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Descending audiometric configuration: tonal means, speech perception and audiological hearing disadvantage

Configuração audiométrica descendente: médias tonais, percepção de fala e desvantagem auditiva

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ABSTRACT

Purpose: To verify the correlation of different tonal means (tritonal, quadritonal and octanol) with the Percentage Index of Speech Recognition and with hearing disadvantage. **Methods:** 56 subjects participated in the study, distributed into two groups, with descendant audiometric configuration: Subjects with tritonal average equal to or less than 25 dB HL(G1) and subjects with a tritone average worse than 25 dB HL(G2), being matched for sex and age (p=0.544). All were safe by Threshold Tone Audiometry, Speech Recognition Percentage Index (IPRF) with a list of keywords, Acoustic I Measures and the Elearing Handicap Inventory for Adults. The correlation analysis was performed between the averages, of three frequencies (M3), of four frequencies (M4) and of eight frequencies (M8) with the IPRF and with auditory disadvantage, using the Spearman correlation test, the significance level being considered <0.05 (5%). **Results:** There was a statistically significant correlation of the IPRF with M8 , for G1, and the IPRF with M4 and M8, for G2. There was a tendency towards significance, both for G1 and G2, in relation to M8 when correlated with hearing impairment, demonstrating that analyzing the eight frequencies of the audiogram (frequencies higher than 4000 Hz) seems to allow a greater understanding of the patient's hearing handicap. **Conclusion:** There was a statistically significant correlation between the IPRF and M8, in both groups, denoting a reduction in the performance of the IPRF, with an increase in the mean, considering the eight frequencies. M8 better reflected the hearing disadvantage caused by the hearing loss in G1.

Keywords: Speech perception; Hearing loss; Audiometry; Adults; Speech acoustics

RESUMO

Objetivo: Verificar a correlação das diferentes médias tonais (tritonal, quadritonal e octonal) com o Índice Percentual de Reconhecimento de Fala e com a desvantagem auditiva. **Métodos:** Participaram do estudo 56 sujeitos, distribuídos em dois grupos, com configuração audiométrica descendente: Grupo 1 (G1) - 28 sujeitos com média tritonal igual ou inferior a 25 dBNA e Grupo 2 (G2) - 28 sujeitos com média tritonal pior que 25 dBNA (G2), sendo pareados quanto ao gênero e idade (p= 0,544). Todos foram submetidos à audiometria tonal liminar, Índice Percentual de Reconhecimento de Fala (IPRF) com lista monossilábica de palavras gravadas, medidas de imitância acústica e ao questionário *Hearing Handicap Inventory for Adults*. A análise de correlação foi realizada entre as médias de três frequências (M3), de quatro frequências (M4) e de oito frequências (M8) com o IPRF e com a desvantagem auditiva, utilizando o teste de correlação de Spearman, sendo o nível de significância considerado <0,05 (5%). **Resultados:** Evidenciou-se correlação estatisticamente significativa do IPRF com a M8, para o G1, e do IPRF com M4 e M8, para o G2. Observou-se tendência à significância, tanto para o G1, como para o G2, em relação à M8, quando correlacionada com a desvantagem auditiva, demonstrando que analisar as oito frequências do audiograma (frequências mais agudas que 4000 Hz) parece possibilitar maior compreensão em relação à desvantagem auditiva do paciente. **Conclusão:** Houve correlação estatisticamente significativa do IPRF com a M8, nos dois grupos, denotando uma redução no desempenho do IPRF, com o aumento da média, considerando as oito frequências. A M8 refletiu melhor a desvantagem auditiva causada pela perda auditiva, no G1.

Palavras-chave: Percepção de fala; Perda auditiva; Audiometria; Adultos; Acústica da fala

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INTRODUCTION

A pure tone audiometry (PTA) is the gold standard assessment to classify and quantify the hearing loss and is of paramount importance for understanding changes in cochlear function and structure[1]. However, to understand hearing ability reliably, it is also necessary to assess an individual's ability to execute and participate in activities of daily living, that is, his or her communicative abilities, with emphasis on speech perception[2,3].

Until then, the literature presented Lloyd & Kaplan[4] and Davis[5], as references for the degree of hearing loss, which take into consideration the mean of the tone thresholds obtained at the frequencies 500, 1000 and 2000 Hz (tritonal mean) and the *Bureau International d'Audiophonologie* (BIAP)[6] which, like the World Health Organization (WHO), considers the mean of the tonal thresholds at frequencies of 500, 1000, 2000 and 4000 Hz (four-tonal mean), all of which stipulated 25 dBHL as the normal limit for airways, until the new WHO classification[7].

In 2020, the WHO presented a new classification for the degree of hearing loss, still based on the four-tonal mean, advocating thresholds below 20 dBHL as the limit of normality of the airway for the frequencies of 250 to 8000 Hz. This classification was proposed by a group of experts who are part of the WHO Global Burden of Disease project because it is better related to the functional consequences presumed for each degree of hearing loss, as well as to represent more accurately the damage caused by sensory privation[8].

In Brazil, there is still a lot of disagreement about which classification would be the most appropriate for use in clinical practice. However, the most commonly used classification is the one proposed by Lloyd & Kaplan[4], which, however, disregards the higher frequencies, ignoring the possibility of impairments in speech intelligibility[9,10].

In clinical audiology, the descending audiometric configuration is repeatedly found in sensorineural hearing loss. This fact may be explained by the initial involvement of the acute frequencies in several pathologies of the auditory system, such as those caused by excessive noise exposure, metabolic diseases, ototoxicity, and presbycusis[11,12].

In 2014, Anjos et al.[13] studied the relationship of tonal thresholds with the Speech Recognition Index (SRI) in elderly subjects and concluded that the means including the frequencies of 3000 Hz and 4000 Hz are the ones that present the highest correlation with this index. However, there are no published studies relating the performance in the SRI with the eight frequencies assessed in the PTA, thus generating a questionary whether the hearing loss in the frequencies of 6000 Hz and 8000 Hz could not also have a relationship with the speech perception and hearing handicap, considering that the greater the impairment in high frequencies, the worse the discrimination of words will be[14] and, consequently, worse the communicative performance of the affected individuals.

Considering the complexity of measuring the real condition of an individual's hearing function, it is pertinent to reflect on the theoretical concepts of psychoacoustics, since the findings of PTA and logoaudiometry depend on the response of the subject, that is, they are influenced by individual subjective perception[15]. The subject's perception and, consequently, his/her response expressed in dBHL, is dependent on individual hearing sensitivity, defined as how much he/she "deviates" from the sound pressure level presented by the headphone at a given intensity and frequency[15]. Thus, speech perception depends not only on peripheral hearing acuity but also on psychoacoustic interpretations of the signal, in which small alterations, even if in high frequencies, tend to negatively influence such aspects, affecting speech recognition and discrimination.

In addition to the findings of the PTA and logoaudiometry, self-assessment questionnaires are essential tools when investigating the degree of hearing disadvantage experienced by the hearing-impaired individual, as they provide complementary information as to the subjects' perception of their communication. These questionnaires are specific for assessing the emotional and social/situational consequences perceived because of hearing loss[16].

Considering the need for the audiological report to be objective, precise, enlightening, and to reflect the real hearing condition of the individuals being evaluated, it is necessary to reflect on the classification of hearing losses, in such a way that they truly indicate the real hearing performance of each subject, which justifies the present study.

Thus, it is believed that, especially in descending hearing losses, all the frequencies investigated are important and, therefore, must be considered when classifying the audiogram to avoid erroneous reports that do not reliably clarify the individual's hearing situation.

Based on the above, this study aimed to verify the correlation of the different tonal means (tritonal, four-tonal and octonal) with the SRI and with hearing handicap in two groups of subjects with a descending audiometric configuration.

METHODS

This research had a quantitative, descriptive, and cross-sectional approach. The Research Ethics Committee of the Universidade Federal de Santa Maria - CEP/UFSM under number 25933514.1.0000.5346, approved it. The sample was selected by convenience, and the subjects came from the Hearing Aid Granting, Electrophysiology of Hearing, and Basic Audiological Assessment outpatient clinics of the institution (n = 100). All the individuals who took part in the study agreed to the study, signing the Free and Informed Consent Form (IC).

As eligibility criteria for sample composition, the subjects had to be aged between 18 and 59 years, have Brazilian Portuguese as their mother tongue, be literate, and have type "A" tympanometric curves bilaterally and a descending audiometric configuration. A descending configuration was considered as the minimum worsening between 5 and 10 dB per octave in all frequencies towards the high frequencies[7].

Subjects were excluded if they had inconsistent answers on the PTA, did not understand any order to carry out certain steps of the study, had conductive or mixed hearing loss, tritonal mean greater than 60 dBHL, and/or were users of Hearing Aid.

Of the 100 subjects invited to participate in the study, 56 met the eligibility criteria. Thus, the final casuistic included 56 subjects, distributed in two groups matched for gender and age.

Group 1 (G1) was made up of 28 individuals (20 females and eight males), aged between 18 and 53 years (mean age 40 years), with mean schooling of eight years and tritone mean equal to or below 25 dBHL. Group 2 (G2) was composed of 28 subjects (21 females and seven males), aged between 18 and 52 years (mean age 40 years), with mean schooling of eight years and tritone average higher than 25 dBHL.

As for the research procedures, all individuals were submitted to visual inspection of the External Acoustic Meatus, PTA, logoaudiometry, acoustic immittance measurements, and the questionnaire Hearing Handicap Inventory for Adults (HHIA).

For the performance of the PTA and logoaudiometry, we used an Interacoustic AC33 audiometer and TDH 39 headphones. During the performance of the PTA, the subjects remained seated inside the acoustically treated cabin and were instructed to raise their hands or press a button, of their choice, every time they heard a sound (whistle). The stimulus used was the pure tone and the method for performing the procedure was the descending-ascending technique.

The Speech Recognition Threshold (SRT) and the Speech Recognition Index (SRI) were investigated in a monaural manner. The SRT was performed with lists of disyllable words, by Russo and Santos[17], starting at 30 dBHL above the tritone mean, being researched out loud, respecting the VU meter of the equipment, which should reach approximately 0 dB. The SRT was stipulated as the lowest intensity at which the subject correctly repeated 50% of the words presented, and the expected value was equal to or up to 10 dBHL above the tritone mean[18]. It is worth noting that among the subjects of the present study there were no cases of SRT incompatibility with the tritonal mean.

For the SRI survey, the monosyllable word lists of Vaucher et al.[19], were presented at the individual's comfort level (from 25 to 40 dBHL above the tritone mean), in a digital recording, using a Toshiba CD player, coupled to the audiometer, duly calibrated, aiming at excluding the influence of the examiner and maintaining standardization among the subjects. To obtain the percentage of correct answers, 4% of each word repeated correctly was considered.

Regarding the acoustic immittance measurements, we used the equipment AT235, from Interacoustics, considering the following criteria[7] classification for the type "A" curve: pressure between +100 and -100 daPa, with the volume between 0.30 and 1.65 ml. The acoustic reflexes were also investigated but were not considered for analysis in this study.

For the research on the hearing handicap, that is, the disadvantage in psychosocial functioning of individuals due to hearing impairment, the HHIA questionnaire was used[20], composed of 25 questions and divided into two scales: social/situational and emotional. The participants were instructed to read the instrument by themselves and to mark one of the three alternatives available for each question: "Yes" (equivalent to 4 points), "Sometimes" (equivalent to 2 points), and "No" (equivalent to 0 points). The distribution of scores is as follows: from 0 to 16 points there is no perception of hearing handicap; from 18 to 42, there is mild/moderate perception; and, above 44, there is a significant perception of hearing handicap. These numerical values were considered for correlation analysis.

For data analysis, the following classifications of means were considered: tritonal mean - M3, four-tonal mean - M4, and octonal mean - M8 (mean of the frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz).

The description and comparison of M3, M4, and M8 were carried out per ear, and the non-parametric Mann-Whitney U test was applied.

For the correlation of SRI and tone means with the degree of hearing loss, we carried out a numerical correlation analysis, that is, we analyzed whether the higher the HHIA value, the worse the SRPI would be, and we checked the possibility of an inversely proportional correlation. To this end, we used Spearman's non-parametric correlation test, considering values < 0.05 (5%) as the significance level.

RESULTS

When comparing M8 with M3 and with M4 in subjects with tritone mean equal to or below 25 dBHL, we found a statistically significant difference in both comparisons (p=0.003). On the other hand, when performing the same comparison in subjects with a tritone mean higher than 25 dBHL, we noticed a significant difference only between M3 and M8 (Table 1).

When correlating the different tonal means with the hearing handicap observed using the questionnaire responses in each group, we found a moderate correlation which tended toward significance, between hearing handicap and M8 in G1 (Table 2).

As for the correlation of the SRI with the different tonal means, we observed a statistically significant relationship between the SRI with the M8 for G1 and the SRI with the M4 and M8 for G2 (Table 3).

DISCUSSION

This study was designed due to the need to search for evidence that proves the importance of considering the whole audiogram

Table 1. Description and comparison of the three-tone mean and four-tone mean with the octone mean, per ear, in Group 1 and Group 2

			n	Mean	Median	Min	Max	value of p[1]
GROUP 1	**M3 x M8**	M3	56	15	15	5	25	0.003*
		M8	56	30	35	15	40	
	M4 x M8	M4	56	20	25	5	4	0.003*
		M8	56	35	35	15	40	
GROUP 2	**M3 x M8**	M3	56	40	45	25	60	0.004*
		M8	56	50	50	65	75	
	M4 x M8	M4	56	45	50	25	60	0.106
		M8	56	50	50	65	75	

[1]Mann-Whitney U-test; *Statistically significant result

Subtitle: n = number of ears; Min = minimum; Max = maximum; M3 = tritonal mean; M4 = four-tonal mean; M8 = octonal mean

Table 2. Correlation of the different tone averages and the degree of hearing handicap measured by the Hearing Handicap Inventory for Adults, according to groups

	Variables	n	r	value of p[1]
GROUP 1	M3 and Hearing impairment	28	0.43	0.18
	M4 and Hearing impairment	28	0.23	0.48
	M8 and Hearing impairment	28	0.57	0.06**
GROUP 2	M3 and Hearing impairment	28	0.40	0.10
	M4 and Hearing impairment	28	0.28	0.25
	M8 and Hearing impairment	28	0.31	0.21

[1]Spearman's Correlation Test; **Trend to significance

Subtitle: M3 = tritonal mean; M4 = four-tonal mean; M8 = octonal mean; n = number of subjects; r = correlation coefficient

Table 3. Correlation of the Speech Recognition Index with the different tone averages of the subjects, divided by groups

	Variables	N	r	value of p[1]
GROUP 1	M3 and SRI	28	0.45	0.18
	M4 and SRI	28	0.33	0.48
	M8 and SRI	28	0.77	**0.04***
GROUP 2	M3 and SRI	28	0.40	0.10
	M4 and SRI	28	0.68	**0.03***
	M8 and SRI	28	0.81	**0.02***

[1]Spearman's Correlation Test; *Statistical significance

Subtitle: M3 = tritonal mean; M4 = four-tonal mean; M8 = octonal mean; SRI = Percent Speech Recognition Index; n = number of subjects; r = correlation coefficient

in the elaboration of the audiological report, highlighting that the hearing thresholds of the acute frequencies are where, frequently, hearing losses begin[13].

The audiological report should, as much as possible, show the real hearing and communication performance of the subject, and conventional PTA has the role of closing this report[21]. Thus, this study sought to verify the correlation between different tonal means (M3, M4, and M8) with hearing handicap and SRT, aiming to show whether M8 correlates better with these measures and whether it really predicts more efficiently the hearing performance of the subject.

In 2007, a study had already pointed out the importance of using a classification based on several frequency ranges to determine the degree of hearing loss in elderly people with acute threshold changes[22]. Yet, another study observed that sensorineural hearing losses affect mainly the high frequencies, which explains most of the communication difficulties reported by individuals, i.e., the result of PTA will not always correspond to the result found in the assessment of the functional use of hearing[23]. Therefore, the importance of the findings of the present study is emphasized, which aimed to show the hearing disadvantage caused by hearing loss in the acute frequencies[2].

In this study, when comparing M3 and M4 with M8, statistically significant differences were seen in G1 (subjects with tritonal mean equal to or below 25 dBHL). These differences were expected, due to the descending audiometric configuration, the focus of the study. It is believed that no statistical difference was found when comparing M4 with M8 in G2 because the hearing loss presented by the subjects in this group already starts in the lower frequencies.

When correlating the hearing handicap, measured numerically using the HHIA with the different tonal means, we could see that when observing M8, in G1 there was a tendency to significance in this correlation, denoting that the higher the number of frequencies under consideration, the greater the perception of hearing handicap. Recent studies[24,25] mention the importance of investigating the subjects' perception of their difficulties, in addition to the tests.

This result shows the importance of a distinct classification for hearing loss, especially in high frequencies to represent more reliably the hearing performance of the individual assessed, considering the influence of frequencies above 2000 Hz[13,26] in the communication of the subjects.

Also about the correlation of the hearing handicap with the different tone means, it was shown that in G2 the correlation was equivalent in the tritone mean with weak correlation strength. These data show that subjects who already have altered hearing thresholds in the frequencies of 500Hz, 1000Hz, and 2000Hz have the degree of hearing handicap increased to the point that the high frequencies do not interfere in the participation of the result, a finding that has already been reported in the literature[27,28].

When we correlated the SRPI with the different tone means, we noticed a higher correlation strength and a statistically significant difference with M8 for G1. This data agrees with two studies, which aimed to check the influence of different audiometric averages in sensorineural descending hearing loss and its relation with speech discrimination. In these studies, we concluded that the SRPI shows an excellent correlation when considering the frequencies from 0.5 kHz to 4 kHz, and the importance of including the frequencies of 3 kHz and 4 kHz to determine it more reliably[13,27].

When it comes to speech recognition thresholds, the literature describes that frequencies from 500 to 2000 Hz are more important than high frequencies, but there is no evidence that frequencies below 500 Hz and above 2000 Hz are not important for speech intelligibility[27]. A study that analyzed the spectral characteristics of sounds and the human hearing range observed that frequencies above 1000 Hz are responsible for the impact of 60% of the intelligibility of information. An example is the middle fricative phonemes /s,z/, which have frequencies from 4500 Hz to 8000 Hz[26].

Although it was not the focus of this study, it is pertinent to reflect on the concepts proposed by the psychoacoustics study, since they reflect the complexity of obtaining response values expressed in dB HL, especially when it comes to evaluating individuals who present descending audiometric configurations with large variations in intensity by frequency; and for each variation, there is a reference value of sound pressure level exerted by the headphone audiometer[15]. This fact confirms a disparity in not considering the dB NPS and dB NA conversion aspects, further denoting the importance of proper calibration of the equipment.

Considering such fundamentals in clinical practice is relevant to try to understand all aspects of the hearing condition of those being evaluated, both to obtain tonal thresholds and to measure speech recognition. However, it is also appropriate to include in the analysis of the audiological evaluation the most compromised frequencies in the case of the population in question. It is also noteworthy that the speech energy in frequencies above 2000Hz is 20 to 35 dB weaker than in lower frequencies, justifying the difficulty in speech recognition presented by individuals with hearing loss in the high frequencies[29].

The results of this study pointed out that when the high frequencies are considered in the audiological report, especially in hearing losses with a descending configuration, it becomes more reliable and compatible with the hearing performance of the subject, facilitating the orientation and acceptance process and, consequently, the hearing rehabilitation process[27,30].

It is also believed that an average that uses all the PTA frequencies may be successful in future studies, since all of them have their degree of participation in the communication process, translating the real auditory performance of the individual assessed.

This study had a sample size limitation due to a rigid methodological design, which restricts data generalization because of the lack of statistical significance. There is then a possibility for future studies, including multicenter ones.

CONCLUSION

There was a statistically significant correlation between SRI and M8 in both groups, showing a reduction in SRI performance as the mean increased, considering the eight frequencies.

The M8 reflected better the hearing handicap caused by the hearing loss in G1, showing the importance of including the eight evaluated frequencies in the audiological report, especially in cases of hearing loss exclusively in the high frequencies (from 4000Hz on), since they will more faithfully represent the hearing performance of the assessed individual.

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