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Standardization of Latency and Amplitude Values of Short, Middle and Long Latency Auditory Evoked Potentials in Adults

Andressa Pelaquim[1] Milaine Dominici Sanfins[2] Marco Aurélio Fornazieri[3,4]

[1] Health Sciences Center, State University of Londrina (UEL), Londrina, Brazil
[2] Department of Audiology, Albert Einstein Instituto Israelita de Ensino e Pesquisa, São Paulo, Brazil
[3] Department of Clinical Surgery, State University of Londrina (UEL), Londrina, Brazil
[4] Department of Clinical Surgery, Pontifical Catholic University of Paraná, Londrina, Brazil

Address for correspondence Andressa Pelaquim, MSc, Health Sciences Center, Londrina State University (UEL), Robert Koch, 60. Londrina, PR, 86038350, Brazil (e-mail: andressa.pelaquim@uel.br).

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Abstract

Introduction Auditory processing refers to the efficiency and effectiveness with which the central auditory nervous system uses auditory information. Middle- and long-latency auditory evoked potentials are objective electrophysiological tests that can complement the diagnosis of alterations involving central auditory processing.

Objective To standardize latency and amplitude values for short-, middle-, and long-latency auditory evoked potentials in adults with normal hearing thresholds.

Methods This is a cross-sectional study. Thirty-three adults with normal hearing thresholds, without hearing complaints, and with normal central auditory processing were evaluated. All underwent basic audiological evaluation, central auditory processing assessment, and short-, middle-, and long-latency auditory evoked potentials.

Results Absolute latency and interpeak values for middle- and long-latency auditory evoked potentials were lower than internationally suggested. However, for the brainstem auditory evoked potential, the means were within the range considered as normal, as suggested in the equipment.

Conclusion The present study provided measurements of normal latencies and amplitudes for short-, middle-, and long-latency auditory evoked potentials in adults.

Keywords
- electrophysiology
- hearing
- adults
- audiology

Introduction

The research of auditory evoked potentials (AEPs) is an objective method, which seeks, through an acoustic stimulus, to assess the neuroelectric activity of the auditory nerve to the cerebral cortex.[1] They are widely used clinically to check the detection threshold of acoustic stimuli, to assess the functional integrity of the central auditory pathway, to monitor the maturation of the auditory pathway in babies, and to check whether sound information adequately reaches the auditory cortex.[2,3]

Electrophysiological exams are performed on specific equipment that has mechanisms to generate stimuli, amplify, convert, and process data.[4] All equipment has its normative values, based on studies in different populations.

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In Brazil, many types of equipment that perform AEPs are no longer marketed, as is the case of the Biologic Navigator (Pleasanton, California, USA). Therefore, the SmartEP equipment (Intelligent Hearing Systems, Miami, FL, USA), which has software for the realization of short-, middle-, and long-latency AEPs, started to be used by many professionals in clinics and universities for differential audiological assessment. It appears, however, that there is a lack of normative studies on latency and amplitude values for all potentials in this equipment. The manufacturer has reference values for Auditory Brainstem Response (ABR) and long latency auditory evoked potential (LLAEP) based on some studies. In the case of LLAEP, it is possible to verify that the tables with the reference values were adapted and that the data were obtained through a sample composed of children, adolescents, and adults, without any analysis by age group. However, in the case of middle latency auditory evoked potentials (MLAEPs), there are no reference values for the latencies of the components, as well as for the value of the Na-Pa interamplitude.

Webster[5] studied the ABR latencies and amplitude values for the Smart EP in the Canadian adult population. However, no similar studies were found in the Brazilian population that include, in addition to ABR, middle- and long-latency AEPs.

The present work is justified not only by the scarcity of studies with this equipment, but mainly by the methodological quality of those that have already been published. Scientific rigor is essential to achieve a result of excellence, and it is possible to notice that this rigor was not applied during the choice of data by the manufacturer to compose the normal reference values. It is also known that the sample size, sample selection, and how the study was designed directly influence the reliability of the results obtained.

Furthermore, it is observed in AEP standardization studies that issues involving central auditory processing are not considered. However, it is known through studies that adult individuals can have auditory processing disorder (APD) even without having specific complaints. In the present study, we performed a complete assessment of the Auditory Processing (AP) in all individuals in the sample, to rule out alterations in auditory skills that could interfere with the reliability of the results.

Therefore, the aim of the present study was to standardize the latency and amplitude values for short-, middle-, and long-latency AEPs in adults with normal hearing thresholds.

Materials and methods

This is a cross-sectional study that is part of a larger project and was approved by the Ethics Committee for Research in Human Beings, protocol: 95467918.2.0000.5231. Data were collected in an audiological clinic specializing in hearing and balance (Audioclínica – Institute of Hearing and Balance), which has a partnership with UEL, in the city of Londrina, Paraná, Brazil, between August 2018 and August 2019. All participants were instructed and signed the informed consent (IC).

From an invitation sent by email to the UEL academic community, 147 adults attended the audiological clinic. Only 33 individuals were considered able to participate in the research. Another 10 individuals were recruited in the audiological clinic.

A total of 43 adults of both genders, aged between 18 and 55 years old, participated in the study. All participants had normal meatoscopy; normal hearing thresholds, with airway values between 250 and 8,000 Hz < 25 dBHL and bone conduction between 500 and 4,000 Hz up to 15 dBHL[6]; tympanometry with type A curve, with compliance between 0.3 and 1.65 ml and peak within - 100 to $+$ 200 daPA, associated with the presence of ipsilateral and contralateral acoustic reflexes present and at normal levels in both ears[7]; and without auditory complaints such as tinnitus, ear fullness, vertigo, difficulty in understanding speech in silence and in noise, difficulty in auditory memory and/or inattention complaints.

Individuals with APD, mental disorders, neurological disorders, genetic syndromes, neurodegenerative diseases, with a history of otological alteration or middle ear pathology, with type I or II diabetes, hypertension, who underwent previous speech therapy, who used or had used drugs and/or alcohol were excluded from the study.

Procedures

The execution of the procedures was divided into two steps:

First Stage

a) Audiological anamnesis

The audiological anamnesis consisted of questions related to hearing complaints, auditory processing, lifestyle habits, and past and current health history.

b) Immitanciometry

The immitanciometry was performed with the equipment OTOFLEX 100 (GN Otometrics, Copenhagen, Denmark) and with a 226 Hz tone probe. The acoustic reflexes were investigated in both ears at sound frequencies of 500 Hz, 1,000 Hz, 2,000 Hz, and 4,000 Hz.[7]

c) Pure tone audiometry and speech audiometry

Audiometry was performed in an acoustic booth, using the audiometer MADSEN ITERA II (GN Otometrics, Copenhagen, Denmark), two-channel, calibrated to the ANSI-69 standard and supra-aural headphones, model TDH39 (Vibrasom Tec Acústica, São Paulo, Brazil), as a stimuli transducer. Airway auditory thresholds were investigated at frequencies from 250 Hz to 8,000 Hz. Subsequently, speech audiometry was performed, using hands-free speech, consisting of the percentage index of speech recognition (PISR) and the speech recognition threshold (SRT).

d) Central Auditory Processing Assessment

The behavioral evaluation of central auditory processing followed a minimum protocol, as recommended by the American Speech-Language-Hearing Association (ASHA)[8] and the American Academy of Audiology.[9] The examination was performed in a soundproof booth, using the

audiometer MADSEN ITERA II (GN Otometrics, Copenhagen, Denmark), two-channel, calibrated to the ANSI-69 standard and supra-aural headphones, model TDH39 (Vibrasom Tec Acústica, São Paulo, Brazil), as a stimuli transducer. The following tests were used: speech in noise test, dichotic digits test binaural separation and interaction, frequency pattern test, random gap test detection (RGTD), and masking level difference (MLD).
The normative values suggested by Pereira et al.,[10] Auditec,[11] and Mendes et al.,[12] were considered in the auditory processing exam. Only individuals with normal audiological assessment and auditory processing assessment were selected to participate in the second stage of the study.

Second Stage

a) Electrophysiological Assessment

The electrophysiological evaluation was performed with the SmartEP equipment (Intelligent Hearing Systems, Miami, FL, USA), and with ER – 3A insert transducers (Natus Medical, Pleasanton, CA, USA) in an acoustic and electrically prepared room. The individuals were accommodated in a reclining chair and in a comfortable position. The skin of each subject was cleaned using a Nuprep abrasive paste (Weaver and Company, Aurora, CO, USA) in the places where the Solidor (São Paulo, Brazil) disposable electrodes were fixed. The electrodes were fixed using Tem 20 electrolytic paste (Weaver and Company, Aurora, CO, USA) to improve the electrical conductivity.

The patients were instructed to keep their eyes closed during the assessment to avoid artifacts; however, awake. All assessments were performed monaurally under two conditions: right ear assessment and left ear assessment.

The assembly of the electrodes followed the standards established by the International Electrode System (IES) 10–20 for their correct use. The electrode impedance remained < 3 kOhms, and the difference between the electrodes was < 2 kOhms. The parameters for the acquisition of AEPs used in the present study were based on international recommendations,[13–15] with some changes in accordance with the protocols suggested by the SmartEP equipment.

The electrophysiological assessment was performed in three steps:

a1) Auditory Brainstem Response (ABR) with non-verbal click stimulus

Sample description

A total of 43 individuals (86 ears) of both genders, aged between 18 and 55 years old, participated in the study. Among the participants, 31 (72.1%) were female and 12 (27.9%) were male, with a mean age of 26 years old (range: 20 to 47 years old).

Description of the procedure

The active electrode (positive) was placed in the frontal region (Fz); the reference electrodes (negative) were placed on lobes A1 and A2, and the ground electrode was placed on the forehead, laterally to Fz.

The ABR was investigated with a click stimulus, at an intensity of 80 dBHL, in rarefied polarity and in a presentation rate of 21.1/sec. High-pass filters of 100 Hz and low-pass of 3,000 Hz, rectangular envelope, 100K gain and 12 milliseconds window were used. Two collections containing 2,000 averaged and artifact-free stimuli were performed.[13] The waves were reproduced to confirm the presence of response. After performing the exams, the waves were visually identified and three waves were marked by the examiner: I, III, and V. The waves were evaluated for absolute latencies, interpeak latencies I-III, III-V, and I-V and amplitudes, according to the reference values suggested by the equipment manual: wave I = 1.65 milliseconds, wave III = 3.76 milliseconds, wave V = 5.61 milliseconds; interpeak values: I–III = 2.11 milliseconds, III–V = 1.86 milliseconds, and I–V = 3.94 milliseconds.

In the analysis of the amplitude of the I–V interpeak, a cutoff value for the V/I amplitude ratio > 0.5 µV was used, indicating a normal functioning auditory system.[16]

a2) Middle latency auditory evoked potential with click stimulus

Sample description

A total of 31 individuals (62 ears) participated in the study. Among the participants, 19 (61.29%) were female and 12 (36.37%) were male, with a mean age of 27 years old (range: 20 to 47 years old). Two women were excluded from the sample, as it was not possible to place the electrodes in the coronal region of the scalp due to their hair.

Description of the procedure

Solidor brand disposable electrodes were used. The electrodes were arranged as follows: ground electrode on the forehead (A); active electrodes (positive) in the right and left coronal region (C4 and C3); and the reference electrodes (negative) on the lobes of the right and left ears (A2 and A1), using the two channels of the equipment.

Middle latency auditory evoked potential was researched with click stimulus, 70 dBHL intensity, rarefied polarity, and presentation rate of 9.8/sec. Filters for the high-pass acquisition of 20 Hz and low-pass of 1,500 Hz, rectangular envelope, high-pass analysis filters of 10 Hz and low-pass of 100 Hz, a gain of 75K, and with a window of 70 milliseconds were used. Two collections containing 1,000 averaged and artifact-free stimuli were performed, and the responses were recorded twice in each condition (C3A1, C4A1, C3A2, and C4A2) to increase the reliability of the comparisons.[14]

An analysis of the latency of the components Na, Pa, Nb, and Pb and of the interamplitude of Na-Pa and Nb-Pb was performed. The component was the first negative peak identified between 16 and 30 milliseconds; Pa was the next largest positive peak observed between 30 and 45 milliseconds; Nb was the second negative peak between 46 and 56 milliseconds, and Pb was the second negative peak identified between 55 and 65 milliseconds. The responses of the Na-Pa

interamplitude on one side and the other that did not exceed 50% in the same individual were normal.[14]

a3) Long latency auditory evoked potential with tone burst (nonverbal) stimulus

Sample description

A total of 33 individuals (66 ears) participated in the study. Among the participants, 21 (63.63%) were female and 12 (36.37%) were male, with a mean age of 27 years old (range: 20 to 47 years old). In the analysis of the LLAEP component, 3 individuals had absence of the P300 cognitive component in the right ear, and 1 individual had bilateral absence.

Description of the procedure

The active electrodes were positioned at the vertex (Cz) channel A and channel B at (Fz) to perform the acquisition of four waves (two rare stimuli and two frequent stimuli), in both positions, to verify the reproducibility of the waves. The reference electrodes were placed on the right (A2) and left (A1) lobes and the ground electrode was placed laterally to the Fz.

The tone burst stimulus was randomly elicited at the intensity of 75 dBHL, at the frequency of 1,000 Hz (frequent stimulus) and 2,000 Hz (rare stimulus), with a window of 533 milliseconds and stimulation rate of 1.1/sec, through the oddball paradigm with a total of 300 stimuli, including 80% frequent stimuli (1,000 Hz) and 20% rare stimuli (2,000 Hz). The 1–30 Hz high-pass and low-pass filter was used. Collections with artifact values $>$ 10% were repeated to obtain a reliable response and with fewer artifacts. Subjects were instructed to keep their eyes closed during the procedure and to count out loud the number of rare stimuli. In this way, the examiner was able to ensure that the patients performed the task correctly.

After training with an evaluator experienced in the analysis of AEP, 5 components were visually identified and manually marked by the researcher: P1, N1, P2, N2, and P300. The components were identified in the trace corresponding to the rare stimulus, being analyzed for latency and amplitude values, as suggested by McPherson.[17] All markings were supervised by a researcher experienced in hearing electrophysiology.

Data analysis and statistics

To analyze the results, the study population was stratified according to gender and ear.

The absolute latencies, interpeak and amplitudes of the ABR, the latencies of the Na, Pa, Nb, and Pb components, and the Na-Pa and Nb-Pb interamplitude of the MLAEP and the latencies and amplitudes of the LLAEP components were described as means accompanied by standard deviation (SD). The *t*-test was used in the ABR and LLAEP to compare the mean latencies of the right and left ear, after being checked for normality by the Shapiro-Wilk test. Data that did not follow a normal distribution were analyzed using the nonparametric Mann-Whitney test. P-values $<$ 0.05 were considered significant. A 95% confidence interval (CI) was considered. Data were analyzed using the IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA).

Table 1 Analysis of the values of absolute latencies, interpeak latencies, and amplitudes of the brainstem auditory evoked potential according to ear and gender

Ear	Gender		Wave I (ms)	Amplitude (μV)	Wave III(ms)	Amplitude (μV)	Wave V (ms)	Amplitude (μV)	Interpeak I-III (ms)	Amplitude (μV ratio)	Interpeak III-V (ms)	Amplitude (μV ratio)	Interpeak I-V (ms)	Amplitude (μV ratio)
RE	F	Mean	1.58	0.39	3.73	0.33	5.49	0.42	2.15	0.94	1.77	1.65	3.90	1.44
		SD	0.09	0.19	0.14	0.17	0.19	0.15	0.14	0.40	0.14	1.20	0.17	0.85
	M	Mean	1.57	0.26	3.73	0.25	5.59	0.41	2.15	0.98	1.86	1.80	4.01	1.69
		SD	0.10	0.11	0.20	0.11	0.86	0.17	0.72	0.42	0.40	0.78	0.13	0.89
		p – value	0.40	0.29	0.42	0.34	0.86	0.52	0.72	0.79	0.40	0.93	0.53	0.99
LE	F	Mean	1.59	0.37	3.75	0.31	5.53	0.43	2.15	0.94	1.78	1.68	3.93	1.40
		SD	0.11	0.16	0.15	0.15	0.18	0.15	0.13	0.56	0.12	0.89	0.17	1.08
	M	Mean	1.65	0.27	3.92	0.22	5.67	0.39	2.26	0.88	1.75	1.92	4.01	1.68
		SD	0.11	0.10	0.97	0.07	0.17	0.13	0.13	0.40	0.15	0.59	0.18	0.90
		p – value	0.41	0.20	0.03*	0.19	0.22	0.46	0.04*	0.64	0.51	0.75	0.35	0.31

Abbreviations: μV, microvolt; F, female; LE, left ear; M, male; ms, milliseconds; *N*, 43 adults; RE, right ear; SD, standard deviation.
*Statistically significant values ($p \leq 0.05$) – Student *t* test; Mann-Whitney test.

Table 2 Analysis of absolute latency and interamplitude values of middle-latency auditory evoked potential regarding ear and gender

			Components (ms)				Interamplitude (μV)	
Derivation	Gender		Na	Pa	Nb	Pb	Na-Pa	Pb-Nb
A2C4	F	Mean	15.44	28.38	41.76	53.14	1.08	0.55
		SD	2.19	4.15	6.55	9.66	0.35	0.35
	M	Mean	16.28	28.32	40.58	52.90	1.13	0.57
		SD	2.37	3.72	4.41	4.31	0.38	0.22
		p-value	0.09	0.41	0.04*	0.78	0.46	0.49
A2C3	F	Mean	15.92	28.34	42.11	51.36	1.06	0.45
		SD	2.38	4.11	6.00	11.77	0.39	0.31
	M	Mean	16.62	28.65	40.88	47.26	1.02	0.48
		SD	2.43	4.00	4.93	14.05	0.38	0.28
		p-value	0.23	0.29	0.01*	0.25	0.89	0.12
A1C3	F	Mean	16.29	29.71	44.58	44.79	0.83	0.43
		SD	2.01	3.37	7.06	6.88	0.30	0.26
	M	Mean	17.25	29.38	43.68	55.28	0.88	0.52
		SD	2.84	4.19	7.29	9.92	0.43	0.35
		p-value	0.33	0.74	0.53	0.61	0.54	0.56
A1C4	F	Mean	16.36	29.71	44.58	55.79	1.06	0.54
		SD	2.21	3.37	7.06	6.88	0.36	0.30
	M	Mean	17.07	29.38	43.68	55.28	1.10	0.54
		SD	2.87	4.19	7.29	9.92	0.47	0.38
		p-value	0.33	0.74	0.53	0.61	0.72	0.95

Abbreviations: μV, microvolt; F, female; M, male; ms, milliseconds; *N*, 31 adults; SD, standard deviation.
*Statistically significant values ($p \leq 0.05$) – Student *t* test; Mann-Whitney Test.

Results

The normative values of the short-, middle-, and long-latency potentials for the SmartEP equipment can be seen in ►**Tables 1**, **2**, and **3**.

In the ABR study, the means found were similar to the values suggested for adults by the equipment. We observed absolute latencies between 1.50 and 1.65 milliseconds for wave I, between 3.73 and 3.92 milliseconds for wave III, and between 5.49 and 5.67 milliseconds for wave V. As for the interpeak latencies, we obtained the I–III interpeak between 2.15 and 2.26 milliseconds; III–V between 1.77 and 1.86 milliseconds; and I–V between 3.90 and 4.01 milliseconds. In the left ear, females had lower latency for wave III and for interpeak I–III (►**Table 1**).

The analysis of the MLAEP showed lower latencies compared with what is suggested internationally.[14] There was a difference in the mean latencies of the Nb component in leads A2C4 and A2C3. As for the values of the interamplitude of Na –Pa, these were from 0.83 μV to 1.13 μV. (►**Table 2**).

In LLAEP, lower latency values were found for all components compared with internationally suggested values.[17] The amplitude of the P1 component was smaller in the right ear for females. Furthermore, a lower latency was observed for the P2 component in the right ear and a difference in amplitude for males in the left ear (►**Table 3**).

Discussion

The analysis of latencies and amplitudes of the short-, middle-, and long-latency AEPs in the present study enabled the creation of normative data to be used by Brazilian audiologists and otolaryngologist who use the SmartEP – IHS. The normative values present in the equipment manual are commonly used, in which it is not possible to know the condition and criteria adopted in data collection, nor how the compilation of data from other studies was performed, as can be seen in the tables in the manual of the equipment.

The present study presents an important differential: our results were extracted from individuals without alterations in auditory thresholds and without alterations in auditory skills, as we included the auditory processing evaluation to identify APD, since adults do not complain and often do not notice difficulties in memory, attention, auditory

Table 3 Analysis of absolute latency and interamplitude values of the long-latency auditory evoked potential, regarding ear and gender

COMPONENTS												
EAR	Gender		P1 (ms)	Amplitude (μV)	N1 (ms)	Amplitude (μV)	P2 (ms)	Amplitude (μV)	N2 (ms)	Amplitude (μV)	P300 (ms)	Amplitude (μv)
RE	F	Mean	53.20	3.82	105.40	6.17	169.25	2.92	209.70	11.12	283.85	10.82
		SD	15.00	1.66	16.92	4.02	31.61	2.10	29.55	7.71	99.73	8.04
	M	Mean	60.42	2.31	105.42	4.80	171.00	2.61	210.83	7.41	294.25	7.29
		SD	17.92	1.71	14.54	2.83	31.75	2.77	27.67	3.39	94.88	3.59
		p -value	0.35	0.01*	0.95	0.22	0.02*	0.92	0.98	0.78	0.26	0.26
LE	F	Mean	54.30	4.17	102.00	5.25	168.55	2.72	207.55	11.49	296.45	11.64
		SD	16.48	2.27	25.92	3.98	38.98	2.13	38.62	8.82	73.97	8.63
	M	Mean	52.25	3.16	105.92	3.58	203.58	1.71	203.58	8.04	298.42	7.80
		SD	15.74	1.45	21.54	1.24	14.91	1.25	14.91	3.36	28.36	3.53
		p - value	0.75	0.43	0.87	0.11	0.48	0.02*	0.48	0.52	0.48	0.48

Abbreviations: μV, microvolt; F, female; M, male; ms, milliseconds; *N*, 33 adults; SD, standard deviation.
*Statistically significant values ($p \leq 0.05$) - Student's *t*-test; Mann-Whitney Test

discrimination, etc. In this way, we eliminated the possible interference of APD in the results. In addition, we excluded individuals with existing illnesses, which could also contaminate the findings.

The main parameter analyzed in the ABR is latency.[13] In the present study, there was a difference in the latency value for wave III and interpeak I–III, in the left ear, regarding gender (►**Table 1**). It is observed that women tend to have waves with lower absolute latencies and interpeak compared with men, due to greater hearing sensitivity and higher body temperature.[18] A similar study performed with the SmartEP – IHS showed differences in wave V latency and in the I–V interpeak in the right ear in females.[19] The hypothesis that can be raised for this difference is that, in the present study, the authors considered a broader age group, from 9 to 66 years old, and that, therefore, elderly people were included in the sample.

The second parameter analyzed in ABR is amplitude.[13]

The studies found in the literature that used the SmartEP – IHS, did not analyze the values of the amplitudes of waves I, III, and V, nor the amplitude ratio of interpeak I–III, III–V, and I–V.[19,20] We found only an international standardization study for the SmartEP – IHS in adults, which analyzed the amplitudes of waves I and V and interpeak I–V.[5] In the present study, the amplitude of all waves and interpeak were analyzed. The amplitude ratio value found in the present study (1.55 μV) corroborated what is recommended in the literature,[16] which must be > 0.5 μV, indicating the absence of retrocochlear alteration.

The main application of ABR in the clinical routine is the differentiation of cochlear and retrocochlear alterations. In addition to latency values, the analysis of wave V and I–V interpeak amplitudes can help in the diagnosis of abnormalities present in the auditory nerve and in the brainstem.[21] The difference between the amplitude value of wave I and wave V has been investigated and reported in cases of children with autism.[22] In autism, the literature reports that the amplitude of wave I is greater than the amplitude of wave V, after 2 years of age. However, after the maturation period of the brainstem auditory pathway, it is expected that the amplitude of wave V be greater than that of wave I.[23] Therefore, we recommend that the analysis of the amplitudes of waves I, III, and V, the comparison between the amplitudes of waves I and V, as well as the amplitude ratio of interpeak I–III, III–V, and IV, especially of interpeak I–V, be included in the differential audiological diagnosis.

For ABR absolute latencies and interpeak intervals, we recommend using ± 2 SDs in relation to the mean in the present study, based on the Gaussian probabilistic model.[24] According to the model, using only 1 SD would represent 68.27% of the population, while using 2 SDs would represent 95.45%. Thus, the goal is to seek greater representation and fewer misdiagnoses and misconduct.[25]

The standardization of normality values for the MLAEP was performed considering the four main derivations analyzed in the literature and regarding gender. In the present study, a significant difference was observed only for the latency of the Nb component, in leads A2C4 and A2C3. As

for the interamplitude analysis, Na-Pa presented greater interamplitude, in all derivations, in relation to Pb-Nb (►**Table 2**). The literature recommends analyzing only the Na-Pa interamplitude, as the Pb component is highly variable in individuals with normal hearing.[14] In this sample, there was the presence of the Pb component in all individuals. In all derivations, there was no electrode effect nor ear effect, which are changes likely to be found in MLAEP.[26]

No normative studies performed with the SmartEP – IHS for the MLAEP were found in the literature. Thus, the MLAEP is a potential that still lacks standardization regarding latency and interamplitude values for this equipment.

The LLAEP, on the other hand, is the most used potential to assess central auditory pathways, at all ages and for various pathologies. In the present study, there was a difference in the latency of the P2 component in the right ear and in the amplitude of the left ear in males. The P1 component showed a difference regarding gender in the right ear (►**Table 3**). Previous studies found no difference in latency and amplitude values between genders and ears for the LLAEP components.[27,28] Thus, the differences found for the P2 component suggest that there was an influence of the state of attention and alertness of the individual during the evaluation.[24] As for the P1 component, data from one study showed greater latency and amplitude for P1 in males.[29] The P1 component represents the entrance of the sound stimulus in the auditory cortex and, therefore, the anatomical difference that exists between the male and female skull can influence the propagation of the sound wave. Another hypothesis would be the non-homogeneity of the sample regarding gender.

In a Brazilian study of standardization of LLAEP components P1, N1, P2, N2 and P300, in the SmartEP–IHS in adults, it was observed that latency values corroborated the present study, but the protocol used by the researchers differed in terms of frequencies used for the rare and frequent stimuli, they did not perform the auditory processing assessment to identify possible changes in auditory skills, and only measured the P300 amplitude.[30] In the analysis of the P300 cognitive component, the normality pattern for the P300 latency found in the present study corroborated two other studies[30,31] that also did not find differences between ears in the SmartEP–IHS. The P300 latency value ranged between 286 milliseconds and 337 milliseconds, corroborating an international normative study[17] that suggests that the P300 should appear between 220 milliseconds and 361 milliseconds in the adult population.

Still regarding latency, the values of the present study were lower compared with the only Brazilian study on P300 standardization found for the SmartEP–IHS equipment in adults with normal thresholds.[31] One hypothesis would be that the study authors did not use the auditory processing evaluation as an inclusion criterion, and that this should be normal for standardization, especially regarding temporal ordering and resolution skills. Furthermore, they did not exclude subjects with existing diseases, such as metabolic ones, and individuals with others diseases. Alvarenga et al.[32] found an increase in P300 latency in individuals with diabetes mellitus.

A limitation of the present study is that it was not possible to obtain a larger sample, as 77.55% of the adults who attended the first-stage exams had complaints of APD in the anamnesis and many, even without complaints, had abnormalities in the auditory processing exam. This fact confirms that normal hearing thresholds do not mean that hearing is normal, as it is necessary that the acoustic signal is properly analyzed and interpreted by the central nervous system along the auditory pathways, so that it becomes a meaningful message.[33]

Furthermore, the sample in the present study was different for each potential. During the selection described in the methodology, we selected 33 participants. However, for the ABR, we had previously evaluated 10 individuals to standardize latency and amplitude values, following the same methodology. Thus, we added these 10 individuals to the 33 participants who were selected exclusively for the study. As for the MLAEP, in two female participants, it was not possible to perform the exam due to the presence of electrical artifacts, most likely due to the amount of hair. In the LLAEP, there was an absence of the P300 component in 3 individuals, even after repeating the exam. As the generation of this component depends on the active involvement of the individual during the performance of the cognitive task,[24] the hypothesis is that these participants got tired and, consequently, showed decreased attention during the assessment.

Another point is that there was a low adherence of male adults to the survey, which made it difficult to form a homogeneous sample regarding the gender variable. Esteves et al.,[19] in a study similar to the present one, obtained in their sample 21 males and 39 females.

Conclusion

The present study shows that the SmartEP – IHS equipment has a standard of normality of latencies and amplitudes for short-, middle-, and long-latency auditory evoked potentials in adults.

Conflict of interests
The authors have no conflict of interests to declare.

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