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Computer-based auditory training for elderly with hearing aids provided by the Health Care System

Treinamento auditivo computadorizado em idosos protetizados pelo Sistema Único de Saúde

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ABSTRACT

Purpose: To check effectiveness of a computer-based auditory training program for elderly citizens with hearing aids. **Methods:** The study was conducted with 72 senior patients, between 60 and 89 years old, with an average age of 74 years (±7.8), all users of hearing aids fitted in a health center. The patients were divided in an experimental group, 48 users (66.7%), and a control group, 24 (33.3%). They were all part of the same behavioral tests (speech in noise, random gap detection and dichotic digit test) and also the Hearing Handicap Inventory for the Elderly - Screening Version restriction questionnaire. The experimental group was tested before and after the auditory training (four sessions), while the control group was tested at the delivery of the individual hearing aids and 40 days later. The neurocognitive auditory training was customized to each participant with the use of varied resources. **Results:** After comparing the behavioral tests results and the restriction questionnaire answers, in both evaluation moments, we noticed a statistical advantage for both groups. The analysis using a delta coefficient of each variable allowed us to visualize the variation from pre-evaluation to post-evaluation. The result showed a significant increase in the auditory processing tests and a not significant increase in the restriction questionnaire. **Conclusion:** The computer-based auditory training program was effective, producing improvements in the hearing abilities. The restriction questionnaire did not reflect the effects of the auditory training.

Keywords: Hearing loss; Hearing aids; Rehabilitation; Aging; Health services

RESUMO

Objetivo: Verificar a efetividade de um programa de treinamento auditivo computadorizado em idosos protetizados. **Métodos:** O estudo foi realizado com 72 idosos, entre 60 e 89 anos de idade, média de 74 anos (±7,8), protetizados em um centro de saúde. Os participantes foram divididos em grupo experimental, 48 (66,7%) e grupo controle, 24 (33,3%). Todos foram submetidos aos testes comportamentais (Fala no Ruído, *Random Gap Detection Test* e Dicótico de Dígitos) e ao questionário de restrição de participação *Hearing Handicap Inventory for the Elderly - Screening Version*. O grupo experimental foi avaliado antes e após o treinamento auditivo (quatro sessões) e o grupo controle, na entrega do aparelho de amplificação sonora individual e 40 dias após. O treinamento auditivo neurocognitivo foi elaborado conforme as necessidades de cada participante, com a utilização de recursos variados. **Resultados:** Ao comparar o desempenho nos testes comportamentais e no questionário de restrição de participação, nos dois momentos de avaliação, identificou-se diferença estatística para ambos os grupos. O coeficiente delta de cada variável permitiu a análise da variação entre a pré-avaliação e a pós-avaliação e constatou diferenças estatisticamente significativas para os testes comportamentais e não significativas para o questionário de restrição de participação. **Conclusão:** O programa de treinamento auditivo computadorizado se mostrou efetivo, indicando melhora das habilidades auditivas alteradas. O questionário não refletiu os efeitos do treinamento auditivo.

Palavras-chave: Perda auditiva; Auxiliares de audição; Reabilitação; Envelhecimento; Serviços de saúde

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INTRODUCTION

The hearing plays an important role in society[1]. Among the sensory changes that accompany the aging process, the auditory impairment is one of the most incapacitating, because the auditory system deterioration causes a deficit in speech understanding, generating difficulties in social insertion[2,3].

In addition to the hearing loss, another issue that should be emphasized is the auditory handicap which is also related to other aspects that are not specific to the hearing, implying a limitation to the individual to perform his activities[4].

The process of auditory rehabilitation aims at minimizing the disadvantages of an individual with hearing loss. From this point, he becomes a candidate for A hearing aid (HA)[3]. To ensure that the process of selection, indication and adaptation of the hearing aid is effective, the individual has to make effective use of the device, which depends on his own satisfaction with the results of the adaptation[5].

For this reason, it is important to know the associations between the hearing impairment and the auditory processing disorder, because it is usual to observe elderly presenting peripheral auditory integrity, and/or prosthetized elderly with functional gain suitable for their hearing loss, that persist with difficulties in speech understanding, especially in the presence of noise. Recent studies have shown that such difficulties may be related to auditory processing disorders[6].

The auditory processing is the way the auditory system receives, organizes and interprets the sounds heard. It consists of a brain function essential for identification, location, discrimination and memorization of acoustic stimuli, comprising a set of specific abilities that the individual depends on, in order to understand what he hears[7,8].

The evaluation of the auditory processing investigates how the individual receives the acoustic information and it can help identifying the underlying aspects of some difficulties, especially in elderly patients that often report complaints about their understanding ability[9]. Besides the decline of the hearing function, some cognitive functions also decrease with aging. Studies have indicated that the central auditory abilities would be related to cognitive functions and, for this reason, the auditory processing behavioral tests check the auditory abilities whose results may reflect the effects of aging[1,10,11].

The auditory training is one of the strategies applied to the auditory rehabilitation of wearers of hearing aids who present changes in the skills evaluated, and it has as its foundation the auditory stimulation with the goal of maximizing the effects of the central nervous system plasticity[12,13].

Thus, the computerized auditory training allows the control of data and the hierarchy of activities, and it has been applied to strengthen the synapses and promote the formation of new Engrams, thus improving the auditory abilities. Specialized software programs are used in the intervention, being an innovative practice[13].

Briefly, the auditory training stimulates the central auditory pathways for the individual to become a more active and skillful listener[12,13], however, it is necessary to identify the variables that interfere in this process, such as the benefits of the hearing aid and the cognitive performance of the individual.

Based on the mentioned information and on the scarcity of studies about the auditory training conducted by Health Care System (HCS), which recommends only four sessions, it is justified the realization of this research that may contribute not only to the verification of the importance of effective use of hearing aids, but also to the preparation of the auditory training in order to minimize the changes in the auditory abilities caused by sensory deprivation. Thus, this study had the objective of verifying the effectiveness of a computerized auditory training program for elderly prosthetized by HCS, by means of measures of auditory processing and of a questionnaire of restriction of participation.

METHODS

The research was conducted at Clélia Manfro Health Center/ - Hearing Unit and received approval from the Research Ethics Committee of Nossa Senhora de Fátima College, under the protocol number 918.462/2014. It is characterized by being a longitudinal with intervention, retrospective and prospective, observational, contemporary and individual study.

Initially, the Hearing Health Center head signed the Term of Institutional Knowledge (TCI). In the sequence, the elderly of the hearing health program that met the inclusion criteria were invited to participate in the project, and after acceptance, they signed the Informed Consent Form (ICF), which was read by the group.

The sample was composed by subjects of both genders, with minimum age of 60 and maximum of 89 years old, diagnosed with sensorineural hearing loss from mild to moderately severe, who were forwarded to the sector of hearing prosthesis from April 2014 to December 2015.

Patients with bilateral sensorineural hearing loss, symmetric[14], mild to moderately severe[15], were included, referred to selection, indication and adaptation of hearing aids.

The experimental group was composed of the elderly who attended all the stages of the research, i.e., completing the questionnaire Hearing Handicap Inventory for the Elderly - Screening Version (HHIE-S), performing the behavioral tests after delivery of the ha and, attending the four sessions of auditory training as recommended by HCS. After the training, they returned for the reassessment and for another application of the HHIE-S. The control group was composed of the elderly who performed the behavioral tests and completed the HHIE-S after the delivery of the HA and returned, after 40 days of use, for reassessment. All the elderly, in both groups, used bilateral hearing aids, with receiver in the canal.

Patients who did not attend any of the stages of the research, who were diagnosed with profound level of hearing loss and/or conductive or mixed hearing loss, who presented clinical history of changes in the external and/or in the medial ear, who presented auditory alterations in acoustic immittance measures and old patients with hearing aids were excluded from participating in the study. Also, those who presented severe cognitive impairment or neurological changes that prevented the use of the protocols were excluded. The following tests were also applied: Geriatric Depression Scale (GDS), subtest of word recognition of the Assessment Scale for Cognitive Alzheimer's Disease (ADAS-Cog) and test of verbal fluency. The individuals who could not perform them were excluded from the study.

When the patients of both groups came for the delivery of the hearing aids, their interest to participate in the research was verified and, after the acceptance, the informed consent was read and signed. On the same date, the HHIE-S questionnaire was completed and a meeting was scheduled for the performance of the behavioral tests.

The HHIE-S is a version of sorting, with ten items taken from the Hearing Handicap Inventory for the Elderly - HHIE, which was developed to evaluate the impact of hearing loss in emotional and social adjustment of the elderly patient. The restriction degree of participation is determined according to the criteria of scoring the answers. The higher the index, the greater the individual's perception in relation to his handicap, i.e., the greater the difficulties caused by the hearing loss(16).

The behavioral tests chosen for this study were: Speech in Noise test, Random Gap Detection Test (RGDT)) conventional or expanded (the latter only performed in case the patient could not answer the conventional test) and dichotic digits. The Speech in Noise test was chosen on the basis of the main complaint of elderly, i.e., their difficulty in understanding speech in competitive environments. We also we opted for the RGDT test since it is a briefer measure of temporal resolution when compared to the other available test. On the other hand, the dichotic digits test was proposed to evaluate the binaurality for verbal sounds with less linguistic load when compared to the other measure. After the completion of the behavioral tests, the experimental group patients returned for the four sessions of auditory training and, after them, the reassessment was performed using the same tests. The control group patients returned after 40 days of use of the hearing aid (period of time in which the experimental group performed the auditory training), for the reassessment.

The tests were performed with the participant in acoustic cabin, using supra-aural TDH-39 headphones, without the hearing aid. They were recorded on CD and applied by means of an audiometer of two channels (AC 33, of the Interacoustics®), coupled to a notebook (Inspiron142620, Dell®). All tests were performed at the intensity of 40 dBNS above the audiometric average of the individual's frequencies from 500 Hz to 2000Hz. It should be emphasized that 60 dB NA was the maximum average of the frequencies found(15). All the equipment was calibrated in the period in which the evaluations were performed.

First, the test Speech in Noise was performed. It consists of simultaneous presentation of 25 monosyllables and white noise, in the same ear. The patient is asked to repeat the words heard, ignoring the ipsilateral noise. The signal to noise ratio used was 0 dB, because the sample was composed of elderly patients with peripheral hearing loss(17). This test is intended to evaluate the hearing ability in auditory closure.

Then, we applied the RGDT test in which pure tones paired with short intervals of silence are presented. If the individual does not respond to conventional RGDT whose time intervals are shorter, ranging from 0 to 40 ms, the expanded RGDT whose time intervals vary from 50 to 300 ms is applied to facilitate the intervals identification.

The orientation to the subject in assessment is to answer verbally or to show with fingers if he heard one or two stimuli. The threshold of the interval detection is considered the shortest interval from where the individual, consistently, has identified the occurrence of two stimuli. The reference value for this test comprises the responses ranging between 2 ms and 10 ms(18). The test assesses the temporal resolution which is defined as the ability of the auditory system in detecting rapid changes in sound stimulus or the smallest time interval required to discriminate one acoustic stimulus from the other.

Finally, we carried out the dichotic digits test – binaural integration which consists of a recording with 20 pairs of digits. Four digits in a dichotic way, simultaneously, are presented to the participants, being two in one ear and two in the other. The expected response was the oral repetition of the digits presented(17).

For the computer-based auditory training the software resources - Escuta Ativa®, Duo Training®, Memo Training®and Pedro no Acampamento® were used, as well as the audio CD Escutando com Interferentes®. Four sessions of auditory training as the proposition of the 587 SAS/MS Decree of October 7th, 2004(19) were performed, being one-hour session per week. The auditory training was performed with supra-aural Bose® headphone, connected to the computer. As it is a light accessory, it does not occlude the ear to the point of generating microphony, allowing the realization of training for wearers of mini retroauricular hearing aids.

The activities were planned according to each patient needs detected in the anamnesis, in the basic audiological evaluation, in the results of the questionnaire of restriction of participation (HHIE-S) and in the behavioral tests conducted prior to the adaptation of hearing aids namely the verbal fluency test (measure of executive function); the subtest of word recognition of the Assessment Scale for Cognitive Alzheimer's Disease (ADAS-Cog) which evaluates short-term memory and the Geriatric Depression Scale (GDS). The data of the last three instruments will not appear in the results of this study, given the space limitations of the article, but they were considered in the proposition of the auditory training. The activities used in the four sessions of auditory training were based on the stimulation of the impaired auditory skills of the participants with hearing loss, including the training of cognitive functions of attention, memory, language and executive function.

The skills observed to be impaired in the evaluated elderly, through the dichotic digits test, were stimulated by means of the activities "Bem na Mira" and "Esquerda e Direita" from the Escuta Ativa® software, and the lists of words "Simple Oppositions" and "Pairs in Opposition" from the Duo Training® software, aiming at improving the binaurality. The ability of discrimination in silence and in noise, observed to be impaired in the evaluated elderly through the Speech in Noise test, was stimulated by means of the activity "Which sound did you hear?" from the Escuta Ativa® software and by means of the tracks on the audio CD Escutando com Interferentes®, aiming at improving the auditory discrimination.

The activities from Pedro no Acampamento® and Memo Training® were developed only with those participants who had presented in the assessments indications of impairment in the cognitive functions of attention, memory, language and/or executive function. The mostly used tasks were: "Crossing the River", "Treasure Chest" and "Dining-Hall".

Whenever the verbal fluency test resulted altered, the following activities were proposed: "Reception" which involves planning, "Dining-Hall" which involves mental flexibility and "Tend", which involves planning and mental flexibility. On the other hand, when the word recognition subtest of ADAS-Cog was altered, in association or not with the GDS, the activities called" Crossing the River", "Treasure Chest", "Cavern" or "Dormitory" as well as the Memo Training® software were proposed. It should be noted that, in presence of depression, the participant was referred to a psychology center.

At each session, the level of complexity of the activities gradually increased, respecting the complexity of the tasks in each auditory and /or cognitive ability worked, and considering difficulties and the needs presented by the participants.

The results were statistically analyzed by means of descriptive analysis of all variables. To carry out the comparison between the behavioral tests, taking into consideration the two moments of evaluation in each group, the Wilcoxon test was used for related samples. But in order to perform the comparison between groups, the Mann Whitney test for independent samples was used. The analysis of correlation between the variables was carried out using the Spearman's correlation coefficient. The Statistical Package for Social Sciences (SPSS), version 17.0 was used, and significance level was 5%, i.e., $p<0.05$.

RESULTS

The sample comprised 72 elderly people, being 25 (35.4%) women and 47 (64.6%) men, with minimum age of 60 and maximum of 89 years old, average age of 74 years (±7.8).

The experimental group was composed of 48 (66.7%) elderly patients and the control group of 24 (33.3%). The average age of the experimental group was 74 years and 35 months (±7.8), while the average of the same variable of the control group was 72 years and 4 months (±6.09). This difference was not significant (p=0.205).

In the experimental group, 32 (66.7%) out of the 48 elderly patients were men and 16 (33.3%), women. The control group was composed of 24 elderly, 15 (62.5%) men and 9 (37.5%) women.

The performance of both groups in the behavioral tests in the two moments of evaluation is shown in Table 1.

In relation to the performance of the experimental group in the questionnaire of restriction of participation (HHIE-S), in the initial evaluation, 6 (12.5%) participants had mild to moderate restriction, 40 (83.3%), severe restriction and only 2 (4.2%) participants showed no restriction of participation. After the completion of the auditory training, 5 (10.4%) participants had mild to moderate restrictions, 1 (2.1%) presented severe restriction and 42 (87.5%) participants showed no restriction of participation. As for the control group, the data were available for only 8 participants, for reasons outside the researchers' control. All the 8 participants (100%) presented severe restriction of participation in the pre-evaluation and absence of restriction in the post-evaluation. The performance in the questionnaire is shown in Table 2.

Afterwards, we carried out a comparative analysis of the variables of interest between experimental and control groups, by means of the delta coefficient for each variable, calculated by the formula: X variable (final variable - initial variable) * 100/initial variable. After the creation of the new variable, the comparison between the groups was made using the Mann Whitney test, as shown in Table 3.

In relation to the comparative analysis of the variables between the genders, no significant differences were observed for the variables of interest.

The analyses of correlation were performed between the variables. Figure 1 shows the correlation between the age and the performance in the RGDT test, of the experimental group, when comparing the pre- auditory training (p=0.039) and the post- auditory training (p=0.028) evaluations. It was observed that the performance decreased (increase in the gap interval, in ms), as the age increased. In relation to the control group, observing the data the same result was identified, however, the analysis was not significant, being the pre-training evaluation p=0.50 and the post-training evaluation, p=0.56.

Table 1. Performance in behavioral tests (mean and standard deviation) of experimental and control groups in pre- and post-evaluation

	Pre-evaluation					Post--evaluation				
	SN RE %	SN LE %	RGDT ms	DD RE %	DDLE %	SN RE %	SN LE %	RGDT ms	DD RE %	DDLE %
Experimental Group (n=48)	28.00 (±16.1)	27.66 (±17.1)	78.47 (±34.5)	45.88 (±14.5)	50.78 (±14.4)	48.58 (±17.9)	48.41 (±18.2)	49.66 (±24.7)	65.62 (±15.2)	68.90 (±14.5)
Control Group (n=24)	28.83 (±16.2)	30.00 (±17.2)	53.15 (±42.4)	47.91 (±22.4)	61.66 (±22.8)	35.50 (±19.8)	37.16 (±20.5)	49.19 (±43.7)	54.27 (±23.0)	65.64 (±19.3)
	Control Group					**Experimental Group**				
p value	**0.002***	**0.021***	**0.005***	**0.004***	**0.060***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***

*Wilcoxon Test for related samples

Subtitle: SN = Speech in Noise; RGDT = Random Gap Detection Test; DD = Digits Dichotic; RE = right ear; LE = left ear; ms = milliseconds

Table 2. Performance in the questionnaire of restriction of participation (mean and standard deviation) of the experimental and control groups in pre- and post- evaluation

	Pre-evaluation	Post-evaluation
	HHIE-S	HHIE-S
Experimental Group (n=48)	63.54 (±21.8)	10.41 (±8.2)
Control Group (n=8)	76.87 (±7.9)	11.87 (±3.7)
	Experimental Group	**Control Group**
p value	**0.000***	**0.011***

*Wilcoxon Test for related samples

Subtitle: HHIE-S = Hearing Handicap Inventory for the Elderly-Screening

Figure 2 shows the correlation between the performance in the Speech in Noise test for the right ear and the performance in the dichotic digits test for the right ear, of the experimental group, when comparing the pre-auditory training (p=0.005) and post-auditory training (p=0.001) evaluations. There is a directly proportional correlation between variables, which was not observed in the results obtained in the left ear.

The analysis of correlation between the performance in the questionnaire of restriction of participation (HHIE-S) and the performance in the behavioral tests did not present significant relations.

Table 3. Performance in the behavioral tests and in the questionnaire of restriction of participation (median) of the experimental and control groups

Delta	Experimental Group					HHIE-S
	SN RE	SN LE	RGDT	DD RE	DD LE	
Esxperimental Group (Median)	83.3%	79.1%	-30.7m	34.0%	38.6%	-83.3%
Control Group (Median)	16.6%	9.0%	-9.0m	15.0%	6.1%	-82.8%
p value	**0.000***	**0.000***	**0.000***	**0.002***	**0.000***	0.991

*Mann Whitney Test for independent samples

Subtitle: SN = Speech in Noise; RGDT = Random Gap Detection Test; HHIE-S = Hearing Handicap Inventory for the Elderly-Screening; DD = Digits Dichotic; RE = right ear; LE = left ear; m = milliseconds

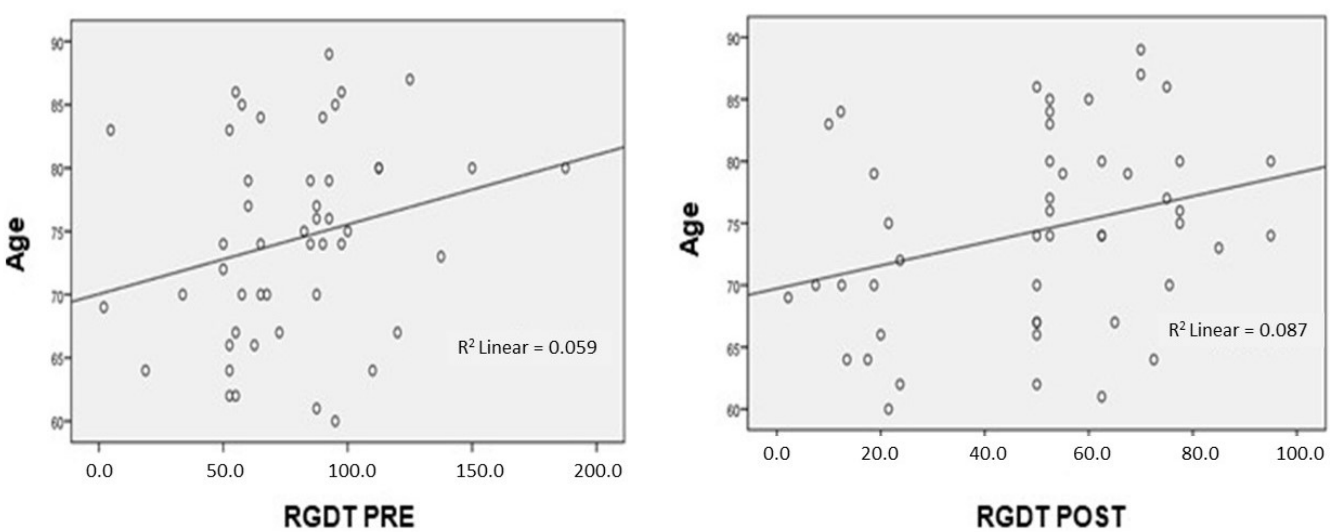

Figure 1. Correlation between the age and the performance in the Random Gap Detection Test, of the experimental group when comparing evaluation pre- and post-auditory training. Spearman correlation coefficient
Subtitle: RGDT = Random Gap Detection Test

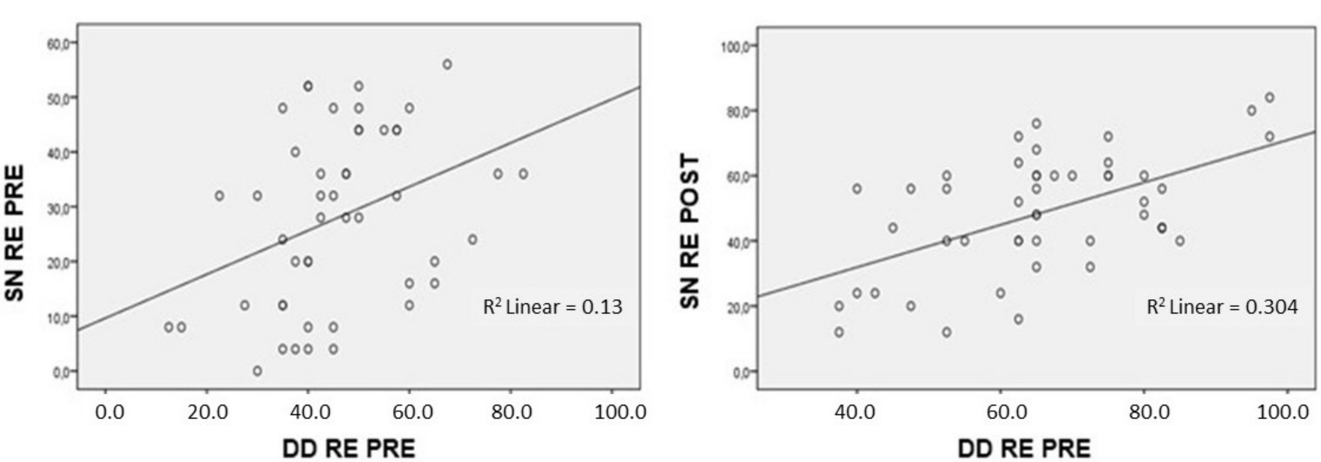

Figure 2. Correlation between the performance in the speech in noise test to right ear and the digits dichotic test to right ear of the experimental group when comparing evaluation pre-and post-auditory training. Spearman correlation coefficient
Subtitle: SN = Speech in Noise; DD = Digits Dichotic; RE = right ear

DISCUSSION

The research was composed of 72 elderly divided in an experimental group and in a control group, being 25 women and 47 men, with average age of 74 years, similar to other two studies conducted with the same sampling, whose elderly participants were subject to a program of auditory rehabilitation, in which the sample was composed of 17 individuals, being six women and 11 men aged between 60 and 84[9,20].

The sample consisted of a larger number of men, but in other studies that included auditory training, women were in a larger number[21,22]. This fact may be related to the great demand from women for finding early speech-auditory diagnosis and to the fact that they seek for health care more often than men, as verified in another study which found lower participation of men in primary healthcare services and in which it was observed that the preventive practices, for various reasons, no matter they were structural and/or cultural, they were not part of the daily routine of the male population[23]. In contrast, a research reported a higher incidence of hearing loss in male subjects because they possibly already presented a decline of auditory acuity with the advance of age, as an independent risk factor for hearing loss. In addition, they were more exposed than women to environmental factors and causes, such as exposure to occupational noise and ingestion of alcoholic drinks[2]. These factors could justify the greater demand from men for the care provided by the auditory health center, once the sample of the present study was not matched.

The experimental group was composed of 48 elderly patients and the control group of 24, as this group was made by the participants who did not want to perform the auditory training due to difficulties in relation to the displacement.

Concerning the results of the second evaluation of auditory processing, there was significant relationship for both groups regarding the use of hearing aid for the control group and the use of the hearing aid, associated to hearing/speech therapy, for the experimental group. The same result was found in a study that evaluated the effects of auditory rehabilitation through the analysis of the quantitative and qualitative aspects of the Alternate disylables dichotic test (SSW) in elderly new users of hearing aids[20]. In another study, the performance of elderly people in behavioral tests was evaluated at the delivery of the hearing aid, after a month of use of the device, and after the auditory training. It was observed that all participants increased their scores in the behavioral tests, gradually reaching better performance after the auditory training in the second moment of evaluation, suggesting that both the process of adaptation to the hearing aid and the auditory training produced an improvement in the impaired auditory abilities[21].

As regards the performance in the HHIE-S, results showed statistically significant differences, not only in the experimental group, but also in the control group (eight participants), qualitatively superior to the processing tests, which indicates that the use of the HA contributed to a better hearing, reducing considerably the restriction of participation. A research applied the same questionnaire to 29 elderly, before the use of the hearing aid and after one year of use, resulting in a significant reduction in the restriction of participation after the use of hearing aid, in the group studied[24]. Another study, also similar, demonstrated that the elderly showed reduction in the self-perception of the restrictions of participation after the use of the hearing aid, attributing this improvement to the adaptation and the use of hearing aids[25].

In the comparative analysis of the variables of interest carried out by means of the delta coefficient, it was examined how much each group improved, taking into consideration the median which, in a way, did not include those participants who had not improved and those whose improvement had been well above average. From this coefficient, we applied the Mann Whitney test by means of which it was found that the experimental group presented improvement superior to the control group, in the second moment of the evaluation, being observed statistically significant differences for all behavioral tests, except for the questionnaire of restriction of participation. This result was also found in a study conducted with the objective of verifying the effects of the auditory training, in which only the experimental group of individuals with cognitive impairment obtained statistically significant results for the behavioral tests, in the second moment of assessment[22]. In another study, also conducted with elderly patients, it was observed the effect of the hearing rehabilitation in the ability of temporal ordering, and it was also verified that the performance of the experimental group presented evolution, when considered the results obtained before and after the auditory training,but the same result was not observed in the control group[9].

It was observed that the performance obtained in the RGDT and in the digits dichotic tests (reduction and increase, respectively, around 30% to 38%), in the second moment of evaluation, did not improve like the performance obtained in the Speech in Noise test (an increase of around 80% for both ears), as it is demonstrated in Table 3. This fact may be related to the cognition that is characterized by slowness in the elderly, suggesting some deficit in the transmission of the temporal processing, and also related to the reduction in the efficiency of the corpus callosum. The same observation was found in relation to the performance in these tests, when analyzing the results obtained in another study[21].

As proposed by the 587 SAS/MS Decree (19), four sessions of hearing speech therapy are offered to the adult population with hearing disabilities. A study of systematic review concluded that the rehabilitation process should be comprised of at least eight sessions held weekly, lasting from 45 minutes to an hour[26].

The above mentioned study found that an effective program of auditory training could involve binaural interaction tasks, auditory closure and speech discrimination, temporal resolution, temporal ordering and dichotic stimuli associated to the cognitive functions of attention, language, memory and executive functions. The present research included a computerized auditory training, consisting of a set of acoustic conditions and/or tasks to activate the auditory system and related systems, in such a way that the associated auditory behavior and its neural basis were changed in a positive way. The program included activities for stimulating all the skills cited by the study, carried out by means of software that, according to the studied literature, offer important gains in auditory perception after the training and, in addition, attract and keep the attention of users, providing cognitive conditions that foster the learning[27]. Furthermore, the program focused first and foremost on the functions in which the participants presented greater difficulty, which reinforces the understanding that the results could have been better if there were a greater number of sessions.

The computerized auditory training was carried out by means of software and computers outside the acoustic booth.

The literature has highlighted that the neurocognitive auditory training can be complementary to the formal auditory training, resulting in intensive and extensive practice, which includes the training of cognitive functions, maximizing the generalization and the effectiveness of the treatment[28].

Also through the analysis performed with the delta coefficient, it was observed that both groups showed improvement in the restriction of participation, without statistically significant differences observed, suggesting that the improvement of the results obtained through the questionnaire, in this research, is more associated with the use of hearing aid than with the hearing/speech therapy itself. This finding confirms the results of another study in which the restriction of participation, investigated by means of the HHIE-S, was reduced only with the effective use of the HA[29].

In relation to the comparative analysis of the variables between the genders, no significant differences were observed for the variables of interest, agreeing with other studies found in the researched literature[20,21].

By relating the age and the performance in the RGDT test of the experimental group, pre-auditory training and post-auditory training, it was observed that as the age increased, the performance decreased. The same fact was observed in the control group (it was noticed that older participants showed greater time intervals), however, the correlation analysis was not significant, perhaps due to the smaller number of participants. The objective of this analysis was to pay close attention to the aging process which causes the decline in central auditory function. Thus, there are several behavioral phenomena involved in this function, among them the temporal resolution and the temporal ordering. One study showed that the aging process causes deterioration in the temporal processing which may be associated to the decrease in the processing speed in the primary auditory cortex[29]. A study that evaluated the auditory perception temporal in centenarians showed results that confirmed the reduction of temporal resolution related to age and attested that the greater the age, the greater the impairment, which can be explained by the deceleration of the information processing, commonly postulated as the oldest and the most distinguishing symptom of cognitive aging[30].

Regarding the analysis of the correlation between the performance in the Speech in Noise test and the performance in the dichotic digits test, both for the right ear, in the pre- and in the post-auditory training of the experimental group, we observed a directly proportional correlation. The dichotic digits test was performed only in the binaural integration stage which evaluates the ability to process the auditory message presented in both ears, and requires the integrity of the corpus callosum, providing the intra-hemispheric and inter-hemispheric integration. The Speech in Noise test evaluates the ability of auditory closure and requires the integrity of the whole brainstem. Although both tests do not measure the same skill, they are relevant to discrimination.

As to the analysis of correlation between the HHIE-S questionnaire and the auditory processing tests, no significant relationships were observed because they are distinct measures. The HHIE-S is a subjective measure[23], as well as the auditory processing tests, but the latter evaluate the functioning of the auditory pathways of the central nervous system and/or the functioning of the integrative areas, measured by the evaluator by means of the application of tests. It is worth noting that, although they do not measure the same construct, they can be complementary measures in the rehabilitation process.

Finally, the improvement of the distinct auditory abilities provided by the neurocognitive auditory training is probably more related to the capability of the central auditory nervous system to changing in view of environmental stimulation, and this capability can be defined as neural plasticity. In this way, it is possible to affirm that the computer-based auditory training, used in the present study, led to beneficial changes in the elderly's central nervous system, mainly among the experimental group. These beneficial changes could be confirmed by an improvement in the performance of the subjects in the dichotic digits, the RGDT and the Speech in Noise tests.

Therefore, further researches need to be carried out with similar number of individuals in the experimental and in the control groups, including a placebo group, and a larger number of sessions for auditory abilities training, in a formal and/or informal modality in this way, it will be possible to promote a higher gain in the communication quality of these individuals and add important information about the influence of these skills in the speech perception, considering that the improvement of the hearing condition will bring greater benefits for the elderly and for society.

It is also worth noting the importance of integrating cognitive and electrophysiological evaluations in similar studies in order to confirm the results and to spread such knowledge to health services.

CONCLUSION

The computer-based neurocognitive auditory training program proved to be effective, indicating an improvement in the impaired auditory abilities, which was observed through the behavioral tests, with only four sessions. The questionnaire of restriction of participation did not reflect the effects of the auditory training.

It is important to highlight the relevance and impact of this work for the services of hearing health, reinforcing the use of cognitive measures associated to the auditory processing in these services. However, considering that funds come from the Health Care System, planning a more reduced protocol becomes imperative.

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