Frequency Measurement of Vowel Formants Produced by Brazilian Children Aged Between 4 and 8 Years

*Flávia Viegas, †Danieli Viegas, and ‡Heidi Elisabeth Baeck, *†‡*Rio de Janeiro, RJ, Brazil*

Summary: Objective. To investigate frequency measurement of the first three formants of the seven oral Brazilian Portuguese vowels of healthy children aged 4–8 years.

Methods. Two hundred seven children of both genders were selected by oral expression screening and perceptive-auditory analysis. They were separated into four age groups (G1, G2, G3, and G4) and by gender. The voice signals were obtained from key sentence utterance and segments of the seven Brazilian Portuguese oral vowels in tonic position used to estimate formant frequency measurement. Software Praat was used to for processing the recordings.

Results. Findings were presented by mean values of each of the investigated parameters. A rate of 61.90% of statistically significant differences between genders was found, and when analyzing the age groups and genders, we observed that 65 of the 84 items studied (seven vowels × three formant frequencies × four groups) had higher frequencies of formants for girls. There was a decrease in the frequencies values of the first three formants with age. The results recommended grouping of G1 and G2, and they showed a clear difference between this new formed group and G4. In the age groups of 5-year old to 6 years 11 months (G2 and G3) and 6-year old to 7 years 11 months (G3 and G4), there were statistically significant changes that were random for parameter and vowel. There was a decrease in the frequencies values of the first three formants with age.

Conclusion. Formant frequencies showed a tendency to differentiate genders and their absolute values were in general higher in girls. Age increases showed decreases in formant frequencies. Tests for statistical differences led to grouping of G1 and G2 and a clear difference between this new formed group and G4. The comparison between G2 and G3 and G3 and G4 showed random changes. The changes during this age period (5-year old to 7 years 11 months) were attributed to a transition stage of acoustic measurements in children. As formant frequencies vary according to structural and postural aspects of the vocal tract and speech organs, their study in healthy children contributes for the understanding of the development of the pediatric phonation system, in addition to offering a reference data set for future studies of children with vocal disorders that can potentially impact the resonance system.

Key Words: Vowels–Formant frequencies–Infant vocalization–Acoustical analysis–Vocal tract development.

INTRODUCTION

Acoustic assessment methods are valuable tools to study speech and voice development and their disorders. Although acoustic analyses may present some limitations, technological advances, especially in digital signal processing, have favored their reliability and validity.[1]

Most of the studies using acoustic analysis have focused on adults, but many investigations in children's voice have gained momentum in the literature.[1–13] Similarly to other countries, when assessing children's voice, Brazilian investigators follow the trend to assess laryngeal parameters.[14–17] Supralaryngeal parameters, such as formant frequencies, are presented by few authors.[18,19]

The study of formant frequencies during childhood is important, given that it portrays the different development processes, such as growth of vocal tract structures, changes in its geometry, maturation of speech motor control, and convergence into adult speech patterns.[1] Gender analysis is equally important because some authors have reported differences in those measures in children.[3,4,7] Collecting data of formant frequencies from normal children is extremely relevant because it can serve as baseline measures in clinical applications, as they can be used to compare against data from children with speech and voice disorders.

Taking into account the scarcity of supraglottic acoustic data for Portuguese spoken in Brazil, the present study intended to investigate frequency measures of the first three formants of seven oral vowels in Portuguese in healthy children aged 4–8 years.

METHODS

This present study is a cross-sectional analysis of seven vowel segments produced by 207 children, both genders, between the age of 4 and 8 years. The subjects were grouped according to age range: 4 years to 4 years 11 months (G1); 5 years to 5 years 11 months (G2); 6 years to 6 years 11 months (G3), and 7 years to 7 years 11 months (G4). The study protocol was approved by the Research Ethics Committee of the City Health Department of Rio de Janeiro, under number 180/2008.

There were two steps to set the final sample: a preselection phase and a selection phase. In the preselection phase, the authors went to the Sectors of Pediatrics and Dental Care of the Policlinica Maria Cristina Roma Paugartten (City Health

TABLE 1.
Distribution of the Informants by Age Group and Gender

Gender	4-Year-Olds to Uncompleted 5-Year-Olds (n)	5-Year-Olds to Uncompleted 6-Year-Olds (n)	6-Year-Olds to Uncompleted 7-Year-Olds (n)	7-Year-Olds to Uncompleted 8-Year-Olds (n)
Male	22	28	24	24
Female	21	33	29	26

Department, Rio de Janeiro) and in two schools to explain pre-selection criteria to health care professionals (pediatricians and dentists) and educators (teachers). The inclusion criteria were aged between 4 years and 7 years 11 months, good general health status, and fluent oral expression. Following these inclusion criteria, 232 children were selected.

After preselection, they were referred to the Sector of Speech and Hearing Therapy of the health care unit. After complying with the ethical procedures, the children underwent two selection procedures: (1) oral expression screening and (2) perceptive-auditory analysis of the voice. During these procedures, 25 children were excluded.

In the first selection procedure, oral expression was systematically analyzed using Phonetic Test Realfa (*Exame Fonetico Realfa*)[20] whose main purpose was to exclude children with oral expression below the expected performance for the age range. In the second selection procedure, spontaneous speech and repetition of key sentences were recorded to be used for perceptive-auditory assessment and data collection, respectively. In a quiet room, a Shure microphone (model number: SM 58) (SHURE, UK) was positioned 10 cm from the child's lips, and the speech was recorded in monochannel and the sample rate was 22.050 Hz, using software *Praat* (version 4.3.27), generating .wav files.

The perceptive-auditory analysis, based on spontaneous speech, was performed by the authors who are speech and voice therapists, specialized in voice. The laryngeal source was assessed based on the RASATI scale,[21] the Brazilian adaptation of grade, roughness, breathiness, asthenia, strain (GRBAS) scale. The resonance system was assessed using a script,[21] which included the following items: nasal, pharyngeal, laryngopharyngeal, "cul-de-sac," and balanced resonance.

Children who presented inappropriate patterns in one or more assessments were excluded. Voices were considered appropriate if they scored grade 0 (absent) in the items of scale RASATI, except for the parameter breathiness, which was considered appropriate for grade 1 (mild) as well. This tolerance level was adopted because in children, the normal range may include mild breathiness.[15] When assessing resonance, voices were considered appropriate when they had balanced resonance, that is, when the focus of the resonance was distributed without predominance of any other focus.

Recordings used to carry out the present study included segments of the seven oral vowels in Portuguese in tonic position, obtained from the key sentence: "*Fale___ para mim*" (Say ____ to me), completed with the words "pápa," "pépe," "pêpe," "pípi," "pópo," "pôpo," and "púpu." Using software *Praat*, each vowel segment was cut and processed, estimating the frequency of the three first formants (F_1, F_2, and F_3).

Vowel cutting was made manually based on clearly defined criteria. Initial cutting was made at the ascending moment in which energy reached 20% of its maximum energy. Likewise, the final cut was defined at the descending moment in which energy reached 20% of its maximum energy. The 20% cutoff was defined based on experimental investigations, and it is a conservative measure to reduce the likelihood of reaching nonstationary excerpts. It is important to explain that the cutting criteria have completely excluded the obstruent /p/ from the analyzed excerpt. The main function of the obstruent was exclusively to facilitate vowel production by the children.

As a result of the large number of estimates involved (8.694), the authors have developed a *Praat* script that enabled the estimate of parameters in an automated and standardized fashion. The formants measurements were obtained from this script using the technique of burg (Appendix).

Data obtained from processing were submitted to statistical analysis using software SAS 6.04 (SAS Institute, Inc., Cary, NC).

TABLE 2.
Average and Standard Deviation (SD) of the Frequencies of the First, Second, and Third Formants of the Vowel /a/

Parameters	Sex	G1, 4-Year-Olds to Uncompleted 5-Year-Olds		G2, 5-Year-Olds to Uncompleted 6-Year-Olds		G3, 6-Year-Olds to Uncompleted 7-Year-Olds		G4, 7-Year-Olds to Uncompleted 8-Year-Olds	
		Average	SD	Average	SD	Average	SD	Average	SD
F_1 (Hz)	Male	1093	193.9	1010	219.8	984	88.5	870	195.4
	Female	1187	163.3	1256	154.3	1131	175.6	1048	132.1
F_2 (Hz)	Male	2003	156.4	1889	180.5	1814	157.6	1668	201.3
	Female	2157	190.0	2141	143.8	2063	174.8	1914	187.2
F_3 (Hz)	Male	3593	408.7	3536	404.2	3480	224.0	3326	211.8
	Female	3661	357.7	3528	310.5	3476	316.9	3402	276.0