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ARTICLES

Respiratory muscular strength in children with hearing impairment and their relationship with hearing and language categories

Força muscular respiratória em crianças com deficiência auditiva e a sua relação com categorias de audição e linguagem

Fuerza muscular respiratoria en niños con discapacidad auditiva y su relación com las categorías de audiencia y lengua

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Abstract

Introduction: hearing impaired children have greater difficulty in controlling voice, breathing and articulation; this is characterized by lower syllable production per respiratory cycle and greater phonatory effort. **Objective:** to analyze respiratory muscle strength data and its relationship with hearing and language skills in children with hearing impairment. **Methods:** fifty hearing impaired children were availed, from both genders, with ages between 7 and 12 years, hearing aid users. Maximum respiratory pressures were measured using the manuvacuometer equipment and analyzed by the predicted values for PImáx and PEmáx, hearing and language categories, sentences classified according to hearing and language categories, sentences perception in open set, from the application of the instruments: GASP; ABFW vocabulary; Word Association for Syllable Perception (WASP); Sentences Perception Threshold. **Results:** most of the children have hearing loss classified by the best ear as moderate (42%); however,

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Authors' contributions:
RJF, GMS - data collection, results interpretation and article writing.
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the same subjects showed results with small difference between the PImax results (n= 11 subjects – 26%) above predicted and 10 subjects (24%) bellow. The availed children with oral communication present 2% of difference between PImax and PEmax results. **Conclusion:** It can be said that children with hearing impairment have respiratory muscle weakness regardless of the degree of hearing loss, type of communication and classification in the hearing and language categories.

Keywords: Hearing Loss; Respiratory Function Tests; Hearing; Language

Resumo

Introdução: crianças com deficiência auditiva possuem uma dificuldade maior no controle de voz, respiração e articulação, que se caracteriza por uma menor produção de sílabas por ciclo respiratório e maior esforço fonatório. **Objetivo:** analisar os dados da força muscular respiratória e a sua relação com as habilidades de audição e linguagem em crianças com deficiência auditiva. **Métodos:** participaram do estudo 50 crianças com deficiência auditiva, de ambos os sexos, com idades entre 7 e 12 anos usuárias de aparelho de amplificação sonora individual. As pressões respiratórias máximas foram mensuradas por meio do equipamento manovacuômetro e analisadas pelos valores dos preditos para PImáx e PEmáx, a audição e linguagem das crianças foram classificadas de acordo as categorias de audição e linguagem, a partir da aplicação dos instrumentos: GASP; ABFW-vocabulário; Word Association for Syllable Perception; Limiar de Reconhecimento de Sentenças. **Resultados:** constatou-se que crianças com deficiência auditiva apresentam fraqueza muscular respiratória em relação a crianças ouvintes, de acordo com valores preditos, independentemente do tipo de perda auditiva. Grande parte das crianças tem perda auditiva classificada pela melhor orelha como grau moderado (42%); entretanto, essas mesmas crianças apresentaram resultados com pequena diferença em porcentagem entre os resultados de pressão inspiratória máxima (n=11, 26%) acima do predito e 10 crianças (24%) abaixo do predito. As crianças avaliadas que possuem comunicação oral estão a 2% de diferença nos resultados entre PImáx e PEmáx. **Conclusão:** Pode-se afirmar que as crianças com deficiência auditiva apresentam fraqueza muscular respiratória independentemente do grau de perda auditiva, tipo de comunicação e classificação nas categorias de audição e de linguagem.

Palavras chave: Deficiência Auditiva; Testes de Função Respiratória; Audição; Linguagem.

Resumen

Introducción: los niños con discapacidad auditiva tienen mayor dificultad para controlar la voz, la respiración y la articulación, que se caracteriza por una menor producción de sílabas por ciclo respiratorio y un mayor esfuerzo fonatorio **Objetivo:** analizar los datos de fuerza muscular respiratoria y su relación con las habilidades de audición y lenguaje en niños con discapacidad auditiva. **Métodos:** 50 niños con pérdida auditiva, de ambos sexos, con edades comprendidas entre 7 y 12 años, con un audífono individual, participaron en el estudio. Las presiones respiratorias máximas se midieron usando el equipo de manovacuómetro y se analizaron mediante los valores predichos para MIP y MEP, la audición y el lenguaje de los niños se clasificaron según las categorías de audición y lenguaje; de la aplicación de los instrumentos: GASP; Vocabulario ABFW; Asociación de palabras para la percepción silábica; Umbral de reconocimiento de oraciones. **Resultados:** se encontró que los niños con discapacidad auditiva tienen debilidad muscular respiratoria en relación con los niños con audición, independientemente del tipo de pérdida auditiva, de acuerdo con los valores pronosticados. La mayoría de los niños tienen pérdida auditiva clasificada por el mejor oído como moderada (42%); sin embargo, estos mismos niños mostraron resultados con una pequeña diferencia porcentual entre los resultados de la presión inspiratoria máxima (n = 11, 26%) por encima de lo previsto y 10 niños (24%) por debajo de lo previsto. Los niños evaluados que tienen comunicación oral tienen una diferencia del 2% en los resultados de MIP y MEP. **Conclusión:** Se puede decir que los niños con discapacidad auditiva tienen debilidad muscular respiratoria, independientemente del grado de pérdida auditiva, tipo de comunicación y clasificación en las categorías de audición y lenguaje.

Palabras clave: Deficiencia auditiva; Pruebas de función respiratoria; Audiencia Idioma

Introduction

Speech production and perception can be described as related processes, since the experience with the perception determines the characteristics of the production and, in turn, the possibility of experience and living with the speech production can modify the perception. The difference in the development of children with hearing impairment lies in the number and quality of opportunities that children have to experience situations of production and perception, which leads to changes in auditory feedback and consequently determines peculiarities in their speech[1].

There is great variation in the effect of hearing loss on the development of oral language and speech skills. The more severe the hearing loss and the earlier the diagnosis and intervention, the greater the effects on communication[2].

At the same time, the acquisition of language and vocabulary, in particular, is extremely complex, subject to influences and interferences from the environment, from the established social relationships and from the particular characteristics of each individual. The greater the degree of the hearing loss, the lower the receptive vocabulary, phonological awareness and auditory discrimination, and also the greater the incidence of articulation difficulties, changes and omissions[3].

The use of personal sound amplification products and cochlear implant may increase the amount of acoustic information that the child is able to receive. However, the use of audible acoustic signal through the amplification systems varies in each person, which must be, among other things, related to the perceptual possibilities that characterize their dynamic field.

It is important to assess the speech perception ability to understand how much the hearing impaired child can extract from the acoustic information of the signal that reaches their dynamic hearing field, since the better use of acoustic information increases the chances of developing oral language. Phonemes, syllables, words or sentences can be used to assess speech perception ability[4].

Children with severe or profound hearing loss who use personal sound amplification products may experience greater difficulty in establishing auditory feedback, as they are unable to match the sounds that they produce in a situation with the sounds that they will later produce, or with sounds produced by others. These children also have a greater difficulty in controlling voice, breathing and articulation, which is characterized by a lower production of syllables per respiratory cycle and greater phonatory effort[5,6].

In turn, this phonatory effort may result from insufficient air flow and subglottal pressure, which disturbs the aerodynamics of vibration, requiring greater muscle effort and/or increasing vocal strain to complete phonation. Thus, the speech of hearing impaired people may have changes and, thus, be more fatigued. There is a waste of effort/energy, which results in a poorer speech intelligibility for some subjects. In addition to a strong tendency to deviations from the normal voice pattern, such as: harshness, lack of rhythm, high pitch, decreased power and sudden vocal attack[7].

Respiratory muscles are divided into inspiratory and expiratory. The force generated by the inspiratory muscles is defined as the maximal inspiratory pressure (MIP), while the force generated by the expiratory muscles is defined as the maximal expiratory pressure (MEP). These variables are measured using a manovacuometer[8,9].

Clinically, the measurement of MIP indicates the respiratory capacity, the development of respiratory failure and determinant of tidal volume. On the other hand, MEP measurement is important to assess the weakness of expiratory muscles, which is directly related to the effectiveness of cough, especially in patients with neuromuscular diseases[10,11]. When measuring the maximal inspiratory and expiratory pressure, it was necessary to compare the values obtained with the reference values predicted for age, gender, weight and height, in order to verify the potential presence of respiratory muscle weakness[12-14].

Given the above, there is great relevance in the analysis of respiratory muscle strength and its relationship with speech, as it can provide relevant information regarding communication and thus, lead to a more effective therapeutic process.

Therefore, this study aimed to analyze and show data on respiratory muscle strength with hearing and language skills in order to improve clinical therapeutic techniques in children with hearing impairment.

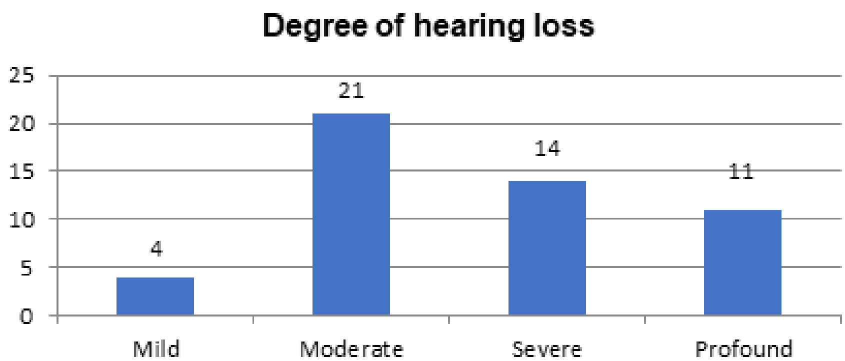
Methods

This is a cross-sectional study that included 50 children without respiratory diseases, with hearing loss, of both genders, aged between 7 and 12 years old with an average of 39.7 kg, non-obese, being 21 girls and 29 boys, who attended a hearing health institution and a school for the deaf. All children had congenital hearing loss (from x to y degrees) and had been PSAPs users since the audiological diagnosis performed in this institution.

This study was approved by the Research Ethics Committee of the institution (under the protocol no. 1.532.676/2016). All participating children and their guardians were informed on the study objectives and methods. Data were collected after the participant's authorization by signing the informed consent form (ICF) by the guardians and the children were informed and invited to participate.

Audiological data were extracted from the medical records of children who underwent audiological monitoring at the institution and participated in the study.

Figure 1 shows the distribution of the degree of hearing loss, considering the characteristic of the best ear for subjects with bilateral hearing loss (n=46) and the degree of hearing loss for subjects with unilateral loss (n=4).



Legend: N = number of subjects.

Figure 1. Distribution of the degree of hearing loss in the best ear of subjects with hearing loss (n=50)

The protocol according to clinical developmental markers was used to collect data on hearing and language skills: attribution of language and hearing categories[15,16] by understanding sentences in an open set (GASP), word list (WASP) and ABFW part B.

Live voice training and the adequate guidance were provided before starting the speech perception task to ensure the proper functioning of the PSAP. Two lists were presented with 24 words applied in the same order to all children, always starting with the list of trisyllabic words to facilitate the understanding of the task and, in sequence, the understanding of ten sentences in an open set (GASP). The repetitions were recorded, transcribed and analyzed according to the criteria established by Koch (1999) in the WASP protocol; the words were analyzed according to the correct phonemes (vowels and consonants), in addition to the analysis by percentage of correct words. As the analysis was carried out by the researchers without the aid of acoustic analysis equipment or a greater number of repetitions by the subjects, small changes were disregarded due to the intelligibility of the word produced.

In turn, the children's language test in the vocabulary (ABFW) consisted of the individual presentation of 118 colored figures on a white background, distributed in nine conceptual fields: clothing, animals, food, means of transport, furniture and utensils, professions, places, shapes and colors, toys and musical instruments, which should be named by the participants. The answers were transcribed to the response sheet and then analyzed and classified according to the criteria. The test proposes a calculation of the percentage of correct answers for each of the conceptual fields: Usual word designation (UWD): in cases where the child used the correct word; No Designation (ND): in cases where the child was not able to find a word; Substitution process (SP): in cases where the child used any replacement process. This study included only the responses for Usual Word Designation (USW). In order to obtain a quantitative analysis of the test by means of a raw and unique score and not by semantic categories, this study proposed a percentage deviation from the performance achieved by the subjects subtracted by the expected (for the age group of 6-years, since all subjects were 6 years old or older) in each semantic category. Then, an average was calculated for all categories to obtain a single test score for each subject. Thus, if the subject achieved a performance as expected (for the age group of 6-years) the results will be close to 100%, if the results are above the expected, they will be greater than 100% and if the results are above the expected, they will be lower than 100%. Thus, a general score was obtained considering the weight given to each semantic category, as the test proposes. This variable was called categorized ABFW.

Hearing and language skills of the subjects were assessed by combining the following aspects: clinical observation of the subjects; analysis of data from medical records (which included information on performance and evaluations performed during the follow-up visit of the child); application of speech perception tests (GASP, WASP and sentence recognition); assessment of the oral communication behavior of the child in an interaction situation. Then, the skills were classified as follows.

The assignment of Hearing Categories was made as proposed by Geers[15], “What category of hearing does the child fall into?”, among seven categories.

The proposal by Moret[16] was used with respect to the language category of the child, and the researcher determined which of the five categories the child’s language development stage fit best.

The maximal respiratory assessments were performed using an analog manovacuometer and a nasal clip, with the child seated to provide more reliability to the result. The MIP was measured from the residual volume after a forced maximal expiration, while the MEP was measured from the total lung capacity, that is, after a maximal inspiration[11].

Three measurements were made and the best one was chosen for further analysis. A one-minute rest interval was given between measurements. In addition, the participant made a sustained maximal effort of one to three seconds, thus validating the measurement value.

Then, the body mass index (BMI) of the participants was calculated using an anthropometric mechanical scale, certified by Inmetro, with a maximum of 150 kg and a minimum of 2 kg to calculate weight and height.

A descriptive analysis of the data was performed and the paired t-test was applied to compare the means of the variables, while the One-Way ANOVA was applied for the analysis of variance between the groups. A significance level of 0.05 was adopted, and the study considered as statistically significant differences those whose value of the descriptive level (*p*) was less than 0.05.

Heinzmann et al.[17] validated and defined the predicted values of maximal respiratory pressures for the Brazilian population. The following formulas were used to calculate the predicted values:

MIP (cmH_2O):

Boys = 17.879 – [0.674 X Height (cm)] – [0.604 X Weight (Kg)]

R^2 = 0.586/Standard error of estimate = 13.211.

Girls = 14.226 – [0.551 X Height (cm)] - [0.638 X Weight (Kg)]

R^2 = 0.589/Standard error of estimate = 14.579.

MEP (cmH_2O):

Boys = 47.417 + [0.898 X Weight (Kg)] + [3.166 X Age (Years)]

R^2 = 0.465/Standard error of estimate = 18.670.

Girls = 30.045 + [0.749 X Weight (Kg)] +[4.213 X Age (Years)]

R^2 = 0.515/Standard error of estimate = 19.200.

The measured values of maximal respiratory pressures in hearing impaired children of both genders were compared with the values predicted by the equations described[17], adding the data of hearing categories[15] and language[16].

Results

The study included 50 children of both genders aged between 7 and 12 years old and with an average age of 9.9 years old. 29 boys (58%) and 21 girls (42%) were evaluated, 31 of whom were students from regular schools, while 18 children attended special schools and 1 child attended both schools.

All subjects used personal sound amplification products, which were adjusted in the hearing health service and had congenital sensorineural hearing loss. However, this study did not consider the characteristics of the sound amplification.

Parents or guardians answered questions about the main mode of communication in order to provide information regarding the communication of children. With regard to the total sample, 29 children used oral communication, 12 children used BSL (Brazilian Sign Language) and 9 children used BSL and oral communication.

Table 1 shows the average of the measured and predicted values of MIP and MEP, and the relationship of the measured values of MIP and MEP with the level of hearing loss and the type of communication.

Table 1. Relationship between the measured values of MIP and MEP with predicted values, level of hearing loss and type of communication**

		MIP	P	MEP	P
Predicted*		-90.1±31.2	*0.00	55.9 ±15.3	*0.00
		-94.0 ±14.5		107.2±15.1	
Hearing loss	Mild	-92.5±34.0		59.2±12.2	
	Moderate	-88.9±32.5	*0.81	54.4±13.8	*0.21
	Severe	-96.0±27.9		50.6±11.3	
	Profound	-84.7±34.4		62.2±19.8	
Communication	BSL	-85.8±31.6	*0.40	52.7±17.1	*0.21
	Oral	-93.3±31.0		58.2±13.7	

Legend: MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure.
**Paired t-test and One-Way ANOVA
*p<0.05

There was a statistically significant difference, both for MIP and MEP (*p<0.00*) when comparing the averages of the measured values with the averages of the predicted values of hearing children for maximal respiratory pressures in children with hearing impairment.

On the other hand, no statistically significant differences were observed (p=0.81 for MIP and p=0.21 for MEP) when comparing the mean values of the maximal respiratory pressures between groups with different levels of hearing loss.

Table 2 shows the data in relation to the hearing and language categories.

Table 2. Distribution of the classification of hearing and language categories of children with hearing loss (n=50)

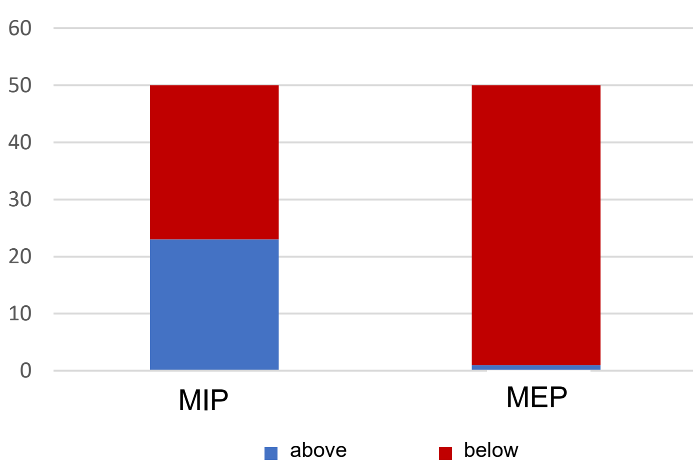
	1 and 2	3 and 4	5 and 6
Hearing category	32%	8%	60%
	1 and 2	3 and 4	5 and 6
Language category	32%	12%	56%
	Above expected	Below expected	As expected
Expressive language	14	15	1

Legend: N = number of subjects.

60% of the children in the study are considered to have a good use of hearing, that is, they are classified in categories 5 and 6 (identification of words through consonant recognition and recognition of words in an open set). Regarding the language categories, 56% of the participating children are considered fluent in oral language (category 5 - build sentences of more than 5 words, using connective elements, conjugating verbs, using plurals, etc.). The ABFW Expressive Vocabulary test was not applied to the 20 children who communicate using BSL, as the test requires oral production. It was possible to notice that as the age increases, the performance in the vocabulary test improves. However, it should be noted that the age group of 6-years was taken into account for the result of this test, since all children were over 6 years old.

According to the maximal respiratory pressure measurements performed, 54% of the children had results below the expected for MIP. In turn, 98% of the children had measurements below the predicted for MEP.

Chart 1. Distribution of airflow measurements for maximal IP and maximal EP (n=50).



Legend: MIP = maximal inspiratory pressure. MEP = maximal expiratory pressure.

Discussion

According to the literature, children with hearing loss of any type and degree may have changes in their language development and speech production. In line with the findings of this study, children with severe and profound hearing loss tend to have greater difficulty in language development, both with regard to the reception of sounds and the ability to monitor their own speech, which is known as acoustic-articulatory feedback. This difficulty in breathing coordination for speech production is characterized by a lower production of syllables per respiratory cycle[5].

Children who had a better performance in the hearing and language categories are those who use oral communication (n=29; 58%), who attend regular school, except for a child who attends special school, but has moderate hearing loss. Among these, 15 (52%) had values above the predicted for MIP and 14 (48%) had values below the predicted. Only one child was above the predicted for MEP.

Children who communicate only through BSL (n=12; 24%) are all from school for the deaf and had a worse performance in the classification of the categories of hearing and language. These children were excluded from speech perception tests, as it was necessary to have oral communication to conduct these tests. Regarding maximal respiratory pressures, five of these children were above the predicted for MIP and 7 children were below the predicted, while all children were below the predicted for MEP.

Among children who have bilingual communication, that is, oral and BSL (n=9; 18%), three children were above (33%) and six (67%) were below the predicted for MIP. However, all children were also below the predicted for MEP.

Hearing impaired people may have difficulty in breathing coordination for speech production[5]. In this study, 98% of the children evaluated were below the predicted level of maximal expiratory pressure when compared to hearing children. This can be explained by the incoordination of movements between the respiratory muscles and the adjustment of the glottis, resulting in a great waste of air[2]. On the other hand, 46% of the children had results within the normal range according to the predicted maximal inspiratory pressure. There is a hypothesis, which has not been proven, that the more the child uses speech, the better would be the use of airflow, due to the greater use of the abdominal muscles; however, the evaluated children who have oral communication had a 2% difference from the predicted in the results between MIP and MEP.

The phonatory effort may result from insufficient air flow and subglottal pressure, which disturbs the aerodynamics of vibration, requiring greater muscle effort and/or increasing vocal strain to complete phonation. Thus, the speech of hearing impaired people may have changes, distortion and, thus, be more fatigued. There is a waste of effort/energy, which results in a poorer speech intelligibility[7]. This may explain the findings of the study regarding airflow; however, the language data does not match the breathing data.

According to the literature, air flow measurements, among others, indicate the relationship between respiratory and phonatory processes and can be used to differentiate normal and disturbed vocal function[18]. Accordingly, relating airflow data to fluency data in language and hearing could help us to better understand the findings.

Similarly to other studies, three inspirations and expirations were measured as methodology, using the best result measured for data analysis. Researchers found no statistically significant difference in a comparative study of four different ways of measuring the maximum phonation time, and reported that the subject's position, the presence of stimulus and the final calculation of the measurement were similar, with a difference only between genders and weight, as part of the formula to calculate the predicted value[17]. The measures of this study corroborate the findings of Mendes et al.[19], who found no relationship with data on the type of communication or hearing loss.

Most children have a hearing loss classified according to the best ear as moderate (42%); however, the same children had results with little difference in percentage between the results of MIP (n=11, 26%) above the predicted and 10 children (24%) below the predicted. There is great variation in the effect of hearing loss on the development of oral language and speech skills. The more severe the hearing loss and the earlier the onset, the greater the effects on communication[20]. For this reason, the analysis included language data.

The ABFW Child Language Test allowed to notice that only in one conceptual field ("clothing") in the usual word designation (UWD), 50% of the children responded within the expected for their age, while the other children were classified as below the expected for age (30%) and above expected for age (20%). The conceptual field named as "local" was the only one that had higher results in the classification below (57%) than above (43%) the expected. The rest of the sample had a test result above the expected for their age, since the age group of 6 years was taken into account for the result of this test and all children were over 6 years old, as described in the study method.

The findings suggest that vocal and breathing aspects should also be considered in the therapeutic planning of hearing impaired children aiming at a better quality of oral communication. In turn, children who use BSL may have other priorities in their planning, instead of specific oral work.

Conclusion

The study found that hearing impaired children have respiratory muscle weakness regardless of the degree of hearing loss, type of communication and classification in the hearing and language categories.

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