchiori LLM. Análise das respostas obtidas por potenciais evocados auditivos de estado estável em indivíduos

normais. Rev Bras Otorrinolaringol. 2002;68(4):480-6. http://dx.doi.org/10.1590/S0034-72992002000400005.

20. Calil DB, Lewis DR, Fiorini AC. Achados dos potenciais evocados auditivos de estado estável em crianças ouvintes. Distúrb Comun. 2006;18(3):391-401.

21. Picton TW, Van Roon P, John MS. Multiple auditory steady state responses (80-101 Hz): effects of ear, gender, handedness, intensity and modulation rate. Ear Hear. 2009;30(1):100-9. http://dx.doi.org/10.1097/AUD.0b013e31819003ef. PMid:19125032.

22. Perez-Abalo MC, Savio G, Torres A, Martín V, Rodríguez E, Galán L. Steady state responses to multiple amplitude-modulated tones: an optimized method to test frequency-specific thresholds in hearing-impaired children and normal-hearing subjects. Ear Hear. 2001;22(3):200-11. http://dx.doi.org/10.1097/00003446-200106000-00004. PMid:11409856.

23. Martínez-Beneito P, Morant Ventura A, Pitarch Ribas MI, García Callejo FJ, Marco Algarra J. Potenciales evocados auditivos de estado estable a multifrecuencia como técnica de determinación de umbrales auditivos. Acta Otorrinolaringol Esp. 2002;53(10):707-17. http://dx.doi.org/10.1016/S0001-6519(02)78367-2. PMid:12658837.

24. Aoyagi M, Kiren T, Furuse H, Fuse T, Suzuki Y, Yokota M, Koike Y. Pure-tone threshold prediction by 80-Hz amplitude-modulation following response. Acta Otolaryngol Suppl. 1994;511:7-14. http://dx.doi.org/10.3109/00016489409128294. PMid:8203246.

25. Rance G, Rickards F. Prediction of hearing threshold in infants using auditory steady-state evoked potentials. J Am Acad Audiol. 2002;13(5):236-45. PMid:12120716.

26. Rance G, Roper R, Symons L, Moody LJ, Poulis C, Dourlay M, Kelly T. Hearing thresholds estimation in infants using auditory steady-state responses. J Am Acad Audiol. 2005;16(5):291-300. http://dx.doi.org/10.3766/jaaa.16.5.4. PMid:16119256.

27. Duarte JL. A utilização da resposta auditiva de estado estável para estimar limiares auditivos em indivíduos com perda auditiva neurossensorial [dissertação]. Bauru: Faculdade de Odontologia de Bauru, Universidade de São Paulo; 2007.

28. Picton TW, Dimitrijevic A, Perez-Abalo MC, Van Roon P. Estimating audiometric thresholds using auditory steady-state responses. J Am Acad Audiol. 2005;16(3):140-56. http://dx.doi.org/10.3766/jaaa.16.3.3. PMid:15844740.

29. Beck RMO, Ramos BF, Grasel SS, Ramos HF, Moraes MF, Almeida ER, Bento RF. Comparative study between pure tone audiometry and auditory steady-state responses in normal hearing subjects. Braz J Otorhinolaryngol. 2014;80(1):35-40. PMid:24626890.

30. Farias VB, Sleifer P, Pauletti LF, Krimberg CF. Correlação dos achados do potencial evocado auditivo de estado estável e da avaliação auditiva comportamental em lactentes com perda auditiva sensorioneural. CoDAS. 2014;26(3):226-30. http://dx.doi.org/10.1590/2317-1782/201420140491. PMid:25118919.