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Aerodynamic, eletroglottographic and acoustic measures of the voiced postalveolar fricative

Medidas aerodinâmicas, eletroglotográficas e acústicas na produção da fricativa pós-alveolar vozeada

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Keywords

Speech Sound Disorders
Speech Production Measurement
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ABSTRACT

Purpose: Describe and correlate phonological and complementary measures regarding aerodynamics, electroglottography, acoustics, and perceptual judgment of production of the voiced fricative sound /ʒ/ comparing the performance of Brazilian Portuguese-speaking children with and without speech sound disorders. **Methods:** Study participants were 30 children aged 5 years to 7 years and 11 months divided into a group of children with typical development - Control Group (CG) and a group of children with speech sound disorders - Research Group (RG). Phonology (PCC, PCC-R, and occurrence of phonological processes) and the aerodynamic (amplitude of the oral airflow and f0), eletroglottographic (open quotient) and acoustic (classification of voicing) measures were evaluated. **Results:** Numerically, children with speech sound disorders presented higher relative oral airflow amplitude, lower relative f0, and open quotient indicative of less efficient voicing production compared with those of children with typical development. The weak voicing values showed that 66.1% of the children with speech sound disorders presented weaker voicing of the fricative sound /ʒ/ compared with that of the posterior vowel sound, and between-groups comparison demonstrated that these children presented greater difficulty in voicing. The acoustic analysis of speech used to classify the weak/strong voicing showed variations, especially regarding the classification partially devoiced. **Conclusion:** Results suggest that the strategies for voicing production and voicing maintenance of the fricative sound /ʒ/ are still variable in children aged 5 years to 7 years and 11 months; however, children with speech sound disorders seem to have more difficulties in using them effectively. In addition, the study shows the importance of applying complementary tests to obtain a more detailed diagnosis.

Descritores

Transtorno Fonológico
Medida da Produção da Fala
Avaliação
Criança
Fonoaudiologia

RESUMO

Objetivo: Descrever e correlacionar medidas fonológicas à aerodinâmica, EGG, acústica e julgamento perceptivo da produção do som /ʒ/, comparando o desempenho de crianças com e sem transtorno fonológico, falantes do Português Brasileiro. **Método:** Participaram 30 crianças com idade entre 5:0 e 7:11 anos separadas em grupo controle e grupo de crianças com transtorno fonológico. Avaliou-se a fonologia (cálculo de PCC e PCC-R e ocorrência dos processos fonológicos) e as medidas aerodinâmicas (amplitude do fluxo aéreo oral e f0), eletroglotográficas (quociente de abertura) e acústicas (classificação do vozeamento). **Resultados:** As crianças com transtorno fonológico apresentaram, numericamente, amplitude do fluxo oral relativo maior, f0 relativo menor e quociente de abertura indicativo de uma voz menos eficiente na produção do vozeamento quando comparadas às crianças sem transtorno fonológico. Os valores de *weak voicing* demonstraram que, em 66,1% das crianças com transtorno fonológico, o vozeamento da fricativa foi mais fraco, comparado ao da vogal seguinte, e a comparação entre grupos indicou que essas crianças apresentaram maior dificuldade no vozeamento. Quanto à descrição da classificação de vozeamento, de acordo com a análise acústica e do *weak/strong voicing,* verificou-se que há algumas variações, principalmente para a classificação "parcialmente desvozeado". **Conclusão:** Os resultados sugerem que as estratégias de produção e manutenção do vozeamento da fricativa vozeada /ʒ/ ainda são variáveis em crianças na idade estudada, porém as crianças com transtorno fonológico parecem ter mais dificuldades em utilizá-las de modo eficaz. Além disso, o estudo aponta para a importância da aplicação de provas complementares para um diagnóstico mais detalhado.

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INTRODUCTION

In Brazilian Portuguese (BP), voicing in speech production is an important aspect in distinguishing speech sounds, and children with speech sound disorders (SSD) present difficulties in their production and maintenance. SSD is one of the most frequent communication disturbances in children[1]. It is characterized by impairments in sound production caused by cognitive-linguistic, auditory-perceptual, and/or motor speech difficulties. Presence of SSD may cause speech intelligibility of varying degrees and manifestations, which can lead to reading and writing problems because these skills depend on phonological awareness for their learning and development[2].

SSD of undefined cause may be associated with difficulties in organization of the phonological rules of a language. During the process of language development, children may manifest some simplifications of these rules, called phonological processes[3].

The phonological process of fricative devoicing (FD), the focus of this study, has been observed in children with SSD, and is characterized by lack of vocal fold vibration in the voiced fricative phonemes /v, z, ʒ/[4,5].

Its diagnosis is based on the evaluation of the different fields of language (phonology, vocabulary, pragmatics, and fluency). After assessment of phonology, which can be conducted using the tasks of picture naming, imitation of words, and/or spontaneous speech, it is important to establish an index that indicates the initial severity of SSD and that can also show the evolution of the case after Speech-language Therapy[5], such as Percentage of Consonants Correct (PCC)[6] and Percentage of Consonants Correct-Revised (PCC-R)[7].

Refinement of SSD diagnosis can be obtained through the application of other tests, called complementary tests, such as acoustic analysis of speech, electroglottography (EGG), and aerodynamic measures. Complementary tests, such as acoustic analysis of speech, enable spectrographic analysis of the sounds[8]. EGG captures the variations in tissue conductance when the vocal folds are open or closed during phonation[9]. Aerodynamic measurements enable determination of the oral airflow amplitude, an inference of the aerodynamics of trans-glottal oral flow, as well as estimation of fundamental frequency (f0). This is important because there are several anatomical structures and mechanisms involved in the voicing of fricatives[10], such as the lungs, which act as a source of air pressure during phonation, and this pressure can indicate how efficiently the larynx converts aerodynamic energy into acoustic energy[11,12].

Given the lack of research in this area, the study of EGG and aerodynamic and acoustic measures can contribute to a detailed analysis of the strategies used by children in voicing production and maintenance. Therefore, the objective of this study was to describe and correlate phonological and complementary measures regarding aerodynamics, EGG, and perceptual judgment of production of the voiced fricative sound /ʒ/, comparing the performance of Brazilian Portuguese-speaking children with and without SSD.

This study aims to answer the following questions: The lower the severity index, PCC and PCC-R, the greater the relative oral airflow amplitude and open quotient? Do children with and without SSD present different strategies for voicing production and maintenance of the voiced fricative sound /ʒ/ (aerodynamic measures and EGG)?

METHODS

This survey was approved by the Research Ethics Committee (CaPPesq) of Hospital das Clínicas and Faculdade de Medicina da Universidade de São Paulo (HC/FMUSP) under protocol number no. 036/14. After being informed about the procedures, all parents and/or legal guardians of the participants signed an Informed Consent Form (ICF) prior to study commencement. All children agreed to participate in the study.

Study sample

Study participants were 30 children aged 5 years to 7 years and 11 months divided into two groups: 15 children with typical speech-language development – Control Group (CG) and 15 children with speech sound disorders – Research Group (RG).

The RG was divided into two subgroups according to percentage of fricative devoicing (FD) in the phonological process: children with FD≤25% and FD>25%.

To compose the RG, children with speech sound disorders (SSD) were selected at the Laboratory of Speech-language Pathology Research in Phonology (LIF-Fonologia) of the Speech-language Pathology course of the Departamento de Fisioterapia, Fonoaudiologia e Terapia Ocupacional of the Faculdade de Medicina da Universidade de São Paulo, where this study was conducted between 2014 and 2016. Inclusion criteria for the RG were as follows: children aged 5 years to 7 years and 11 months (60 to 95 months); with presence of phonological processes not expected for the age in the assessment by the Phonology task from the Infantile Language Test-ABFW[13]; audiological evaluation within normality (thresholds <20dB at 500, 1000, 2000 and 4000 Hz frequencies); non-verbal IQ within the limits of normality[14]; speakers of Brazilian Portuguese (BP) whose parents were also speakers of BP.

The CG was composed of children with speech-language development typical for the age, selected at an Elementary School located in the district of Butantã (west zone of the city of Sao Paulo), as well as by means of voluntary participation after invitation. Inclusion criteria for the CG were as follows: children aged 60 to 95 months; without complaints of communication impairment reported by parents and/or legal guardians and teachers; with adequate performance on the vocabulary[15] and phonology[13] sections of the Infantile Language Test-ABFW; without hearing complaints; speakers of Brazilian Portuguese (BP) whose parents were also speakers of BP.

Material and procedures

Phonology assessments of the Infantile Language Test-ABFW were recorded in audio (portable recorder Zoom H4N) and video (camcorder Sony HDR-CX220) and subsequently transcribed phonetically by two speech-language pathologists experienced in the field of speech sound disorders (SSD). For each of the phonology tasks, namely, picture naming (PN) and imitation of

words (IW), the phonological processes and phonetic inventory were analyzed and the Percentage of Consonants Correct (PCC) and Percentage of Consonants Correct–Revised (PCC-R) indices were calculated. Only substitutions and omissions were considered as errors for the PCC-R index[7], whereas the adaptation to BP performed by Wertzner[16] was used for the PCC index.

Speech electroglottography (EGG) and oral airflow amplitude measures were collected simultaneously using the respective equipment, Glottal Enterprise - EG2-PCX2 and Aeroplus - AeroviewPro Phonatory Aerodynamics System. The pieces of equipment connect an audio interface (iMic, Griffin, USA) to a laptop computer (Dell Inspiron 114-3437-A45) running Waveview Pro 4.5. Prior to data collection, two electrodes were placed on the sides of the thyroid cartilage to capture the EGG and a Rothenberg mask was placed in the mouth for oral airflow collection. A short training was conducted to adjust the Rothenberg mask to each child for collection of oral airflow amplitude.

For acoustic analysis of speech, three extra naming items of each stimulus were audio recorded using a microphone (Behringer ECM8000). Collection and analysis of the speech samples regarding duration of the fricative sound and voicing classification were processed using the Praat 6.0.20 software.

For collection of speech samples, a sequence of 12 pictures (randomly repeated four times each, totaling 48 naming items) was presented with one of the fricative consonants (/f/ or /v/ or /s/ or /z/ or /ʃ/ or /ʒ/) followed by a high vowel and a low vowel. The pictures were named by the children and the files saved in the laptop computer. This study is linked to a research that involves all the aforementioned fricative sounds, but only the words with the target sound /ʒ/ were analyzed: <jogo> and <jota>. The /ʒ/ sound was chosen for analysis because it is a more posterior sound, thus more difficult to be produced. The description of the EGG and aerodynamic measures that children with and without SSD use to produce friction and voicing in the /ʒ/ sound can contribute to a better understanding of this mechanism. Among the four repetitions, the three best repetitions of each word were selected by an experienced speech-language therapist, totaling six naming items analyzed with the target sound /ʒ/ for each child.

In EGG, the open quotient (OQ) was analyzed, which is associated with efficiency of voice use. It is not always possible to observe/calculate the OQ for the voiced fricatives because the moments of closing and opening of the vocal folds cannot always be defined accurately[4,10,11].

In the aerodynamic analysis, the measures of oral airflow amplitude and fundamental frequency (f0) of the consonant and the posterior vowel of each emission were calculated. The relative measures of oral airflow amplitude and f0 (calculated from the absolute measures) were calculated as proposed by Pinho et al.[10,17]. This measure was adopted because the absolute measures are important for the analysis of vocal quality, but from the linguistic (phonological) standpoint, the relative measures (from the consonant in relation to the posterior vowel) are more adequate because they assist with understanding laryngeal behavior during sound production. The values of f0 reflect the voicing strategies in sound production that combine lowering of the larynx with abduction of the vocal folds and the trans-glottal pressure required to maintain vibration. In general, voiced fricatives tend to present lower f0 values as a function of lowering of the larynx, with a greater longitudinal tension of the vocal folds[10], indicating weaker voicing of the vowel. The percentage of weak voicing, a measure defined based on the amplitude of the relative oral airflow, indicates the relation of the voiced fricative with the posterior vowel. Weak voicing values >70% indicate that the voicing of the fricative is weak compared with that of the posterior vowel, whereas lower values indicate strong voicing[10].

Analysis of the measures occurred in three stages: first, the collected data was saved in *.wav* format and segmented into 48 files that were then converted into *.prt* files using the Praat 6.0.20[18] software; next, the fricatives and the posterior vowel were recorded following the criteria established by Pinho et al.[10,17]; finally, six scripts were applied using Praat 6.0.20 and Matlab[12,15] to extract the necessary measures.

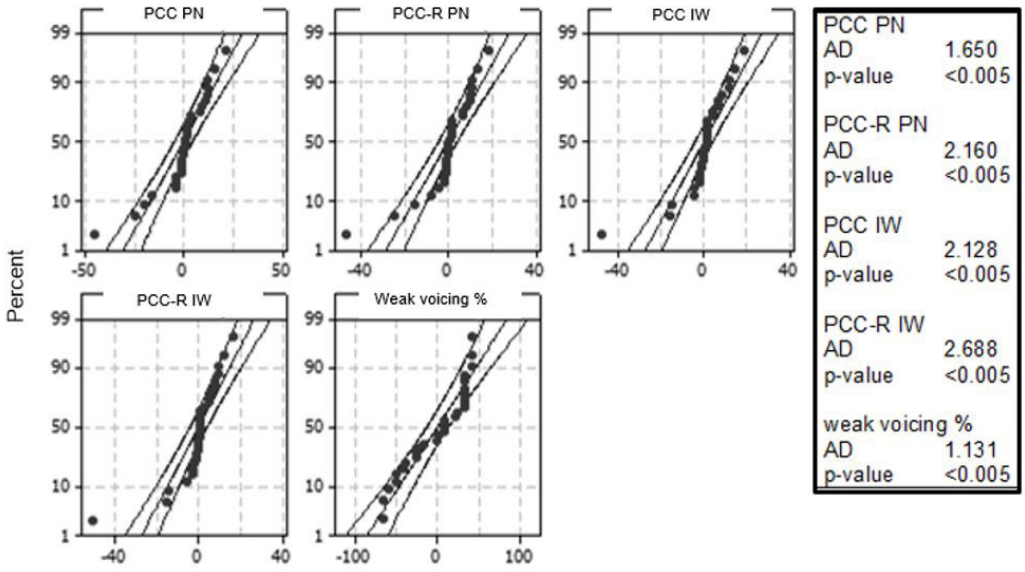
The speech samples collected for acoustic analysis of speech enabled classification of the voicing category of fricatives as proposed by Jesus and Shadle[19]. Fricatives were classified as (1) devoiced, when less than one-third of the frication interval showed periodic curve; (2) partially devoiced, when more than one-third but less than half of the frication interval contained steady periodic acoustic signals; (3) voiced, when more than half of the frication interval showed steady periodic signals, even if the amplitude was lower than in the vowels. To this end, the scripts were applied in Praat 6.0.20 as established by Pinho et al.[10,17].

It is worth noting that the classification of weak voicing/strong voicing is based on oscillations of the oral airflow signal, which are associated with sound production, whereas the three categories of voicing are associated with the periodic measures of the acoustic signal of the sound[10].

In addition to these analyses, an auditory-perceptual assessment of the productions of all children was conducted by a speech-language pathologist experienced in the area. The same classification of voicing proposed by Jesus and Shadle[19] was used, and each repetition of the words was heard twice. The data were tabulated in Excel spreadsheet.

Statistical analysis

Non-parametric tests were applied in the statistical analysis because the data did not present distribution of assured normality (Figure 1). For the comparison analyses regarding age, aerodynamic measures, and EGG between the groups, the Mann-Whitney test was applied at significance level of 0.05 with 95% confidence intervals. The Spearman's correlation coefficient was used to measure correlation between Percentage of Consonants Correct (PCC), Percentage of Consonants Correct–Revised (PCC-R), relative oral airflow amplitude, and absolute open quotient (OQ) of each group. The Kappa interrater agreement index was used to analyze the concordance between the Control Group (CG) and Research Group (RG) regarding the classification of devoiced, partially devoiced, and voiced between the Praat script and the auditory-perceptual analysis of the speech-language therapist.



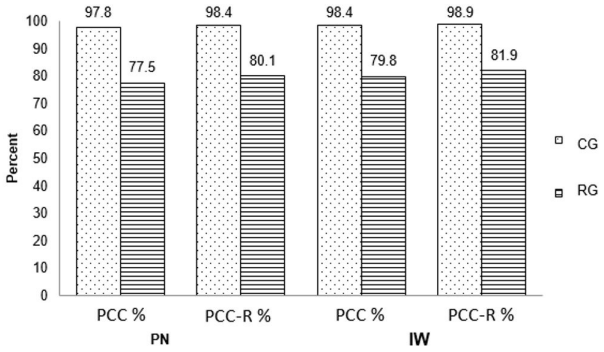
Anderson Darling Test. Caption: PCC = percentage of consonants correct; PCC-R = percentage of consonants correct-revised; PN = picture naming task; IW = imitation of words task
Figure 1. Normality distribution

RESULTS

Description of participants' ages and phonological measures

No statistically significant difference was observed between the mean ages of the children in the Control Group (CG) (79 months) and Research Group (RG) (78 months), (p=0.787).

Figure 2 shows the mean values of the Percentage of Consonants Correct (PCC) and Percentage of Consonants Correct–Revised (PCC-R) indices for the children in the two groups. The mean PCC-R values of the RG indicate presence of speech sound disorders (SSD), whereas the mean values of the CG indicate speech with occurrence of few or no phonological processes.



Caption: PCC = percentage of consonants correct; PCC-R = percentage of consonants correct-revised; PN = picture naming task; IW = imitation of words task; CG = control group; RG = research group
Figure 2. Mean values for the PCC and PCC-R indices at the tasks of picture naming and imitation of words for the CG and RG

Analysis of aerodynamic measures and Electroglottography (EGG)

Table 1 presents the comparisons between the CG and RG for the relative oral airflow amplitude measures, fundamental frequency (f0), weak voicing, and open quotient (OQ). No statistically significant differences were found between the groups for any of the measures analyzed.

No statistically significant correlations were observed between measures of PCC, PCC-R, relative oral airflow amplitude, and OQ in the CG and RG, in both groups (Table 2).

Comparison between the subgroups (individuals with fricative devoicing (FD) production of FD≤25% and FD>25%) of the RG regarding the measures of relative oral airflow amplitude, relative f0, and absolute OQ did not show significant differences between them (Table 3).

Classification of voicing by acoustic and weak voicing analyses

Figure 3 presents the occurrences, in percentage, of voicing classification by the Praat script according to the weak voicing value of individuals in the CG(a) and RG(b). The descriptive analysis of weak voicing and the acoustic analysis by the Praat script suggest that the greater the weak voicing, the higher the percentages of classifications 1 and 2.

Classification of voicing by acoustic and auditory-perceptual analyses

Agreement was observed regarding voicing classification between the Praat script and the auditory-perceptual analysis of the speech-language therapist; however, this concordance was considered weak for both the CG (Kappa=0.110) and the RG (Kappa=0.282).

Table 1. Comparison between the CG and RG regarding the measures of relative airflow amplitude, weak voicing, relative fundamental frequency, and absolute open quotient

		Mean	Median	Standard deviation	Q1	Q3	N	CI	*p*-value
Relative oral airflow amplitude (%)	CG	70.8	71.0	16.2	57.3	83.7	15	8.2	0.591
	RG	73.3	83.0	21.2	60.1	88.2	14	11.1	
Weak voicing (%)	CG	57.3	67.0	32.7	33.0	81.5	15	16.6	0.421
	RG	66.1	87.5	41.1	25.3	100.0	14	21.5	
Relative f0 (%)	CG	3.8	1.2	6.0	0	8.0	13	3.3	0.437
	RG	1.1	-0.3	13.8	-10	8.5	12	7.8	
Absolute open quotient (%)	CG	51.8	50.0	17.5	47.0	57.6	9	11.4	0.167
	RG	61.4	61.3	20.4	53.8	74.0	8	14.1	

Mann-Whitney test
Caption: f0 = fundamental frequency; CG = control group; RG = research group; Q1 = 1st quartile; Q3 = 3rd quartile; N = sample size; CI = confidence interval

Table 2. Correlation between PCC, PCC-R, mean of relative oral airflow amplitude, and mean of absolute open quotient in the CG and RG

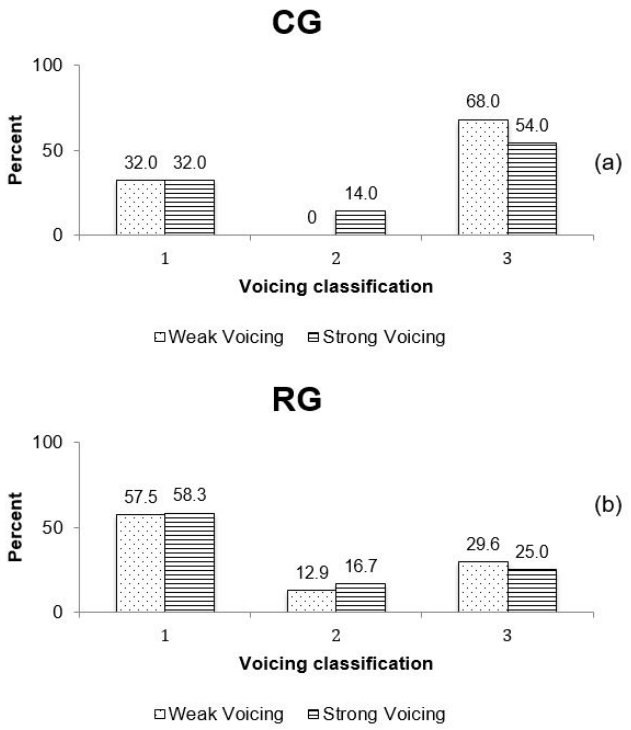
CG		PN		IW	
		PCC	PCC-R	PCC	PCC-R
Relative oral airflow amplitude	CC (*r*)	30.40%	30.40%	34.10%	32.60%
	p-value	0.270	0.270	0.214	0.236
Absolute open quotient	CC (*r*)	5.10%	5.10%	-18.00%	-21.00%
	p-value	0.896	0.896	0.642	0.587
RG		**PN**		**IW**	
		PCC	**PCC-R**	**PCC**	**PCC-R**
Relative oral airflow amplitude	CC (*r*)	14.30%	14.30%	2.90%	-8.40%
	p-value	0.625	0.625	0.923	0.776
Absolute open quotient	CC (*r*)	10.90%	10.90%	-15.70%	-22.90%
	p-value	0.797	0.797	0.711	0.586

Spearman's rank correlation coefficient
Caption: CC (*r*) = correlation coefficient; CG = control group; RG = research group; PN = picture naming task; IW = imitation of words task; PCC = percentage of consonants correct; PCC-R = percentage of consonants correct-revised

Table 3. Comparison between the RG subgroups regarding the measures of relative oral airflow amplitude, relative fundamental frequency, and absolute open quotient

		Mean	Median	Standard deviation	Q1	Q3	N	CI	*p*-value
Relative oral airflow amplitude (%)	FD≤25%	72.1	83	23.1	60.1	88.8	10	14.3	>0.999
	FD>25%	76.3	83.7	18.4	72.1	87.9	4	18	
Relative f0 (%)	FD≤25%	7.9	7.1	15.1	2.2	12.8	4	14.8	0.283
	FD>25%	-2.3	-5.4	12.7	-10.5	5	8	8.8	
Absolute open quotient (%)	FD≤25%	59.6	57.6	23.5	51.3	75.4	6	18.8	0.643
	FD>25%	67.1	67.1	6.7	64.7	69.4	2	9.3	

Mann-Whitney test
Caption: f0 = fundamental frequency; FD = fricative devoicing; Q1 = 1st quartile; Q3 = 3rd quartile; N = sample size; CI = confidence interval



Caption: 1 = devoiced; 2 = partially devoiced; 3 = voiced; CG = control group; RG = research group

Figure 3. Analysis of the occurrence of voicing classification according to the weak voicing measure in children in the CG (a) and RG (b)

DISCUSSION

Studies conducted with children speakers of Brazilian-Portuguese with manifest speech sound disorders (SSD) have demonstrated that voicing production and voicing maintenance of fricative sounds are among their most frequent difficulties[4,5,17,20].

The use of equipment for collection of aerodynamic data in children is little reported in the literature. Thus, this study sought to employ equipment and techniques of collection, mainly of data analysis, already used for adult speakers. The relative oral airflow amplitude, relative fundamental frequency (f0), and weak voicing were investigated. These three measures were first proposed by Pinho et al.[10,17] and address measures associated with the posterior vowel that offer better conditions for comparing data between individuals. These measures provide information on airflow, laryngeal configuration, and vocal fold tension, which are important elements for the production and maintenance of voicing.

Subsequently, the open quotient of the vocal folds (OQ) was analyzed. OQ enables verification of the control of vocal fold abduction. This is another important element in the voicing production and maintenance of fricative sounds.

Analysis of the aerodynamic and eletroglottographic measures of the fricative sound /ʒ/ showed that the Research Group (RG) presented relative oral airflow amplitude higher than that of the Control Group (CG); values of fundamental frequency (f0) were higher in the RG compared with those in the CG; the open quotient (OQ) indicated less efficient voice in the RG when the means between the two groups were compared; the weak voicing values obtained show that in 66.1% of RG voicing of the investigated fricative was weaker compared with that of the posterior vowel; comparison between the subgroups of the RG regarding fricative devoicing (FD) (FD≤25% and FD>25%) showed that the FD>25% subgroup presented greater difficulty in voicing, although no statistically significant difference was found between the groups.

It is worth emphasizing the factors that influence voicing maintenance: place of articulation – the more posterior the places of articulation, the greater the chances of devoicing; word-position – a voiced obstruent is more likely to be produced in medial position than in the initial and final positions; consonant duration - the longer the consonant duration, the greater the chance of devoicing; context - coarticulation with open vowels facilitates voicing maintenance[10].

Previous studies conducted with adults have shown that the articulation zone of the sound interferes with voicing production and maintenance, and it is more difficult to maintain voicing during the production of posterior sounds[19]. The /ʒ/ sound, object of this study, is a posterior fricative sound; the position of the sound in the stimulus word is initial and coarticulated with a closed vowel and, because it is fricative, it is a long-duration sound. As noted, these characteristics indicate that production of the /ʒ/ sound may be more difficult for children with SSD, as demonstrated by the descriptive results of this study. It is worth noting that there were sample losses for some productions due to problems of data acquisition in children, which prevented their analysis from being performed.

In general, fricative sounds are among the most impaired in children with SSD[17,20]. Considering the voiced fricative sounds, in addition to the need to produce friction, it is also necessary to maintain the voicing.

Voicing occurs when the vocal folds are adducted and tense, when trans-glottal pressure is sufficient to cause positive airflow pressure in the glottis to maintain vibration. However, maintenance of voicing in fricatives can be problematic, because the constriction needed to produce the friction noise can only be sustained with sufficient decrease in trans-glottal pressure[21].

These factors assist with explaining the qualitative difference found between the CG and the RG regarding the voicing production and maintenance of the /ʒ/ sound. The absence of significant difference between the groups also reflects speech motor development, which is still occurring in children from this age group[22]. The correlation analysis between aerodynamic measures and electroglottography (EGG) regarding the severity indexes in both groups of children suggests that, in this age group, children do not demonstrate a differentiation in the strategies used to produce voicing, which indicates absence of association of phonological measures with speech production.

With respect to description of the voicing classification according to the acoustic analysis of the Praat script and weak/strong voicing, variations were observed, mainly for the classification of the acoustics (partially devoiced), in relation

to the weak/strong voicing values. This difference between the two analyses may occur because of their specific natures. As reported by Pinho et al.[10], such difference arises from the fact that the oscillations recorded in the airflow of the fricatives present low amplitudes and few high frequencies and, therefore, do not produce significant acoustic excitation and are weakly associated with the periodic measures of the acoustic signal.

Weak concordance was observed regarding voicing classification between the Praat script and the auditory-perceptual analysis of the speech-language therapist. This finding can be explained by the fact that the acoustic cues used by the listeners for the classification of voicing vary widely, and a listener can prioritize one cue to the detriment of others, e.g., duration of the fricative[23].

Results of this study suggest that the strategies for voicing production and voicing maintenance of the fricative sound /ʒ/ are still variable in children aged 5 years to 7 years and 11 months (60 to 95 months), as observed in the aerodynamic measures and EGG; however, children with speech sound disorders seem to have more difficulties in using them effectively. These findings demonstrate that, in Brazilian Portuguese, the /ʒ/ sound represents a great challenge for children with SSD and voicing difficulties. Therefore, there is evidence that speech-language pathologists should avoid initiating, whenever possible, interventions on the production and maintenance of voicing with this sound.

CONCLUSION

In the present study, it was possible to analyze the phonological, acoustic, aerodynamic, and EGG measures of the voiced fricative sound /ʒ/. Results suggest that the strategies for voicing production and voicing maintenance of the fricative sound /ʒ/ are still variable in children within the age group investigated; however, children with speech sound disorders seem to have more difficulties in using them effectively. In addition, the study shows the importance of applying complementary tests to obtain a more detailed diagnosis.

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Author contributions

PTH participated in the collection and analysis of the data and writing of the manuscript; LOPN and LMTJ participated in the analysis and interpretation of the data and writing of the manuscript; HFW was the study adviser, responsible for its design, and participated in the analysis and interpretation of the data and writing of the manuscript.