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Artigo Original

Voice of hearing impaired children and adolescents and hearing peers: influence of speech auditory perception on vocal production

Voz de crianças e adolescentes deficientes auditivos e pares ouvintes: influência da percepção auditiva da fala na produção vocal

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Keywords

Cochlear Implants
Hearing Aids
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Speech Perception
Voice Quality

ABSTRACT

Purpose: To compare the acoustic and perceptual-auditory results of the hearing impaired children and adolescents with hearing pairs and to correlate these results with parents' reports regarding speech auditory perception. **Method:** The participants were divided into two groups: Group I, 20 hearing-impaired children and adolescents and Group II, 20 children and adolescents with normal hearing. Acoustic analysis of the vowel /a/ and perceptual-auditory assessment of the vowel /a/ and speech were performed. The speech auditory perception of the GI was assessed using the Infant-Toddler Meaningful Auditory Integration Scale and the Meaningful Auditory Integration Scale with adaptation for adolescent participants. The acoustic and perceptual-auditory voice results of the GI and GII were compared and these results were correlated with the performance in the auditory perception of the GI group. **Results:** The groups I and II presented similar results, differing statistically in the long-term frequency variation (vF_0) and the long-term amplitude variation (vAm) parameters of the vowel /a/ and speech resonance parameter. It was found a negative correlation between auditory perception performance with jitter, vF_0 and general degree of vowel /a/. **Conclusion:** The vocal quality in GI was similar to their hearing peers in almost all the vocal parameters that were analyzed. The auditory perception influenced jitter, vF_0 and general degree of voice parameters, in which hearing-impaired children and adolescents who presented higher scores for auditory perception were also able to keep a more controlled vocal emission.

Descritores

Implante Coclear
Auxiliares de Audição
Perda Auditiva
Percepção da Fala
Qualidade Vocal

RESUMO

Objetivo: Comparar os resultados acústicos e perceptivo-auditivos da voz de crianças e adolescentes deficientes auditivos com pares ouvintes e correlacionar estes resultados com o relato dos pais em relação à percepção auditiva da fala. **Método:** Os participantes foram divididos em dois grupos: grupo I, 20 crianças e adolescentes deficientes auditivos, e grupo II, 20 crianças e adolescentes ouvintes. Foi realizada análise acústica da vogal /a/ e avaliação perceptivo-auditiva da vogal /a/ e da fala. A percepção auditiva do GI foi avaliada utilizando a Escala de Integração Auditiva Significativa para Crianças Pequenas e a Escala de Integração Auditiva Significativa, com adaptação para participantes adolescentes. Os resultados acústicos e perceptivo-auditivos da voz de GI e GII foram comparados e, para o GI, estes resultados foram correlacionados com o desempenho na percepção auditiva. **Resultados:** Os grupos I e II apresentaram resultados similares, diferenciando-se estatisticamente nos parâmetros variação da frequência fundamental (vF_0) e variação da amplitude (vAm) da vogal /a/ e ressonância da fala. Houve correlação negativa entre o desempenho na percepção auditiva com os parâmetros de jitter, vF_0 e grau geral da vogal /a/. **Conclusão:** A qualidade vocal do GI foi semelhante em praticamente todos os parâmetros vocais analisados a dos seus pares ouvintes (G2). A percepção auditiva influenciou os parâmetros jitter, vF_0 e grau geral do impacto da voz, em que crianças e adolescentes deficientes auditivos que apresentaram maiores escores para a percepção auditiva também foram capazes de manter a emissão vocal mais equilibrada.

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INTRODUCTION

Hearing loss can cause communication problems related to speech and voice. Voice is an extremely important factor since voice alterations have a negative impact on the social integration of the hearing-impaired population[1].

Technological devices that enable access to speech sounds, such as hearing aids (HA) and cochlear implants (CI), are very efficient at remediating hearing loss. Among their advantages, benefits regarding speech perception and, consequently, language development stand out[2]. In addition, the use of HA and CI allows balanced speech production, as these technological resources provide hearing feedback, which is indispensable for vocal control[3].

Studies have proven the benefits provided by the use of these devices specifically for the voice, among them, greater control of the fundamental frequency (F_0) and reduction and balance of noise levels, acoustic signal disturbance and perceptual-auditory parameters of roughness, tension and pitch[4-6].

The literature also provides ample evidence of differences in certain vocal aspects (acoustic and perceptual) in users of HA and CI, such as speech intelligibility, values of vowel formants, F_0 and vocal quality, which are closer to normality standards in CI users than in users of HA[6-12].

However, it should be stressed that the use of the device for accessing sounds is not the single factor to be taken into account in the development of hearing-impaired children and adolescents, as they only allow audibility of environmental sounds and speech, speech therapy provided in partnership with parents and healthcare professionals is still necessary[13]. Furthermore, other factors such as early intervention, time of using CI, speech detection thresholds, hearing age and speech processing strategy can also impact the speech characteristics of hearing-impaired individuals[5,6,12,14,15].

In Brazil, current public policies aim at granting hearing-impaired children access to speech sounds through early diagnosis and technological resources. Hearing-impaired children increasingly have the opportunity to reduce the impact of hearing impairment in their lives.

Voice quality stands among the impact factors that can be mitigated[16]. Currently, some hearing-impaired children are undergoing a therapeutic process, benefiting from hearing-related diagnostic and technological advances, while other children start intervention at a later age[17].

To follow up and to acquire more in-depth knowledge of the aspects involved in the communication of hearing-impaired children, among which voice quality, will help to improve the speech therapy process. It should also be emphasized the need to obtain more information on the subject to understand whether children, who use technological devices for accessing speech sounds, associated with variables such as the auditory perception of these speech sounds, can manifest different vocal quality characteristics.

Thus, the present study aimed at comparing the acoustic and auditory-perceptual results of the voice of hearing-impaired children and adolescents to hearing peers and correlating these results with parents' reports regarding auditory speech perception.

METHOD

This work is part of a project approved by the Research Ethics Committee of Faculdade de Filosofia e Ciências of Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Marília Campus, in accordance with opinion No. 1.299.760. All participants and/or their legal guardians signed an Informed Consent Form. Participants between 11 and 17 years and 11 months of age also signed a Term of Assent. This is a controlled cross-sectional clinical study.

The sample consisted in two groups: group I (GI), including 20 children and/or adolescents with bilateral sensorineural hearing loss of moderate (n= 2), severe (n= 5) and profound degree (n=13), users of CI (n= 13) or HA (n= 7), aged between three years and six months and 18 years (average age: 10 years and four months); and group II (GII), comprising 20 hearing children and/or adolescents, matched by age and gender to each hearing-impaired participant.

Inclusion criteria for the GI were: children and/or adolescents using HA and/or CI who were participating or had participated in the same rehabilitation program, with emphasis on the development of hearing and spoken language, absence of other associated deficiencies and non-users of the Brazilian Sign Language (LIBRAS), and who were able to perform the requested speech tasks. Participants selected for Group II had hearing thresholds within normal parameters, confirmed by audiological evaluation, and absence of changes in vocal quality, confirmed by perceptual-auditory evaluation performed by a speech therapist with expertise in voice.

Vocal evaluation was performed by recording the voices of each participant in a room with acoustic treatment using a MARANTZ digital recorder model PMD660 and a Sennheiser e835 microphone, positioned 5 centimeters away from participants' mouths. Emission of the sustained vowel /a/ and speech were recorded using the instrument *Avaliação Fonológica da Criança* – AFC [Phonological Assessment for Children][18] as a stimulus to elicit emission, and including the themes kitchen, bathroom, living room items, means of transportation, and the zoo. These words are part of the vocabulary of children over three years of age[18].

Recording of the sustained vowel was edited, cutting out the beginning and end of the emission so that vocal attack and instability did not interfere with data analysis, preserving approximately five seconds of recording. These edited samples were used for both auditory-perceptual assessment and acoustic analysis. As for speech, 10 words from the AFC were drawn randomly for the auditory-perceptual assessment, two participants of GI were excluded from this task, as they presented unintelligible emissions that interfered in the quality of the evaluation.

The auditory-perceptual assessment was carried out by two speech therapists experienced in vocal assessment, by means of consensus, in a silent environment. Recordings were organized, having been divided according to type of emission (vowel /a/ or speech) and randomized so that judges would not know which child was hearing-impaired and user of CI or HA, or presented normal hearing. Four recordings were repeated for each group for analysis of interjudge agreement. Judges were guided to play back each recording as necessary, with no limits, until a consensual judgement was reached.

The following parameters were analyzed using a 100-millimeter (mm) visual analog scale: overall degree of voice impact, roughness, breathiness, tension, presence of pitch deviation, loudness, instability and resonance. The scale was scored by measuring with a ruler and noting down the value of each parameter – the closer to zero millimeter, the smaller the deviation, and the closer to 100 mm, the greater the deviation of the respective parameter.

Acoustic analysis was undertaken at the Laboratório de Análise Acústica – LAAc of UNESP – Marília, using the Multi-Dimensional Voice Program (MDVP) software from Key-Pentax, and the following parameters were analyzed: F_0, jitter, shimmer, noise-to-harmonic ratio (NHR), variation of fundamental frequency (vF_0) and variation of amplitude (vAm) of the vowel /a/.

Information was collected from the records of the GI participants regarding chronological age, age of the child/adolescent at the time of diagnosis, age as of the adaptation of the hearing aid or activation of the CI, time of sensory deprivation and time of therapy, with focus on development of hearing and spoken language. Hearing thresholds of GI participants were also recorded with the device at the frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz by means of audiological evaluation.

The above mentioned hearing thresholds were recorded to ensure that participants used devices that enabled access to auditory perception of speech sounds. Additionally, the study sought to complement this information, based on the parents' report on the use of the auditory function in everyday situations, which was undertaken using the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS)[19] and the Meaningful Auditory Integration Scale (MAIS)[20].

The use of these scales is grounded on the possibility of applying the same procedure to the entire group of participants, considering that part of the sample had been hearing-impaired from their early years. Thus, the questions of the aforementioned protocol were adapted lexically to the adolescent participants to make them suitable to their age group[17].

The statistical analysis consisted of application of the Mann-Whitney test to compare the results of the acoustic and auditory-perceptual analysis of the vowel and of speech between the groups. The Spearman Correlation Test was used to analyze the relationship between the results of the acoustic and auditory-perceptual analysis and perception of speech sounds of GI participants. The Kappa Agreement Index was also used to verify interjudge agreement in the auditory-perceptual assessment of both types of emissions: sustained vowel and speech. A significance level of 5% was adopted for all tests.

RESULTS

Table 1 presents the data pertaining to Group I.

Table 1. Characterization of group I regarding the data surveyed

Variables	Mean	Standard Deviation (+/-)
Age at diagnosis (months)	22.95	11.94
Age at hearing aid fitting (months)	28.85	16.71
Age at activation of cochlear implant (months)	24.05	19.36
Time of therapy (months)	88.10	36.91
Time of hearing deprivation (months)	28.85	16.71
Mean hearing thresholds with use of device (dB)	29	7.20
IT-MAIS/MAIS score (%)	90.34	8.36

Captions: IT-MAIS - Infant-Toddler Meaningful Auditory Integration Scale; MAIS - Meaningful Auditory Integration Scale

As for the demographic variables of the group of participants surveyed, some children were diagnosed early, but the mean ages at diagnosis (22.95 months), HA adaptation (28.85 months), CI fitting (24.05 months) and sensory deprivation time (28.05 months) showed a late start of interventions and its impact on the mean period of the therapeutic process (88.10 months). Average hearing thresholds with the use of the device demonstrated that the group of participants had the possibility of accessing speech sounds (29 dB). The parents' report on the performance of auditory speech perception configured the average value of 90.34% as the IT-MAIS / MAIS score of GI.

Table 2 shows F_0 averages per age range and gender of each group (GI and GII).

Table 2. Distribution of F_0 averages per age range and gender of each group

Age ranges	F_0 average (Hz)							
	N	GI Male	N	GII Male	N	GI Female	N	GII Female
3 to 4	1	348.334	1	322.547	1	377.822	1	259.558
5 to 6	2	265.727	2	244.160	1	235.554	1	292.484
7 to 11	2	240.312	2	202.324	3	244.223	3	227.189
12 to 14	4	250.100	4	201.376	3	236.978	3	195.425
15 to 18	2	180.278	2	171.719	1	264.800	1	239.130

Captions: F_0 - Fundamental frequency; Hz – Hertz

Results have shown that changes in the F_0 average for the male gender take place in chronological order in both groups, with higher pitches at younger ages and lower pitch voices at 18 years of age. In females, the F_0 average dropped, i.e. the pitch lowered, however, change in pitch appeared in a disorderly manner in both groups.

It is worth noting that these findings showed a trend toward the F_0 average in the group studied, as a lower number of participants is observed in the distribution per age range.

Table 3 compares the results of the acoustic parameters of the vowel /a/ in the GI and GII groups.

Table 3. Comparison of acoustic parameters of vowel /a/ between GI and GII groups

Parameters	Groups	Mean	Standard Deviation	N	p-value
F_0(Hz)	GI	252.2	52.8	20	0.194
	GII	221.2	51.7	20	
Jitter(%)	GI	0.836	0.485	20	0.482
	GII	1.015	0.733	20	
Shimmer(%)	GI	2.638	1.045	20	0.570
	GII	2.711	0.810	20	
NHR(%)	GI	0.124	0.014	20	0.755
	GII	0.121	0.019	20	
vF_0(%)	GI	2.596	1.307	20	0.011*
	GII	2.140	2.047	20	
vAm(%)	GI	13.73	5.29	20	0.099*
	GII	11.13	4.09	20	

Captions: F_0 - Fundamental frequency; Hz – Hertz; NHR – Noise-to-harmonic ratio; vF_0 – Fundamental frequency variation; vAm – Amplitude variation

* Significant values (p<0.05) = Mann-Whitney Test

Among the parameters analyzed, there was a statistically significant difference between groups only with respect to the vF_0 (p= 0.011) and vAm (p= 0.099) acoustic parameters.

Table 4 compares groups GI and GII regarding the results of perceptual-auditory assessment of the vowel /a/ and speech.

A statistically significant difference was observed in the speech resonance parameter, whereas GI showed deviations in this respect (p=0.011) characterized by hyponasality (n = 1), hypernasality (n = 6) and laryngopharyngeal resonance (n = 1). No difference was found between groups with respect to the remaining parameters, both regarding the vowel /a/ and with respect to speech.

There was an interjudge agreement in the assessment of the sustained vowel for parameters: roughness, breathiness, tension, presence of pitch and loudness deviation. No agreement was reached with regard to the overall degree of voice impact, instability and resonance. In relation to speech, no agreement was reached only on the resonance parameter, whereas intra-concordance agreement was obtained on the other parameters previously described.

Table 4. Comparison between perceptual-auditory parameters of the vowel /a/ and speech in groups GI and GII

Type of emission	Parameters	Groups	Mean (millimeters)	Standard Deviation	N	p-value
Vowel /a/	Overall Degree	GI	3.40	6.21	20	0.986
		GII	2.95	6.90	20	
	Roughness	GI	2.15	4.85	20	0.638
		GII	1.30	3.73	20	
	Breathiness	GI	7.65	12.02	20	0.975
		GII	6.25	8.25	20	
	Tension	GI	0.00	0.00	20	1.000
		GII	0.00	0.00	20	
	Pitch	GI	4.00	10.71	20	0.638
		GII	1.75	4.67	20	
	Loudness	GI	0.35	1.57	20	0.317
		GII	0.00	0.00	20	
	Instability	GI	9.85	9.95	20	0.562
		GII	9.95	12.60	20	
	Resonance	GI	12.00	4.10	20	0.681
		GII	11.50	3.66	20	
Speech	Overall Degree	GI	1.67	4.85	18	0.842
		GII	1.40	3.44	20	
	Roughness	GI	0.00	0.00	18	0.343
		GII	0.75	3.35	20	
	Breathiness	GI	3.33	10.98	18	0.848
		GII	1.25	3.93	20	
	Tension	GI	0.00	0.00	18	1.000
		GII	0.00	0.00	20	
	Pitch	GI	5.94	14.48	18	0.333
		GII	3.00	10.44	20	
	Loudness	GI	0.00	0.00	18	1.000
			0.00	0.00	20	
	Instability	GI	0.00	0.00	18	1.000
		GII	0.00	0.00	20	
	Resonance	GI	18.89	10.79	18	0.011*
		GII	10.00	0.00	20	

* Significant values (p<0,05) = Mann-Whitney Test

Table 5 presents the relation between the acoustic and auditory-perceptual results of voice and speech perception of GI participants.

Table 5. Correlation between acoustic and auditory-perceptual parameters of the voice with speech perception in group I

Evaluation	Parameters	Speech perception – IT-MAIS/MAIS	
Vowel /a/ Acoustics	F_0	Corr (r)	-26.2%
		p-value	0.279
	Jitter	Corr (r)	-47.0%
		p-value	0.042*
	Shimmer	Corr (r)	-40.6%
		p-value	0.085
	NHR	Corr (r)	-25.2%
		p-value	0.297
	vF_0	Corr (r)	-47.8%
		p-value	0.038*
	vAm	Corr (r)	-32.1%
		p-value	0.180
Auditory-perceptual of vowel /a/	Overall Degree	Corr (r)	-54.9%
		p-value	0.015*
	Roughness	Corr (r)	-44.7%
		p-value	0.055
	Breathiness	Corr (r)	-26.8%
		p-value	0.267
	Tension	Corr (r)	- x -
		p-value	- x -
	Pitch	Corr (r)	17.4%
		p-value	0.475
	Loudness	Corr (r)	28.5%
		p-value	0.237
	Instability	Corr (r)	-28.1%
		p-value	0.244
	Resonance	Corr (r)	-5.4%
		p-value	0.827
Auditory-perceptual of speech	Overall Degree	Corr (r)	-3.8%
		p-value	0.884
	Roughness	Corr (r)	- x -
		p-value	- x -
	Breathiness	Corr (r)	-1.1%
		p-value	0.966
	Tension	Corr (r)	- x -
		p-value	- x -
	Pitch	Corr (r)	-32.8%
		p-value	0.199
	Loudness	Corr (r)	- x -
		p-value	- x -
	Instability	Corr (r)	- x -
		p-value	- x -
	Resonance	Corr (r)	18.1%
		p-value	0.487

Captions: F_0 - IT-MAIS - Infant-Toddler Meaningful Auditory Integration Scale; MAIS- Meaningful Auditory Integration Scale; F_0 – Fundamental frequency; NHR – Noise-to-harmonic ratio; vF_0 – Variation of fundamental frequency; vAm – Amplitude variation; - x –Unable to use statistics

* Significant values ($p<0.05$) = Spearman Correlation Test

A negative correlation could be observed between the IT-MAIS / MAIS scores of the auditory perception of speech sounds and the acoustic parameters of jitter (r = -47.0%, p = 0.042) and vF_0 (r = -47.8%, p = 0.038) of vowel /a/, and between the former and the perceptual-auditory parameter of overall degree of vowel /a/ (r = -54.9%, p = 0.015).

DISCUSSION

This study aimed at comparing acoustic and auditory-perceptual results of the voice of hearing-impaired children and adolescents with their hearing peers and correlating these results with parents' reports on auditory speech perception.

Regarding the fundamental frequency, it was observed that, although the group of hearing-impaired children and adolescents presented numerically higher-pitch voices than that of children and adolescents with normal hearing, the mean F_0 values of both groups were close to each other, corroborating the findings of the literature available[3,9,12].

Studies show mean normal values for F_0 of 263.15 Hz in males between 4 and 6 years old; 263.74 Hz, between 5 and 7; 245.90 Hz, between 7 and 9; 237.97 Hz, between 8 and 9; 231.41 Hz, between 10 and 11; 234.29 Hz, between 10 and 12; 195.84 Hz, at 12 years old; 128.28 Hz, between 13 and 15; 121.34 Hz, between 16 and 18; a total of 209 Hz for males between 4 and 18 years of age, where the total range spans from 103 Hz to 297 Hz[21-23].

The same authors found average values for F_0 of 261.28 Hz in females between 4 and 6 years old; 267.98 Hz, between 5 and 7; 249.81 Hz, between 7 and 9; 241.24 Hz, between 8 and 9; 238.29 Hz, between 10 and 11; 242.60 Hz, between 10 and 12; 226.13 Hz, at 12 years old; 219.03 Hz, between 13 and 15; 223.79 Hz, between 16 and 18; a total of 247 Hz for females between 4 and 18 years of age, where the total range spans from 277 Hz to 208 Hz[21-23].

Mean normal values of F_0 are also described for both genders, as follows: 241.50 Hz for children between 3 and 9 years old; 255.06 Hz at 5; 253.18 Hz at 6; 248.87 Hz at 7; 250.06 Hz, between 4 and 12; and 270.93 Hz between 5 and 7 years old[21,24,25,26].

A wide variation is observed in the data found in the literature, which is probably due to the methods employed. However, comparing results found for hearing-impaired children in this research, it can be said that they are compatible with normal values found in other surveys[21-26].

The results of this study also showed that the mean fundamental frequencies of males in GI and GII were higher in the age range between 3 and 4 years old, and lower in the age range between 15 and 18, which can be explained by significant differences resulting from the anatomical and physiological development of the organism which, consequently, impact the functional characteristics of the larynx, modifying the voice[22,23,27].

Among females, F_0 averages varied both in GI and GII in the different age ranges, which is explained by the constant maturation of phonatory structures that takes place at this stage and by the non-linearity of vocal changes in different genders and age groups[22,23,28]. Furthermore, the literature reports that the normality standard of the fundamental frequency in females is reached at age 14, with a transition period beginning at 11, when the F_0 decreases[22,23].

As for the acoustic parameters of vowel /a/, it was found that the voices of children and adolescents who are users of HA and CI showed close results when compared with those of hearing children and adolescents. Only the vF_0 and vAm parameters differed between groups, with hearing-impaired individuals (GI) and hearing peers (GII), conforming to the results found in the literature[5,14,29].

The vF_0 and vAm parameters are indicators of vocal instability, which is considered a feature typical of the voice of hearing-impaired individuals, due to the difficulty in vocal control caused by the deficit in auditory feedback. As auditory feedback is established and the hearing-impaired person starts to experience the world of sound, he/she can develop the vocal maturation and phonatory control necessary to balance vocal quality[5,14,29].

Regarding the perceptual-auditory results of vowel /a/ and speech, a similarity was also observed between the vocal production of hearing-impaired individuals and normal hearers, where only the resonance deviation in speech emission of the participants of GI was different. It is worth noting that resonance was the only parameter of the speech task in which the interjudge agreement was not obtained. We emphasize the importance of auditory-perceptual assessment in complementing the global impression of vocal quality[30]. Although this evaluation was carried out by consensus of two experienced speech therapists, its result pointed out difficulties in perception of the resonance of children and adolescents with hearing loss, indicating a need to understand aspects that may have influenced these data and, still, to perform appropriate and specific training for this parameter, when evaluating this population.

The correlation between acoustic and perceptual-auditory vocal parameters and speech perception of GI participants showed that the higher the IT-MAIS/MAIS score, the lower the deviation from jitter parameters, fundamental frequency variation and overall degree of impact of the voice regarding the vowel /a/. Bearing in mind that jitter and fundamental frequency variation are measures of frequency disturbance in the short and long term, respectively, and reflect voice control, the results found reinforce the benefits of using hearing aids and IC and of auditory rehabilitation in vocal control[15].

The literature reports the relation between higher voice perception scores and lower deviation in vocal quality aspects—among which are the overall degree of voice impact and pitch deviation—in addition to showing that hearing-impaired children who use spoken language and have participated in a hearing rehabilitation program show jitter measurements and overall degree of voice impact similar to those of their hearing peers[1,3,5].

The findings of this study reinforce the importance of using technological devices (HA and CI), as these provide access to speech sounds and, thus, the hearing feedback indispensable for vocal control and balance of acoustic and auditory-perceptual measures of the voice of hearing-impaired individuals[3].

Additionally, this work showed the impact of auditory rehabilitation—with an emphasis on the use of auditory skills and spoken language—on vocal aspects, emphasizing its relevance and that of the focus on the specific vocal work during the speech therapy process. The findings of this survey also contribute to guide appropriate interventions in the auditory rehabilitation process.

It is worth noting that the number of participants is justified by the fact that this population was served by the same hearing rehabilitation program, which used the inclusion criteria of the survey.

In the future, with the impact of public policies contemplating early diagnosis and intervention, this research may be replicated analyzing all demographic variables (chronological age, age of the child/adolescent at the time of diagnosis, type and degree of hearing impairment, age at adaptation of HA or CI activation, period of sensory deprivation, time of therapy centered on the development of hearing and spoken language) and auditory capacity in relation to vocal aspects.

CONCLUSION

Results have shown that access to perception of speech sounds with technological devices (HA or CI) by a group of children who used spoken language and took part in a hearing rehabilitation program were similar to that of their hearing peers in practically all-vocal parameters analyzed, differing in the fundamental frequency variation (vF_0), amplitude variation (vAm) and resonance parameters.

A negative correlation was observed between the IT-MAIS/MAIS score and jitter, vF_0 and overall degree of voice impact, i.e. the auditory perception of speech sounds influenced the vocal control of the studied group, in which hearing-impaired children and adolescents who presented higher scores for speech perception were also able to maintain a more balanced vocal emission.

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REFERENCES

1. Coelho ACC, Bevilacqua MC, Oliveira G, Behlau M. Relationship between voice and speech perception in children with cochlear implant. Pró-Fono R. Atual. Cient. 2009; 21(1):7–12. https://doi.org/10.1590/S0104-56872009000100002
2. Moret ALM, Bevilacqua MC, Costa OA. Cochlear implant: hearing and language in pre-lingual deaf children. Pró-Fono R. Atual. Cient. 2007;19(3):295–304. https://doi.org/10.1590/s0104-56872007000300008. PMid:17934605
3. Souza LBR de, Bevilacqua MC, Brasolotto AG, Coelho AC. Cochlear implanted children present vocal parameters within normal standards. Int J Pediatr Otorhinolaryngol. 2012;76(8):1180–3. https://doi.org/10.1016/j.ijporl.2012.04.029. PMid:22652499
4. Coelho AC, Brasolotto AG, Bevilacqua MC. Systematic analysis of the benefits of cochlear implants on voice production. J Soc Bras Fonoaudiol. 2012;24(41):395–402. https://doi.org/10.1590/S2179-64912012000400018.
5. Knight K, Ducasse S, Coetzee A, Van der Linde J, Louw A. The effect of age of cochlear implantation on vocal characteristics in children. South

African J Commun Disord. 2016;63(1):1–6. https://doi.org/10.4102/sajcd.v63i1.142. PMid:27380914

6. Fabron EMG, Garcia YS, Delgado-Pinheiro EMC. The voice of the hearing impaired: a literature review. Distúrbios Comum. 2017;29(1):55–67. https://doi.org/10.23925/2176-2724.2017v29i1p55-67
7. Van Lierde KM, Vinck BM, Baudonck N, De Vel E, Dhooge I. Comparison of the overall intelligibility, articulation, resonance, and voice characteristics between children using cochlear implants and those using bilateral hearing aids: A pilot study. Int J Audiol. 2005;44(8):452–65. https://doi.org/10.1080/14992020500189146. PMid:16149240
8. Horga D, Liker M. Voice and pronunciation of cochlear implant speakers. Clin Linguist Phonetics. 2006;20(2–3):211–7. https://doi.org/10.1080/02699200400027015. PMid:16428239
9. Souza LBR. Differences between vocal parameters of cochlear implanted children and children who use individual sound amplification device. Rev CEFAC. 2013;15(3):616–21. https://doi.org/10.1590/S1516-18462013005000027
10. Jafari N, Yadegari F, Jalaie S. Acoustic Analysis of Persian Vowels in cochlear implant Users: A Comparison With Hearing-impaired Children Using Hearing Aid and Normal-hearing Children. J Voice. 2016;30(6):763.e1–763.e7. https://doi.org/10.1016/j.jvoice.2015.10.006. PMid:26725549
11. Jafari N, Izadi F, Salehi A, Dabirmoghaddam P, Yadegari F, Ebadi A, et al. Objective Voice Analysis of Pediatric cochlear implant Recipients and Comparison With Hearing Aids Users and Hearing Controls. J Voice. 2017;31(4):505.e11–505.e18. https://doi.org/10.1016/j.jvoice.2016.10.018. PMid:27865551
12. Joy J V, Deshpande S, Vaid N. Period for Normalization of Voice Acoustic Parameters in Indian Pediatric cochlear implantees. J Voice. 2017;31(3):391.e19–391.e25. https://doi.org/10.1016/j.jvoice.2016.09.030. PMid:28029557
13. Novaes BCAC, Versolatto-Cavanaugh MC, Figueiredo RSL, Mendes BCA. Determinants of communication skills development in children with hearing impairment. J Soc Bras Fonoaudiol. 2012;24(4):335–41. PMid:23306683
14. Coelho AC, Brasolotto AG, Bevilacqua MC. An initial study of voice characteristics of children using two different sound coding strategies in comparison to normal hearing children. Int J Audiol. 2015;54(6):417–23. https://doi.org/10.3109/14992027.2014.998784. PMid:25634776
15. Coelho AC, Brasolotto AG, Bevilacqua MC, Moret ALM, Júnior FB. Hearing performance and voice acoustics of cochlear implanted children. Braz J Otorhinolaryngol. 2016;82(1):70–5. https://doi.org/10.1016/j.bjorl.2015.11.002
16. Cysneiros HRS, Leal MC, Lucena JA, Muniz LF. Relação entre percepção auditiva e produção vocal em implantados cocleares: uma revisão sistemática. CoDAS. 2016;28(5):634–9. https://doi.org/10.1590/2317-1782/20162015165
17. Bicas RS, Guijo LM, Delgado-Pinheiro EMC. Oral communication and auditory skills of hearing impaired children and adolescents and the speech therapy rehabilitation process. Rev CEFAC. 2017;19(4):465–74. https://doi.org/10.1590/1982-0216201719412516
18. Yavas M, Hernandorena CLM, Lamprecht RR. Avaliação Fonológica da Criança. 1st ed. Porto Alegre: Artmed; 2001
19. Castiquini EAT. Escala de integração auditiva significativa: procedimento adaptado para a avaliação da percepção da fala [dissertação]. São Paulo(SP): Pontifícia Universidade Católica; 1998. Adopted from: Zimmerman-Phillips S; Osberger MJ; Robbins AM. Infant-Toddler: Meaningful Auditory Integration Scale (IT-MAIS). Sylmar, Advanced Bionics Corporation, 1997
20. Castiquini EAT, Bevilacqua MC. Escala de integração auditiva significativa: procedimento adaptado para a avaliação da percepção da fala. Rev Soc Bras Fonoaudiol. 2000;4(6):51–60
21. Tavares ELM, Brasolotto A, Santana MF, Padovan CA, Martins RHG. Epidemiological study of dysphonia in 4-12 year-old children. Braz J Otorhinolaryngol. 2011;77(6):736–46. PMid:22183280
22. Maturo S, Hill C, Bunting G, Ballif C, Maurer R, Hartnick C. Establishment of a normative cepstral pediatric acoustic database. Arch Otolaryngol Head Neck Surg. 2012;138(10):956–61. https://doi.org/10.1001/jamaoto.2014.3545. PMid:25612091
23. Spazzapan EA. Características acústicas da voz de falantes do português brasileiro nos diferentes ciclos da vida [dissertação]. São Paulo(SP): Universidade Estadual Paulista; 2018
24. Cappellari VM, Cielo CA. Vocal acoustic characteristics in pre-school aged children. Braz J Otorhinolaryngol. 2008;74(2):265–72. https://doi.org/10.1016/s1808-8694(15)31099-5. PMid:18568207
25. Natour YS, Wingate JM. Fundamental Frequency Characteristics of Jordanian Arabic Speakers. J Voice. 2009;23(5):560–6. https://doi.org/10.1016/j.jvoice.2008.01.005. PMid:18640820
26. Lopes LW, Lima ILB, Almeida LNA, Cavalcante DP, Almeida AAF. Severity of voice disorders in children: Correlations between perceptual and acoustic data. J Voice. 2012;26(6):819e7-819e12. https://doi.org/10.1016/j.jvoice.2012.05.008. PMid:23177753
27. Soltani M, Ashayeri H, Modarresi Y, Salavati M, Ghomashchi H. Fundamental frequency changes of persian speakers across the life span. J Voice. 2014;28(3):274–81. https://doi.org/10.1016/j.jvoice.2013.10.012. PMid:24461477
28. Stathopoulos ET, Huber Je, Sussman JE. Changes in Acoustic Characteristics of the Voice Across the Life Span: Measures From Individuals 4–93 Years of Age. J. Speech Lang. Hear. Res. 2011;54(4):1011–21. https://doi.org/10.1044/1092-4388(2010/10-0036). PMid:21173391
29. Holler T, Campisi P, Allegro J, Chadha NK, Harrison RV., Papsin B, et al. Abnormal Voicing in Children Using cochlear implants. Arch Otolaryngol Head Neck Surg. 2010;136(1):17–21. https://doi.org/10.1001/archoto.2009.194. PMid:20083772
30. Oates J. Auditory-perceptual evaluation of disordered voice quality.Folia Phoniatr Logop. 2009;61(1):49–56. https://doi.org/10.1159/000200768. PMid:19204393

Authors contributions

EMCDP: Study design, data collection and preparation of the database, analysis of results and preparation of the manuscript; JCB: Study design, data collection and preparation of the database, analysis of results and preparation of the manuscript; FRS: Bibliographic updating, review of analyzed data and preparation of the manuscript; EMGF: Study design, data collection and preparation of the database, analysis of results and preparation of the manuscript.