Neurology, Psychiatry and Brain Research 32 (2019) 4–7

Contents lists available at ScienceDirect

Neurology, Psychiatry and Brain Research

journal homepage: www.elsevier.com/locate/npbr

Auditory brainstem response (ABR) findings in males and females with comparable head sizes at supra-threshold and threshold levels

Mohd Normani Zakaria[a,*], Noor Alaudin Abdul Wahab[b], Nashrah Maamor[b], Bahram Jalaei[c], Ahmad Aidil Arafat Dzulkarnain[d]

[a] Audiology and Speech Pathology Programme, School of Health Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia
[b] Audiology Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Temerloh, 53200 Kuala Lumpur, Malaysia
[c] Department of Audiology, Arak School of Rehabilitation, Arak University of Medical Sciences, Markazi, Iran
[d] Department of Audiology and Speech-Language Pathology, Kuliyyah of Allied Health Sciences, International Islamic University Malaysia, 25200 Kuantan, Pahang, Malaysia

ARTICLE INFO

Keywords:
Auditory
Brainstem
Gender
Head size
Threshold

ABSTRACT

Background and purpose: Gender disparities in auditory brainstem response (ABR) results have been reported but the exact reasons remain controversial. Difference in head size between genders has been suggested but the literature is lacking, particularly at threshold levels. In this short communication, we compared ABR results between males and females with comparable head sizes at supra-threshold and threshold levels.

Materials and methods: In this comparative study, of 58 healthy young adults, 30 of them (17 females and 13 males) with comparable head sizes underwent the standard ABR testing. Wave V latencies and ABR thresholds were determined and analyzed accordingly.

Results: At the supra-threshold level, significantly shorter wave V latencies were found in females than in males ($p = 0.029$). This difference was substantive ($d = 0.86$) and persisted even when the head size was included in the analysis ($p = 0.032$). In contrast, no significant differences in ABR thresholds were found between genders ($p > 0.05$).

Conclusions: Significant gender differences in ABR results among young adults were only found at the supra-threshold level, which were not related to the head size. Based on the study outcomes, gender-specific normative data for ABR are still beneficial for clinical applications, particularly when recording ABR at high stimulation levels.

1. Introduction

Auditory brainstem response (ABR) is the far-field sum of action potentials generated within the brainstem when evoked by auditory stimuli such as clicks, tone bursts and chirps (Hall, 2006). It typically consists of five prominent peaks (waves I-V) generated by specific portions of the auditory brainstem. In the fields of neurology and neuro-otology, ABR has been used in various clinical applications for many decades including neurodiagnostic testing, hearing threshold estimation, intra-operative monitoring, hearing implant candidacy, along with others (Hall, 2006; Kim et al., 2008; Mastronardi, Di Scipio, Cacciotti, & Roperto, 2018). For accurate clinical diagnoses, specific normative data for ABR have been established. As such, notable gender differences in ABR results have been reported and gender-specific normative data are recommended (Aoyagi et al., 1990; Jerger & Hall, 1980; Jalaei, Zakaria, Mohd Azmi, Nik Othman, & Sidek, 2017).

Fundamentally, the exact reasons for these result disparities remain controversial. Head size difference between sexes has long been acknowledged as the possible factor for explaining the ABR differences (Aoyagi et al., 1990; Hall, 2006). Due to smaller head circumferences, earlier latencies and bigger amplitudes were seen in females than in males (Aoyagi et al., 1990; Hall, 2006). On the other hand, contradictory outcomes have also been reported. That is, more robust ABR waveforms were still noted in females even when their head sizes were equivalent to their male counterparts (Trune, Mitchell, & Phillips, 1998). In this regard, some other factors have been suggested as the possible contributors for the differences in ABR results between genders including skull thickness, cochlear length and hormonal influence (Dehan & Jerger, 1990; Don, Ponton, Eggermont, & Masuda, 1993; Hall, 2006).

* Corresponding Author.
E-mail address: normppsk@hotmail.com (M.N. Zakaria).

https://doi.org/10.1016/j.npbr.2019.03.001
Received 24 May 2018; Received in revised form 3 February 2019; Accepted 1 March 2019
Available online 08 March 2019

In addition, it is worth noting that the majority of studies compared ABR results between genders at high stimulation levels (i.e. supra-thresholds). The literature on gender comparisons at low stimulation levels (i.e. thresholds), on the other hand, is currently lacking. In this study, we report the ABR findings in healthy males and females with equal head sizes at supra-threshold and threshold levels.

2. Materials and methods

2.1. Participants

In this comparative study, 58 adults (33 females and 25 males) were selected randomly among students of Universiti Sains Malaysia. All of them were healthy and had hearing within the normal limits (hearing thresholds ≤20 dB HL between 250 and 8000 Hz in pure tone audiometry). This study was approved by the institutional ethics committee, which is in accordance with the 1975 Declaration of Helsinki and its later amendments.

2.2. Head size measurement

The head size of each participant was measured according to the standard clinical protocol (Kimmel & Ratliff-Schaub, 2011). The head circumference was calculated using a non-elastic measuring tape based on the distance from halfway between the eyebrows and the hairline to around the back of head. Head circumference and 50th percentile values were computed for each gender group. As an effort to obtain comparable head sizes between sexes, the following selection method was employed: in the male group, only those with head sizes less than or equal to 50th percentile (≤57.5 cm) were included and in the female group, those with head sizes more than or equal to 50th percentile (≥55.5 cm) were selected. Accordingly, seventeen females (mean age = 22.6 ± 1.1 years) and thirteen males (mean age = 21.9 ± 1.4 years) fulfilled these criteria and were eligible for ABR testing.

2.3. Auditory brainstem response (ABR) recording

The ABR waveforms were recorded from each participant according to the standard procedure and test parameters as outlined in Table 1. All recordings were made with a two-channel Biologic Navigator Pro AEP system (Natus Medical Inc., Mundelein, USA). For supra-threshold testing, the click stimuli were presented monaurally to each ear at 80 dB nHL. Then, to obtain the ABR threshold, the intensity level was decreased by 10-dB step until no clear waveform was observed. The intensity level was increased by 5-dB step until a clear ABR waveform was identified. Herein, the ABR threshold was defined as the lowest intensity level that produced an identifiable wave V. To ensure good waveform replicability, the recording was repeated twice for each trial. The impedance of electrodes was kept below 5 kΩ throughout the testing. All the measurements were performed in a sound proof room within the Audiology Clinic, University Hospital.

Table 1
Test parameters for recording auditory brainstem response in the present study.

Parameter	Selection
Electrode placement:	
Non-inverting	Vertex (Cz)
Inverting	Ipsilateral mastoid (M1 or M2)
Ground	Low forehead (Fpz)
Transducer	Headphones (TDH-39)
Stimulus	0.1 ms alternating clicks
Stimulus rate	11.1/s
Intensity	80 dB nHL or lower (for threshold testing)
Presentation	Monaural
Filter setting	100–3000 Hz
Amplification	×100,000
Analysis time	−1.0 to 10 ms
Sweeps	2000

2.4. Data analyses

Wave V latencies and ABR thresholds were carefully identified by three experienced researchers. Since the data were found to be normally distributed, parametric analyses could be conducted. Based on the insignificant paired *t*-test analyses ($p > 0.05$), left and right data were then averaged. Independent *t*-test analyses were conducted to compare the head size and ABR results between males and females. Analysis of covariance (ANCOVA) was performed to rule out the influence of head size (as the covariate) on ABR results. The correlations between head size and ABR results were determined with Pearson correlation. The statistical significance level was set at $p < 0.05$. To determine the magnitude of gender difference, Cohen's effect size (d) was computed. The effect sizes were interpreted as small (d = 0.20), medium (d = 0.50) and large (d = 0.80) (Cohen, 1998). All analyses were carried out with SPSS software version 20 (SPSS Inc., Chicago, IL, USA).

3. Results

As shown in Table 2, the head sizes between genders were indeed comparable as the statistical result was insignificant ($t = 0.383$, $df = 28$, $p = 0.705$) with a small effect size (d = 0.14). At the supra-threshold stimulation level, compared to males, significantly shorter wave V latencies were seen in females ($t = 2.301$, $df = 28$, $p = 0.029$) with a large effect size (d = 0.86). This gender difference was still significant even when the head size was included as the covariate ($F = 5.108$, $df = 1, 27$, $p = 0.032$). In contrast, no significant differences were found in ABR thresholds between sexes ($p > 0.05$ for both *t*-test and ANCOVA) and the effect size was small (d = 0.42). In addition, the head size had no significant correlation with either wave V latency ($r = 0.34$, $p = 0.068$) or ABR threshold ($r = 0.29$, $p = 0.119$).

4. Discussion

Recall that the present study aimed to provide some answers on the controversial, yet fundamental, aspects of ABR (i.e. head size and gender influences on ABR). Since wave V is the most prominent peak of ABR and peak latency is more reliable than peak amplitude (Hall, 2006), only the wave V latency data were analyzed for the supra-threshold ABR testing in the present study.

Consistent with the study outcomes by Trune et al. (1998), the present study found females to have significantly shorter wave V latencies than males even though their head circumferences were equivalent. This finding was supported by the large effect size, implying that the latency difference between sexes was in fact substantive. Furthermore, this significant result persisted even when the head size was included in the analysis (i.e. as the covariate). Likewise, no significant correlation was found between head size and wave V latency. Collectively, the findings from the present study support the notion that the ABR results at high stimulation levels are not influenced by the head size. That is, the gender disparities in ABR results are contributed by factors other than the head size (Dehan & Jerger, 1990; Don et al., 1993; Hall, 2006; Jalaei et al., 2017). In a study by Jalaei et al. (2017), speech-evoked auditory brainstem response (speech-ABR) results were compared between healthy males and females. They then found that the latencies of onset peaks of speech-ABR (that are analogous to wave V of click-evoked ABR) were significantly shorter in females than in males. In line with the present study outcomes, these differences became insignificant after controlling for the head circumference of participants (Jalaei et al., 2017).

Hormonal influence is among the favored factors that might contribute to gender differences in ABR findings (Dehan & Jerger, 1990;

Table 2
Mean, standard deviation (SD), *p* value and effect size (*d*) for head size, wave V latency and auditory brainstem response (ABR) threshold in females and males.

	Females Mean (SD)	Males Mean (SD)	p value (*t*-test)	p value (ANCOVA)	Effect size (d)
Head size (cm)	56.16 (0.49)	56.25 (0.76)	0.705	–	0.14
Wave V latency (ms)	5.42 (0.20)	5.58 (0.17)	0.029*	0.032*	0.86
Threshold (dB nHL)	9.26 (3.83)	11.35 (5.92)	0.253	0.289	0.42

* Statistically significant at $p < 0.05$.

Don et al., 1993; Hall, 2006). Sex steroid hormone such as estrogen has been shown to play some role in enhancing synaptic transmission and neural conduction (Tremere & Pinaud, 2011; Tremere, Jeong, & Pinaud, 2009). Since the estrogen levels are higher in females than in males, more robust ABR waveforms found in females might be contributed by this hormonal factor (Tremere & Pinaud, 2011; Tremere et al., 2009).

It is worth noting that in the study by Trune et al. (1998), the ABR results were compared between males and females with equal head sizes using descriptive statistics. The present study, on the other hand, compared the ABR outcomes between genders using several inferential statistical analyses, so that more concrete conclusions could be made.

Different from the supra-threshold finding, the present study found no significant differences in ABR thresholds between sexes. The exact reason for this is unknown and the literature on this aspect of ABR is limited, making the comparison difficult. Relative to supra-threshold levels, the discharge rate of action potentials is lower at thresholds. As the sound intensity increases, the neural discharge rate also increases leading to more robust ABR waveforms (Hall, 2006). It appears that at thresholds, the neural discharge rate within the auditory brainstem is comparable between males and females. In addition, as robustly demonstrated elsewhere, the basal and apical regions of cochlea are responsive to high frequency and low frequency sounds, respectively (Robles & Ruggero, 2001). At high intensity levels, the neural responses are mostly contributed by the basal area of cochlea (Picton, Stapells, & Campbell, 1981). On the other hand, at lower intensity levels, the site of excitation moves towards the apical part of cochlea (Picton et al., 1981). In relation to the present study findings, since all participants had normal hearing at all frequencies tested (250–8000 Hz), it is unclear why the ABR findings between sexes were different at supra-threshold and threshold levels. On the other hand, if the male participants have normal hearing at low frequencies but with significant hearing loss at high frequencies (while females have normal hearing at all frequencies), the reasons for the shorter wave V latencies in females at the supra-threshold level and the comparable ABR thresholds between males and females can be justifiable. Nevertheless, the supra-threshold outcomes may not always agree with the threshold findings (Vander Werff & Brown, 2005). Vander Werff and Brown (2005) recorded auditory steady state response (ASSR) evoked by amplitude modulated tones from normally hearing (n = 10) and hearing impaired (n = 20) adults at thresholds and multiple supra-threshold levels. They then concluded that due to the small ASSR amplitude and individual variability, the supra-threshold ASSR findings were not advantageous in estimating the ASSR thresholds. Taken together, further large-scale research is warranted to verify this issue. As such, the inclusion of otoacoustic emission (to provide more precise information on the cochlear function) can be beneficial to shed light on this controversial aspect of ABR.

The present study had several limitations. Firstly, the sample size was modest and future large-scale studies are beneficial to support the present study findings. Secondly, in the supra-threshold testing, the ABR waveforms were recorded at only one intensity level (i.e. 80 dB nHL). In this regard, perhaps more informative study findings would be gathered if ABR is recorded at multiple supra-threshold levels. Lastly, the hormonal levels of participants were not measured and the possible influence of sex hormones on ABR (at both supra-threshold and thresholds levels) could not be determined. This is subject to further research.

5. Conclusion

Significant gender differences in ABR results among young adults were only found at the supra-threshold level, which were not related to the head size. As revealed by the large effect size (that suggests a clinically significant result) (Polit, 2017), gender-specific normative data for ABR are still beneficial for clinical applications, particularly when recording ABR at high stimulation levels.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical statement

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guidelines on human experimentation (Human Ethics Committee of USM, USM/PPP/JEPeM [245.3(5)]), and with the Helsinki Declaration of 1975, and its later amendments.

Financial disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Aoyagi, M., Kim, Y., Yokoyama, J., Kiren, T., Suzuki, Y., & Koike, Y. (1990). Head size as a basis of gender difference in the latency of the brainstem auditory-evoked response. *Audiology, 29*(2), 107–112.
Cohen, J. (1998). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
Dehan, C. P., & Jerger, J. (1990). Analysis of gender differences in the auditory brainstem response. *Laryngoscope, 100*(1), 18–24.
Don, M., Ponton, C. W., Eggermont, J. J., & Masuda, A. (1993). Gender differences in cochlear response time: an explanation for gender amplitude differences in the unmasked auditory brainstem response. *Journal of Acoustical Society of America, 94*(4), 2135–2148.
Hall, J. W. (2006). *New handbook of auditory evoked responses.* Boston: Pearson.
Jalaei, B., Zakaria, M. N., Mohd Azmi, M. H. A., Nik Othman, N. A., & Sidek, D. (2017). Gender disparities in speech-evoked auditory brainstem response in healthy adults: Any relation to head size? *Annals of Otology, Rhinology & Laryngology, 126*(4), 290–295.
Jerger, J., & Hall, J. (1980). Effects of age and sex on auditory brainstem response. *Archives of Otolaryngology, 106*(7), 387–391.
Kim, A. H., Kileny, P. R., Arts, H. A., El-Kashlan, H. K., Telian, S. A., & Zwolan, T. A. (2008). Role of electrically evoked auditory brainstem response in cochlear implantation of children with inner ear malformations. *Otology and Neurotology, 29*(5), 626–634.
Kimmel, S. R., & Ratliff-Schaub, K. (2011). Growth and development. In R. E. Rakel, & D. P. Rakel (Eds.). *Textbook of family medicine* (pp. 421–441). Philadelphia: Saunders.
Mastronardi, L., Di Scipio, E., Cacciotti, G., & Roperto, R. (2018). Vestibular schwannoma and hearing preservation: Usefulness of level specific CE-Chirp ABR monitoring. A retrospective study on 25 cases with preoperative socially useful hearing. *Clinical Neurology and Neurosurgery, 165*, 108–115.
Picton, T. W., Stapells, D. R., & Campbell, K. B. (1981). Auditory evoked potentials from the human cochlea and brainstem. *Journal of Otolaryngology Supplement, 9*, 1–41.
Polit, D. F. (2017). Clinical significance in nursing research: A discussion and descriptive analysis. *International Journal of Nursing Studies, 73*, 17–23.

Robles, L., & Ruggero, M. A. (2001). Mechanics of the mammalian cochlea. *Physiological Reviews, 81*(3), 1305–1352.

Tremere, L. A., & Pinaud, R. (2011). Brain-generated estradiol drives long-term optimization of auditory coding to enhance the discrimination signals. *Journal of Neuroscience, 31*(9), 3271–3289.

Tremere, L. A., Jeong, J. K., & Pinaud, R. (2009). Estradiol shapes auditory processing in the adult brain by regulating inhibitory transmission and plasticity-associated gene expression. *Journal of Neuroscience, 29*(18), 5949–5963.

Trune, D. R., Mitchell, C., & Phillips, D. S. (1998). The relative importance of head size, gender and age on the auditory brainstem response. *Hearing Research, 32*(2–3), 165–174.

Vander Werff, K. R., & Brown, C. J. (2005). Effect of audiometric configuration on threshold and suprathreshold auditory steady-state responses. *Ear and Hearing, 26*(3), 310–326.