ORIGINAL ARTICLE

Reference values of auditory brainstem responses

Milagros Sotelo Muñoz[1], Brandon E. Guillen-Calle[2], Peggy Carol Martínez-Esteban[3]

[1] Clinical Neurophysiology Service, Instituto Nacional de Salud del Niño San Borja, Lima 15037, Peru.
[2] Faculty of Medicine, Universidad Científica del Sur, Lima 15067, Peru.
[3] Research and Technological Innovation Subunit, Instituto Nacional de Salud del Niño San Borja, Lima 15037, Peru.

ABSTRACT

Objective: To determine reference values of auditory brainstem responses (ABR) in individuals with normal hearing.
Methods: A descriptive, non-experimental, cross-sectional study was conducted in 50 volunteer workers (33 women and 17 men) aged between 18 and 40 years, with normal hearing, from a national pediatric referral center in Lima, Peru. ABR recordings were obtained using a Nihon Kohden PV-230B device, employing click-type stimuli of 0.1 ms duration, rarefaction polarity, and intensities of 25, 40, 60, and 80 dB. Latencies of waves I, III, and V were analyzed, as well as the interpeak intervals I–III, III–V, and I–V.
Results: The mean age was 31.46 ± 4.43 years. Latencies of waves I, III, and V progressively decreased as stimulus intensity increased from 25 to 80 dB. At 60 dB, the mean latencies were 1.89 ± 0.21 ms (wave I), 4.02 ± 0.25 ms (wave III), and 5.89 ± 0.31 ms (wave V) in the left ear, with very similar values in the right ear. The interpeak intervals at this intensity were 2.12 ± 0.23 ms (I–III), 1.87 ± 0.25 ms (III–V), and 4.00 ± 0.30 ms (I–V). At 80 dB, latencies decreased to 1.49 ± 0.09 ms, 3.66 ± 0.16 ms, and 5.59 ± 0.26 ms, respectively, with interpeak intervals of 2.17 ± 0.14, 1.92 ± 0.23, and 4.09 ± 0.24 ms. Differences between ears were minimal, and women showed shorter latencies in all waves, particularly in waves III and V.
Conclusions: Reference values for ABR were established at the national pediatric referral center for individuals with normal hearing. Latencies and interpeak intervals showed high symmetry between ears, and slight sex-related differences were observed, with lower values in women.

Keywords: Auditory Brainstem Response; Hearing; Neurophysiology (Source: MeSH)

Cite as:
Sotelo Muñoz M, Guillen-Calle BE, Martínez-Esteban PC. Reference values of auditory brainstem responses. Investig Innov Clin Quir Pediatr. 2026;4(1):28-35.
doi: 10.59594/iicqp.2026.v4n1.157

Corresponding author:
Brandon E. Guillen-Calle
Email: 100162890@cientifica.edu.pe

ORCID iDs
Milagros Sotelo Muñoz
https://orcid.org/0009-0003-3212-0082
Brandon E. Guillen-Calle
https://orcid.org/0009-0001-5161-266X
Peggy Carol Martínez-Esteban
https://orcid.org/0000-0002-2513-5839

Received : 11/06/2025
Accepted : 02/16/2026
Published : 04/15/2026

Valores referenciales de los potenciales evocados auditivos del tronco encefálico

RESUMEN

Objetivo: Determinar valores de referencia de los potenciales evocados auditivos del tronco encefálico (ABR) en personas con audición normal.
Métodos: Estudio descriptivo, no experimental y transversal en 50 trabajadores voluntarios (33 mujeres y 17 hombres) de entre 18 y 40 años, con audición normal, de un centro pediátrico de referencia nacional en Lima, Perú. Los registros de ABR se obtuvieron con un equipo Nihon Kohden PV-230B, utilizando estímulos tipo click de 0,1 ms, polaridad de rarefacción e intensidades de 25, 40, 60 y 80 dB. Se analizaron las latencias de las ondas I, III y V, así como los intervalos interpico I–III, III–V e I–V.
Resultados: La edad promedio fue de 31,46 ± 4,43 años. Las latencias de las ondas I, III y V disminuyeron progresivamente al aumentar la intensidad del estímulo de 25 a 80 dB. A 60 dB, las latencias promedio fueron de 1,89 ± 0,21 ms (onda I), 4,02 ± 0,25 ms (onda III) y 5,89 ± 0,31 ms (onda V) en el oído izquierdo, con valores muy similares en el derecho. Los intervalos interpico a esta intensidad fueron de 2,12 ± 0,23 ms (I–III), 1,87 ± 0,25 ms (III–V) y 4,00 ± 0,30 ms (I–V). A 80 dB, las latencias disminuyeron a 1,49 ± 0,09 ms, 3,66 ± 0,16 ms y 5,59 ± 0,26 ms, respectivamente, con intervalos interpico de 2,17 ± 0,14, 1,92 ± 0,23 y 4,09 ± 0,24 ms. Las diferencias entre oídos fueron mínimas y las mujeres mostraron latencias menores en todas las ondas, especialmente en III y V.
Conclusiones: Se establecieron valores referenciales de ABR en el centro pediátrico de referencia nacional para personas con audición normal. Las latencias e intervalos interpico mostraron alta simetría entre oídos y se observaron ligeras diferencias según el sexo, con valores menores en mujeres.
Palabras clave: Potenciales Evocados Auditivos del Tronco Encefálico; Audición; Neurofisiología (Fuente: DeCS)

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INTRODUCTION

The study of auditory brainstem responses (ABR) is an objective and non-invasive procedure that evaluates neuroelectrical activity from the auditory nerve to the cerebral cortex (1). ABR are essential in audiological diagnosis to determine hearing thresholds and assess the integrity of central and peripheral auditory pathways (2).

ABR are based on stimulation of auditory pathways using a "click" stimulus, which mainly activates cochlear regions associated with frequencies above 1500 Hz (3). This acoustic stimulation generates responses through the sequential and synchronized activation of nerve fibers along the auditory pathway (3). It is considered a short-latency potential because it generates a series of seven waves that appear within the first 10 milliseconds after stimulus presentation (4).

Evaluation is performed by measuring the absolute latencies of waves I, III, and V, together with the interpeak intervals I–III, III–V, and I–V, allowing localization of auditory alterations (cochlear, retrocochlear, or conductive) (5,6) and detection of dysfunction in the auditory pathway or central nervous system, even in cases where the clinical presentation and neurological examination are not clear.

Normal latency values and interpeak intervals in ABR may vary due to several factors. On one hand, technical aspects such as electrode placement, stimulus frequency, intensity, and polarity (7), and on the other hand, physiological factors such as age (extremes of life), sex, and hearing acuity (8). Therefore, it is recommended that each institution establish its own set of standard parameters.

In the pediatric population, ABR are particularly relevant because they facilitate early detection of hearing alterations and timely implementation of interventions. Likewise, neurophysiological characteristics observed in adults are comparable to those recorded in children older than two years, since the latency of ABR responses stabilizes after 24 months, when brainstem maturation is considered complete (9). Therefore, this study aimed to determine the reference values of ABR in the clinical neurophysiology laboratory of the Instituto Nacional de Salud del Niño San Borja.

METHODS

Study design

A quantitative, non-experimental, cross-sectional study.

Population and sample

The sample consisted of 50 participants (33 women and 17 men), selected through non-probabilistic convenience sampling among workers of the Instituto Nacional de Salud del Niño San Borja.

Inclusion criteria

Adults aged between 18 and 40 years with hearing within normal ranges were included, evaluated according to semiological criteria of hearing acuity and otoscopy, and with a normal pure-tone audiometry result. All individuals who met these criteria and signed informed consent were considered eligible to undergo ABR testing.

Exclusion criteria

Individuals with a history of acute or chronic otitis media, diabetes or arterial hypertension, or prolonged use (more than 2 months) of ototoxic medication were excluded.

Data collection procedures

Data were collected in the Clinical Neurophysiology Laboratory of the Instituto Nacional de Salud del Niño San Borja. A questionnaire was used to obtain demographic data from participants. After selecting participants who met the inclusion criteria, ABR recordings were performed and recorded in a data collection form. Values were entered and monitored on the REDCap platform (Research Electronic Data Capture; Vanderbilt University, Nashville, TN, USA). After the final review of the database, records were exported for analysis.

Audiological evaluation procedures

1. Pure-tone audiometry

Audiometric evaluation was performed in a certified acoustic booth using a Sibelmed-Sibelsound audiometer calibrated according to ANSI S3.6-2018 standards. During audiological assessment, tonal frequencies between 125 and 8000 Hz were analyzed. Hearing thresholds above 20 dB HL were considered indicative of hearing loss, following criteria established by the International Office of Audiology classification.

2. ABR recording

ABR evaluation was carried out using a Nihon Kohden PV-230B device manufactured in Japan.

Neurophysiological responses were recorded while the participant remained in a comfortable supine position on an examination table. Before electrode placement, the skin was cleaned using an abrasive paste. Electrode placement followed the international 10–20 system, positioning the active electrode at Cz (vertex of the skull), the reference electrode at the left mastoid (A1) or right mastoid (A2), and the ground electrode at Fz. Electrode impedance was maintained below 5 kΩ to ensure recording quality.

During the procedure, participants were asked to keep their eyes closed to facilitate spontaneous sleep induction. The protocol included monaural recording of "click" stimuli with a stimulation frequency of 10 Hz, duration of 0.1 ms, and rarefaction polarity, delivered through external earphones.

The stimulus was administered first to the left ear and then to the right ear, using contralateral masking with white noise at −40 dB. Each recording consisted of an average of 1000 stimuli, processed using low-pass and high-pass filters set at 100 Hz and 3000 Hz, respectively.

The obtained data were analyzed through visual inspection, identifying and manually marking the peaks of waves I, III,

and V. The equipment software automatically calculated the corresponding interpeak intervals (I–III, III–V, and I–V) to evaluate latency and integrity of the central auditory pathways. Potentials were recorded at stimulus intensities of 25, 40, 60, and 80 dB (Figure 1).

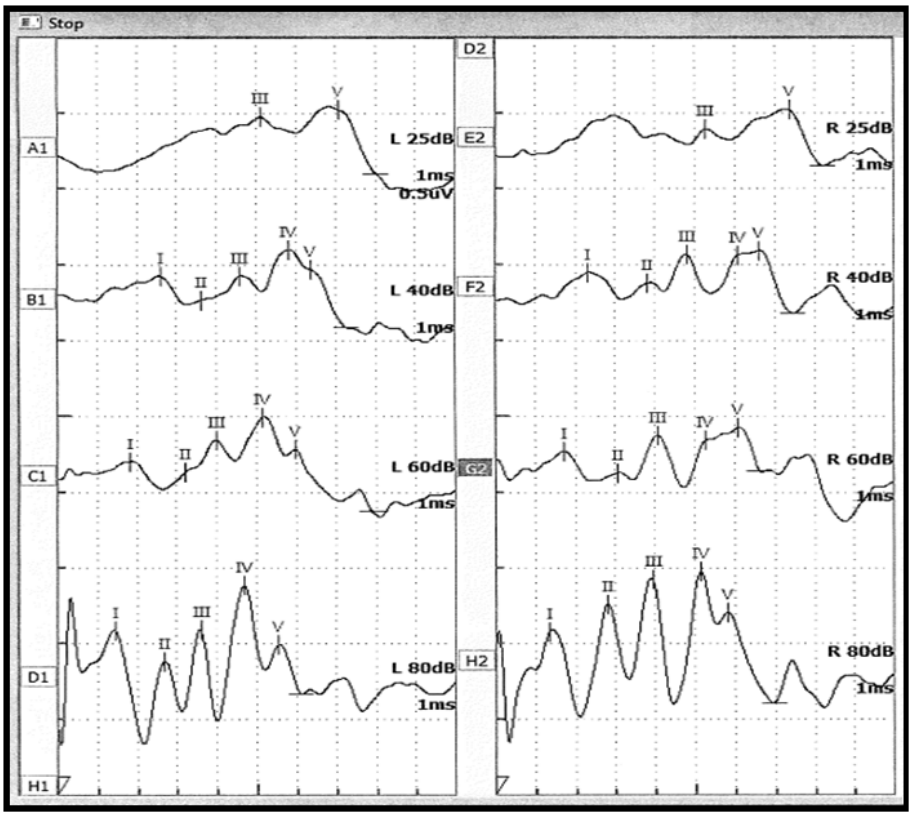

Figure 1. ABR recording

Data analysis

Measures of central tendency, dispersion, and position (percentiles) were used to report numerical variables, while categorical variables were described using frequencies and percentages.

The age variable was categorized as ≤ 30 years and ≥ 31 years based on age-related physiological changes that begin after 30 years of age. Statistical analysis was performed using Stata version 17 (StataCorp LLC, College Station, TX, USA).

For graphical representation of the distribution of means, Microsoft Excel version 2019 (Microsoft Corporation, Redmond, WA, USA) was used, and visualization of latency changes across decibel levels was performed using R version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical considerations

This descriptive cross-sectional study was approved by the Research Ethics Committee (approval number 054-2017). Written informed consent was obtained from all participants.

RESULTS

Sample characteristics

The sample consisted of 50 adults with a mean age of 31.46 ± 4.43 years. Most participants were in the ≤30 years age group (64.0%), while 36.0% were between 31 and 40 years. Regarding sex, 66.0% were women and 34.0% men, reflecting greater female participation in the study (Table 1).

ABR results

At 60 dB, the mean latency of wave I was 1.89 ± 0.21 ms in the left ear and 1.95 ± 0.20 ms in the right ear. Wave III showed means of 4.02 ± 0.25 ms and 4.05 ± 0.22 ms, respectively, while wave V presented values of 5.89 ± 0.31 ms in the left ear and 5.95 ± 0.29 ms in the right ear. Regarding interpeak intervals, I–III recorded 2.12 ± 0.23 ms in the left ear and 2.10 ± 0.18 ms in the right ear; III–V reached 1.87 ± 0.25 ms and 1.89 ± 0.20 ms, respectively; and I–V was 4.00 ± 0.30 ms in the left ear and 3.99 ± 0.23 ms in the right ear. Overall, latencies were very similar between both ears (Table 2).

Table 1. Characteristics of the population

Characteristics	n	%
Age (years)		
≤30	32	64.0
≥31	18	36.0
Mean ± SD	31.46 ± 4.43	
Sex		
Male	17	34.0
Female	33	66.0
Total	50	100.0

SD: standard deviation.

At 80 dB, wave I showed a mean latency of 1.49 ± 0.09 ms in the left ear and 1.50 ± 0.10 ms in the right ear. Wave III recorded values of 3.66 ± 0.16 ms and 3.70 ± 0.15 ms, while wave V showed 5.59 ± 0.26 ms and 5.57 ± 0.26 ms, respectively. In the interpeak intervals, I–III was 2.17 ± 0.14 ms in the left ear and 2.20 ± 0.14 ms in the right ear; III–V reached 1.92 ± 0.23 ms and 1.87 ± 0.23 ms; and I–V was 4.09 ± 0.24 ms and 4.07 ± 0.24 ms, respectively. Differences between ears were minimal, maintaining high consistency of responses (Table 3).

Figure 2 shows the decrease in latency in milliseconds as the decibel level increases from 25 to 80 dB. Likewise, Figure 3 shows that when comparing the latencies of waves I, III, and V according to sex, women present shorter latencies in all analyzed waves. Differences are more pronounced in waves III and V, where latency is significantly lower in women ($p < 0.05$), both in the left ear (wave III: 3.75 ms in men vs. 3.62 ms in women; wave V: 5.70 ms in men vs. 5.53 ms in women) and in the right ear (wave III: 3.78 ms in men vs. 3.67 ms in women; wave V: 5.71 ms in men vs. 5.50 ms in women).

Table 2. ABR latencies in adults at 60 dB

Waves and intervals (ms)	Mean	SD	p25	p50	p75	Minimum	Maximum
Wave I							
Left ear	1.89	0.21	1.76	1.85	1.98	1.41	2.46
Right ear	1.95	0.20	1.80	1.93	2.04	1.63	2.47
Wave III							
Left ear	4.02	0.25	3.86	3.98	4.15	3.47	5.04
Right ear	4.05	0.22	3.92	4.04	4.19	3.57	4.68
Wave V							
Left ear	5.89	0.31	5.73	5.88	6.11	5.03	6.51
Right ear	5.95	0.29	5.72	5.93	6.14	5.25	6.58
Interval I–III							
Left ear	2.12	0.23	1.98	2.09	2.23	1.69	2.99
Right ear	2.10	0.18	1.94	2.08	2.25	1.62	2.47
Interval III–V							
Left ear	1.87	0.25	1.73	1.87	2.07	1.08	2.24
Right ear	1.89	0.20	1.75	1.90	2.01	1.21	2.37
Interval I–V							
Left ear	4.00	0.30	3.84	3.99	4.14	3.26	5.10
Right ear	3.99	0.23	3.83	3.93	4.15	3.56	4.65

SD: standard deviation; p: percentile; p25: 25th percentile; p50: median; p75: 75th percentile.

Table 3. ABR latencies in adults at 80 dB

Waves and intervals (ms)	Mean	SD	p25	p50	p75	Minimum	Maximum
Wave I							
Left ear	1.49	0.09	1.42	1.49	1.58	1.36	1.81
Right ear	1.50	0.10	1.43	1.50	1.58	1.32	1.76
Wave III							
Left ear	3.66	0.16	3.56	3.65	3.78	3.31	4.08
Right ear	3.70	0.15	3.60	3.69	3.82	3.34	4.01
Wave V							
Left ear	5.59	0.26	5.42	5.57	5.78	4.89	6.20
Right ear	5.57	0.26	5.40	5.59	5.78	5.03	6.14
Interval I–III							
Left ear	2.17	0.14	2.07	2.17	2.26	1.85	2.57
Right ear	2.20	0.14	2.10	2.18	2.31	1.91	2.61
Interval III–V							
Left ear	1.92	0.23	1.79	1.92	2.12	1.23	2.37
Right ear	1.87	0.23	1.76	1.89	2.02	1.29	2.33
Interval I–V							
Left ear	4.09	0.24	3.93	4.12	4.26	3.41	4.69
Right ear	4.07	0.24	3.92	4.03	4.30	3.53	4.55

SD: standard deviation; p: percentile; p25: 25th percentile; p50: median; p75: 75th percentile.

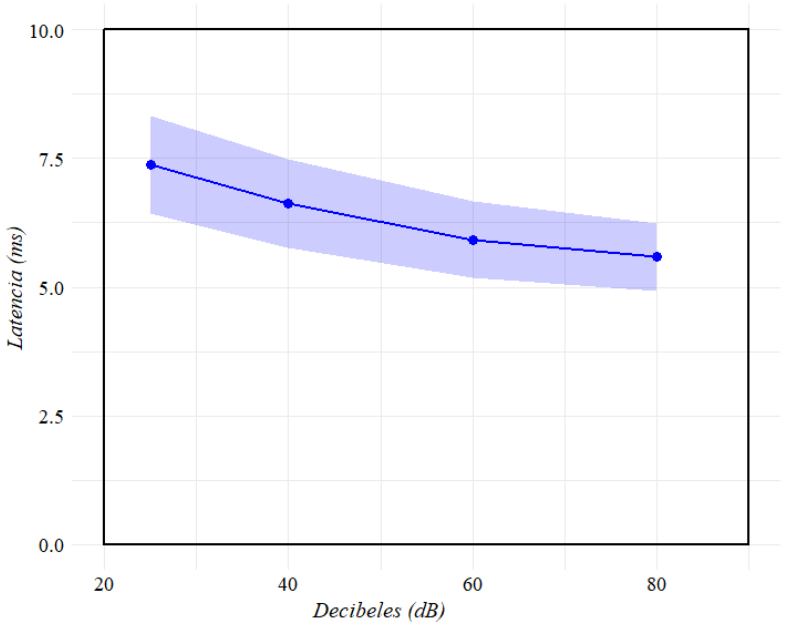

Figure 2. Latency–intensity curve for wave V at 25, 40, 60, and 80 dB

Blue line: mean latency at each stimulus level. Shaded area: standard deviation.

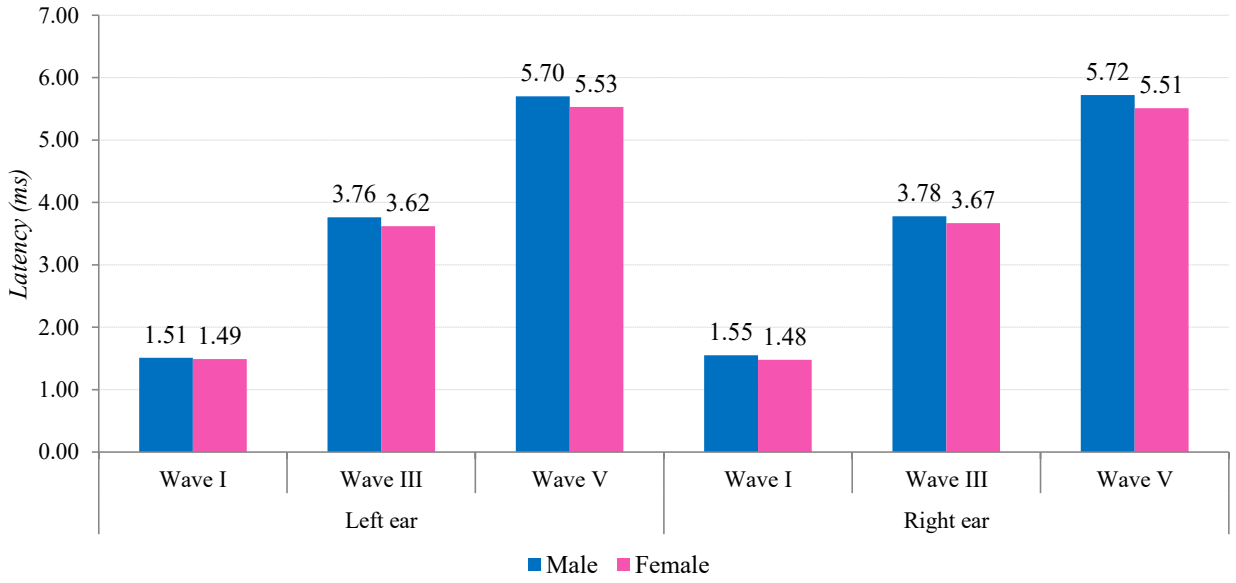

Figure 3. Mean latencies at 80 dB according to sex

DISCUSSION

The present study presents the findings obtained after evaluating ABR responses in subjects with normal hearing in order to establish local reference values. The results showed latencies and interpeak intervals within expected ranges, with high symmetry between ears and slight differences according to sex.

Each neurophysiology unit should develop its own standard parameters to optimize diagnostic accuracy in the electrophysiological evaluation of the auditory pathway. As reported by Estévez et al. (10), different devices and examiners may generate significant variations in results, highlighting the importance of establishing uniform and validated protocols.

The results of this study showed an approximately normal distribution of latencies and intervals. Based on the obtained means and standard deviations (SD), reference limits were defined using ± 2.5 SD, covering approximately 98.8% of the population (11). This criterion increases the reliability of the parameters used and reduces the probability of incorrect diagnostic classifications.

ABR responses were analyzed in individuals with normal hearing exposed to acoustic stimuli of moderate and high intensity (60 and 80 dB nHL). This range of intensities was selected due to its relationship with neuronal synchronization of the vestibulocochlear nerve, ensuring clear and reliable signal transmission to the brainstem at high intensity levels (10,12).

The main parameter analyzed in ABR studies is latency. Chiappa (1) reported the results of absolute latencies and interlatency intervals of ABR obtained at 60 dB SL, corresponding to 60 decibels above the individual auditory threshold (dB HL) for a specific tonal stimulus. The recorded values were expressed with a ± 3 SD range and included the following parameters: latency of wave I (1.7–2.2 ms), wave III (3.9–4.5 ms), wave V (5.7–6.5 ms), interlatency interval I–III (2.1–2.6 ms), III–V (1.9–2.4 ms), and I–V (4.0–4.7 ms) (1).

On the other hand, Schwartz et al. (13) reported ABR responses obtained at an intensity level of 80 dBnHL. These were documented with a ± 2.5 SD range describing the following parameters: latency of wave I (1.29–1.79 ms), wave III (3.32–4.08 ms), wave V (5.12–6.08 ms), interlatency interval I–III (1.60–2.80 ms), III–V (1.42–2.26 ms), and I–V (3.59–4.49 ms). These data are highly consistent with the results obtained in this sample of patients with normal hearing, who presented the following responses to 80 dBnHL stimuli: in the left ear, values were wave I (1.49–1.71 ms), wave III (3.66–4.06 ms), wave V (5.59–6.24 ms), interval I–III (2.17–2.52 ms), interval III–V (1.92–2.50 ms), and interval I–V (4.09–4.69 ms); while in the right ear, ranges were wave I (1.50–1.75 ms), wave III (3.70–4.08 ms), wave V (5.57–6.22 ms), interval I–III (2.20–2.55 ms), interval III–V (1.87–2.45 ms), and interval I–V (4.07–4.67 ms).

A relevant finding in this research was that women presented shorter ABR latencies compared with men. This result is consistent with previous studies reported in the literature (14–18), suggesting that differences are due to anatomical factors such as smaller cranial size in women and neurophysiological variations in subcortical structures. Additionally, according to Al-Mana et al. (19) and Elkind-Hirsch et al. (20), hormones, particularly estrogen, may influence the auditory function of

the central nervous system through modulation of GABAergic, serotonergic, and glutamatergic neurotransmitter systems, contributing to these latency differences.

In the literature, latency differences related to increasing age have been documented (21,22). Particularly, a significant variation between extreme ages of life is mentioned, associated with physiological processes of maturation and aging (21,22). Furthermore, latencies stabilize between 24 and 36 months of age (3), after which responses in children and adults become similar. Conversely, these latencies tend to increase after 65 years of age (23). In this study, participants did not show significant variations in wave latencies, reflecting appropriate sample selection (young normoacoustic adults) and the importance of prior pure-tone audiometry. The findings of this study are relevant for the pediatric population of the Instituto Nacional de Salud del Niño San Borja, where ABR constitute a key tool for early detection of hearing alterations and timely implementation of interventions.

In conclusion, the results of the present study conducted in a sample of individuals with normal hearing contribute to the establishment of reliable reference parameters for the interpretation of ABR tests, enabling a more precise and effective diagnostic tool at the Instituto Nacional de Salud del Niño San Borja.

Author contributions

MSM and PCME conceptualized the study and developed the design. MSM and PCME performed data collection; BEGC conducted data curation and analysis; MSM, PCME, and BEGC carried out supervision. All authors edited and approved both the draft and the final version of the manuscript.

Conflicts of interest

The authors declare no relevant financial or non-financial conflicts of interest.

Funding

This study did not receive external funding.

Data availability

The data supporting the findings of this study are available upon request from the corresponding author.

Acknowledgments

To Ysabel Rubio and Noemí Baldeón for their invaluable technical support in performing the brainstem auditory evoked potentials.

REFERENCES

1. Chiappa KH. Evoked potentials in clinical medicine. 3a ed. Philadelphia: Lippincott-Raven; 1997. p. 158-251.
2. Pelaquim A, Sanfins MD, Fornazieri MA. Standardization of Latency and Amplitude Values of Short, Middle and Long Latency Auditory Evoked Potentials in Adults. Int Arch Otorhinolaryngol. 2023;27(2):e278-85. doi: 10.1055/s-0043-1768203
3. Picton TW, Hillyard SA. Human auditory evoked potentials. I: Evaluation of components. Electroencephalogr Clin Neurophysiol. 1974;36(2):179-90. doi: 10.1016/0013-4694(74)90155-2
4. Borrego JC, Trujillo JM. Potenciales evocados auditivos de tallo cerebral: registro, aplicación y datos normativos. Acta Med Colomb [Internet]. 1985 [cited on 5 November 2025];10(1):1-14. Available from: https://www.actamedicacolombiana.com/ojs/index.php/actamed/article/view/3571/2553
5. Møller AR, Jannetta PJ. Auditory evoked potentials recorded intracranially from the brain stem in man. Exp Neurol. 1982;78(1):144-57. doi: 10.1016/0014-4886(82)90196-0
6. Glasscock ME, Jackson CG, Josey AF, Dickins JR, Wiet RJ. Brain Stem Evoked Response Audiometry in a Clinical Practice. Laryngoscope. 1979;89(7 Pt 1):1021-35. doi: 10.1288/00005537-197907000-00001
7. Dziemba OC, Brzoska T, Hocke T, Ihler F. The Effects of Stimulus Repetition Rate on Electrically Evoked Auditory Brainstem Potentials in Postlingually Deafened Adult Cochlear Implant Recipients. J Clin Med. 2023;12(22):7188. doi: 10.3390/jcm12227188
8. Rowe MJ. Normal variability of the brainstem auditory evoked response in young and old adult subjects. Electroencephalogr Clin Neurophysiol. 1978;44:459-70. doi: 10.1016/0013-4694(78)90030-5
9. Sanfins MD, Colella-Santos MF, Ferrazoli N, Rezende A, Donadon C, Gos E, et al. Latency and Interpeak Interval Values of Auditory Brainstem Response in 73 Individuals with Normal Hearing. Med Sci Monit. 2022;28:e937847. doi: 10.12659/MSM.937847
10. Esteves MC, Dell' Aringa AH, Arruda GV, Dell' Aringa AR, Nardi JC. Brainstem evoked response audiometry in normal hearing subjects. Braz J Otorhinolaryngol. 2009;75(3):420-5. doi: 10.1016/S1808-8694(15)30661-3
11. Reynolds D. Gaussian mixture models. In: Li SZ, Jain A, editors. Encyclopedia of biometrics. 1a ed. Boston: Springer; 2009. p. 659-63.
12. Smith JT, Wolfe J. Sound Advice for ABR Analysis: No Squinting or Guessing. Hear J. 2014;67(6):14. doi: 10.1097/01.HJ.0000451365.01338.5b
13. Schwartz DM, Pratt RE Jr, Schwartz JA. Auditory brain stem responses in preterm infants: Evidence of peripheral maturity. Ear Hear. 1989;10(1):14-22. doi: 10.1097/00003446-198902000-00003
14. Houston HG, McClelland RJ. Age and gender contributions to intersubject variability of the auditory brainstem potentials. Biol Psychiatry. 1985;20(4):419-30. doi: 10.1016/0006-3223(85)90044-7
15. Jerger J, Hall J. Effects of Age and Sex on Auditory Brainstem Response. Arch Otolaryngol Head Neck Surg. 1980;106(7):387-91. doi: 10.1001/archotol.1980.00790310011003
16. Don M, Ponton CW, Eggermont JJ, Masuda A. Gender differences in cochlear response time: An explanation for gender amplitude differences in the unmasked auditory brain-stem response. J Acoust Soc Am. 1993;94(4):2135-48. doi: 10.1121/1.407485
17. Michalewski HJ, Thompson LW, Patterson JV, Bowman TE, Litzelman D. Sex differences in the amplitudes and latencies of the human auditory brain stem potential. Electroencephalogr Clin Neurophysiol. 1980;48(3):351-6. doi: 10.1016/0013-4694(80)90271-0

18. Chan YW, Woo EK, Hammond SR, Yiannikas C, McLeod JG. The interaction between sex and click polarity in brain-stem auditory potentials evoked from control subjects of Oriental and Caucasian origin. Electroencephalogr Clin Neurophysiol. 1988;71:77-80. doi: 10.1016/0168-5597(88)90022-6
19. Al-Mana D, Ceranic B, Djahanbakhch O, Luxon L. Hormones and the auditory system: a review of physiology and pathophysiology. Neuroscience. 2008;153:881-900. doi: 10.1016/j.neuroscience.2008.02.077
20. Elkind-Hirsch K, Stoner W, Stach B, Jerger J. Estrogen influences auditory brainstem responses during the normal menstrual cycle. Hear Res. 1992;60:143-8. doi: 10.1016/0378-5955(92)90016-g
21. Aguilar-Madrid G, Torres-Valenzuela A, Hinojos-Escobar W, Cabello-López A, Gopar-Nieto R, Ravelo-Cortés PE, et al. Latencias de los potenciales evocados auditivos del tallo cerebral, por edad y sexo, en población adulta mexicana. Rev Med Inst Mex Seguro Soc [Internet]. 2015 [cited on 5 November 2025];53(6):690-6. Available from: https://revistamedica.imss.gob.mx/index.php/revista_medica/article/view/297/715
22. Johannesen PT, Lopez-Poveda E. Age-related central gain compensation for reduced auditory nerve output for people with normal audiograms, with and without tinnitus. iScience. 2021;24(6):102610. doi: 10.1016/j.isci.2021.102658
23. Mitchell C, Phillips D, Trune D. Variables affecting the auditory brainstem response: Audiogram, age, gender and head size. Hear Res. 1989;40:75-86. doi: 10.1016/0378-5955(89)90101-9