Original Article

Artigo Original

Percentage of Consonants Correct (PCC) in children with and without hearing impairment

Porcentagem de Consoantes Corretas (PCC) em crianças com e sem deficiência auditiva

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Keywords

Severity of illness index
Hearing loss
Auditory perception
Language development
Cochlear implants/adverse effects
Articulation disorder

ABSTRACT

Purpose: To compare the Percentage of Consonants Correct (PCC) index of children with and without hearing loss, and to verify whether the time using hearing aids, the time in therapy, and the time spent until hearing loss was diagnosed influence the performance of deaf children. **Methods:** Participants were 30 children, 15 with hearing impairment and 15 with normal hearing, paired by gender and age. The PCC index was calculated in three different tasks: picture naming, imitation and spontaneous speech. The phonology tasks of the ABFW – *Teste de Linguagem Infantil* were used in the evaluation. **Results:** Differences were found between groups in all tasks, and normally hearing children had better results. PCC indexes presented by children with hearing loss characterized a moderately severe phonological disorder. Children enrolled in therapy for a longer period had better PCC indexes, and the longer they had been using hearing aids, the better their performances on the imitation task. **Conclusion:** Children with hearing loss have lower PCC indexes when compared to normally hearing children. The average performance and imitation are influenced by time in therapy and time using hearing aids.

Descritores

Índice de gravidade de doença
Perda auditiva
Percepção auditiva
Desenvolvimento da linguagem
Implantes cocleares/efeitos adversos
Transtornos da articulação

RESUMO

Objetivo: Comparar o índice de Porcentagem de Consoantes Corretas (PCC) de crianças com e sem deficiência auditiva e verificar a influência do tempo de uso de prótese auditiva, tempo de terapia e tempo para identificação da deficiência auditiva no desempenho das crianças deficientes auditivas. **Métodos:** Foram avaliadas 30 crianças, sendo 15 deficientes auditivas e 15 audiologicamente normais, pareadas por gênero e idade. O índice de PCC foi calculado por meio de três provas: nomeação, imitação e fala espontânea. Foram utilizadas as tarefas da prova de fonologia do ABFW – Teste de Linguagem Infantil. **Resultados:** Em todas as tarefas realizadas, houve diferença entre os grupos, favorecendo o desempenho das crianças sem deficiência auditiva. Os índices de PCC apresentados pelas crianças com deficiência auditiva representaram um distúrbio fonológico de grau moderadamente grave. Quanto maior o tempo de terapia, melhores foram os índices de PCC e quanto maior o tempo de uso das próteses auditivas, melhor foi o desempenho na prova de imitação. **Conclusão:** Crianças com deficiência auditiva apresentam índices de PCC inferiores aos de crianças sem a deficiência. O desempenho médio e a imitação são influenciados pelo tempo de terapia e tempo de uso de prótese auditiva.

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INTRODUCTION

Among speech and language abnormalities, there is a considerable occurrence of phonological disorder in the child population. Thus, there is concern regarding speech and language use in children, which is often difficult to understand. A phonological disorder should be identified in childhood, as individuals who exhibit such conditions often have abnormal phonological sensitivity. Moreover, such children go on to have difficulties with reading and writing due to inadequate phonological awareness[1].

Phonological disorder is defined as a speech abnormality characterized by the inadequate production of sounds and inappropriate use of the phonological rules of the language with regard to the distribution of sounds and types of syllables, resulting in the breakdown of phonemic contrasts and affecting the meaning of the message. The cause of this disorder is unknown and there are different degrees of severity and unintelligibility of speech[2].

Hearing impairment in childhood can lead to delays in speech and language acquisition, as hearing impairment affects two fundamental processes: the reception of sounds and the ability to monitor one's own speech (acoustic-articulatory feedback). Speech and language abnormalities are generally greater in cases of severe hearing loss[3].

Being deprived of the recognition of the sounds of language since birth due to hearing impairment leads to a delayed emergence of babbling and restricts the production of speech sounds, which can lead to linguistic (phonological, lexical and syntactic) impairment throughout development. Children with congenital deafness generally encounter difficulty organizing their system of sounds, as such children cannot experience and establish the linguistic basis necessary for initiating speech. Auditory feedback is another important aspect in the phonological process and children with hearing impairment may not be able to recognize their distortions, substitutions and omissions[4].

During the present study, no validated instruments were found specifically for quantifying alterations in speech among individuals with hearing impairment. Due to this limitation, assessment tools used to measure phonological alterations in children with hearing thresholds within the range of normality are employed in studies involving children with hearing impairment.

One study compared different criteria for the analysis of mistakes on word recognition among children with hearing impairment who used hearing aids. The authors administered lists of words to children aged six to eight years. The responses were analyzed with different criteria using two assessment tools: Word Associations for Syllable Perception, which assesses the correct recognition of words and syllables and total standard error; and the Confusion Matrix, which assesses substitutions and omissions of phonemes. The relations between the different analysis criteria allowed different perspectives regarding the children's performance on word recognition, leading to reflections on the use of the children' hearing potential and implications for the therapeutic process with an emphasis on residual hearing. The study concluded that combining different criteria in the analysis of errors allows broadening knowledge on deaf children's capability of perceiving speech and consequently contributes toward the establishment of treatment goals[5].

Based on these observations, a need was perceived for quantifying the severity and impact of communication disorders on the diagnostic classification system, the planning of intervention more directed toward the difficulties of the individual and therapeutic control. For such, the Percentage of Consonants Correct (PCC) index was designed based on samples of spontaneous speech. This measure is one of the components of the diagnostic classification system of phonological disorder[6]. The PCC index establishes four degrees of severity: mild, corresponding to more than 85% correct consonants; mildly moderate, with the proportion of correct consonants ranging from 65% to 85%; moderately severe, ranging from 50 to 65%; and severe, corresponding to less than 50% correct consonants[7].

Hearing plays a preponderant, decisive role in the acquisition and development of oral language. The ear enables one of the noblest functions of human beings – communication. It is through language that humans organize life, comprehend the world, understand others, transmit and abstract the thoughts and feelings of others, interact with the environment and acquire knowledge[8].

The perception of the sounds of speech includes the reception and interpretation of speech patterns, the discrimination between the sounds of different spectra, temporal characteristics, sequential forms, rhythm, duration, memorization and the comprehension of units of speech within a particular linguistic system. The effects of neurosensory hearing impairment on the perception of speech include a diminished ability to identify significant phonological contrasts, recognize phonemes and perform auditory figure-background perception. Children with peripheral hearing impairment exhibit quantitative and qualitative difficulties in recognizing the acoustic cues of speech, often resulting in altered speech production. A greater degree of hearing impairment increases the difficulty in perceiving speech, leading to more significant alterations in speech production[9].

Phonological therapy for deaf children based on the auri-oral method emphasizes the acquisition of oral language through residual hearing with the use of a hearing aid, which allows these children to receive the greatest possible amount of acoustic information regarding the sounds of speech. Hearing aids allows a better capturing of acoustic information from the surrounding environment, thereby offering a greater chance for the development of oral language. The aim of hearing rehabilitation is mainly to integrate deaf children to society, ensuing the same opportunities as others and allowing the development of their potentialities through interrelations, respect and cooperation[10].

Knowledge regarding the PCC index can assist therapists who work with educational audiology to create a parameter for the assessment of the efficacy of the treatment plan, allowing the adaptation of the treatment program to the needs of

the patient and contributing toward the success of therapy.

The aim of the present study was to compare scores on the Percentage of Consonants Correct (PCC) index between children with and without hearing impairment and determine whether time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing loss exert an influence over the performance of deaf children.

METHODS

This study received approval from the Human Research Ethics Committee of the Universidade Federal de São Paulo (Brazil) under process number 0739/09 and was carried out at the Audiology and Educational Audiology clinics of the Department of Speech-Language Pathology and Audiology of the university. All parents/guardians gave written informed consent.

The participants with hearing impairment were selected from the Educational Audiology clinic and those with normal hearing were recruited from daycare centers and schools. The two groups were matched for age and gender and each was composed of 15 individuals.

The following were the inclusion criteria for the Study Group (SG): neurosensory hearing impairment; age between three and 10 years; participation in speech and hearing therapy with the auri-oral approach; use of hearing aids in binaural adaptation; absence of other associated pathologies; hearing threshold equal to or less than 60 dBNA with hearing aids; and type A tympanometric curve. The inclusion criteria for the Control Group (CG) were age between 3 and 10 years, hearing thresholds equal to or less than 15 dB between 250 Hz and 8 kHz, absence of delayed speech and language acquisition and type A tympanometric curve.

The study involved the following procedures: interview with parents/guardians; tonal threshold audiometry/logo audiometry, immittanciometry, administration of ABFW and calculation of PCC index.

Interview

The parents/guardians answered a questionnaire with items addressing the identification, clinical history, motor development and language development of the child.

Tonal threshold audiometry and logoaudiometry

The determination of hearing thresholds was performed at frequencies of 250 Hz to 8 kHz. The individuals were instructed to raise their hand for all stimuli heard, even when perceived with weak intensity. For the CG, the test was carried out with headphones and began at a frequency of 1 kHz, followed by frequencies of 2, 3, 4, 6 and 8 kHz as well as 500 and 250 Hz. This test was followed by the determination of the speech reception threshold and speech recognition percentage index. In the SG, free field audiometry was performed with and without hearing aids at frequencies of 2, 4 and 1 kHz as well as 500 and 250 Hz. The voice detection threshold was also determined. The descending-ascending method was used for the determination of hearing threshold. This test was begun at a high intensity, with the intensity reduced by 10 dB for each response. When no response occurred, the intensity was raised by 5 dB for the confirmation of the hearing threshold. This test was performed using the MA-41 audiometer.

Immittanciometry

To seal the external acoustic meatus, a plug of adequate size was inserted. The pressure was then varied from +200 daPa to -200 daPa to determine the point of maximal compliance. The threshold of the stapedius reflex was determined in the contralateral mode at frequencies of 500 Hz and 1, 2 and 4 kHz. The initial intensity was set at 80 dB and increased by 10 dB when no reflex was obtained, reaching a maximum of 120 dB. The AZ-7 equipment was used for this test. The Jerger-Jerger classification (1970) was employed for the analysis of acoustic immittance, for which a type A curve was determined when the peak of maximal compliance occurred between +100 and -100 daPa with the equivalent volume in the middle ear between 0.3 and 1.6 ml[11].

Administration of ABFW

The ABFW is a child language test addressing phonology, vocabulary, fluency and pragmatics that involves pictures and a protocol for annotating the child's response during the evaluation. The participants were only submitted to the phonology portion of the ABFW, which is made up of three tasks: naming, imitation and spontaneous speech. The tasks were administered in the same order to all participants[12]. On the naming task, pictures were shown for the child to name. If the child was unable to do so, the evaluator spoke the name of the figure and, after showing five other pictures, returned to the original picture a second time and asked the child to name it. On the imitation task, the child was asked to repeat the words spoken by the evaluator. When the child failed to do so, the word was presented a second time at the end of the test. On the spontaneous speech task, the evaluator interacted with the child in situations of play with miniature objects that facilitated the acquisition of a 15-minute sample of speech. All speech samples were recorded on a MW141-DL MP3 player. The data were recorded on the response form.

Calculation of PCC

The PCC index was determined by the number of correct consonants in the speech of the child on the three ABFW tasks. The result was obtained through the division of the number of correct consonants by the total number of consonants in the sample (correct consonants + incorrect consonants), multiplying the result by 100[6]. For the calculation, only those consonants for which the evaluation was certain of the correct production were considered. The following were considered errors:

- omission of the target consonant;
- substitution of the target consonant with other consonant;
- distortion of the target consonant;
- addition of a sound to the correct or incorrect target consonant.

The speech sample was assessed by a single examiner. Words that were partially or completely unintelligible were excluded from the sample.

Statistical analysis

The SAS program (version 8.2) was used for all statistical analyses. Analysis of variance (ANOVA) was used to determine differences in the scores of the PCC index between the SG and CG. ANOVA was also used to determine whether time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing impairment exerted an influence over the PCC index score. The level of significance was set at 5% (p-value≤0.05).

RESULTS

Table 1 displays the results of the descriptive measures referring to age and PCC variables in the SG and CG (Table 1).

No significant differences between groups were found in age, demonstrating that the groups were homogeneous with regard to this variable. On the naming, imitation and spontaneous speech tasks, statistically significant differences were found between groups, with the CG performing better than the SG on all tests. On the spontaneous speech task, only 11 individuals from the SG were included in the analysis, as the other four did not achieve the minimum of 50 intelligible words for the calculation of the PCC index. The average of the three subscales was calculated from the results of the separate tasks, for which a statistically significant difference was detected between the SG and CG, with the CG performing better.

In the SG, descriptive measures were performed for time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing impairment. An average of 16.93 months passed before the diagnosis of hearing impairment. Time using hearing aid ranged from 2 months to 7 years (mean: 3 years 7 months). The individuals had been in speech/hearing therapy an average of 3 years 6 months (Table 2).

Correlations were determined for the performance on each PCC test and the overall average in relation to time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing impairment (Table 2). Time in therapy and time using hearing aids both exerted an influence over the performance on the imitation task (p=0.0189), as those with a longer time using hearing aids and a longer time in therapy performed better on this task. Time elapsed until the diagnosis of hearing impairment had no influence over the results of the imitation task. On the naming task, time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing impairment had no influence over the performance of the children (Table 2).

Time elapsed until the diagnosis of hearing impairment had no influence over the performance on the spontaneous speech task (p=0.4913). Due to the strong correlation between time using hearing aids and time in therapy (0.99), it was not possible to perform the task with the two variables in the same model. Thus, the decision was made to adjust two models – one with time in therapy and time elapsed until the diagnosis of hearing impairment and the other with

Table 1. Comparative analysis of descriptive measures of age and PCC variables in study and control groups

Variable	Group	n	Mean	SD	Minimum	Maximum	p-value
Age	Controle	15	6.53	1.41	4.00	8.00	0.8958
	Estudo	15	6.47	1.36	4.00	8.00	
Imitation	Controle	15	1.00	0.01	0.98	1.00	<0.0001*
	Estudo	15	0.63	0.20	0.16	0.87	
Naming	Controle	15	1.00	0.01	0.97	1.00	<0.0001*
	Estudo	15	0.44	0.29	0.02	0.76	
Speech	Controle	15	1.00	0.00	1.00	1.00	<0.0001*
	Estudo	11	0.58	0.17	0.33	0.76	
Mean	Controle	15	1.00	0.00	0.99	1.00	<0.0001*
	Estudo	15	0.52	0.23	0.09	0.78	

* Significant value (p≤0.05) – ANOVA
Legend: SD = standard deviation

Table 2. Descriptive measures of time using hearing aids, time in therapy and time elapsed until diagnosis of hearing impairment

Variable	n	Mean	SD	Minimum	Maximum	p-value			
						Imitation	Naming	Speech	Mean
Time until diagnosis (months)	15	16.93	7.28	2.00	24.00	0.9854	0.4913	0.4913	0.9854
Time using hearing aid (months)	15	44.93	25.70	2.00	84.00	0.0189*	0.1569	0.0767	0.0709
Time in therapy (months)	15	44.03	26.37	0.40	84.00	0.0156*	0.1066	0.0767	0.0492*

* Significant value (p≤0.05) – ANOVA
Note: SD = standard deviation

time using hearing aids and time elapsed until the diagnosis of hearing impairment. Due to the correlation, the p-values were identical (Table 2).

Comparing these variables with regard to the overall PCC score, time in therapy demonstrated an influence on overall performance, as a longer time in therapy was associated to a better performance (p=0.0492). Time using hearing aid and time elapsed until the diagnosis of hearing impairment had no influence on overall performance (Table 2).

DISCUSSION

The SG and CG were similar with regard to age, which was expected due to the matching of the groups. The CG had a better performance on the naming, imitation and spontaneous speech tasks as well as the average of the three tasks. The differences between groups varied depending on the task. The SG had the greatest difficulty with the naming task, on which the performance was nearly 60% below that in the CG, followed in decreasing order of difficulty by the spontaneous speech and imitation tasks.

The performance of the SG came closest to that of the CG on the imitation task. This finding may be related to the fact that children with hearing impairment benefit from visual cues in speech production. The visual cues the interlocutor furnishes in his/her articulatory production of phonemes appears to be an important factor in phonetic development. However, such cues cannot be considered the basis for phonetic acquisition in deaf children[13].

Visual information complements the use of a hearing aid. All deaf individuals use visual cues in order to compensate for their disability. According to the literature, preschool children achieve worse scores on the spontaneous speech task. This occurs due to their difficulty in syntactically organizing more complex tasks, such as parts of a narrative or when participating in a conversation. A large number of factors directly influence the quantity and quality of a child's discourse, such as vocabulary, which explains the much worse performance of the SG on the naming and spontaneous speech tasks[10]. The considerable differences between groups on these tasks allow quantifying the difficulty observed in practice during attempts at communication with the deaf children. Moreover, the results allow inferences regarding the difficulties these children experience, especially at school, as the majority were enrolled in schools geared toward children with normal hearing.

The CG achieved PCC scores of 100% on all tasks. In a previous study applying the naming test to 192 children with typical development in the city of São Paulo (Brazil), the authors found that phonological development is essentially complete by four years of age, as the proportion of correctly produced consonants only increased 10% between the ages of 4 and 6 years (from 87% to 97%). These data are similar to those of the present study, as the children in the CG were over four years of age[1]. Moreover, the data reveal that the SG achieved percentages below those expected for typical development, thereby demonstrating phonological disorder. Based on the overall performance, the children in the SG exhibited a moderately severe degree of phonological disorder, with a PCC index of 52%[6].

Regarding the overall scores derived from the three tasks together, six children in the SG achieved PCC scores between 65 and 85%, characterizing a mildly moderate degree of phonological disorder. Two children had mean PCC results of 50 to 65%, classifying them with moderately severe phonological disorder, and five children had mean PCC results of under 50%, characterizing severe phonological disorder.

The aim of applying descriptive measures to the time using a hearing aid, time in therapy and time elapsed until the diagnosis of hearing impairment was to determine whether these variables exerted an influence over the performance of the children in the SG on the PCC tests. Time elapsed until diagnosis was greater than that considered ideal so that there is no harm with regard to the development of oral language. As hearing impairment, especially severe to profound hearing impairment, is an important sensory deprivation and the deaf children in the present study had their condition identified after the first year of life, experiencing the sounds of language tends to be greatly affected[14,15].

Time using a hearing aid and time in therapy had a positive influence on the performance of the individuals on the imitation task. This finding corroborates the clinical observation that deaf children exhibit good imitation skills, often mimicking the utterances of the therapist without even understanding the meaning. This finding may also stem from the therapeutic strategies employed in the auri-oral approach, which, as a rule, call for the repetition of whatever is being addressed. Time elapsed until diagnosis did not exert

an influence over the performance on this test, as the PCC index scores did not undergo any significant change with the increase or decrease in the time until diagnosis. Despite being an important datum, the average time until diagnosis was long (more than one year), which reflects negatively on language development. The ideal would have been to have a comparison group in which deafness was diagnosed and rehabilitated early in order to determine whether the time until diagnosis exerted an influence over the PCC results.

Time using hearing aids, time in therapy and time elapsed until the diagnosis of hearing impairment had no influence over the performance on the naming test, as the children with hearing impairment did poorly on the test regardless of these variables.

Time elapsed until diagnosis had no influence over the performance of the deaf children on the spontaneous speech test. Moreover, only time in therapy affected the results of the overall performance on the tests combined, with a longer time in therapy associated to better overall performance.

According to different studies, the PCC index is expected to increase with age, with the elimination of all phonological processes by seven years of age. With regard to the children with hearing impairment, the increase in the PCC index was influenced by time in therapy rather than age, demonstrating that deaf children need specific stimulation in order to eliminate phonological processes[1,16]. Adequate linguistic development for children with hearing impairment is possible provided that the process is guided by an adequate amount speech/hearing therapy, as such therapy provides the conditions necessary to avoid delays in the development of oral language and make it adequate[14].

The literature states that children manifest the physiological capacity for producing all sounds of language at birth. However, these sounds are not employed linguistically until the child incorporates the perceptive basis that is fundamental to the identification of his/her language system[17]. Therapeutic strategies that offer qualitative changes in the recognition of acoustic cues in speech are indispensible to improving speech production in deaf children. In the clinical practice of speech therapy, it is necessary to determine the relationship between different acoustic characteristics of amplification systems and perform therapy with an emphasis on auditory perception[5].

The present study had limitations that should be addressed. The speech samples were not analyzed by two examiners and the SG was not subdivided with regard to etiology. Etiology can affect language performance in deaf children, even those with a longer time in therapy and lesser degree of hearing impairment[5].

The impact of hearing impairment depends mainly on the extent to which the perception of the sounds of speech is affected. Aspects inherent to the perception of these sounds (detection, discrimination, recognition and comprehension) may be altered due to a reduction in the hearing threshold, depending on the degree and type of hearing impairment[15].

Based on the results of the present study, speech therapy involving the use of residual hearing with the early employment of hearing aids allows deaf children to receive the greatest possible amount of acoustic information regarding the sounds of language. The greater use and emphasis on such information in speech therapy increases the chances for the development of oral language[5].

CONCLUSION

The results of the present study demonstrate that PCC index scores were lower among the children with hearing impairment in comparison to those with normal hearing. The deaf children exhibited greater difficulty on the naming, imitation and spontaneous speech tasks, the results of which characterized these children as having a moderately severe degree of phonological disorder. Time using hearing aids and time in therapy proved to have a positive influence over the performance of these children on the imitation test and overall PCC results.

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