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Analysis of agreement between different tonal average criteria for defining hearing loss

Análise de concordância entre diferentes critérios de médias tonais para definição da perda auditiva

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ABSTRACT

Purpose: To assess the agreement among different criteria used for the classification of hearing loss. **Methods:** A retrospective, cross-sectional study was conducted by collecting pure-tone thresholds from hearing assessments performed at a university clinic. A total of 240 ears with hearing loss were selected and categorized as normal, mild, or moderate according to the tritonal classification proposed by Lloyd and Kaplan (LK). Subsequently, the same ears were reclassified using the criteria established by the World Health Organization (WHO), the Bureau International d'Audiophonologie (BIAP), and Brazilian Law No. 14.768/2023, which defines the criteria for characterizing hearing disability. **Results:** A comparison among the classification systems was carried out, enabling the measurement of agreement levels. Agreement between the WHO and LK classifications with BIAP was substantial, while agreement between WHO and LK was moderate. The study also compared which cases in the sample are classified as having a hearing disability according to the law versus the other classifications. **Conclusion:** For a descending audiometric configuration, there is agreement among the literature-recommended classification systems. However, this agreement can be quantified to guide professionals in choosing the most appropriate classification for hearing loss when preparing a more accurate audiological report. Regarding the threshold criterion established by Brazilian legislation, the findings indicate that it fails to cover a considerable portion of the population with hearing loss.

Keywords: Persons with hearing impairments; Audiometry; Hearing tests; Speech perception; Hearing

RESUMO

Objetivo: avaliar a concordância entre os diferentes critérios de classificação da perda auditiva. **Método:** estudo retrospectivo, transversal, com a coleta dos limiares tonais dos exames auditivos realizados nos pacientes de uma clínica-escola. Foram selecionadas 240 orelhas com perda auditiva, divididas em grau normal, leve e moderado, segundo a classificação tritonal de Lloyd e Kaplan. (LK). Posteriormente, as perdas foram definidas de acordo com as classificações da Organização Mundial da Saúde – OMS, *Bureau Internacional d'Audiophonologie* - BIAP e com a Lei nº 14.768/2023, que define critérios para a caracterização da deficiência auditiva. **Resultados:** realizou-se a comparação entre as classificações e foi possível conhecer o índice de concordância entre elas. Ao comparar as classificações da OMS e LK com BIAP, a concordância foi substancial, e entre OMS e LK, foi moderada. Compararam-se os casos da amostra que são definidos como deficiência perante a lei e as classificações. **Conclusão:** para perdas de configuração descendentes existe concordância entre as classificações de grau para perda auditiva preconizados na literatura. Entretanto, foi possível mensurar essa concordância para auxiliar o profissional na escolha da classificação da perda auditiva visando à elaboração de um laudo audiológico mais fidedigno. Quanto ao critério do valor referencial da limitação auditiva proposto pela legislação brasileira, o estudo elucida que esse critério deixa de beneficiar uma considerável parcela da população com deficiência auditiva.

Palavras-chave: Pessoas com deficiência auditiva; Audiometria; Testes auditivos; Percepção da fala, Audição

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INTRODUCTION

According to the World Health Organization (WHO), at least 2.5 billion people will have some degree of hearing loss by the year 2050[1]. In Brazil, approximately 2.3 million peoplehave hearing impairment[2].

The human hearing enables the capture, analysis, and assigning of meaning to sounds; when impaired, it can affect the basis of oral communication. A decrease in the ability to hear sounds results in varying degrees of hearing loss[3].

Hearing impairment (HI) may also be associated with cognitive decline, depression, and reduced functional status, especially in people who have not been properly assessed or rehabilitated. As a result, it negatively impacts the individual's daily life, who will have difficulties in understanding speech in quiet or noisy environments, as well as emotional and social changes, leading to social isolation, stress, and frustration[4]

The gold standard for diagnosing hearing loss is through pure tone audiometry. It determines hearing thresholds at frequencies from 250 to 8.000 Hz and provides information on the type and degree of hearing loss[5,6].

The degree of hearing loss is associated with the individual's ability to understand spoken language. To define it, several scientifically validated method classifications are found in the literature. The classifications consider three or four hearing frequencies, that is, the tritonal or quadritonal mean respectively.

A recent literature review which aimed at identifying nationally and internationally adopted criteria for classifying the degree of hearing loss, identified nine criteria for calculating the degree of hearing loss[7].

In Brazil, there is still no consensus on which classification of hearing loss is most appropriate for use in clinical practice. However, the most commonly used is the one proposed by Lloyd and Kaplan[8], which considers the mean value from the 500, 1000, and 2000 Hz frequencies. However, this criterion may not take into account the impairment of speech intelligibility caused by higher frequencies[9,10,11].

According to the recommendation of the Audiological Assessment Guidance Guide from 2023, published by the Speech Therapy Council System[6] the professional is responsible for choosing the classification of the degree of hearing loss, as long as it is scientifically validated method and mentioned at the audiological reports. These reports must cite the classifications calculated based on the arithmetic mean hearing thresholds at frequencies of 500, 1000, and 2000 Hz (tritonal mean) or 500, 1000, 2000, and 4000 Hz (quadritonal mean). The references cited using the tritonal mean are described by several authors in studies[8,12,13], while for the quadritonal mean, the classifications of the International Bureau of Audiophonology (BIAP)[14] and the World Health Organization (WHO)[15] are recommended. These last two classifications, consider the 4000 Hz frequency, covering a higher frequency, which is the most affected in hearing disorders[10]. However, Brazilian legislation, through Decree No. 5.296/2004[16] and Law No. 14.768 of December 22, 2023[17], establishes a reference value for hearing impairment that does not follow any of the criteria of the recommended classifications, as it considers frequencies of 500, 1000, 2000, and 3000 Hz.

In view of this and other questions regarding unilateral hearing loss, with a view to assisting in the preparation and standardization of speech therapy opinions and reports for the population, the Federal Council of Speech Therapy (CFFa) Opinion Nº. 59 on January 28, 2024[18], which provides for the interpretation of the aforementioned law. The opinion mentions and emphasizes that the Brazilian Inclusion Law (LBI)[19] considers a person with a disability to be someone who faces long-term impediments, whether physical, mental, intellectual, or sensory, that hinder their participation in society on an equal basis with others. In addition to the LBI, the opinion mentions the use of the provisions of the International Classification of Functioning (ICF), the WHO International Classification of Diseases (ICD), and other opinions of the CFFa [20,21]. It also emphasizes that speech therapists must always base their work on scientific data, in accordance with ethical and legal principles.

The various classifications use different levels and nomenclatures to establish hearing loss and degree. Some consider hearing loss when the threshold of tritonal averages is above 25 dBHL (Lloyd and Kaplan - LK); others, when the average is above 20 dBHL (BIAP) and, recently, in 2021, the WHO began to consider thresholds below 20 dBHL as the limit of normality[6].

For some time now, studies[9-11] have mentioned the discussion on the classification of hearing loss and shown the importance of the accuracy of audiological reports and that these reports reflect the patient's actual difficulty. To this end, they advocate the inclusion of higher frequencies. The authors conducted a study using the octonal mean of 250 to 8000 Hz to verify the correlation between different tonal averages (tritonal, quadritonal, and octonal) and the Speech Recognition Percentage Index (SRPI) and hearing impairment. They concluded that there was a significant correlation between the reduction in SRPI performance and the increase in the average across the eight frequencies[11].

Therefore, the objective of this study was to evaluate the agreement between the different criteria for classifying hearing loss by calculating and comparing the tonal averages obtained from audiometry.

METHODS

This is a retrospective, cross-sectional study approved by the Human Research Ethics Committee of the Lusíada University Center (CEPSH) under opinion No. 6.737.130. The Free and Informed Consent Form (FICF) was waived by CEPSH, as the data collection was performed from a database.

The sample for this study was obtained from the collection of air conduction hearing thresholds from audiometric tests included in a study on the audiological profile of patients over 12 years of age, conducted at the audiology teaching clinic of a private higher education institution between 2017 and 2022[22]. In this profile, all hearing assessments were reported using the Lloyd and Kaplan classification[8] (tritonal average of 500, 1000, and 2000 Hz).

The calculations and comparisons were performed on hearing losses classified as moderate due to the fact that the reference value of Law No. 14.768/23[17] for bilateral loss is determined based on the arithmetic mean of 41 dB (forty-one decibels) or more at frequencies of 500,1000, 2000, and 3000 Hz.

Considering that symmetrical bilateral losses predominate in the audiological profile[22], only the right ear was selected for the other calculations of tonal averages. In addition, as the sample consisted of 80 ears with moderate hearing loss, it was decided to select the same number of ears with normal and mild hearing loss to include in the study.

Once the study sample was defined, the tonal means were recalculated according to other criteria, with a quadritonal average of frequencies of 500, 1000, 2000, and 4000 Hz and 500, 1000, 2000 and 3000 Hz. After the calculations, the different averages were correlated with some of the scientifically validated classifications recommended by the Audiological Assessment Guidance Guide of the Speech Therapy Council System[6] and with the legal criteria that defines hearing impairment and establishes a reference value for hearing limitation.

The classifications used in this study were Lloyd and Kaplan (LK), 1978[8], Bureau International d'Audiophonologie (BIAP), 1996[14], World Health Organization (WHO), 2021[15], and the reference value for hearing impairment in Law No. 14,768/2023[13].

The criteria for each classification of hearing loss in this study and in the law can be seen in Chart 1.

The nomenclature used for each calculation of means was as follows: MLK – Lloyd and Kaplan Tritonal Mean, MBIAP – BIAP Quadritonal Mean, MOMS for WHO Quadritonal Mean, and MLaw – Quadritonal Mean of Law No. 14.768/2023.

Frequency distribution (number of cases and percentage) was used to describe categorical variables, and measures of central tendency (mean and median) and variability (range and standard deviation) were used for numerical variables and scales.

The Kappa Coefficient (κ) was applied to verify the agreement between the classifications and the following interpretation was considered[23]: κ <0.20 minimal agreement; 0.21-0.40 reasonable; 0.41-0.60 moderate; 0.61-0.80 substantial and 0.81-1.00 almost perfect.

The Stata software, version 18[24], was used to perform all statistical analyses.

RESULTS

In the sample, consisting of 240 ears, 135 (56.2%) individuals were identified as female and 105 (43.8%) as male. Ages ranged from 12 to 95 years (Table 1).

Regarding the type of hearing loss, 197 (82.1%) ears were classified as sensorineural.

The distribution of hearing loss degrees, according to the classifications recommended in the literature and according to the criteria of the law, can be seen in Table 2. The results of this study identified that, of the 240 ears with hearing loss, only 97 (40.4%) were defined as disabled under Law No. 14.768/2023 (Table 2).

The results of the comparison of classifications are shown in Tables 3 and 4 and Figure 1. According to the Kappa Coefficient, there was agreement between classifications. The agreement coefficient value was lower in the comparison between MOMS and MLK, interpreted as moderate, according to authors[23] (κ=0.43). In the other comparisons, the Kappa value was higher, considered substantial, between MLK and MBIAP (κ=0.61) and between MOMS and MBIAP (κ=0.75).

It was observed that one ear (1.8%) was classified as moderate in MLK and mild in MOMS (Table 3). This occurred due to the ascending configuration of hearing loss, in which the threshold at a frequency of 4000 Hz was obtained at 0 dB and at lower frequencies between 50 dB and 65 dB.

The comparison between MLK, MBIAP, and MOMS degrees with reference values lower than 41 dB and greater than or equal to 41 dB (legal criterion) is shown in Table 5. In the column with values lower than 41 dB, the number of cases of moderate degrees of the classifications was highlighted: MLK with 3 (2.1%) ears; MBIAP with 6 (4.2%) and MOMS with 39 (27.3%), cases that, when added together, result in 48 ears (33.6%). This finding revealed the number of individuals with moderate loss who were excluded from the legal criterion. In addition, it showed that the WHO classification was the one that most disagreed with the criterion used by Brazilian legislation, given that it is due to the range with lower tonal threshold levels (from 35 to less than 50 dB) considered in this classification.

Table 5 shows that the LK classification was the one that most mitigated the degree of loss, since it classified as mild

Chart 1. Classification of the degree of hearing loss

Reference	Frequency (Hz)	Grades		
		Normal	Mild	Moderate
World Health Organization (WHO, 2021)[15]	500, 1000, 2000 and 4000	Less than 20dB NA	20 to less than 35dB NA	35 less than 50B NA
Bureau International d'AudioPhonologie (BIAP, 1996) [14]	500, 1000, 2000 and 4000	Less than or equal to 20dB NA	21 to 40 dB NA	Grade I: 41 to 5 dB NA
Lloyd and Kaplan (LK, 1978) [8]	500, 1000 and 2000	Less than 26dB NA	26 to 40dB NA	41 to 55dB NA
Brazilian legislation (Law No. 14.768/2023) [17]	500, 1000, 2000 and 3000	Up to 40dB NA	Greater than or equal to 41dB NA	

Table 1. Distribution of cases according to demographic variables – 240 ears

Variáble	Category / Measures	Freq. (%) / Measures
Gender N (%)	Femele	135 (5.,2)
	Male	105 (43.8)
Age (years)	Range	12 – 95
	Median	68
	Mean (Standard Deviation)	66.3 (16,6)
Age group (years)	12 – 18	9 (3,8)
	19 – 59	48 (20.0)
	≥ 60	183 (76.2)

Table 2. Distribution of hearing impairment degree according to calculations of means scores and legal criteria – 240 ears

Category	MLK	MOMS	MBIAP	MLaw
	Freq. (%)			
Grade normal	80 (33.3)	47 (19. 6)	50 (20.8)	143 (59.6)
Grade mild	80 (33.3)	57 (23.7)	89 (37.1)	
Grade moderate	80 (33.3)	136 (56.7)	101 (42.1)	
Hearing Loss				*97 (40.4)

* Reference value considered hearing loss for Law No. 14.768/2023

Subtitle: MLK = Lloyd & Kaplan Tritonal Mean; MBIAP = International Bureau of Audiophonology Quadritonal Mean; MOMS = World Health Organization Quadri-tonal Mean; MLaw= Law No. 14.768/2023 Quadritonal Mean

Table 3. Comparison between the World Health Organization classification and Lloyd & Kaplan and Bureau International d'Audiophonologie – 240 ears

Grade		MOMS			Kappa Coefficient
		Normal	Mild	Moderate	
		Freq. (%)			
MLK					0.43
	Normal	47 (100.0)	33 (57.9)	0	
	Mild	0	23 (40.3)	57 (41.9)	
	Moderate	0	1 (1.8)	79 (58.1)	
MBIAP					0.75
	Normal	47 (100.0)	3 (5.3)	0	
	Mild	0	54 (94.7)	35 (25.7)	
	Moderate	0	0	101 (7.3)	

Subtitle: MLK = Lloyd & Kaplan Tritonal Mean; MBIAP = International Bureau of Audiophonology Quadritonal Mean; MOMS = World Health Organization Quadri-tonal Mean

Table 4. Comparison between Lloyd & Kaplan and Bureau International d'Audiophonologie classifications – 240 ears

Grade MLK	Grade MBIAP			Kappa Coefficient
	Normal	Mild	Moderate	
	Freq. (%)			
Normal	50 (100.0)	30 (33.7)	0	0.61
Mild	0	54 (60.7)	26 (25.7)	
Moderate	0	5 (5.6)	75 (74.3)	

Subtitle: MLK = Lloyd & Kaplan Tritonal Mean; MBIAP = Bureau International d'Audiophonologie Quadritonal Mean

Table 5. Comparison between classifications with a reference value lower than 41 dB and in accordance with the Law – 240 ears

Grade	Value < 41dB	MLaw ≥ 41
	N (%)	N (%)
MLK		
Normal	80 (55.9)	0
Mild	60 (42.0)	20 (20,6)
Moderate	**3 (2.1)**	77 (79.4)
MBIAP		
Normal	50 (35.0)	0
Mild	87 (60.8)	2 (2.1)
Moderate	**6 (4.2)**	95 (97.9)
MOMS		
Normal	47 (32.9)	0
Mild	57 (39.9)	0
Moderate	**39 (27.3)**	97 (100.0)

Subtitle: MLK = Lloyd & Kaplan Tritonal Mean; MBIAP = International Bureau of Audiophonology Quadritonal Mean; MOMS = World Health Organization Quadritonal Mean; MLaw = Law No. 14.768/2023 Quadritonal Mean

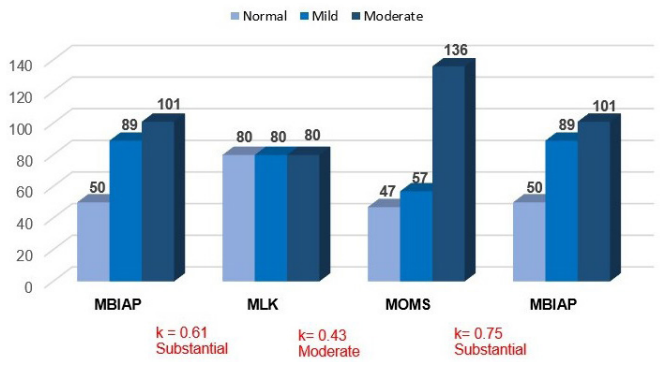

Figure 1. Comparison of means ratings using the Kappa Coefficient – 240 ears

Subtitle: MBIAP = International Bureau of Audiophonology Quadritonal Mean; MLK = Lloyd & Kaplan Tritonal Mean; MOMS = World Health Organization Quadri-tonal Mean; k= Kappa Coefficient

20 ears (20.6%) that the law included in its criteria (average frequencies of 500, 1000, 2000, and 3000 Hz of 41 dB or more).

DISCUSSION

This study analyzed the agreement between different hearing loss classification criteria by calculating and comparing tonal means, seeking scientific evidence of hearing loss classifications to assist speech therapists in choosing the most appropriate audiological report. In addition, it was motivated by the concern to reveal and quantify the number of people with hearing loss who are excluded under the legislation for the social protection of People with hearing Disabilities - PwD.

According to the recommendation of the 2023 Audiological Assessment Guidance Guide, from the Speech Therapy Council System[6], the choice of hearing loss classification is at the discretion of the professional. Therefore, there is no consensus on this, and the same individual may have reports with different nomenclatures, depending on the classification used. This study provided insight into these differences by comparing the hearing loss classifications of LK, BIAP, and WHO.

In the literature, there are studies[5,10,11,25,26] that compare scientifically validated classifications with each other, but applied to a specific group and with descending audiometric configurations. For the purposes of this study, the most recent WHO classification and the reference value for hearing impairment under law No. 14.768/2023[17] were added.

As in this study, data were collected from a predominantly audiological profile of elderly individuals, resulting in a sample of descending sensorineural hearing loss, with subjects aged 60 years or older.

In audiological practice, some authors[9,10] mention that this type of loss and configuration is the most commonly found, which justifies the number of studies available in the literature. However, it should be noted that the comparative analysis performed in this study did not consider ascending and flat (horizontal) configuration losses. A 2014 study[10] mentions that the LK classification is more suitable for classifying flat audiometric configuration hearing losses than descending ones. Therefore, it is believed that for other configurations the results are different, since the degree of loss is influenced by the audiometric configuration. In the results of this study, only one case (Table 3) of ascending configuration loss was found, in which the LK classification was more pronounced than that of the WHO.

In general, the statistical coefficient applied to the findings showed levels of agreement between the classifications for the type of sample studied. The Kappa agreement coefficient used in the comparison of classifications resulted in moderate agreement for LK versus WHO and substantial agreement for LK versus BIAP and BIAP versus WHO. However, a more in-depth analysis of the values found between them is warranted.

A study[26] with elderly individuals that compared BIAP with a classification[13] using the same criterion of LK tritonal mean found a decrease in the occurrence of normal individuals from 17.5% to 2.5%. Our findings were similar, as we identified 33.3% of normal individuals in LK versus 20.8% in BIAP. However, despite the differences found in these two classifications, the Kappa agreement coefficient between them was considered substantial ($\kappa = 0.61$).

Three studies[5,25,26] were found that were conducted with patients with descending audiometric configuration comparing the LK and/or Davis and Silverman classifications[13] with BIAP. The conclusion among them is also similar to the findings of this research, namely that BIAP is the most sensitive for this population because it considers the 4000 Hz frequency. One of them, in addition to comparing BIAP classifications with LK classifications, applied the hearing handicap questionnaire. Therefore, as in this study, the BIAP classification proved to be more reliable than LK for defining hearing loss, since of the 80 ears classified as normal for LK, only 50 remained at the same level for BIAP. There was also a slight increase in the number of ears classified as mild in BIAP, from 80 mild LK to 89 BIAP. In the moderate degree, there was a greater increase from 80 moderate hearing losses in LK to 101 in BIAP. This data proved that the BIAP classification resulted in higher degrees of hearing loss. Therefore, the fact that BIAP uses a lower reference value for hearing loss (less than or equal to 20 dB) and one more frequency (4000 Hz - quadritonal) for the calculation of the degree better expresses the result of the hearing assessment and, consequently, the hearing handicap, especially in descending configuration losses[5].

In this study, in addition to comparing the LK and BIAP classifications, the WHO classification was also included, which considers the quadritonal mean of frequencies of 500, 1000, 2000 and 4000 Hz to calculate the averages, but with other parameters to define loss and degrees. In the comparison between WHO and BIAP, the highest statistical agreement coefficient ($\kappa = 0.75$) was obtained, classified as substantial.

Due to the fact that in 2021, the WHO presented a new classification of hearing loss, with the quadritonal mean of the same frequencies but establishing thresholds below 20 dBHL as the limit of normality by air conduction, a greater distance was generated between the classifications, mainly for LK, in which the tritonal mean is calculated with a normality value lower than 26 dB. This fact can be demonstrated by a lower Kappa coefficient ($\kappa = 0.43$), interpreted as moderate.

In descending configurations, the use of quadritonal means shows a more pronounced degree of hearing loss, which can lead to worse IPRF results and consequently poorer communication performance in patients. In this study, the correlation of averages with IPRF was not performed; however, in the literature[10,11] there is a relationship between the frequencies used in tonal averages and IPRF and hearing impairment. In one of these studies[11], the most significant correlation of the IPRF was with the octonal mean (from 250 to 8000 Hz).

The criteria used to define HI established by Decree No. 5.296/2004[16] and Law No. 14.768 of December 22, 2023[17] may harm the social interaction of individuals with disabilities. The divergence between the proposed legal classification[16,17] and other classifications in the literature recommended by the Speech Therapy Council System[6] raises questions about the importance of choosing and understanding classifications in audiological reports.

A narrative review of the literature[7] revealed that there is no global consensus on the criteria used to classify the degree of hearing loss. However, it found that there is a preference for the quadritonal mean between the frequencies of 500, 1000, 2000, and 4000 Hz.

The choice to include the 3000 Hz frequency in the calculation of the quadritonal mean is not a common practice among professionals, as only four classifications are found in the scientific literature, two of which were developed by the same author[7]. In addition, the inclusion of the 4000 Hz frequency and the fact that a greater number of frequencies are

considered in the calculation of the tonal average better reflect the disadvantage caused by hearing loss[11].

As highlighted in the results, 48 (33.56%) ears classified as moderate, according to the three classifications used, were below 41 dB, that is, the reference value for hearing impairment in the legislation. This data indicates that moderate losses that interfere with individuals' communication performance[6] will not be identified by the legal criterion.

Therefore, this study demonstrated that the choice of hearing loss classification can be left to the discretion of the professional, according to the recommendation of the Audiological Assessment Guidance Guide[6], as the statistical indices obtained in the comparisons did not indicate any disagreement. However, they raised relevant aspects in the choice of classifications, such as the importance of using quadritonal means, including the highest frequency (4000 Hz), especially in descending losses. Regarding the reference value applied by Law 14.768/2023[17], it revealed the exclusion of a considerable percentage of individuals with AD. This finding, according to opinions from the CFFa[18,20], indicates that professionals should refer to the legislation (LBI) and the classification of functionality and disability (CIF) to demonstrate that hearing loss affects the individual's well-being, functionality, and participation in society.

When individuals with hearing loss are not recognized as persons with disabilities, they are deprived of benefits and access to available public policies. A diagnosis with an audiological report that does not reflect the patient's complaints and difficulties may result in the non-recognition of vulnerabilities, which contributes to exclusion rather than social inclusion[7].

CONCLUSION

To classify hearing loss with a descending audiometric configuration, there is moderate to substantial agreement between scientifically validated classifications and those recommended by the Audiological Assessment Guidance Guide of the Speech Therapy Council System. However, it was possible to measure this agreement to assist professionals in choosing the classification of hearing loss in order to prepare a more reliable audiological report for the patient.

As for the criterion of the reference value for hearing impairment proposed by Brazilian legislation, the study clarifies that this criterion fails to benefit a considerable portion of the population with HI.

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