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Original articles

Impact of hearing aid electroacoustic verification on speech perception and user performance in daily activities

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ABSTRACT

Purpose: to assess the impact of electroacoustic verification on the satisfaction level and speech recognition in quiet and noise of hearing aid users.

Methods: 24 individuals who had been using the device for at least 1 year and had not previously performed electroacoustic verification were assessed. In the first session, participants responded to the International Outcome Inventory for Hearing Aids validation questionnaire and indicated their satisfaction level on a visual analog scale. They were, then, subjected to speech perception tests in quiet and noise and electroacoustic verification, returning after 3 months and repeating the first stage assessments. The Wilcoxon test and paired t-test were used for data analysis, with significance set at p-value $\leq$ 0.05.

Results: the visual analog scale assessment, the International Outcome Inventory for Hearing Aids score, the speech perception threshold in quiet and noise, and the signal/noise ratio improved after 3 months.

Conclusion: individuals who had been using the device for at least 1 year had a substantial improvement in their satisfaction level and speech perception in quiet and noise after the electroacoustic verification.

Keywords: Hearing Aids; Assessment Study; Hearing Loss; Speech Perception; Hearing

A study conducted at the Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil.

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INTRODUCTION

Improvements in the quality of life and health conditions and the control of chronic and infectious diseases have increased life expectancy. However, the effects of aging on sensory capabilities remain unchanged, causing related conditions such as hearing loss[1,2].

Studies have indicated that hearing loss begins around the age of 30 and gradually worsens over the years[3,4], being more prevalent in men. These differences can be ascribed to the influence of sex-specific characteristics on both the peripheral and central auditory nervous system, which affect auditory functioning in young and older adults[5-7].

The self-perceived impact of hearing loss on adults must be considered in studies with this population, being observable, for example, in the progression of hearing loss and the moment at which they decide to use hearing aids (HA)[5]. Another aspect is the adult's reluctance to accept hearing loss, attributing their hearing difficulties to an inadequate environment or other people's communication. Older adults commonly have a lower perception of the impact of hearing loss, regardless of the type of loss, which can be justified by their age[8].

HA use is the beginning of the rehabilitation process for people whose hearing loss has no drug or surgical treatment. It mainly aims to correct or alleviate the loss of hearing sensitivity (ensuring the detection of lower intensity signals and comfort with moderate and strong intensities), reduce or eliminate restrictions caused by hearing loss, and reestablish or expand the person's social participation[8].

The guidelines of the Federal Speech-Language-Hearing Council, Brazilian Academy of Audiology, and international institutions stipulate that HA performance be verified during adaptation through objective methods since the main objective of amplification is to make all sound signals and speech characteristics comfortably audible[3,9].

In this context, electroacoustic verification plays an essential role in the hearing adaptation process. Its purpose is to evaluate whether the electroacoustic and physical characteristics defined during the selection, encompassing intrinsic and extrinsic factors, were adequately achieved[4]. The three main objectives of the verification are to ensure the audibility of soft sounds, provide comfort during speech perception, and ensure tolerance to high-intensity sounds. This step plays a fundamental role in improving user satisfaction and contributing to better performance in speech perception with HA[10].

One of the procedures in the electroacoustic verification stage is the visible mapping of amplified speech, which evaluates the accessibility of the speech signal. The Speech Intelligibility Index (SII) is part of the electroacoustic verification and evaluates the patient's accessibility to speech sounds on a scale from 0 to 100%, with or without the use of amplification[11]. The SII acts as a clinical standard to optimize HA adjustment to predetermined goals, making it possible to quantify the percentage of accessible speech signals with the adjustment. Not all speech sounds will be audible, even after amplification, due to the degree and configuration of hearing loss, so adjusting an amplification device is intended to maximize audibility[6].

Thus, this study aimed to assess the impact of electroacoustic verification on HA users' satisfaction level and speech recognition in quiet and noise.

METHODS

Study design and ethical aspects

This longitudinal analytical study was approved by the Research Ethics Committee of the Universidade Federal de Minas Gerais, MG, Brazil, under evaluation report 2.568.729 (CAAE number 84049518.9.0000.5149). All participants were informed about the study objectives, risks, and procedures and were given an informed consent form, which they read and signed after having their questions answered.

Study scenario

The research sample had 24 adults and older adults who had been using bilateral HA for at least 1 year, which had been fitted in an HA company. Chosen at random, the participants attended two sessions for data collection with speech perception assessment and guidance before and after the electroacoustic verification. All participants used HA with proprietary prescription procedures before the electroacoustic verification and started using the NAL-NL2 validated prescription procedures to perform the electroacoustic verification.

Two assessment stages were carried out, one before, lasting 60 minutes, and the other one after 3 months, lasting 30 minutes.

Data were collected over 6 months in a private office from users who had been bilaterally fitted at least 1 year before.

Sample

The inclusion criteria were as follows: having used HA bilaterally for at least 1 year and being over 18 years old. The exclusion criteria were not completing the tests; having psychiatric or neurological changes preventing the evaluation, low visual or auditory acuity limiting the performance of tests and evaluations, and cerumen impaction hindering speech perception tests; and requesting to have the HA prescription procedures changed during data collection.

Data collection procedures

In the first session, named Session 1 (S1), the participants' medical history was surveyed, collecting information about their hearing loss characteristics and history of hearing loss and HA use.

The researcher applied a visual analog scale (VAS) to assess their level of satisfaction with HA adaptation in a picture with five faces, each face corresponding to a grade: "Very dissatisfied" (0 to 2), "Dissatisfied" (3 and 4), "Indifferent" (5 and 6), "Satisfied" (7 and 8), and "Very satisfied" (9 and 10). The participant chose the face that came closest to their satisfaction with HA adaptation.

All individuals answered the International Outcome Inventory for Hearing Aids (IOI-HA) (Figure 1), a self-assessment questionnaire that documents HA performance from the user's perspective regarding daily use, benefit, limitation of basic activities, satisfaction, restriction of participation, impact on other people, and quality of life. It has a total of eight questions, each of them with five answer options, scored on a scale from 1 (indicating the worst result) to 5 (indicating the best result).

They were submitted to otoscopy (to verify the integrity of the external auditory meatus and whether they had cerumen impaction) and to the speech perception tests - which establishes the signal-to-noise ratio (SNR) as the difference in dB between the SRTN (sentence recognition threshold in noise) and the competing noise; if the SNR is negative or the lower it is, the better the result[12].

Then, the electroacoustic verification was carried out, in which the patient's pure-tone thresholds (dB HL) were recorded and automatically converted into sound pressure levels (dB SPL) by the electroacoustic verification equipment[13]. Information about the prescription procedure (in this case, NAL-NL2) for programming and the HA type (behind-the-ear or in-the-ear) was also inserted into the equipment to correctly calculate output levels and discomfort levels in SPL. The size of the ventilation tube, for those who had it, was also included.

The stimulus used for the electroacoustic verification was the International Speech Test Signal (ISTS), which contains acoustic signals with speech characteristics. Calibration was performed before starting the measurement, placing the end of the probe near the reference microphone, positioned 20 cm away from the speaker, thus establishing ideal conditions for collecting acoustic data[14].

After the calibration stage – with the HA turned on and properly positioned in the patient's ear along with the probe microphone to record the SPL in the external auditory meatus –, speech was mapped by presenting the signal at three different levels: 55 dB SPL for weak speech sounds, 65 dB SPL for medium speech sounds, and 75 dB SPL for loud sounds. After amplifying the speech signal, recordings were made for each of these levels, as well as fine adjustments to reach the electroacoustic verification goal. A comparison was made of the mean resonance response values of the external ear with the HA turned on (Real Ear Aided Response – RAR), measured in SPL.

The second session, named Session 2 (S2), took place 3 months after S1. In S2, the researcher applied the VAS to assess their level of satisfaction with HA adaptation and the IOI-HA self-assessment questionnaire and determined the SRTQ and SRTN.

Data analysis

Collected data were descriptively analyzed to characterize the sample regarding their age, sex, time since hearing loss diagnosis, history of HA use, degree of hearing loss, and speech perception test results. The descriptive data analysis used the frequency distribution of categorical variables and the measures of central tendency and dispersion of continuous variables.

The Wilcoxon test and paired t-test were used for the comparison analysis between measurements – significance was set at p-value ≤ 0.05. The tests were chosen based on whether the variables had a normal distribution, verified with the Shapiro-Wilk and Kolmogorov-Smirnov tests.

RESULTS

The final study sample had 24 bilateral HA users, 13 males and 11 females, aged 48 to 95 years (a mean of 75.08 years), having used HA for at least 1 year. All patients were recruited through an HA company's database.

The boxplots of the participants' ages per degree of hearing loss in the right and left ears are shown below (Figure 1).

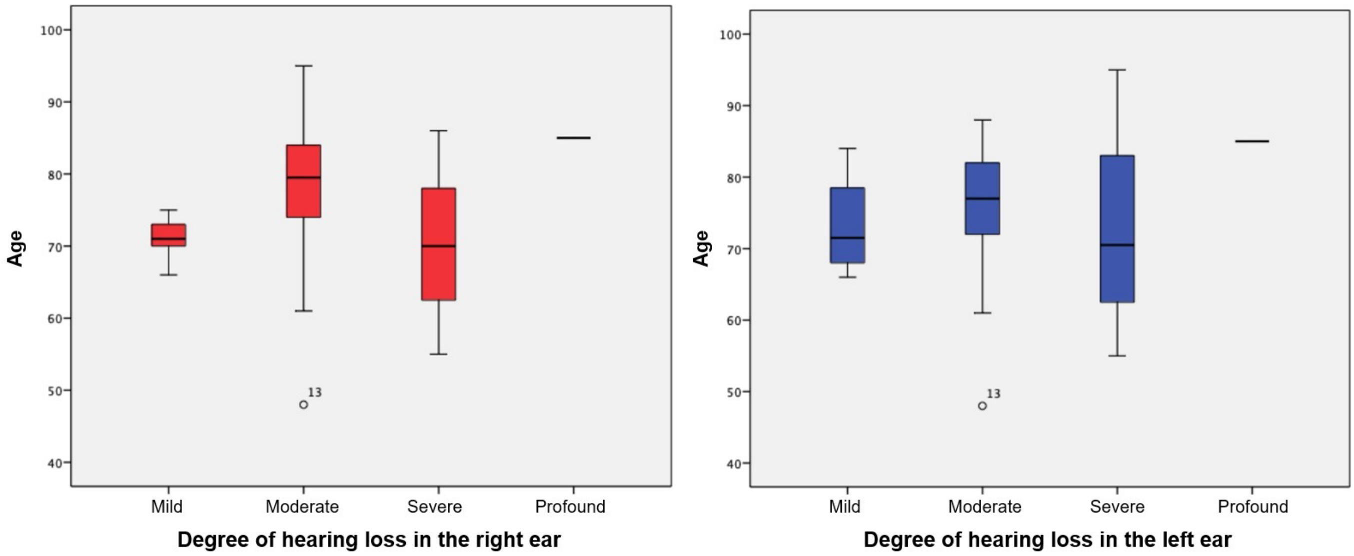
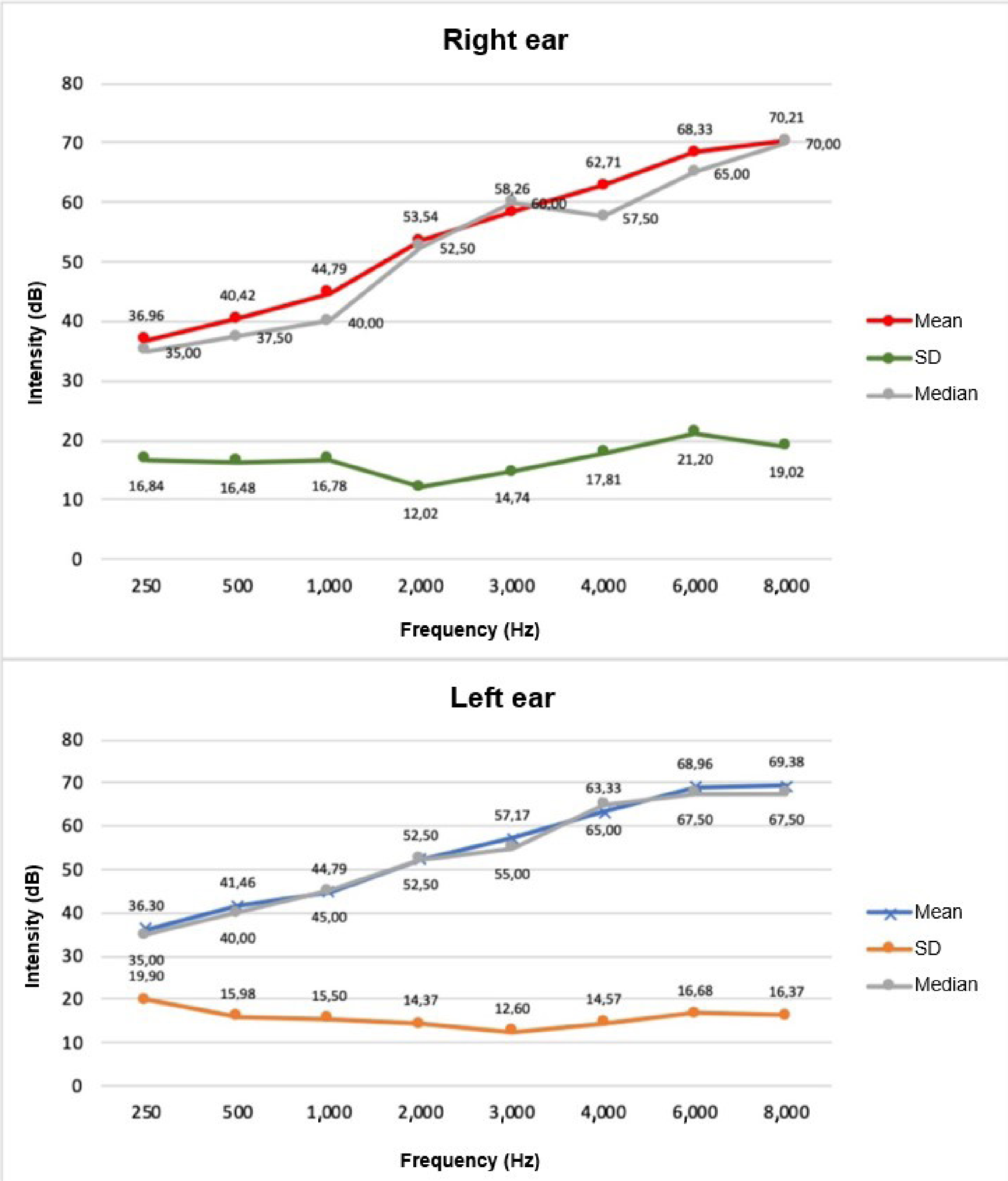


Figure 1. Boxplots of the participants' ages per degree of hearing loss in the right and left ears

In the right ear, five of the 24 participants had mild hearing loss (20.8%), 14 had moderate hearing loss (58.3%), four had severe hearing loss (16.7%), and one had profound hearing loss (4.2%). In the left ear, four had mild hearing loss (16.7%), 15 had moderate hearing loss (62.5%), four had severe hearing loss (16.7%), and one had profound hearing loss (4.2%). %) – all of them sensorineural –, classified according to the World Health Organization classification[15].

The participants' audiometric profiles are described in Figure 2.



Caption: SD = standard deviation.

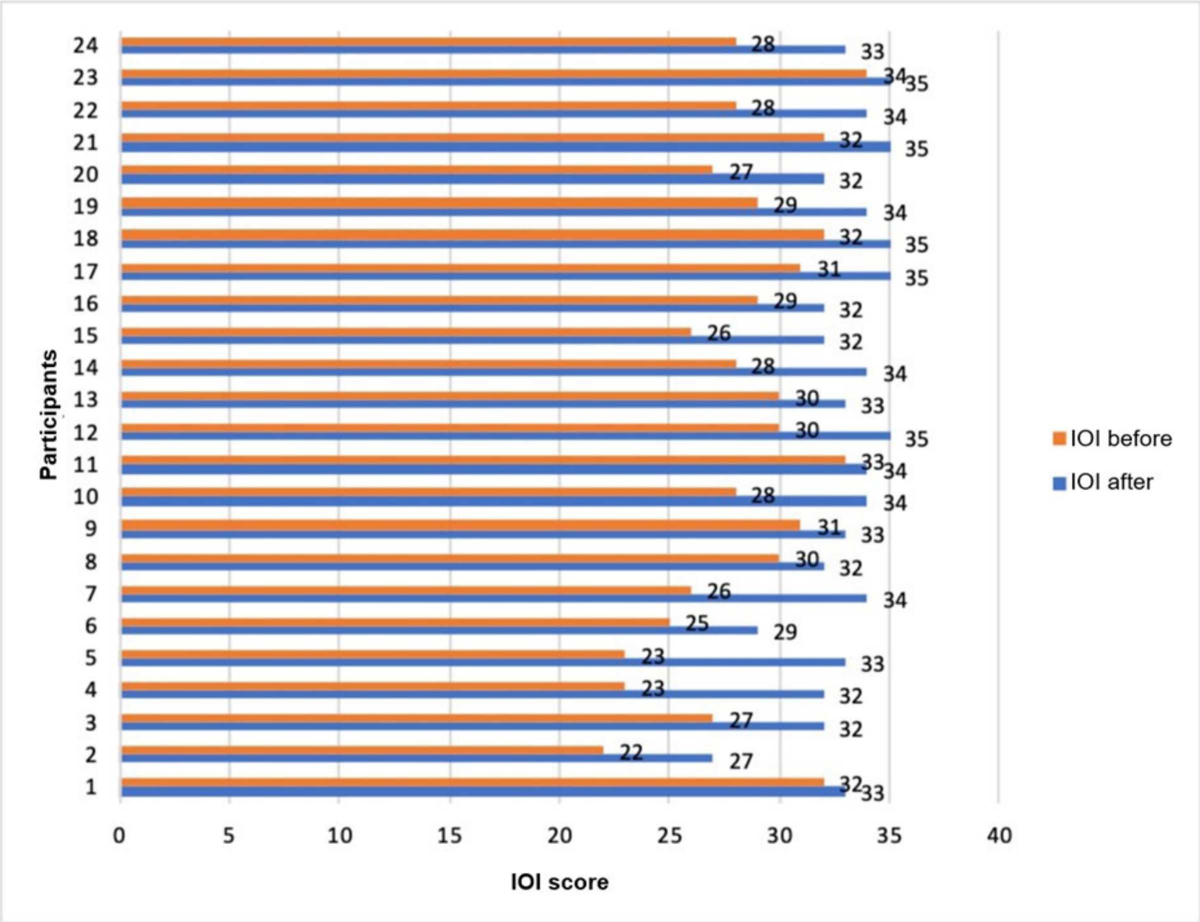
Figure 2. Hearing thresholds in the right and left ears in dB HL at 250 to 8000 Hz

The time of HA use ranged from 1 to 30 years, with a mean of 5.66 years and a median of 4 years (counting from the date of the first fitting). The time since diagnosis ranged from 1 to 35 years, with a mean of 11.16 years and a median of 10 years. This information was based on each patient's self-report.

VAS was applied before and after the electroacoustic verification to descriptively assess the patients' level of satisfaction with the current HA, marking 0 for "Very dissatisfied" and 10 for "Very satisfied". The mean result went from 7 before the verification to 8.88 after the verification.

The IOI-HA scores both before and after the electroacoustic verification showed that most participants used the HA for more than 8 hours a day. Moreover, this score was higher after the electroacoustic verification.

The overall IOI-HA scores per participant before and after the electroacoustic verification are presented in Figure 3 – which shows an improvement in all patient's overall scores after the electroacoustic verification. The questions refer to the time of daily use, improvement in listening in difficult situations with HA use, self-perceived improvement of the quality of life, difficulties faced without using the HA, and degree of difficulty in listening without using the HA.



Caption: IOI : International Outcome Inventory.

Figure 3. International Outcome Inventory for Hearing Aids score per participant in Sessions 1 and 2

The analysis with the Lists of Sentences in Portuguese collected the sentence recognition threshold values in quiet and noise and the SNR, maintaining noise at 65 dB. The mean thresholds in quiet improved in this test applied 3 months after the electroacoustic verification. The thresholds in noise also improved from before to after the electroacoustic verification, as seen in Table 1.

Table 1. Descriptive measures of the sentence recognition test with and without noise in sessions 1 and 2

Variables	N	Mean	SD	Median	Minimum	Maximum
Sentences in quiet (S1)	24	41.88	9.99	42.50	21.00	58.00
Sentences in quiet (S2)	24	35.29	7.32	35.00	21.00	51.00
Sentences in noise (S1)	24	61.21	3.23	61.00	55.00	67.00
Sentences in noise (S2)	24	53.08	3.48	63.00	48.00	61.00

Captions: N = number of individuals; SD = standard deviation; S1 = Session 1; S2 = Session 2.

The SNRs after the electroacoustic verification are presented in Table 2, with an improvement in the results.

Table 2. Descriptive measures of the signal-to-noise ratios

Variables	N	Mean	SD	Median
SNR (S1)	24	1.21	3.23	1.00
SNR (S2)	24	-7.13	3.51	-7.00

Captions: N = number of individuals; SD = standard deviation; SNR = signal-to-noise ratio; S1 = Session 1; S2 = Session 2.

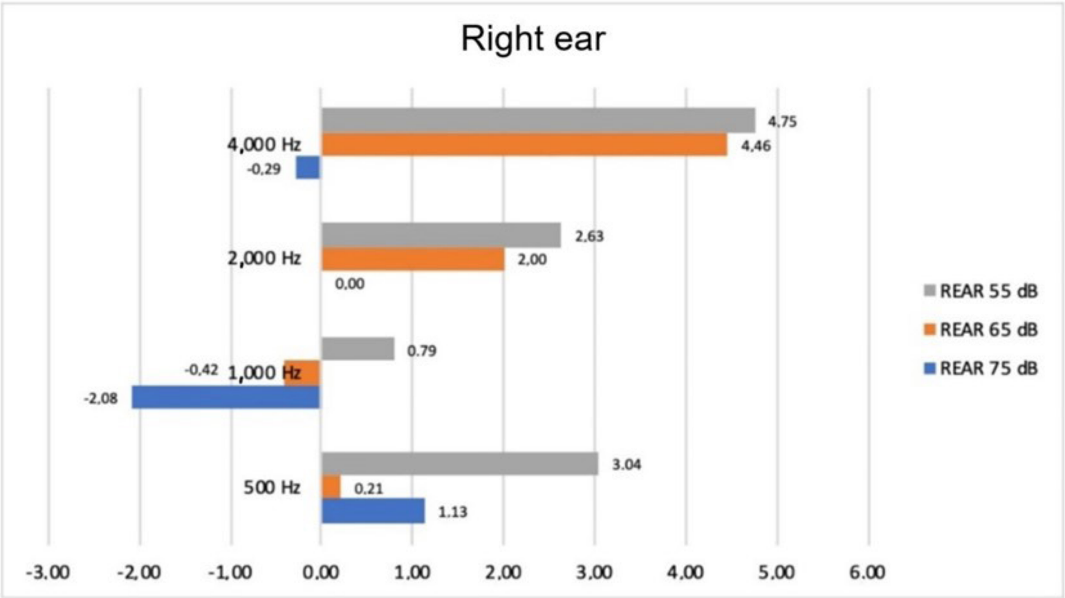
Table 3 presents the comparison between mean resonance response values of the external ear with the HA turned on (REAR), measured in SPL, in relation to the NAL-NL2 prescription procedure goals and the evaluation in 55, 65, and 75 dB SPL at 500, 1000, 2000, and 4000 Hz in the 24 participants' right ears.

Table 3. Descriptive measures of the Real Ear Aided Response in the right ear

Variables	N	Mean	SD	Median
REAR 55 dB				
500 Hz	24	3.04	4.54	3.00
1000 Hz	24	0.79	3.38	1.00
2000 Hz	24	2.63	3.91	3.00
4000 Hz	24	4.75	4.37	5.00
REAR 65 dB				
500 Hz	24	0.21	3.58	0.50
1000 Hz	24	-0.42	3.18	-0.50
2000 Hz	24	2.00	4.13	0.50
4000 Hz	24	4.46	4.73	3.50
REAR 75 dB				
500 Hz	24	1.13	3.46	1.00
1000 Hz	24	-2.08	4.62	-2.00
2000 Hz	24	-2.46	3.56	-3.00
4000 Hz	24	-0.29	3.88	0.00

Captions: N = number of individuals; SD = standard deviation; REAR = Real Ear Aided Response.

Figure 4 illustrates the means presented in Table 4.



Caption: REAR = Real Ear Aided Response.

Figure 4. Mean Real Ear Aided Response in the right ear in dB SPL

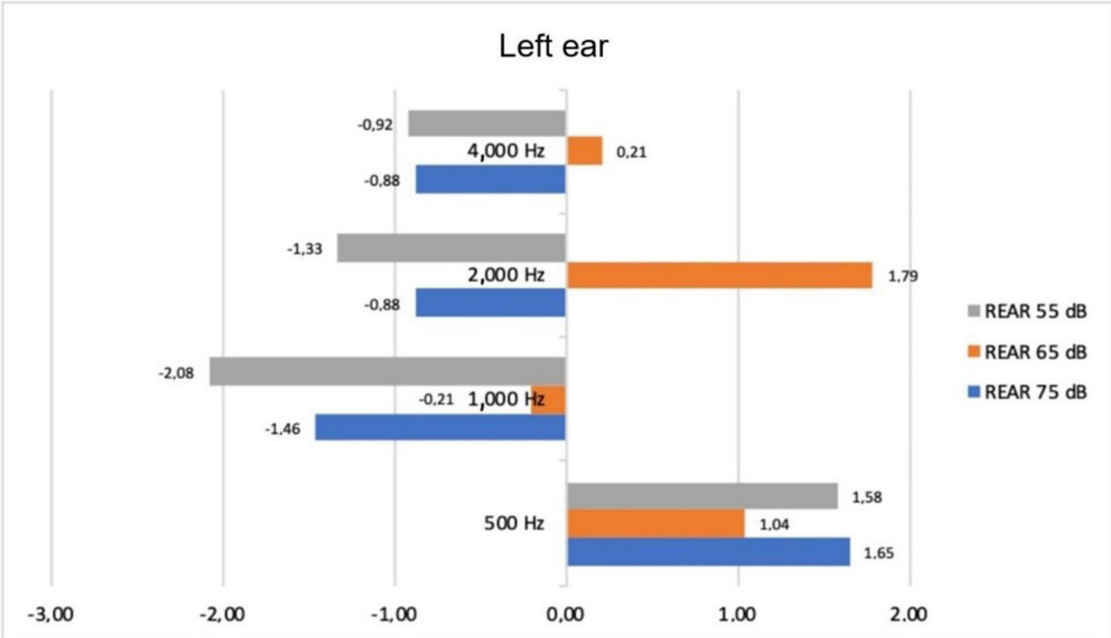
Table 4 shows the comparison of the mean REAR values in relation to the NAL-NL2 prescription procedure goals and the evaluation in 55, 65, and 75 dB SPL at 500, 1000, 2000, and 4000 Hz in the 24 participants' left ears.

Table 4. Descriptive measures of the Real Ear Aided Response in the left ear

Variables	N	Mean	SD	Median
REAR 55 dB				
500 Hz	24	2.92	3.43	2.50
1000 Hz	24	1.46	3.24	0.50
2000 Hz	24	2.13	4.01	2.00
4000 Hz	24	3.13	4.77	4.00
REAR 65 dB				
500 Hz	24	1.04	3.82	0.00
1000 Hz	24	-0.21	3.88	-0.50
2000 Hz	24	1.79	3.22	3.00
4000 Hz	24	0.21	4.28	0.50
REAR 75 dB				
500 Hz	24	1.58	3.45	1.50
1000 Hz	24	-2.08	5.51	-4.00
2000 Hz	24	-1.33	4.73	-2.00
4000 Hz	24	-0.92	5.93	-2.00

Captions: N = number of individuals; SD = standard deviation REAR = Real Ear Aided Response.

The means presented in Table 4 are illustrated in Figure 5.



Caption: REAR = Real Ear Aided Response.

Figure 5. Mean Real Ear Aided Response in the left ear in dB SPL

Table 5 compares the level of satisfaction with HA adaptation, the IOI-HA score, sentence recognition in quiet and noise, and SNR before and after the electro-acoustic verification. The analysis demonstrated statistically significant results from before to after the verification regarding:

- VAS: with higher mean and median after it ($p \leq 0.001$).
- IOI-HA score: with higher mean and median after it ($p \leq 0.001$).
- Sentence recognition in quiet: with higher mean and median before it ($p \leq 0.001$).
- Sentence recognition in noise: with higher mean and median before it ($p \leq 0.001$).
- SNR: with higher mean and median before it ($p \leq 0.001$).

Table 5. Comparison of Visual Analog Scale assessments, International Outcome Inventory for Hearing Aids scores, sentence recognition, and signal-to-noise ratio between Sessions 1 and 2

Variables	Session	N	Mean	SD	Median	Valor-p
VAS	S1	24	7.00	1.72	7.00	≤0.001*[1]
	S2	24	8.88	1.19	9.00	
IOI-HA score	S1	24	28.50	3.23	28.50	≤0.001*[1]
	S2	24	33.00	1.91	33.00	
Sentences in quiet	S1	24	41.88	9.99	42.50	≤0.001*[2]
	S2	24	35.29	7.32	35.00	
Sentences in noise	S1	24	61.21	3.23	61.00	≤0.001*[2]
	S2	24	53.09	3.48	53.00	
SNR	S1	24	1.21	3.23	0.00	≤0.001*[2]
	S2	24	-7.13	3.51	-7.00	

[1]Wilcoxon test; [2]Paired t-test
Captions: SD = standard deviation; * = $p \leq 0.05$; VAS = Visual Analog Scale; IOI-HA = International Outcome Inventory for Hearing Aids; SNR = signal-to-noise ratio.

DISCUSSION

Altogether, 24 patients were invited to participate in the research, 13 being males (54.2%) and 11 females (45.8%), aged 48 to 95 years, with a mean of 74.9 years. The mean time since hearing loss diagnosis was 11.57 years. Many participants had difficulty answering this, mainly because they did not notice the hearing loss early, always reporting the diagnosis close to the intervention.

The mean time of HA use was 5 years, with a minimum of 1 year and a maximum of 30 years, which is quite variable. A study[15] analyzed the effects of HA use in older people after 1 month, 6 months, and 1 year. The results revealed significant changes in participants' hearing performance after 1 and 6 months of use, compared to the results obtained after 1 year of use[15]. Other studies[7,16] demonstrated a progressive improvement in hearing performance as the time of HA use increased.

There was a predominance of moderate hearing loss, which is in line with other previous studies[17]. Various researchers report the frequent occurrence of hearing loss in older adults' both ears[15-18]. Hearing loss bilaterality was one of the inclusion criteria for this study, and this characteristic is crucial to investigate the demand regarding this condition in the research population.

The guidelines[9] that establish good practices for HA selection and fitting recommend the essential set of steps to ensure effective amplification, as follows: candidate evaluation, selection of amplification characteristics, performance verification and device fitting, user guidance and advice, and evaluation of results or validation of amplification[19-22].

REAR measures were assessed in relation to the prescription goal to compare the effectiveness of sound amplification adjustments at different frequencies. The objective was to evaluate how these measures align with established parameters after changing the proprietary prescription procedure to a validated one (NAL-NL2). Objective equivalence results were verified with the criteria by Mueller et al.[22], which establishes a difference of ± 5 dB between REAR values and the prescription goal.

The present research found greater assertiveness at the input levels of 65 dB and 75 dB and at 1000 Hz and 2000 Hz and lower assertiveness at 4000 Hz in the right ear. As for the left ear, greater assertiveness was found at 1000 Hz, 2000 Hz, and 4000 Hz at all input levels (55 dB, 65 dB, and 75 dB). This result does not corroborate a study[18], in which the gain values were close to the prescription goal at 500 Hz, 1000 Hz, and 2000 Hz, respectively; moreover, half of the individuals on average did not reach the prescription value at 3000 Hz and 4000 Hz.

The analysis of VAS results regarding the satisfaction level with HA use in this research showed greater satisfaction after the electroacoustic verification and better results in the comparison analysis with the IOI-HA questionnaire. These findings corroborate a 2016 survey by Tonelli and collaborators[23], which verified significantly improved thresholds in quiet and noise and SNRs in the second moment – i.e., after fine adjustment to reach the prescription goals.

Electroacoustic verification allows adjustment of HA parameters to optimize speech audibility and avoid volume discomfort. It also involves clients and their relatives in the adaptation process, leading to greater understanding and satisfaction. A 2022 study[24] by Chiriboga with 61 HA users compared a group that was mapped with another that was not, showing a 49% decrease in follow-up visits in the group that underwent speech mapping.

Speech recognition validation tests in quiet and noise combined with electroacoustic verification provide more precise guidance to meet patients' real expectations, thus ensuring more targeted advice for HA use. This approach optimizes hearing performance, personal satisfaction, and benefits. Additionally, it significantly reduces the user's follow-up visits for adjustments, highlighting the relevance of considering these procedures as an integral part of protocols in audiology services[25].

CONCLUSION

The study results suggest that HA users who had been using the device for at least 1 year, substantially improved their level of satisfaction and speech perception in quiet and noise, after adjustments with electroacoustic verification. Such findings reaffirm the importance of using this procedure in clinical routines, during HA adaptation and regulation.

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Authors' contributions:

FHL: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Supervision; Validation; Writing – original draft; Writing – review & editing.

LMR: Conceptualization; Formal analysis; Investigation; Methodology; Supervision; Validation; Writing – review & editing.