Are the Normative Values of Sensorineural Acuity Level (SAL) Test Affected by Head Circumferences of Subjects?

Mahamad Almyzan Awang[1], Muhammad Afiq Asyraf Suhaimi[1], Rosdan Salim[2], Nik Adilah Nik Othman[2], Mohd Dasuki Sul'ain[3], Mohd Fadzil Nor Rashid[1] and Mohd Normani Zakaria[1]

[1]*Audiology Programme, School of Health Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia*

[2]*Department of Otorhinolaryngology, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia*

[3]*Biomedical Science Programme, School of Health Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia*

Abstract: *Introduction*: Sensorineural acuity level (SAL) test is believed to be helpful in estimating bone conduction thresholds in masking dilemma cases. However, before the SAL normative data can be used in clinical settings, there is a need to study the fundamental variable related to SAL normative data such as head circumference. As such, the purpose of the current study was to compare SAL normative values between subjects with bigger and smaller head circumferences at different frequencies.

Materials and Methods: In this study, 48 healthy Malaysian adult subjects (aged between 18 and 50 years) were enrolled. Pure tone audiometry (PTA) and SAL test were subsequently conducted based on the recommended protocols. The SAL normative values were then compared between subjects with bigger and smaller head circumferences. Data analysis methods included paired t-test, effect size, and Bayesian approach.

Results: No significant differences were noted in the SAL results when the two groups were compared, implying that the SAL normative data were not influenced by the head circumference ($p > 0.05$, $BF_{10} = 0.232\text{-}0.708$).

Conclusions: Based on the findings of this study it appears that the SAL test results are not affected by the head sizes of the subjects. Future SAL test studies may use the normative SAL values established in the current study as a guide.

Keywords: Pure tone audiometry, Masking dilemma, Sensorineural acuity level test, Bone conduction, Head circumference, Bayesian statistic, Normative data.

1. INTRODUCTION

Having a healthy hearing mechanism makes it possible to hear conversations and converse successfully. The incoming sounds are amplified and encoded accordingly by the outer, middle and inner ears, as well as the respective central auditory nervous system [1]. If any of the hearing organs are compromised, hearing impairment and associated symptoms may occur [2-5]. Among those who suffer from hearing loss, the type of hearing can be either conductive hearing loss (CHL), sensorineural hearing loss (SNHL) or mixed hearing loss (MHL), depending on which part of the ear is affected [1]. An accurate hearing impairment diagnosis is undoubtedly important so that the appropriate and timely management can be provided [1-3].

In clinical settings, subjective and objective audiological tests are performed to gather complete information on the hearing diagnosis [3-10]. Among others, pure tone audiometry (PTA) has been acknowledged as the standard clinical assessment for this purpose [2, 3]. Plotted on an audiogram, bone conduction (BC) and air conduction (AC) thresholds are useful for determining the type and severity of hearing loss for each ear, respectively [1-3]. It is worth noting that for determining the AC thresholds, headphones or insert earphones are used. Whereas in the BC testing, a bone transducer vibrator is utilized to measure the BC thresholds. CHL is indicated when the BC thresholds fall within the normal limit (less than 20 dB HL) and significant air-bone gaps (ABGs) are noted on the audiogram [1]. On the other hand, abnormal AC and BC thresholds (with no ABGs) would suggest the presence of SNHL [1].

It is important to note that PTA results can be invalid if cross-hearing phenomenon occurs during the testing. As such, the masking procedure is typically conducted to address the cross-hearing issue. In particular, while

*Address correspondence to this author at the Audiology Programme, School of Health Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia; Tel: +609-7677691; Fax: +609-7677515;
E-mail: mdnorman@usm.my

presenting a tone to the test ear, a narrowband masking noise is delivered to the other ear so that the cross-hearing phenomenon can be eliminated. “Masked” AC or BC thresholds are then obtained and considered valid for hearing diagnosis. Nevertheless, overmasking (“too much” masking noise is given to the non-test ear) can also occur, in which masked thresholds could not be obtained (resulting in an incomplete diagnosis). To overcome the overmasking problem, sensorineural acuity level (SAL) test was introduced, and it is useful to provide information on the ABGs and the “masked” BC thresholds [11-13].

In order to apply the SAL test in clinical settings, it is imperative to have valid SAL normative data derived from specific populations [13]. The SAL normative data are typically obtained by subtracting AC thresholds (from PTA) from AC thresholds tested in a “noisy” condition at specific frequencies [11]. During the SAL test, the headphones are placed on each ear while the bone vibrator is specifically positioned in the centre of the forehead. The bone transducer generates continuous narrowband noises at its maximum level. Herein, AC thresholds in noise are obtained and subsequently, the SAL normative data can be established [11-13].

Nevertheless, before the SAL normative data can be used for intended applications, there is a need to study the essential fundamental variable such as the head circumference. The literature on the effect of head circumference on the SAL test results is currently lacking. Since individuals with smaller head circumferences were found to have different skull properties (compared to those with bigger head sizes) [14-18], it would be interesting to know if the normative values of SAL test would also differ. Since the BC approach is involved in the SAL test procedure, the aspect of skull size may affect the SAL test results. Essentially, this study was conducted to determine the influence of head circumference on the SAL normative data among Malaysian adult subjects.

2. MAREIALS AND METHODS

2.1. Subjects

In the current study that utilized a cross-sectional design, 48 Malaysian adult subjects (aged between 18 and 50 years) were invited to participate. They were all in good health and had no prior history of hearing loss. As revealed by otoscopic and tympanometric tests, they were found to have a clear ear canal with an intact tympanic membrane bilaterally. Their hearing acuity was also within the normal limit (i.e., hearing thresholds were ≤ 20 dBHL at 0.25 to 8 kHz frequencies) bilaterally, as indicated by PTA testing. Before the data collection, each subject provided his/her consent form and the respective institutional review board granted an ethical approval, which is in accordance with the 1975 Declaration of Helsinki and its subsequent amendments.

2.2. Test Procedure

Using an established clinical audiometer (GSI 61 by Grason-Stadler Inc., United States), all subjects underwent both PTA and SAL assessments. In the PTA testing, it began with the AC testing and supra-aural TDH-39 headphones were used to determine the participants’ AC thresholds (AC quiet). The tested frequencies were at 0.25, 0.5, 1, 2, 4 and 8 kHz bilaterally. For measuring BC thresholds, Radioear B81 bone vibrator was used (and placed on the mastoid area), and frequencies of 0.25, 0.5, 1, 2 and 4 kHz were tested. Throughout this procedure, the subjects were asked to indicate their response by pressing the provided button once the sound was heard. Upon the confirmation of normal hearing bilaterally, the SAL test was then carried out.

The SAL test procedure carried out in the current study was in line with the established test protocol [12, 13]. As depicted in Figure **1**, the bone vibrator was applied to the forehead, and the headphones were used to cover both ears. The bone vibrator was used to continuously provide a narrowband noise at a fixed maximum level, while the headphones were used to deliver a pure tones to one ear at a time. Each subject was instructed to respond only to the presented pure tone stimulus by pressing the button and ignoring the masking noise. The masked air conduction thresholds (AC noise) were recorded at all frequencies (i.e., 0.25, 0.5, 1, 2 and 4 kHz) bilaterally. For each frequency, the SAL normative values were calculated by subtracting the AC quiet results (from PTA) from the AC noise findings (from SAL test) [13].

For the head circumference, each subject's head size was measured using the established clinical technique [19, 20]. Herein, the distance from the hairline to the back of the head, halfway between the eyebrows, was used to calculate the head circumference. Each subject had his/her head circumference measured twice, with the average of the results representing the final result.

Figure 1: The sensorineural acuity level (SAL) test procedure of a representative subject.

2.3. Statistical Analyses

The SAL normative data were computed from all subjects at the specific frequencies. As applicable, the data were presented in mean, standard deviation (SD) and percentage. The data distribution was checked using Shapiro-Wilk normality test, and it was found that the data were distributed normally ($p > 0.05$). Subsequently, paired t-test was used to compare the SAL results between right and left ears. In order to compare the SAL normative values between subjects with smaller and bigger head circumferences, an independent t-test was employed. The results were considered significant if the p values were less than 0.05. Additionally, the Bayesian approach was used to further demonstrate whether the data would support the alternative hypothesis or the null hypothesis [21, 22]. Particularly, if the Bayes factor, $BF_{10} > 1$, the results favour the alternative hypothesis. On the other hand, the null hypothesis is supported if $BF_{10} < 1$. According to the strength of the evidence, anecdotal evidence for the alternative hypothesis is indicated by a BF_{10} value between 1-3, substantial evidence for the alternative hypothesis is represented by a value between 3 and 10, strong evidence for the alternative hypothesis is shown by a value between 10 and 30, and conclusive evidence for the alternative hypothesis is indicated by a value over 100. The JASP statistical software (version 0.11.1) was used for the data analysis.

3. RESULTS

The subjects' mean age was 25.6 years ± 7.6 years, and 60.4% of them (n = 29) were female adults. Of 48 subjects, Malay ethic group had the biggest percentage

Table 1: Normative Data for Sensorineural Acuity Level (SAL) Test for Group A (Bigger Head Circumference) and Group B (Smaller Head Circumference). Mean, Standard Deviation (SD), p Value and BF_{10} Results are Shown.

Frequency (kHz)	Group	Mean (SD) (dB)	P value	BF_{10}
0.25	A	40.0 (8.6)	0.405	0.293
	B	38.5 (8.5)		
0.5	A	52.8 (8.9)	0.386	0.300
	B	51.3 (8.7)		
1	A	61.0 (7.0)	0.248	0.390
	B	59.4 (7.0)		
2	A	50.3 (7.5)	0.676	0.232
	B	50.9 (7.1)		
4	A	48.6 (7.3)	0.103	0.708
	B	51.1 (7.5)		

of subjects (79.2%), followed by Chinese (12.5%), Indian (2.0%), and other ethnicities (6.3%).

Based on the results obtained by individual measurements of study subjects' head circumference, the median value was calculated to be 54.8 cm. Based on this median value, the participants were then divided into two groups, i.e., bigger head circumference (Group A) and smaller head circumference (Group B). Of note, there were 24 participants in each group. The mean head circumferences were 56.3 cm (SD = 1.0 cm) and 53.6 cm (SD = 0.8 cm) for Group A and Group B, respectively.

All 48 participants completed the SAL test successfully for each ear. After determining that the SAL normative values were comparable between the ears ($p > 0.05$), the results of left and right ears were then combined (n = 96 ears). The respective SAL normative data for Group A (participants with bigger head circumferences) and Group B (participants with smaller head circumferences) are presented in Table **1**. As revealed, descriptively, the SAL normative data did not differ much between the groups. The independent t-test confirmed this observation as no significant differences in the SAL results were found between the two head size groups at each of tested frequencies (p

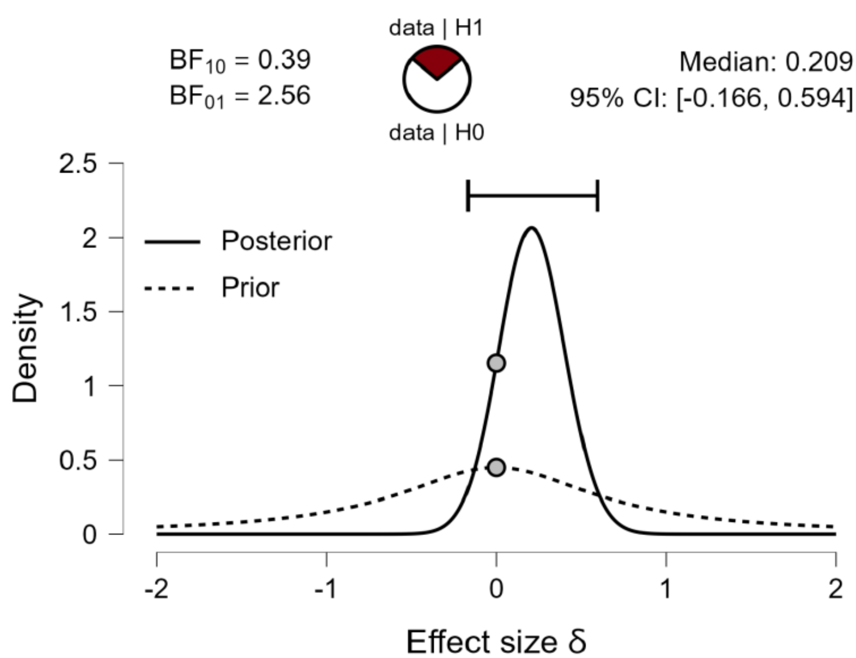

Figure 2: Bayesian inference findings for sensorineural acuity level (SAL) normative values when subjects with bigger and smaller head circumferences are compared (at 1 kHz frequency).

> 0.05). The findings of the Bayesian inference were consistent with the p values, i.e., all frequencies had BF_{10} values less than 1 (0.232-0.708), implying that the null hypothesis was supported. The Bayesian statistical findings when the two groups were compared at a test frequency of 1000 Hz are shown in Figure **2**.

4. DISCUSSION

In clinical settings, it is imperative for hearing diagnosis to be accurate. Having an accurate hearing diagnosis will lead to appropriate treatments and/or interventions. Acknowledged as the standard clinical test, PTA is widely used to provide comprehensive information on the degree and type of hearing loss [1-3]. Despite this, there are drawbacks to PTA testing, particularly when overmasking takes place. That is, it is problematic if the genuine BC thresholds are not established as the type of hearing loss could not be confirmed subsequently (leading to an incomplete hearing diagnosis). It is worth stating that overmasking is a common problem in the PTA testing and must be carefully addressed [12, 13, 23]. The SAL test is valuable in determining masked BC thresholds in cases of overmasking so that an accurate hearing diagnosis can be made. Research efforts regarding the SAL test are warranted to promote its application in clinical settings.

The SAL normative values obtained in the current study are in accordance with the previous findings reported by Awang *et al*. [13] and Kapoor *et al*. [23]. It is worth stating that both studies used the B81 bone vibrator to establish the SAL normative values among healthy Asian adults. On the contrary, the SAL normative values revealed in the current study are notably different when compared with the findings from other studies [11, 24]. This is likely due to the methodological differences as these studies were conducted on Caucasian adults using a different type of bone transducer (i.e., Radioear B-71 bone vibrator).

The main aim of the current study was to ascertain whether the SAL normative data were different between those with bigger and smaller head circumferences. In the SAL test, the bone-conducted noise is delivered at the fixed maximum level while the BC transducer is positioned in the middle of the forehead. The shift in AC thresholds is then noted after obtaining ear-specific AC thresholds in the presence of noise [11]. When the thin section of the skull bone in the temporal area is stimulated, the BC thresholds are lower than when the thicker part of the skull bone is stimulated at the forehead [25]. In line with this, there was a study reported that women may have a lower head bone density especially after menopause [26], and this may affect the sound transmission through the skull. Collectively, it seemed sensible to hypothesize that the SAL normative values would be different between subjects with different head circumferences (due to different skull properties).

Nevertheless, as revealed, no significant differences in the normative results of the SAL test were observed when the two different head size groups were compared at all tested frequencies, which were rather unexpected. The p value and BF_{10} results were consistent from each other, implying that the null hypothesis was in favour. These findings are possibly due to several reasons. Firstly, since the SAL normative data are derived from a specific formula (i.e., AC noise minus AC quiet), the effect of head size (or head density) could be “neutralized” and “absent”. It is important to highlight that in other research, there were no significant gender differences in several variables of the head measurement [27]. Secondly, the sample size in this study was modest (n = 48). In this regard, studies with larger sample sizes may further be required to reveal more significant outcomes.

5. CONCLUSIONS

Having the SAL test in clinical settings is advantageous as it provides exact BC thresholds, (that cannot be obtained from the gold standard hearing test) important in diagnosing hearing loss cases accurately. In the current study, the normative values of the SAL test were compared between Malaysian adults with bigger and smaller head circumferences, an important aspect not evaluated earlier. This study demonstrates that the SAL test results are not affected by the head sizes of the subjects. Future SAL test studies may use the normative SAL values established in the current study as a guide.

DISCLOSURE STATEMENT

All authors declared no conflicts of interest.

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