DIFFERENCES BETWEEN VOCAL PARAMETERS OF COCHLEAR IMPLANTED CHILDREN AND CHILDREN WHO USE INDIVIDUAL SOUND AMPLIFICATION DEVICE

Diferenças entre parâmetros vocais em crianças usuárias de implante coclear e em crianças usuárias de aparelho de amplificação sonora individual

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ABSTRACT

Purpose: to conduct a comparative study of the vocal parameters in the fundamental frequency, first formant and second formant of the voice of children with cochlear implants, the voice of children using personal sound amplification device and normal hearing children. **Method:** the sample of 18 children (12 girls and 6 boys) aged from 5 to 7 years old (average age 6,3 years).The recording of the samples was performed in the voice laboratory at the speech pathology clinic of the University of Rio Grande do Norte, Natal, using the PRAAT software. The analyzed parameters were fundamental frequency and second formant frequency of sustained vowel [a] emission and of first formant and second formant frequencies of vowel [a], for syllables [ka] and [pa]. **Results:** except for the first formant of the vowel [a] of the syllable [pa] that showed a statistically significant difference among cochlear implant users and normal hearing groups, the other parameters showed statistically significant difference among the three groups. **Conclusion:** children users of cochlear implants present acoustic values close to those of normal hearing children, these values being more adequate than those presented by the children using individual sound amplification devices.

KEYWORDS: Voice; Cochlear Implantation; Speech; Child

INTRODUCTION

Normal hearing provides appropriate feedback for the control of voice and speech. Children depend on the feedback provided by audition to control the duration, the fundamental frequency (f_0) and formants in the production of vowels. In subjects with severe and profound hearing impairment, there is the increase in average f_0 due to the absence of auditory feedback[1,2].

The production of voice and speech involve numerous regulatory processes. The stabilization of these processes has its onset in childhood and requires of the motor information of the pathways for articulation and sensory information.

Sensory information is obtained through auditory feedback, which also interferes with the correction and improvement of muscle control of the organs involved in vocal production[3].

Due to the lack of kinesthetic feedback presented by these children, the vowels tend to be produced with a lower distinction. This lack of distinction is acoustically revealed, among other things, increasing the frequency of the first formant (F1) and a decrease in the frequency of the second formant (F2)[4].

There are compromised characteristics in relation to vocal aspects found in children with deficits in hearing. Resonance can present nasality because the language generally presents posteriorized due to laryngeal tension, affecting the quality

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of resonance. The poor monitoring of the speech results in alteration of f_0 intensity and voice duration[5].

In recent years technology has made it possible for deaf people to enter the world of sound and improve their communicative competence through the cochlear implant that electrically stimulates the auditory nerve improving auditory feedback in these individuals. The cochlear implant systems have become increasingly successful in providing basic skills for the recognition of speech sounds.

Study by Seifert et al[5] investigated the f_0 of the sustained vowel [a] performed by 20 children with pre-lingual deafness, implanted before and after 4 years old. The results showed that children implanted before 4 years old showed improvement in voice control faster than children implanted later and better acoustic control over their speech, enabling normalized degrees of f_0 as well as better articulation skills.

Dehqan and Scherer[2] compared the voice of a group of children with profound hearing loss who were hearing aid users and a group of children with normal hearing, through the analysis of the sustained vowel [a]. The results showed that children with profound hearing loss showed increase of the fundamental frequency in relation to the group of children with normal hearing.

It is mentioned in the literature that some parameters of the voice of children with deafness differ considerably from the parameters of voice from normal hearing children. On the other hand, there are data in the literature arguing that the voice of children with cochlear implants, after adequate auditory *feedback* presents the acoustic characteristics closes to normal[6,7].

Given these arguments, we aimed to the realization of this comparative study of the vocal parameters f_0, F1 and F2 of the voice of children with cochlear implants, the voice of children who used hearing aids (HA) and the voice of normal hearing children for the acoustic analysis of the sustained vowel [a] and syllables [ka] and [pa], because it is hypothesized that children with cochlear implants, because they have better *feedback* than the children using hearing aids, can submit parameter values f0 and formants close to the vocal parameters of normal hearing children.

METHOD

This was a transversal study. The sample consisted of 18 children (12 girls and 6 boys), aged from 4 years and 8 months old to 7 years (average age 5.5 years old). The sample was divided into three groups, one group consisting of 06 normal hearing children (normal hearing group-NHG), 06 children with cochlear implants (cochlear implant group-CIG) and 06 children who used hearing aid (hearing aid users group-HAUG), of both genders. The implanted children in this study received a cochlear implant before the age of 4 years old.

Thus, we established the following criteria for inclusion and exclusion:

Children with cochlear implants

- Children with congenital sensor neural hearing loss, severe and/or profound bilateral, lack of intellectual or emotional impairment, participation in (re) habilitation program.

Children using hearing aids

- Children with congenital sensor neural hearing loss, severe and/or profound bilateral, lack of intellectual or emotional impairment, participation in (re) habilitation program.

Normal hearing children

- Children without hearing problems, no voice disorders, absence of intellectual or emotional impairment.

A recording of the speech sample was performed in the voice laboratory from the Phonoaudiology Clinic from the Federal University of Rio Grande do Norte, in Natal, place with environmental noise under 50 dB and analyzed using the PRAAT software program[8] with sampling rate 20050Hz, 16 bit, mono channel, installed on CCE *notebook*, processor I 3 and 3 GB. The samples of sustained vowel were edited and being deleted the beginning and end of each emission. The procedure for recording was the same for all participants. The children were sitting with the microphone positioned 10 cm from the lips and were asked to produce a sustained vowel /a/ and the words *macaco* (monkey) and *papai* (dad).

It was performed acoustic analysis of the vowel [a] and syllables [ka] and [pa] from the words *macaco* (monkey) and *papai* (dad), respectively. The analyzed parameters in the emission of vocal [a] and the sustained vowel [a] of the syllables [ka] and [pa] were the f_0 frequency of formants F1 and F2 of the syllables and F2 from the sustained vowel. The choice of words resided in the fact that they are easy to pronounce for the children and submit syllables [ka] and [pa], which correspond to the opposite configuration of the vocal tract, the posterior articulation of phonemes [k] and anterior [p].

This study was approved by the Ethics and Research Committee of the Hospital University Onofre Lopes from the Federal University of Rio Grande do Norte, under No. 444-10. The children's

parents signed an informed consent form authorizing their children to participate in the study.

The results of the analysis of the group of children with cochlear implants were compared with the results of children who used hearing aids and with the group of children with normal hearing.

Descriptive analysis was performed and the results shown in tables.

To make a comparison between the 3 groups was used the analysis of variance and Tukey test, adopting significance level of 5%.

Table 1 – Demographic characteristics of children with cochlear implant

Subject	Age	Gender	Reasons for Deafness	Age when undergone CI	CI period of use
01	5 years and 11 months old	M	meningitis	4 years and 2 months old	1 years and 9 months old
02	5 years and 5 months old	F	measles	2 years and 5 months old	3 years old
03	4 years and 8 months old	M	meningitis	3 years and two months old	1 years and 6 months old
04	5 years old	F	meningitis	3 years old	2 years old
05	6 years and 2 months old	F	meningitis	3 years and 2 months old	3 years old
06	7 years old	M	meningitis	4 years old	3 years old

RESULTS

Data were tabulated and the results analyzed by comparing the values obtained in the three groups.

Table 2 presents the results of the descriptive analysis of the evaluated parameters of the three groups.

Table 3 presents the results of analysis of variance of the analyzed parameters among the three groups.

The difference between the values of the variable F1 of the vowel [a] of the syllable [pa] was the only result that the NHG and CIG groups showed a statistically significant value.

The remaining parameters showed statistically significant differences among the 3 groups CIG $\neq$ HAUG and NHG $\neq$ HAUG.

Table 2 – Demonstrates the result of descriptive analysis of data objectives by the three groups

Cochlear implant user (CIG)	n	Average	Median	Standard Deviation	Minimum	Maximum
f_0 [a]	6	268	269	13,90	251	287
F2 [a]	6	1.892	1.879	106,99	1.733	2.049
F1 [ka]	6	1.268	1.268	12,95	1.255	1.285
F2 [ka]	6	1.789	1.787	72,15	1.678	1.879
F1[pa]	6	1.159	1.114	253,71	899	1.618
F2 [pa]	6	2.031	1.999	124,36	1.882	2.211
User of hearing aid (HAUG)	**n**	**Average**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
f_0 [a]	6	287	285	13,07	272	303
F2 [a]	6	1.565	1.560	121,89	1.410	1.749
F1 [ka]	6	1.142	1.171	76,17	1.210	1.410
F2 [ka]	6	1.565	1.591	181,13	1.280	1.781
F1 [pa]	6	1.246	1236	34,82	1.210	1.291
F2 [pa]	6	1.577	1.617	251,14	1.147	1.861
Normal hearing children (NHG)	**n**	**Average**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
f_0 [a]	6	252	252,50	5,27	246	259
F2 [a]	6	1.741	1.753	75,01	1.897	2.099
F1 [ka]	6	1.225	1.221	60,29	1.156	1.320
F2[ka]	6	1.959	1.944	131,04	1.512	1.320
F1[pa]	6	1.691	1.720	151,79	1.487	1.876
F2 [pa]	6	2.107	2.090	86,41	2.011	2.230

Table 3 – Demonstrates the result of the analysis of variance and Tukey test

	Analysis of Variance (p)	Tukey's test (multiple comparisons - p<0,05)
f0 [a]	<0,001*	CIG ≠ HAUG; NHG ≠ HAUG
F2 [a]	<0,001*	CIG ≠ HAUG; NHG ≠ HAUG
F1 [ka]	0,005*	GIC ≠ HAUG
F2 [ka]	0,001*	CIG ≠ HAUG; NHG ≠ HAUG
F1[pa]	<0,001*	CIG ≠ GON; NHG ≠ HAUG
F2 [pa]	<0,001*	CIG ≠ HAUG; NHG ≠ HAUG

GCI- grupo usuário de Implante Coclear,HAUG- grupo usuário de AASI,GON- grupo de ouvintes normais CIG- Cochlear Implant user group, HAUG- hearing aid user group, NHG-group of normal hearing children

DISCUSSION

This study was performed to compare the vocal parameters f_0, F1 and F2 of the voice of children with cochlear implants, the voice of children using hearing aids and normal hearing children through the acoustic analysis of the sustained vowel [a] and syllables [ka] and [pa].

The use of the sustained vowel /a/ for voice analysis promotes a significant advantage over other assessment tasks, such as sentences and texts, because this vowel production is easy for young children. Displays the f_0 lower and F1 sharper, which provides a more accurate analysis (LPC)[7].

In the analysis of acoustic parameters shown in Table 2, the average value of f_0 vowel /a/ in the sustained emission of HAUG, was higher (287Hz)

when compared to the CIG, with this group values closer to the values obtained by NHG (252Hz). The highest value of the f_0 of HAUG can be attributed to lack of auditory feedback, the poor laryngeal control involving laryngeal elevation, inability to control the tension of the vocal cords and subglottic pressure[2].

It is believed that the values of f_0 of the CIG closer to the NHG and the difference was statistically significant compared to HAUG (Table 3) are related to the gain control of the hearing (auditory feedback) and, consequently, greater field of motor adjustments made by the CIG in this study, as well as the neuromuscular skills involved in speech and maturity of these controls[9].

The frequency of the second formant F2 is related to the anterior-posterior displacement of the tongue. The value of F2 indicates greater anterior posture of the tongue, while the lower value of F2 indicates posterior position of the tongue[10]. By analyzing the values of F2 of the sustained vowel /a/, there was an increase in this value in the CIG when compared to HAUG demonstrating these values with the presence of a posterior pharyngeal constriction and tongue in HAUG, indicating lower value of F2.

The larger value of F2 in CIG demonstrated in this group a better adjustment control of the vocal tract, agreeing with Garcia[9] when argues that these articulatory changes are related not only to the auditory feedback, as well as the adaptation of neuromuscular skills involved in speech production.

During the speech chained the parameters F1 and F2 of the syllables [ka] and [pa] demonstrated that the CIG was more stable with values closer to the NHG. Hocevar-Boltezar et al[11] argues that children with pre-lingual deafness who received a cochlear implant before 4 years old can show improvement in speech between 6 to 10 months after the use of this device.

However, when comparing the frequency of formant F1 of the vowel [a] in the syllable [pa] of the word *papai* (daddy) there was no difference between groups CIG and NHG (Table 3). This was the only variable in which children with cochlear implants showed divergence in respect to children with normal hearing. It is believed that this difference is related to the reduction of mouth opening in children of the CIG, favoring decreasing the frequency of the first formant F1, demonstrating that the quality of a vowel can be described from the point of view of perception via the phonetic or from the point of view of acoustic analysis by the frequency of its formants[8].

We can point out, according to the results, that children of the CIG showed better results for the other analyzed parameters that children from HAUG, when compared to the NHG. Children belonging to HAUG showed average values of F2 of the vowel [a] lower than the average values given by the subjects of the CIG in articulating words (*macaco* – Monkey and *papai* – Dad). The children who used hearing aids, by the lack of adequate auditory feedback, often have pharyngeal constriction and a dorsal tongue more posterior, which contributes to an increase in the space of the anterior oral cavity, reducing the values of F2.

Acoustic analysis of this study contributed to the understanding of motor adjustments developed by HAUG and the CIG, demonstrating that cochlear implant users are benefited by auditory feedback, had the opportunity to better coordinate articulatory adjustments, revealing better control in the source mechanism and filter.

CONCLUSION

Although cochlear implants do not restore the experience of perception of sound in the same way it is perceived by the normal hearing people, it provides to the user a better auditory feedback providing opportunities in their communicative competence.

We concluded that children of this study, cochlear implant users, showed values of acoustic parameters closer to the values obtained by normal hearing children, these values being more suitable than the values presented by children using hearing aids.

RESUMO

Objetivo: realizar um estudo comparativo entre os parâmetros vocais freqüência fundamental, frequência do primeiro formante e frequência do segundo formante da voz de crianças usuárias de implante coclear, da voz de crianças usuárias de aparelho de amplificação sonora individual e da voz de crianças ouvintes normais. **Método:** a amostra foi composta por 18 crianças (12 meninas e 6 meninos), numa faixa etária entre 5 e 7 anos (média de idade 6,3 anos). A gravação das amostras foi realizada no laboratório de voz da Clínica de Fonoaudiologia da Universidade Federal do Rio Grande do Norte, em Natal. A análise acústica foi realizada utilizando-se o programa PRAAT. Os parâmetros analisados foram frequência fundamental e frequência do segundo formante da emissão da vocal [a] sustentada e frequência dos primeiro e segundo formante da vogal [a] das silabas [ka] e [pa]. **Resultados:** com exceção do primeiro formante da vogal [a] da silaba [pa] que apresentou diferença estatisticamente significante entre os valores dos grupos de usuários de implante coclear e do grupo de ouvintes normais, os demais parâmetros apresentaram diferença estatisticamente significante entre os três grupos. **Conclusão:** as crianças usuárias de implante coclear apresentaram valores acústicos próximos aos apresentados pelas crianças ouvintes normais, sendo esses valores mais adequados do que os apresentados pelas crianças usuárias de aparelho de amplificação sonora indivdual.

DESCRITORES: Voz; Implante Coclear; Fala; Criança

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