CoDAS
ISSN 2317-1782 (Online version)

Original Article
Artigo Original

Hearing aid fitting in the elderly: prescription of acoustic gain through frequency thresholds obtained with pure tone and narrow band stimuli.

Adaptação de próteses auditivas em idosos: prescrição de ganho acústico por meio dos limiares de audibilidade obtidos com tom puro e narrow band.

Gabriela Fireman Martines Dias[1]
Marilia Rodrigues Freitas de Souza[1]
Maria Cecília Martinelli Iorio[1]

Keywords

Aging
Aged
Hearing Aids
Auditory Threshold
Hearing Loss

ABSTRACT

Purpose: To verify the benefit obtained by the prescription of acoustic gain based on the auditory thresholds obtained with pure tones modulated in frequency and with Narrow Band Noise. **Methods.** The sample consisted of 30 elderly people, aged 60 years or over with moderate to severe descending sensorineural symmetrical hearing loss with thresholds at 4kHz equal to or less than 70dBHL. There were two groups. GTP (pure tone group): 15 elderly people had their hearing aids fitted through the auditory thresholds obtained with pure tone and the GNB group (narrow band group): 15 elderly people had their hearing aids fitted through the auditory thresholds obtained with NB. The procedures performed before the fitting of hearing aids and after three months of amplification use were: COSI, WRS (Word Recognition Score), Signal/Noise ratio. The International Outcome Inventory for Hearing Aids (IOI-HA) was applied only after three months of hearing aid fitting. **Results:** The elderly people in the group in which the hearing aids were fitted with a prescribed gain based on the hearing thresholds obtained with the Narrow Band stimulus showed better performance in the following tests: WRS on the right ear, total score of the IOI-HA inventory, COSI and longer use of hearing aids compared to the GTP group. **Conclusion:** There was a greater benefit with the use of hearing aids, due to the total score of the IOI-HA inventory, COSI scale and longer daily use time of hearing aids, in the group whose prescription of acoustic gain was based on the auditory thresholds obtained with narrow band.

Descritores

Envelhecimento
Idoso
Auxiliares de Audição
Limiar Auditivo
Perda Auditiva

RESUMO

Objetivo: Verificar o benefício obtido pela prescrição de ganho acústico baseada nos limiares audiométricos obtidos com tons puros (Warble) e com ruído de faixa estreita (NB). **Método:** Amostra de 30 idosos, com idade igual ou superior a 60 anos, perda auditiva neurossensorial de grau moderado a severo simétrica bilateral de configuração descendente com limiares em 4kHz iguais ou inferiores a 70dBNA. Foram dois grupos. GTP (grupo tom puro): 15 idosos tiveram as próteses auditivas adaptadas com emprego dos limiares obtidos com tom puro e grupo GNB (grupo Narrowband):15 idosos tiveram as próteses auditivas adaptadas por meio dos limiares obtidos com NB. Os procedimentos realizados antes da adaptação de próteses auditivas e após três meses de uso de amplificação foram: Escala COSI, IPRF (Índice Percentual de Reconhecimento de fala), Relação Sinal/Ruído e análise do tempo de uso do AASI. O Questionário Internacional de Aparelho de Amplificação Sonora Individual (QI-AASI) foi aplicado após três meses. **Resultados:** Os idosos do grupo em que as próteses auditivas foram adaptadas com ganho prescrito com base nos limiares auditivos obtidos com o estímulo Narrow Band apresentaram melhor desempenho nos seguintes testes: IPRF à orelha direita, pontuação total do questionário QI-AASI, escala COSI e maior tempo de uso do AASI em comparação ao grupo GTP. **Conclusão:** Observou-se maior benefício com o uso de próteses auditivas, pela pontuação total do questionário QI-AASI, escala COSI e maior tempo de uso do AASI, no grupo cuja prescrição do ganho acústico baseou-se nos limiares audiométricos obtidos com o Narrowband.

Correspondence:
Maria Cecília Martinelli Iorio
Departamento de Fonoaudiologia, Escola Paulista de Medicina, Universidade Federal de São Paulo – UNIFESP
Rua Tome de Souza, 1338, São Paulo (SP), Brasil. CEP: 05079-200.
E-mail: cmartinelli@uol.com.br

Received: June 22, 2020

Accepted: October 15, 2020

Study conducted at Universidade Federal de São Paulo – UNIFESP - São Paulo (SP), Brasil.

[1] Departamento de Fonoaudiologia, Universidade Federal de São Paulo – UNIFESP - São Paulo (SP), Brasil.

Financial support: Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (2017/25719-9) Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) – Edital Universal número 429276/2016-8 Grupo de Pesquisa Audição e Auxiliares de Audição.

Conflict of interests: nothing to declare.

INTRODUCTION

Pure tone audiometry, which is the gold standard procedure for the assessment of audibility[1], is the starting point for the process of selection and fitting of hearing aids, as the gain values per frequency, that is, the target of amplification (gain) is determined, usually based on a validated prescriptive rule.

Often to obtain auditory thresholds, pure tones modulated "warble" frequency are used, as they enable better responses in the perception of the stimulus, especially in patients with tinnitus, and also because it reduces the possibility of acoustic effects generated by the positioning of the headphones during the test[2].

In some studies, comparable thresholds were obtained using pure tones and narrow band noise in individuals with normal hearing[3] and with sensorineural loss with flat configuration[4]. Individuals with descending hearing loss, however, presented better thresholds using the NarrowBand[5] as a stimulus. There are, therefore, studies that report that the research of audiometric thresholds with narrow-band noise stimulus "Narrow Band noise" enables better audiometric thresholds [6], which would lead to the prescription of different gain values.

Patients with descending configuration hearing losses have the biggest complaints in the process of fitting hearing aids. This audiometric configuration can be compatible with the presence of dead regions in the basal region of the cochlea[7].

The Threshold Equalizing Noise (TEN) test was developed after the definition of dead regions in the cochlea, to detect areas with inactive inner hair cells[8].

Based on a study performed using the TEN test, it was found that when the hearing threshold at 4kHz is greater than 70 dB HL, it is necessary to be cautious in the amplification at high frequencies to avoid distortion of acoustic information, as in these cases there is 65% of chance of occurrence of the dead regions[9]. Individuals who have a region of high frequencies with a dead region in the cochlea are better able to process acoustic information at low frequencies[10].

The use of hearing aids with frequency lowering, in the case of dead regions at high frequencies, is recommended to improve speech recognition[11]. However, there is a study that showed worsening in the recognition of sentences in noise in individuals with descending configuration hearing loss with the use of this resource[12].

Thus, it is observed that the application of frequency lowering techniques in clinical practice has become a challenge for science in favor of the technology of sound amplification devices and has generated diversified results in relation to the benefits provided by this technology.

Considering that stimuli with a wider frequency range enable stimulation of a larger area of the basilar membrane, patients with cochlear dead regions may present better audibility thresholds when obtained with different stimuli due to energy dissipation. In these cases, the thresholds obtained with Narrow Band noise can be better, especially at high frequencies, as the critical noise range increases as the frequency become higher[13].

If different stimuli are used to obtain auditory thresholds and provide different information, especially in cases of descending configuration hearing losses, with thresholds below 70 dBHL at 4kHz, what would be the most appropriate stimulus for researching the thresholds to be considered for the prescription for acoustic gain? Those obtained with warble tone or those obtained with narrowband noise?

In order to choose strategies in audiological clinical practice to improve the fitting of hearing aids in patients with descending hearing loss, the hypothesis that guided this research realized that adults/elderly people with descending sensorineural hearing loss with thresholds above 70dBHL at 4000 Hz present greater satisfaction with the use of hearing aids when the calculation of acoustic gain is performed from the thresholds studied with the Narrow Band stimulus than with the frequency-modulated pure tone stimulus - Warble. Therefore, the objective of this research is to verify the benefit obtained by the elderly with the use of hearing aids from the acoustic gain prescription based on audiometric thresholds obtained with pure tones modulated in frequency and with Narrow Band noise.

METHODS

The convenience sample of this study consisted of 30 elderly people aged 60 years or over with moderate to severe bilateral sensorineural hearing loss of descending configuration with thresholds at 4kHz equal to or less than 70 dBHL. This is a longitudinal intervention study that was approved by the research ethics committee under number 2,749,636. All participants agreed to participate in the research by signing the Informed Consent Form.

The elderly were randomly divided into two groups: The Pure Tone group - GTP, with 15 elderly aged 62 to 93 years old, 8 females and 7 males, in which the gain calculation was prescribed based on the auditory thresholds obtained with the pure tone stimulus modulated in frequency (warble). The GNB group, also with 15 elderly aged 61 to 90 years of age, 5 females and 10 males paired according to the variable hearing loss, had the gain calculation prescribed based on the auditory thresholds obtained with the Narrow Band stimulus. The acoustic gain prescriptive formula used was DSL v5.

Inclusion criteria were: Age equal to or greater than 60 years old; presenting bilateral symmetrical sensorineural hearing loss with descending configuration, a threshold of 70 dB HL or less at the frequency of 4kHz; no cognitive impairment.

The elderly participating in the research were evaluated before fitting the hearing aids and after three months of use.

The process of fitting hearing aids took place after the audiological evaluation was carried out and the patients were randomly allocated to the two groups.

The process of fitting hearing aids followed the recommendation of the hearing health ordinance[14]. The elderly received hearing aids provided by the Unified Health System (SUS).

Hearing health services dispense hearing aids classified, according to technology, into types A, B and C. The hearing aids used by the participants in this study were all type B and approximately 70% were of the same brand and model. There was also the possibility of choosing between the adaptation with a conventional mold or a thin tube with an olive, which was decided according to the configuration of the hearing loss and the patient's dexterity in handling the device. Therefore, the technological characteristics were the same or very similar. The algorithms activated in all cases were: feedback suppressor and noise reduction. The frequency lowering algorithm was not activated in any of the cases as it is known that thresholds of up to 70 dB HL probably refer to regions with preserved inner hair cells and therefore it is possible to take advantage of the amplification in the high-frequency range without the need of using the downgrade feature. The prescriptive formula used to calculate the acoustic gain was the DSL v5 rule. The initial adjustment and the necessary adjustments were made according to the participant's self-perception. Then, the in situ verification was carried out using visible mapping of amplified speech (speech mapping), using the In Situ Measurement equipment, model Verifit VF-1, from the Audioscan brand. Before carrying out this research, the equipment was calibrated. The patient was positioned seated at 0º azimuth and 80 cm from the equipment loudspeaker, with the probe microphone positioned at 5 mm from the tympanic membrane, the reference microphone just below the ear and the hearing aid placed in the external acoustic meatus. Initially, the type of hearing aid, the type of adaptation (in all cases bilateral), the patient's age, the transducer used for the investigation of pure tone thresholds, the DSL v5 prescriptive method for the determination of targets were selected in the equipment. the patient's auditory thresholds obtained by air conduction from 250 to 6000 Hz were inserted and the bone conduction from 500 to 4000 Hz. The stimulus used for this measurement was the International Speech Test Signal (ISTS)[15], created from recordings in six different languages, completely unintelligible, but internationally accepted for hearing aid verification. From this measurement, the values of REAR (real-ear aided response) were obtained, and these values for amplified speech should be located between the target values ± 4 dB. The equipment calculates and makes available the Speech Intelligibility Index (SII) for speech signals with and without the hearing aids being the speech signal presented at 65 dB SPL. Such data allowed us to quantify, in percentage, the audibility of speech sounds. After verification, the elderly (and their companions) were instructed on the use and conservation of hearing aids. From the adaptation of the hearing aids, the elderly started using them in activities of daily living and weekly visits were made until effective use was achieved. At each return visit, the data record was read (datalogging-DL) and guidance and adjustments were made whenever necessary. It was considered effective use 8 hours a day. Values referring to daily use of hearing aids were included as data for statistical analysis between groups.

The protocol of this research included the application of the following procedures:

1. Pure tone l audiometry investigating thresholds with warble and narrowband stimuli at frequencies from 250 to 8000 Hz;

2. The Word Recognition Score (WRS) with recorded monosyllabic stimuli. The WRS Survey with Monosyllables was obtained at the most comfortable level in a soundproof booth. This research was carried out through the presentation of recorded speech material[16]. The speech material contains 25 monosyllables arranged in different orders, giving rise to four lists called D1, D2, D3 and D4. The WRS was obtained in the initial evaluation without the hearing aids, through the presentation of lists D1 and D2 respectively, for the right and left ears;.

   The audiological evaluation was carried out in a soundproof booth, using a two-channel digital audiometer brand Grason-Stadler, model GSI 61 Clinical Audiometer, with supra-aural headphones TDH-50P.

3. Lists of sentences in Portuguese (LSP)[17]. This material is composed of a list of 25 sentences (List 1A), 7 lists of 10 sentences (1B to 7B) and a speech spectrum noise. It is recorded on a compact disc CD, in which sentences and noise were recorded in independent channels, allowing its presentation both in silence and in noise. In this study, the signal/noise (S/N) ratios were obtained, in which 50% of the sentences presented in the free field with and without hearing aids were recognized. Three lists were used: list 1A for the familiarization (training) of the patient with the test; list 1B for obtaining S/N ratios without hearing aids and list 2B with hearing aids. The application of the test in free field condition was carried out in a soundproof booth, with the individual positioned at 1m from the sound source, in the 0º azimuth condition. In order to obtain the sound pressure levels in the free field, the measurement was performed following the ascending-descending strategy[18]. Continuous noise was presented at 65 dB SPL level. Sentence presentation was started at a zero S/N ratio (noise at 65 dB SPL and speech at 65 dB SPL). After the patient's first correct or incorrect response, the level of sentence presentation was respectively decreased or increased by 4dB and after changing the pattern of responses, additions or subtractions were always 2 dB. From the change to 2 dB, the levels of presentation of each sentence were recorded and the average of the level of presentation was calculated. To obtain the S/N ratio, this value was subtracted from the competitive noise presentation level;

4. Application of the International Outcome Inventory – (IOI-HA)[19]. The IOI-HA (International Outcome Inventory for Hearing Aids - IOI - HA) is composed of seven questions that subjectively assess the result of the adaptation of the

electronic sound amplification device under the following aspects: 1- Use; 2- Benefit; 3- Residual limitation of activities; 4- Satisfaction; 5- Residual restriction of participation; 6- Impact on others; 7- Quality of life. Each question allows five answer options ranging from 1 to 5 points. Thus, the total score of the IOI-HA can vary from a minimum of 7 (seven) points, which indicates worse patient performance, to a maximum of 35 (thirty-five) points, which corresponds to the best performance with the use of hearing aids;

5. Client Oriented Scale of Improvement (COSI): Scale in which the speech-language pathologist asks the client to indicate up to five specific situations in decreasing order of difficulty in which they would like to hear better. These responses are logged and archived. After fitting the hearing aids, the descriptions are read back to the subject and for each situation, the degree of change is asked.

In the initial evaluation, the COSI scale was applied and the basic audiological evaluation was carried out with the search of thresholds by the frequency with the pure tone stimulus, and then, on the same day, the search of the thresholds by the frequency with the Narrow Band stimulus was carried out. Word Recognition Score (WRS) research with recorded monosyllabic stimuli using lists D1 and D2, presented respectively to the right and left ears, and the LSP test was also performed with the application of lists 1A (training) and 1B (without hearing aids).

After three months of effective use, the assessments were carried out with the LSP in the free field (list 2B), the IOI-HA questionnaire and the COSI scale were applied.

Statistical analysis of data was performed using as a basis a sample of 30 hearing aid users organized into two groups. Comparisons were performed using the Mann-Whitney U test (non-parametric) or Student's t-test for independent samples (parametric). The size of the effect of the difference between the groups was measured using the d or r coefficients[20 - 21]. For analyzes involving at least one distribution that violated the assumption of normality (that is, those that presented p-value ≤ 0.05, presented in bold and accompanied by an asterisk in the table), we chose to use non-parametric tests, since the use of a parametric test on a dataset with non-normal distribution could lead to bias in the calculations. For analyzes involving only distributions that did not violate the assumption of normality, we chose to use parametric tests.

The value of statistical significance adopted was equal to 5% ($p \leq 0.05$). SPSS Statistics software, version 25.0 (IBM Corp., Armonk, NY, USA) was used.

To calculate the 95% confidence intervals, the corrected and accelerated bias method was used based on 2000 bootstrap samples. The values in square brackets in the tables indicate the upper and lower limits of the 95% confidence intervals.

RESULTS

Table 1 presents the measures of central tendency and dispersion of the hearing thresholds obtained by pure tone and narrowband according to the group, as well as the comparative study between them. The results of this table demonstrate that there was a difference between the groups in relation to the hearing thresholds of the right ear in the frequencies of 1000 Hz (NB), 2000 Hz (TP and NB) and 4000 Hz (NB), and for all cases, GNB presented higher values compared to GTP. Still, in Table 1, the results show that there was a difference between the groups in relation to the hearing thresholds of the left ear in the frequencies of 1000 Hz (TP and NB), 2000 Hz (TP and NB), 3000 Hz (NB) and 4000 Hz (NB), considering that, for all cases, the GNB thresholds were also higher compared to the GTP.

Table 2 shows the measures of central tendency and dispersion of the WRS per ear according to the group, as well as their comparison using Student's t-test for independent samples. The results show that there was a statistically significant difference between the groups in relation to WRS to the RE, and the GTP presented a higher value in relation to the GNB.

Table 3 shows the measures of central tendency and dispersion of the IOI-HA responses for each question and total score. The results reveal that there was no statistically significant difference between the groups in relation to the answers to each question of the IOI-HA and that there was a statistically significant difference between the groups in relation to the total score, with the GNB presenting a higher score value compared to the GTP. Thus, individuals whose acoustic gain prescription was made based on the auditory thresholds obtained with narrowband presented a better evaluation of the results regarding the use of hearing aids compared to individuals whose acoustic gain prescription was made based on the auditory thresholds obtained with pure tone.

Table 4 presents an analysis of the distribution of data referring to data logging (Datalogging), COSI Scale and performance in lists 1B and 2B according to the group.

The results of this study demonstrate that individuals whose acoustic gain prescription was made based on narrowband auditory thresholds had better performance in COSI and longer hearing aid use in the right ear compared to individuals in the group whose acoustic gain prescription was made based on auditory thresholds obtained with pure tone. The two groups were similar in terms of performance on the lists and the length of time using hearing aids to the LE.

Table 5 presents the complaints reported by patients based on the application of the COSI Scale in order of frequency (from the most frequent to the least frequent) according to the group. The degree of improvement, in percentage, for each complaint is also presented, according to the patients' perception. The results for each group are variable, since the COSI allows a multitude of responses and both groups were adapted to hearing aids, that is, minimally satisfied with the amplification used.

Table 1. Descriptive values and comparative analysis of groups in relation to hearing thresholds obtained by pure tone and narrowband in the right and left ear

Variable	Group	Average	SD	Median	Min.	Max.	p	E.S.
Threshold – PT– 250 Hz (dBHL)RE	GTP	31.33 [25.33. 37.33]	12.74	30.00 [20.00. 40.00]	15.00	50.00	0.873[a]	0.052[d]
	GNB	30.67 [26.33. 34.33]	9.61	35.00 [25.00. 40.00]	10.00	45.00		
Threshold – PT– 500 Hz (dBHL)RE	GTP	34.67 [28.67. 41.00]	13.16	35.00 [30.00. 40.00]	10.00	55.00	0.384[a]	0.304[d]
	GNB	38.67 [33.33. 43.80]	11.57	40.00 [35.00. 50.00]	15.00	50.00		
Threshold – PT– 1000 Hz (dBHL)RE	GTP	40.67 [34.33. 46.67]	12.80	45.00 [40.00. 45.00]	15.00	60.00	0.079[a]	0.599[d]
	GNB	48.33 [43.33. 53.00]	10.12	50.00 [50.00. 50.00]	30.00	60.00		
Threshold – PT– 2000 Hz (dBHL)RE	GTP	49.33 [42.65. 55.67]	11.93	50.00 [45.00. 50.00]	25.00	65.00	0.003*[a]	0.978[d]
	GNB	61.00 [57.33. 64.33]	7.12	65.00 [65.00. 65.00]	45.00	70.00		
Threshold – PT – 3000 Hz (dBHL)RE	GTP	56.67 [53.67. 60.00]	6.99	60.00 [60.00. 60.00]	45.00	70.00	0.073[a]	0.763[d]
	GNB	62.00 [57.00. 66.33]	8.62	65.00 [65.00. 65.00]	40.00	75.00		
Threshold – PT – 4000 Hz (dBHL)RE	GTP	60.67 [56.33. 64.67]	8.21	60.00 [60.00. 60.00]	45.00	70.00	0.231[a]	0.406[d]
	GNB	64.00 [61.00. 67.33]	6.60	65.00 [60.00. 65.00]	55.00	75.00		
Threshold – PT– 6000 Hz (dBHL)RE	GTP	69.67 [64.67. 75.33]	10.93	75.00 [60.00. 75.00]	55.00	90.00	0.559[a]	0.213[d]
	GNB	72.00 [67.00. 77.00]	10.66	70.00 [65.00. 75.00]	50.00	90.00		
Threshold – – PT 8000 Hz (dBHL)RE	GTP	77.67 [70.00. 86.33]	16.24	70.00 [70.00. 90.00]	55.00	110.00	0.525[a]	0.205[d]
	GNB	74.33	11.78	70.00 [70.00. 85.00]	55.00	100.00		
Threshold – NB – 250 Hz (dBHL)RE	GTP	27.33 [22.67. 31.67]	10.33	25.00 [20.00. 35.00]	10.00	40.00	0.548[a]	0.226[d]
	GNB	25.00 [20.33. 29.33]	10.69	25.00 [25.00. 25.00]	5.00	45.00		
Threshold – NB – 500 Hz (dBHL)RE	GTP	28.67 [22.67. 35.33]	13.16	25.00 [20.00. 35.00]	5.00	50.00	0.368[a]	0.304[d]
	GNB	32.67 [27.67. 37.33]	10.67	35.00 [35.00. 35.00]	15.00	45.00		
Threshold – NB – 1000 Hz (dBHL)RE	GTP	32.67 [27.67. 37.67]	10.50	35.00 [25.00. 35.00]	15.00	50.00	0.001*[b]	0.605[r]
	GNB	43.00 [38.00. 47.67]	10.66	45.00 [45.00. 45.00]	25.00	55.00		
Threshold – NB – 2000 Hz (dBHL)RE	GTP	40.33 [35.00. 45.33]	9.72	40.00 [40.00. 40.00]	20.00	55.00	0.002*[a]	1.029[d]
	GNB	50.33 [48.00. 52.67]	5.81	50.00 [50.00. 50.00]	40.00	60.00		

p: statistical significance, Student t-test for independent samples ([a]), Mann-Whitney U-test ([b]), effect size for comparison between two groups according to Cohen, 1992 ([d]), effect size for comparison between two groups according to Rosenthal, 1991 ([r]), *: Statistically significant value at the 5% level ($p \leq 0.05$)

Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; RE: Right Ear; LE: Left Ear; PT: Pure tone; NB: Narrowband; SD: Standard deviation; Min.: Minimum; Max: Maximum; E.S.: Effect size

Table 1. Continued...

Variable	Group	Average	SD	Median	Min.	Max.	p	E.S.
Threshold – NB – 3000 Hz (dBHL)RE	GTP	46.67 [44.33. 49.00]	5.23	45.00 [45.00. 50.00]	40.00	55.00	0.013*[a]	1.147[d]
	GNB	52.67 [49.00. 56.00]	7.04	50.00 [50.00. 60.00]	35.00	60.00		
Threshold – NB – 4000 Hz (dBHL)RE	GTP	51.33 [47.67. 54.67]	7.43	50.00 [50.00. 50.00]	40.00	60.00	< 0.001*[b]	0.653[r]
	GNB	56.00 [52.67. 59.00]	7.12	55.00 [55.00. 55.00]	40.00	70.00		
Threshold – NB – 6000 Hz (dBHL)RE	GTP	59.00 [54.67. 63.67]	8.90	60.00 [60.00. 60.00]	45.00	75.00	0.852[a]	0.075[d]
	GNB	59.67 [54.67. 64.33]	10.43	60.00 [60.00. 60.00]	35.00	75.00		
Threshold – NB – 8000 Hz (dBHL)RE	GTP	62.33 [58.67. 66.33]	7.99	60.00 [60.00. 60.00]	50.00	80.00	0.989[b]	0.004[r]
	GNB	58.67 [52.33. 64.33]	11.87	65.00 [65.00. 65.00]	35.00	75.00		
Threshold – PT – 250 Hz (dBHL)LE	GTP	32.00 [26.67. 37.67]	11.62	30.00 [30.00. 30.00]	15.00	55.00	0.755[a]	0.115[d]
	GNB	33.33 [26.33. 39.11]	11.60	35.00 [30.00. 40.00]	5.00	50.00		
Threshold – PT – 500 Hz (dBHL)LE	GTP	35.33 [29.67. 41.33]	12.02	35.00 [35.00. 35.00]	15.00	60.00	0.320[a]	0.360[d]
	GNB	39.67 [34.00. 46.00]	11.41	40.00 [30.00. 45.00]	25.00	60.00		
Threshold – PT – 1000 Hz (dBHL)LE	GTP	40.67 [33.67. 47.33]	13.35	40.00 [35.00. 45.00]	15.00	65.00	0.003*[a]	0.974[d]
	GNB	53.67 [50.21. 57.00]	7.90	55.00 [55.00. 55.00]	40.00	65.00		
Threshold – PT – 2000 Hz (dBHL)LE	GTP	52.67 [48.77. 56.67]	9.61	50.00 [45.00. 55.00]	40.00	75.00	0.007*[a]	0.867[d]
	GNB	61.00 [58.33. 63.67]	5.41	60.00 [60.00. 65.00]	50.00	70.00		
Threshold – PT – 3000 Hz (dBHL)LE	GTP	58.00 [55.23. 61.00]	7.02	60.00 [50.00. 65.00]	45.00	70.00	0.110[a]	0.570[d]
	GNB	62.00 [59.00. 65.00]	6.21	65.00 [55.00. 70.00]	50.00	70.00		
Threshold – PT – 4000 Hz (dBHL)LE	GTP	62.67 [60.00. 65.33]	6.23	60.00 [60.00. 70.00]	55.00	70.00	0.253[b]	0.217[r]
	GNB	65.33 [63.33. 67.33]	4.81	65.00 [65.00. 65.00]	55.00	70.00		
Threshold – PT – 6000 Hz (dBHL)LE	GTP	68.33 [62.67. 74.00]	11.44	65.00 [60.00. 75.00]	50.00	90.00	0.252[a]	0.379[d]
	GNB	72.67 [69.00. 76.67]	8.63	70.00 [70.00. 75.00]	60.00	95.00		
Threshold – PT – 8000 Hz (dBHL)LE	GTP	76.33 [69.33. 84.00]	14.82	75.00 [65.00. 85.00]	55.00	105.00	0.561[a]	0.202[d]
	GNB	73.33 [67.33. 79.33]	13.05	70.00 [70.00. 70.00]	50.00	100.00		
Threshold – NB – 250 Hz (dBHL)LE	GTP	23.33 [18.00. 29.00]	12.20	20.00 [15.00. 20.00]	10.00	50.00	0.284[b]	0.199[r]
	GNB	26.67 [19.67. 33.33]	12.34	25.00 [25.00. 25.00]	.00	45.00		

p: statistical significance, Student t-test for independent samples ([a]), Mann-Whitney U-test ([b]), effect size for comparison between two groups according to Cohen, 1992 ([d]), effect size for comparison between two groups according to Rosenthal, 1991 ([r]), *: Statistically significant value at the 5% level ($p \leq 0.05$)

Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; RE: Right Ear; LE: Left Ear; PT: Pure tone; NB: Narrowband; SD: Standard deviation; Min.: Minimum; Max: Maximum; E.S.: Effect size

Table 1. Continued...

Variable	Group	Average	SD	Median	Min.	Max.	p	E.S.
Threshold – NB – 500 Hz (dBHL)LE	GTP	27.00 [20.67. 33.67]	13.34	25.00 [25.00. 25.00]	5.00	55.00	0.152[a]	0.525[d]
	GNB	34.00 [27.33. 40.52]	12.71	35.00 [30.00. 35.00]	15.00	55.00		
Threshold – NB – 1000 Hz (dBHL)LE	GTP	31.00 [25.00. 37.33]	12.56	30.00 [30.00. 30.00]	10.00	60.00	0.001*[a]	1.141[d]
	GNB	45.33 [41.67. 49.00]	8.12	45.00 [40.00. 45.00]	35.00	60.00		
Threshold – NB – 2000 Hz (dBHL)LE	GTP	41.00 [37.33. 44.67]	8.06	40.00 [40.00. 40.00]	25.00	60.00	< 0.001*[a]	1.736[d]
	GNB	55.00 [52.33. 58.00]	5.98	55.00 [55.00. 55.00]	45.00	65.00		
Threshold – NB – 3000 Hz (dBHL)LE	GTP	45.67 [43.33. 48.00]	5.30	45.00 [45.00. 45.00]	40.00	55.00	< 0.001*[b]	0.634[r]
	GNB	54.33 [52.00. 56.67]	5.30	55.00 [55.00. 55.00]	45.00	60.00		
Threshold – NB – 4000 Hz (dBHL)LE	GTP	50.67 [47.67. 53.67]	7.04	50.00 [50.00. 50.00]	40.00	60.00	< 0.001*[b]	0.653[r]
	GNB	61.00 [59.00. 63.00]	4.71	60.00 [60.00. 60.00]	55.00	70.00		
Threshold – NB – 6000 Hz (dBHL)LE	GTP	57.33 [53.33. 61.67]	8.63	55.00 [50.00. 60.00]	45.00	75.00	0.267[a]	0.425[d]
	GNB	61.00 [57.00. 65.33]]	9.10	60.00 [60.00. 60.00]	50.00	85.00		
Threshold – NB – 8000 Hz (dBHL)LE	GTP	62.00 [58.67. 65.67]	8.41	60.00 [60.00. 60.00]	50.00	80.00	0.776[a]	0.119[d]
	GNB	61.00 [56.33. 65.67]	10.56	65.00 [65.00. 65.00]	45.00	80.00		

p: statistical significance, Student t-test for independent samples ([a]), Mann-Whitney U-test ([b]), effect size for comparison between two groups according to Cohen, 1992 ([d]), effect size for comparison between two groups according to Rosenthal, 1991 ([r]), *: Statistically significant value at the 5% level ($p \leq 0.05$)
Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; RE: Right Ear; LE: Left Ear; PT: Pure tone; NB: Narrowband; SD: Standard deviation; Min.: Minimum; Max: Maximum; E.S.: Effect size

Table 2. Descriptive values and comparative analysis of groups in relation to WRS

Variable	Group	Average	SD	Median	Min.	Max.	Statistic	p[a]	p[b]	p[c]	E.S.
WRS– RE (%)	GTP	74.67 [69.60. 79.47]	11.38	76.00 [72.00. 80.00]	48.00	88.00				0.029*	0.797
	GNB	65.60 [60.43. 70.67]	10.23	68.00 [56.00. 72.00]	44.00	80.00					
WRS – LE (%)	GTP	74.20 [69.39. 79.15]	10.72	72.00 [68.00. 80.00]	60.00	92.00				0.077	0.628
	GNB	67.47 [62.67. 72.03]	9.30	68.00 [68.00. 68.00]	48.00	80.00					

p: statistical significance, Shapiro Wilk test ([a]), Levene test ([b]) Student's t-test ([c]) for independent samples *: Statistically significant value at the 5% level ($p \leq 0.05$)
Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; WRS = Word Recognition Score; SD = Standard deviation; Min.: Minimum; Max: MaxImum; E.S. = Effect size

Table 3. Descriptive values and comparative analysis of the groups in relation to the answers for each question and the total score of the IOI-HA

Question	Group	Median	Min.	Q1	Q3	Max.	p	E.S.
1	GTP	5.00 [5.00. 5.00]	4.00	5.00	5.00	5.00	0.483	0.263
	GNB	5.00 [5.00. 5.00]	5.00	5.00	5.00	5.00		
2	GTP	5.00 [5.00. 5.00]	4.00	4.00	5.00	5.00	0.215	0.265
	GNB	5.00 [5.00. 5.00]	3.00	5.00	5.00	5.00		
3	GTP	4.00 [4.00. 5.00]	3.00	4.00	5.00	5.00	0.216	0.261
	GNB	5.00 [5.00. 5.00]	3.00	4.00	5.00	5.00		
4	GTP	5.00 [5.00. 5.00]	3.00	5.00	5.00	5.00	> 0.999	0.000
	GNB	5.00 [5.00. 5.00]	3.00	5.00	5.00	5.00		
5	GTP	5.00 [5.00. 5.00]	3.00	5.00	5.00	5.00	0.732	0.099
	GNB	5.00 [5.00. 5.00]	4.00	5.00	5.00	5.00		
6	GTP	5.00 [5.00. 5.00]	2.00	4.00	5.00	5.00	0.100	0.385
	GNB	5.00 [5.00. 5.00]	5.00	5.00	5.00	5.00		
7	GTP	4.00 [3.00. 5.00]	2.00	2.00	5.00	5.00	0.411	0.162
	GNB	4.00 [4.00. 4.00]	2.00	3.00	5.00	5.00		
8	GTP	3.00 [3.00. 3.00]	1.00	1.00	3.00	3.00	0.399	0.184
	GNB	2.00 [1.00. 3.00]	1.00	1.00	3.00	3.00		
Score Total	GTP	31.00 [31.00.33.00]	27.00	-	-	35.00	0.027*	0.401
	GNB	34.00 [34.00.34.00]	27.00	-	-	35.00		

p: statistical significance, Mann-Whitney U test. * : Statistically significant value at the 5% level ($p \leq 0.05$)
Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; Q1 = First quartile; Q3 = Third quartile; Min.: Minimum; Max: Maximum; E.S. = Effect size

Table 4. Descriptive values and comparative analysis of groups in relation to DL, COSI Scale and performance in lists 1B and 2B

Variable	Group	Average	SD	Median	Min.	Max.	p	E.S.
DL - RE (hours/day)	GTP	8.13 [6.53. 9.53]	3.03	9.00 [9.00. 9.00]	3.00	13.00	0.049*[a]	0.685
	GNB	10.20 [9.07. 11.33]	2.46	10.00 [8.00. 12.00]	7.00	14.00		
DL - LE (hours/day)	GTP	8.73 [7.12. 10.20]	2.80	9.00 [8.00. 11.00]	4.00	13.00	0.191[a]	0.455
	GNB	10.00 [8.93. 11.13]	2.39	10.00 [10.00. 10.00]	6.00	14.00		
COSI scale	GTP	8.00 [7.47. 8.60]	1.41	8.00 [7.00. 10.00]	6.00	10.00	0.044*[b]	0.374[r]
	GNB	9.00 [8.60. 9.33]	.93	9.00 [9.00. 9.00]	7.00	10.00		
List 1B (S/R ratio)	GTP	5.52 [1.08. 9.58]	9.46	7.60 [5.00. 9.00]	-16.00	20.00	0.127[a]	0.474
	GNB	10.00 [6.96. 12.71]	5.65	12.30 [8.00. 13.60]	-2.00	17.20		
List 2B (S/R ratio)	GTP	3.24 [-0.96. 6.82]	7.70	6.20 [4.50. 7.40]	-15.00	12.00	0.151[b]	0.265[r]
	GNB	7.12 [3.93. 9.38]	5.29	7.60 [6.00. 10.00]	-9.00	12.80		

p: statistical significance, Student's t-test for independent samples (a), Mann-Whitney U test (b), effect size for comparison between two groups according to Rosenthal, 1991 ([r]) *: Statistically significant value at the 5% level ($p \leq 0.05$)
Caption: GTP = Tone Pure Group; GNB = Narrow Band Group ; DL – RE = Datalogging right ear; DL – LE = Datalogging left ear; SD = Standard deviation; Min.: Minimum; Max: Maximum; E.S. = Effect size

Table 5. Descriptive analysis of the most frequent complaints and perceived improvement for each complaint from the application of the COSI questionnaire

GTP				GNB			
Complaint	Occurrence of the complaint		Average of perceived improvement	Complaint	Occurrence of the complaint		Average of perceived improvement
	N	%	%		N	%	%
TV	14	93.33	93.57	TV	9	60.00	95.00
Telephone	7	46.67	89.29	Telephone	8	53.33	86.88
Listening in noise	6	40.00	70.00	Group chat	7	46.67	95.00
Understanding speech	4	26.67	73.75	Listening in noise	5	33.33	79.00
Talking	4	26.67	73.75	Church	3	20.00	88.33
Buzz	4	26.67	72.50	Understanding speech	3	20.00	95.00
Group chat	4	26.67	67.50	Buzz	2	13.33	95.00
Church	3	20.00	65.00	Location	2	13.33	95.00
Location	2	13.33	95.00	Individual conversation	2	13.33	95.00
Watching TV and someone calls	1	6.67	75.00	Noisy environment	1	6.67	75.00
Lectures	1	6.67	75.00	Understanding people	1	6.67	95.00
Hearing conversations	1	6.67	50.00	Talking with people	1	6.67	95.00
Hearing people with their backs turned	1	6.67	75.00	Talking with people	1	6.67	75.00
Hearing street sounds	1	6.67	95.00	Family parties	1	6.67	95.00
Dizziness	1	6.67	50.00	Hearing	1	6.67	75.00
Annoyance of people	1	6.67	95.00	Long-distance understanding	1	6.67	50.00
Hearing the sounds of nature	1	6.67	95.00	Understanding conversations	1	6.67	95.00
Stop getting closer to people to listen	1	6.67	95.00				
Annoyance in a noisy place	1	6.67	75.00				
Hearing two things at once	1	6.67	25.00				
Decrease repeat request in conversations	1	6.67	75.00				
Hearing environmental sounds	1	6.67	95.00				

Caption: GTP = Tone Pure Group; GNB = Narrow Band Group; N = population size

DISCUSSION

In the present study, it was observed that randomly distributed individuals whose acoustic gain prescription was based on narrowband auditory thresholds had worse auditory thresholds in the right ear at frequencies of 1000 Hz (NB), 2000 Hz (TP and NB) and 4000 Hz (NB) and worse auditory thresholds in the left ear in the frequencies of 1000 Hz (TP and NB), 2000 Hz (TP and NB), 3000 Hz (NB) and 4000 Hz (NB) compared to individuals whose prescription of acoustic gain was based on auditory thresholds obtained with pure tone (Table 1).

Regarding the stimulus used for the research of auditory thresholds, differences of up to 20 dB were found in the literature between the stimuli in the frequencies of 2 and 4 kHz, being always better with the NarrowBand[22]. In a study carried out with individuals with tinnitus, the difference between normal-hearing and hearing-loss groups was evidenced, regardless of the presence of tinnitus, and in the intergroup analysis, the thresholds obtained with Narrow Band were statistically better[23].

A possible explanation is that the Narrow Band is characterized by the concentration of sound energy in a region of frequencies wider than the pure tone. Considering that subjects with sensorineural hearing loss have a reduction in the sensitivity of the basilar membrane, which can change the frequency selectivity in the cochlea, with this there is a possibility that broader stimuli can generate better responses when compared to those that stimulate a more specific region of the cochlea[24]. Another explanation for these findings is that the status of hair cells that fall between the octaves of frequencies, assessed by conventional audiometry, is not evidenced/detected in the traditional assessment with pure tone[25]. In the present study, the thresholds obtained with pure tone and narrow band in the same individual were not compared. However, in the random distribution of the elderly into the two groups, it was found that those in whom narrowband surveyed thresholds were used for the prescription of acoustic gain were worse in most frequencies than those obtained in the elderly whose gain was prescribed based on the thresholds searched with pure tone.

Sensorineural hearing loss with descending audiometric configuration is the most common type found in clinical audiology practice, including age-related hearing loss[26], and was an inclusion criterion for the current study. This type of hearing loss is often related to difficulty in speech intelligibility. The Word Recognition Score (WRS) assesses speech recognition. In speech, vowels are naturally more intense and present acoustic energy at low frequencies (400 to 500 Hz). Consonants, on the other hand, are sounds that present spectral energy at high frequencies, above 2000 Hz, but 20 to 35 dB weaker than vowels. Consonant sounds, however, contribute with 60% to speech intelligibility, while vowel sounds account for 40% of this measure. Due to the spectral characteristics of these sounds and the range of human audibility, it is possible to understand why individuals with high-frequency hearing loss have difficulty in speech recognition[27].

As observed in relation to auditory thresholds, the elderly in the GTP presented a better performance in the WRS compared to the elderly whose acoustic gain prescription was based on the auditory thresholds obtained with narrowband (Table 2).

Regarding the test of sentences in noise, it was possible to verify that the two groups were similar in terms of performance on the lists, that is, both the individuals whose acoustic gain prescription was made based on the auditory thresholds obtained with pure tone, as with Narrow Band presented a signal-to-noise ratio in which 50% of similar sentences were recognized both in the condition without prostheses and with prostheses (Table 4). It can be highlighted that, although not significant, the GTP presented better results, which can be explained by the better hearing presented by the participants in this group. It should also be considered that this is a test applied in a clinical setting and may not express exactly what happens in activities of daily living (outdoor environments).

Speech tests are useful to assess the benefit of using hearing aids, as they objectively measure, with known reliability, speech comprehension. It is important to emphasize that the inability to properly understand speech is what most motivates people to seek services for the selection and fitting of hearing aids[28]. The disadvantage of speech tests to assess the benefit of using hearing aids is that the results obtained depend strongly on the measurement conditions used. Large improvements in scores can be obtained if tests are administered silently. These benefits diminish and may disappear or become negative if the same test is presented with noise because speech recognition is determined by the signal-to-noise (S/N) ratio. Individuals with hearing loss will experience a variety of speech levels in a multitude of S/N ratios in their everyday environments.

It can be said that the LSP test had its acoustic parameters controlled with great reliability, however, in the day-to-day patients suffer from environmental changes, which makes it difficult to measure the level of improvement in the signal/noise ratio with the hearing aid in everyday life.

The International Outcome Inventory – Hearing Aid (IOI-HA) aims to document, from the individual's point of view, the evolution of the daily use of the prosthesis, considering not only the degree of satisfaction, but also the limitations of basic activities, the restriction of participation, impact on others and quality of life(19).

In the present research, it was possible to verify that there was no statistically significant difference between the groups regarding the answers given to each question of the IOI-HA (Table 3). In the analysis of the psychometric properties of the IOI-HA in Portuguese, it was found that the questionnaire has a moderate internal consistency. Several test items are correlated with each other (analysis of the first application – retest)[29]. Thus, the use of the IOI-HA is suggested in the rehabilitation process of hearing aid users, but it is considered that the questionnaire can be difficult to understand for subjects with low socioeconomic status in the self-applied situation.

Although no statistical differences were identified between the two groups per question, the analysis of the total score obtained in the IOI-HA revealed a statistically significant difference between the groups. The elderly in whom the acoustic gain prescription was made based on the hearing thresholds obtained with Narrow Band presented better results evaluation regarding the use of the hearing aid compared to individuals whose acoustic gain prescription was made based on the hearing thresholds obtained with tone pure.

In the literature, when the analysis of the IOI-HA scores per question was performed and the total score was subsequently calculated, it could be observed that the scores showed excellent results, consequently providing better performance in activities of daily living[30]. However, analyzing the data individually, it is clear that some users still were dissatisfed and had difficulties with the use of hearing aids. It was evident that there can naturally be differences between the total score and the performance per question in the same test, which was similar to the findings of the present research.

It is noteworthy that even with greater impairment of speech intelligibility in the GNB group, it obtained better results with the use of hearing aids, as evidenced by the total score on the IOI-HA.

Regarding the time of daily use of hearing aids, it was found that this was greater in the GNB than in the GTP, with this difference being statistically significant in the Right Ear (Table 4). In the literature, there is a report that the longer the hearing aid usage time, the greater the benefit provided to the user; the longer the usage time, the greater the satisfaction; the greater the benefit, the lower the residual activity limitation and the lower the impact of hearing loss on relationships with other people(29). Thus, it can be said that the higher data logging values (datalogging) of the GNB group users evidenced a better adaptation of the hearing aids and/or these higher Datalogging values are products of a good adaptation.

The study of the responses obtained in the application of the Client Oriented Scale of Improvement (COSI) showed a statistically significant difference between the groups, with the GNB showing a higher value compared to the GTP (Tables 4 and 5). Patients were instructed to mark a position on a visual analogue scale that ranged from "nothing improved with hearing aid" to "perfect adaptation". In the statistical analysis, the answers were converted into a score from 0 to 10, where 0 represented the worst answer and 10 the best possible answer. Individuals in the GNB group had better responses on the scale.

In a study carried out with this same instrument, COSI has attributed the potential to reflect the individuals' assessment of the benefits they obtained through rehabilitation. These benefits can be expressed in terms of reduced activity limitation or participation restriction in activities of daily living (for example, increased participation in social events)[28].

Therefore, the data obtained by the GNB group in this study, together with the findings of the study mentioned above, show that the GNB group obtained more benefits and was closer to the "best adaptation". It can be said that this group is auditory more able to communicate, participate socially and present less limitation in activities of daily living.

Complaints from both groups ranged from improving speech perception by: watching TV, in individual and group conversations, in church, in lectures, in noise; or even complaints related to balance and tinnitus.

The self-reported complaints in the initial assessment were reassessed after three months and were based on the needs that sought to be resolved by the rehabilitation process. The individuals were asked to analyze the previous report and were instructed to say the percentage of improvement and/or worsening of that previously mentioned complaint. In both groups, the answers were positive, but very varied quantitatively and represented a great improvement in user satisfaction three months after using the hearing aids (Table 5). COSI is recommended for use in clinical practice as it is effective in patient self-assessing the hearing needs. In a study carried out, some justifications for the use of the COSI scale were listed. It can be said that this scale fits into a well-conducted clinical interview in a non-intrusive manner, in which the individual responses are more useful to the clinician than the responses from a much longer questionnaire would be. The correlation between COSI and improvement measures is reasonable, as people are possibly better able to provide accurate information when asked about situations that are important to them than when they are being asked about generic situations, some of which may not apply to your daily life. For these reasons, the COSI scale was classified as useful and convenient for use in clinical practice[28].

What can be inferred is that both the IOI-HA (multidimensional assessment) and the COSI (assessment of limitations in activities of daily living) are a questionnaire and a scale, respectively, in which the self-perception of the elderly using a hearing aid in daily life activities is evaluated. Therefore, it can be justified that a test in controlled situations demonstrates that individuals with better hearing (GTP) perform better, while self-assessment protocols reveal the individual's self-perception in their daily environment, which may have led to the GNB group to present in these instruments the best result. In addition, it is worth noting that the time of daily use of hearing aids by the GNB participants was greater than that of the GTP. This finding reinforces the explanation that there may be differences obtained in controlled situations (LSP) and situations of daily living.

The hypothesis that guided this study was confirmed that sound signals that stimulate a larger cochlear region may be more effective for the prescription of acoustic gain, since the sounds to which patients are exposed in their daily lives are complex (e.g.: speech). No studies similar to those carried out in this research were found.

CONCLUSION

There is a better evaluation of results with the use of hearing aids, revealed by the total score of the IOI-HA questionnaire, COSI scale and longer use of hearing aids, in the group whose prescription of acoustic gain was based on audiometric thresholds obtained with noise from Narrow Band.

REFERENCES

1. Engdahl B, Krog N, Kvestad E, Hoffman H, Tambs K. Occupation and the risk of bothersome tinnitus: results from a prospective cohort study (HUNT). BMJ Open. 2012;2(1):e000512. http://dx.doi.org/10.1136/bmjopen-2011-000512. PMid:22267709.
2. Dockum GD, Robinson DO. Warble tone as an audiometric stimulus. J Speech Hear Disord. 1975 Aug;40(3):351-6. http://dx.doi.org/10.1044/jshd.4003.351. PMID: 1234948.
3. Simon R, Northern L. Automatic noise band audiometry. J Aud Res. 1966;6:403-7.
4. Gengel RW. Acceptable speech-to-noise ratios for aided speech discrimination by the hearing impaired. J Speech Hear Res. 1971;11:219-22.
5. Norrix L, Anderson A. Audiometric thresholds: stimulus considerations in sound field and under earphones. Am J Audiol. 2015;24(4):487-93. http://dx.doi.org/10.1044/2015_AJA-15-0031. PMid:26650376.
6. Stephens MM, Rintelmann WF. The influence of audiometric configuration on pure-tone, warble-tone and narrow-band noise thresholds of adults with sensorineural hearing losses. J Am Audiol Soc. 1978;3(5):221-6. PMid:659294.
7. Moore BC, Huss M, Vickers D, Glasberg B, Alcántara J. A test for the diagnosis of dead regions in the cochlea. Br J Audiol. 2000;34(4):205-24. http://dx.doi.org/10.3109/03005364000000131. PMid:10997450.
8. Moore BCJ, Glasberg BR. A revised model of loudness perception applied to cochlear hearing loss. Hear Res. 2004;188(1-2):70-88. http://dx.doi.org/10.1016/S0378-5955(03)00347-2. PMid:14759572.

9. Aazh H, Moore BCJ. Dead regions in the cochlea at 4 khz in elderly adults: relation to absolute threshold, steepness of audiogram, and pure-tone average. J Am Acad Audiol. 2007;18(2):97-106. http://dx.doi.org/10.3766/jaaa.18.2.2. PMid:17402296.
10. Moore BCJ, Vinay. Amplitude modulation detection by listeners with unilateral dead regions. J Am Acad Audiol. 2009;20(10):597-606. http://dx.doi.org/10.3766/jaaa.20.10.2. PMid:20503798.
11. McDermott HJ, Knight MR. Preliminary results with the AVR impact frequency-transposing hearing aid. J Am Acad Audiol. 2001;12(3):121-7. [0006] PMid:11316049.
12. Scolie S. 20Q: the ins and outs of frequency lowering amplification [Internet]. Audiology Online; 2013. p. 1-15. [citado em 2020 Jun 22]. Disponível em: https://www.audiologyonline.com/articles/20q-ins-and-outs-frequency-11863
13. Myers CK. Noise bands vs pure tones as stimuli for audiometry. Speech and Hearing Dis. 1957;22(5):757-60. http://dx.doi.org/10.1044/jshd.2205.757. PMid:13492332.
14. Brasil. Ministério da Saúde. Secretaria de Atenção à Saúde. Portaria SAS nº 387, de 06 de julho de 2005. Estabelece procedimentos às empresas que tenham como ramo de atividade a comercialização de aparelhos de amplificação sonora individual (AASI), fornecedoras de unidades que prestam serviços ao Sistema Único de Saúde. Diário Oficial da União; Brasília; 7 jul. 2005.
15. Pen M, Mangabeira-Albernaz PL. Desenvolvimento de testes para logoaudiometria - discriminação vocal. In: Anales de Congresso Pan-americano de Otorrinolaringologia y Broncoesofagia; 1973; Lima - Peru. Lima: [s.n.]; 1973. p. 223-6.
16. Holube I, Fredelake S, Vlaming M, Kollmeier B. Development and analysis of an International Speech Test Signal (ISTS). Int J Audiol. 2010,49(12):891-903. PMID: 21070124.
17. Costa MJ. Lista de sentenças em português: apresentação e estratégias de aplicação na audiologia. Santa Maria: Pallotti; 1998. p. 26-36
18. Henriques MO, Miranda EC, Costa MJ. Limiares de reconhecimento de sentenças no ruído, em campo livre: valores de referência para adultos normo-ouvintes. Rev Bras Otorrinolaringol. 2008;74(2):188-92. http://dx.doi.org/10.1590/S0034-72992008000200006.
19. Cox RM, Alexander GC. The international outcome inventory for hearing aids (IOI-HA): psychometric properties of the english version. Int J Audiol. 2002;41(1):30-5. http://dx.doi.org/10.3109/14992020209101309. PMid:12467367.
20. Cohen J. A power primer. Psychol Bull. 1992;112(1):155-9. http://dx.doi.org/10.1037/0033-2909.112.1.155. PMid:19565683.
21. Rosenthal R. Meta-analytic procedures for social research. 2nd ed. Newbury Park, CA: Sage; 1991. 168 p. http://dx.doi.org/10.4135/9781412984997.
22. Stephens MM, Rintelmann WF. The influence of audiometric configuration on pure-tone, warble-tone and narrow-band noise thresholds of adults with sensorineural hearing losses. J Am Audiol Soc. 1978;3(5):221-6. PMid:659294.
23. Fratti RRA. Comparação dos limiares audiométricos obtidos com diferentes estímulos em sujeitos com perdas auditivas com e sem a presença de zumbido [dissertação]. São Paulo (SP): Pontifícia Universidade Católica de São Paulo – PUC – SP; 2009.
24. Oxenham AJ, Plack CJ. A behaviorak measure of basilar- membrane nonlinearity in listeners with normal and impaired hearing. J Acoust Soc Am. 1997;101(6):366-75. http://dx.doi.org/10.1121/1.418327.
25. John AB, Vinay, Kreisman BM. Equivalence and test-retest reproducability of conventional and extended-high-frequency audiometric thresholds obtained using pure-tone and narrow-band-noise stimuli. Int J Audiol. 2017;56(9):635-42. http://dx.doi.org/10.1080/14992027.2017.1309084. PMid:28388868.
26. Miller GA, Nicely PE. An analysis of perceptual confusions among some English consonants. J Acoust Soc Am. 1955;27(2):338-14. http://dx.doi.org/10.1121/1.1907526.
27. Fletcher H. Speech and hearing communication. New Jersey: D.VanNostrand; 1953.
28. Dillon H, James A, Ginis J. Client Oriented Scale of Improvement (COSI) and its relationship to several other measures of benefit and satisfaction provided by hearing aids. J Am Acad Audiol. 1997;8(1):27-43. PMid:9046067.
29. Gasparin M, Menegotto IH, Cunha CS. Propriedades psicométricas do questionário internacional: aparelho de amplificação sonora individual. Braz J Otorhinolaryngol; 2010;76(1):85-90. http://dx.doi.org/10.1590/S1808-86942010000100014.
30. Arakawa AM, Picolini MM, Sitta ÉL, Oliveira AN, Bassi AKZ, Bastos JRM, et al. Evaluation of user satisfaction of Hearing Aids (HA) in the Amazon. Int Arch Otorhinolaryngol. 2010;14(1):38-44.