Long-term Average Spectra Analysis of Voice in Children With Cleft Palate

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Summary: Objectives. The purpose of this study was to survey the spectral characteristics and to compare, using an acoustic analyzer, the objective data obtained from patients with cleft palates with the objective data of normal children using long-term average spectra (LTAS) analysis.

Methods. Participants were divided into a clinical group and a control group. All participants were asked to practice reading a sentence to become fluent. The duration of each recording was about 60 seconds. All samples were subjected to acoustic analysis using *Praat* software. All recordings were analyzed acoustically using LTAS.

Results. In this study, there was no significant difference between the control group and the clinical group in the low-frequency region (boys: 0–2720 Hz; girls: 0–2240 Hz). LTAS measurements showed a great difference between the control group and the clinical group in the middle-frequency region (boys: 2720–4000 Hz; girls: 2240–4000 Hz). We also found that the energy distributed in the clinical group was lower than that of the control group in the high-frequency region (4000 Hz–8000 Hz) in both boys and girls.

Conclusions. The results reveal a lack of flat region in the middle-frequency range in the clinical group (both boys and girls) in comparison with the control group. The results also reveal that there is no significant difference across the control group and the clinical group in the low-frequency region.

Key Words: Long-term average spectra (LTAS)–Acoustic analyzer–Cleft palate–Spectra analysis–Velopharyngeal insufficiency.

INTRODUCTION

A cleft palate is one of the most common congenital malformations in the maxillofacial region. It seriously affects oral and maxillofacial morphology and function, particularly speech. Velopharyngeal insufficiency (VPI) is a common problem resulting from cleft palate repair. Whenever there are structural anomalies in the cavities of the vocal tract, there is a risk for distortion in speech sound, production, and resonance. Therefore, a secondary surgery may be needed to treat VPI, especially because speech therapy is much more effective if it is begun after the normalization of the structure.[1,2] Patients with cleft palate often exhibit nasality, which is a distinctive feature and an important target in speech therapy. The voice and speech of patients with cleft palate have been studied using many techniques including spectral, perturbation, and formant analyses.[3] There are several spectral characteristics associated with the hypernasality of patients with a cleft palate, such as a reduction of the first formant (F1), the presence of extra resonance, and a decrease of second formant (F2).[4] Several indexes based on voice spectral analysis have been proposed to evaluate hypernasality, such as the difference between the amplitude of F1 and the amplitude of the extra peak,[5] the difference between the amplitude of F1 and the amplitude of the first nasal peak, and one-third octave spectral analysis.[4]

Auditory-perceptual evaluation has been commonly used to assess the quality of voice and the severity of voice and speech disorders. This method is convenient in terms of expense, time, and complexity of the procedure. However, it relies on subjective judgment, thus entailing the limitation of interobserver variability. Fortunately, voice characteristics can now be objectively analyzed with numerical values, using an acoustic analyzer. Acoustic analysis programs are able to generate data related to speech disorders easily and noninvasively in a relatively short time, and in a sensitive, objective, and quantitative manner.[6]

Using recent developments in digital technology and methods for processing speech, it is possible to make effective and objective acoustic diagnostics for the assessment and management of voice disorders. Often, however, greater objectivity is needed in characterizing certain features of the spectrograms. A more objective measure can be offered by long-term average spectra (LTAS), which provides information on spectral energy distribution of speech signals during a relatively long speech sample. LTAS have been applied to assessing overall perceived voice quality, evaluating overall intelligibility of speech and speech clarity, providing a normal database for spectral measurements,[7–9] differentiating sex and age groups from each other,[10–12] studying the voice therapeutic process and comparing the effectiveness of different treatment approaches,[13] developing a formula for fitting more suitable hearing aids for native speakers of each language, and studying emotional states and effects.[14] Most studies of LTAS have been concerned with normal speakers of English[15–18] and many statistically significant differences have been found among them. Few articles, however, have been found to report the use of LTAS for assessing the voices of individuals with cleft palates.[19] In addition, few studies have been conducted in Chinese.

LTAS analysis allows quantifying the quality and provides an overview of the mean spectral characteristics of voice. Therefore, the aim of the present study was to compare differences among Chinese children with cleft palates and normal Chinese children based on the source characteristics of dynamic speech using LTAS.

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MATERIALS AND METHODS

Participants

Participants were divided into a clinical group and a control group. Each participant was recorded phonating a short text containing 80 words in his or her natural voice and at a normal reading speed. The 80 words in the short text contained all the vowels of Chinese. Before recording, all participants were asked to practice reading the sentence to become fluent. The duration of each recording was about 60 seconds (mean duration: 61.8 seconds; standard deviation [SD]: 4.3). All samples were subjected to acoustic analysis using *Praat* software version 4.1.2 (developed by Boersma and Weenink, the University of Amsterdam, Amsterdam, the Netherlands). All recordings were analyzed acoustically by LTAS.

The clinical group comprised 20 boys (mean age: 7.1 years; SD: 1.1) and 20 girls (mean age: 7.4 years; SD: 1.3), ranging in age from 6 to 9 years. All the patients in the clinical group experienced VPI after cleft palate surgery. All participants in the clinical group were aged younger than 3 years when they underwent the surgery, a two-flap palatoplasty. There is no fistula in all the palates after surgery. VPI was diagnosed by an experienced laryngologist using an endoscopy procedure when the children were in resting position. The medical treatment was not initiated in any of the participants at the time of voice recording. All the patients in the clinical group presented with various voice disorders. No fistula or dehiscence occurred in any of the patients. All patients with VPI in the clinical group then underwent surgery after the data collection and accepted speech therapy 3–4 months after surgery. Normal hearing was tested by using a behavioral pure-tone audiometry. Patients with neurological disorders were excluded.

The control group comprised 20 boys (mean age: 7.4 years; SD: 1.2) and 20 girls (mean age: 6.9 years; SD: 1.3), ranging in age from 6 to 9 years. The following criteria were fulfilled to be included in the clinical group: (1) none of them had a history of vocal abuse or misuse; and (2) none of the participants in the control group were reported to have had a history of speech or hearing anomalies by an experienced laryngologist.

The participants were all reported to have Chinese as their primary language. The study protocol was carefully explained to the parents or legal guardians. All participants cooperated in the study voluntarily. Informed consent was obtained from all the participants and their parents or legal guardians. The institutional ethics committee approved the protocol.

Experimental procedure

Each participant was instructed to vocalize the same several sentences containing 80 words for about 60 seconds at a comfortable voice level and tone. They all were not instructed to control the loudness during the reading. All vocalizations were recorded with a microphone (YM-63F; Yamaha Corporation, Shizuoka-ken, Japan) and *Cool Edit Program* software (Version 2.1; Adobe Systems Corporation, San Jose, CA) in a soundproof room, and the distance of the microphone from the participants' mouths was 10 cm. The frequency response of the microphone is 100 Hz to 10000 Hz.

Analysis

Acoustic analysis was performed using the aforementioned *Praat* software. All recordings samples were digitized on a computer at a 22-kHz sampling rate, with 16 bits of resolution. Using a Hanning window, the amplitude values were measured at intervals of 160 Hz with a frequency range of 0–8 kHz, and a time resolution of 40 ms. For each speaker, a total of 50 amplitude measurements were obtained. The acoustic measurements were all obtained automatically using the *Praat* software. Similar to previous studies,[20] 40 seconds of the center of each sample were analyzed, which is regarded as sufficient to get the LTAS independent of the speech material. According to Lofqvist and Mandersson,[21] unvoiced elements in the LTAS analysis would corrupt data. Therefore, to perform the LTAS, all devoiced sounds, pauses, and silences were automatically excluded from the analysis by the script used by da Silva et al.[16]

The Statistical Package for the Social Science, Version 16.0 (SPSS Inc, Chicago, IL) was used to perform all statistical analyses.

RESULTS

Mean spectral energy

The mean spectral energy values for boys in the control group and clinical group at each of the 50 frequency levels are shown in Figure 1. The results for girls are shown in Figure 2.

The highest amplitude in the normal boys and boys with cleft palate occurred in the region of 320 Hz, and it was also observed in the region of 320 Hz in the normal girls and girls with cleft palate. The average spectrum for each group of participants demonstrated that there is a peak in the region of 320 Hz, with a reduction at the higher frequencies.

Boys

In the normal boys, a 24.2-dB decrease was found from the frequency of 320 Hz to 2720 Hz. The difference was less than 4 dB between 2720 Hz and 4000 Hz, so there was a flat region between 2720 Hz and 4000 Hz. A 35.8-dB intensity decrease was observed between 4000 Hz and 8000 Hz. In the boys with cleft palate, a 19.3-dB decrease was found from the frequency of 320 Hz to 2720 Hz. The difference between 2720 Hz and 4000 Hz was 10.1 dB. It is much bigger than 4 dB of the normal boys in this region. Thus, there was not a flat region observed in this range of boys with cleft. A 29.2-dB decrease was found in 4000 Hz–8000 Hz (Figure 3).

Girls

In the normal girls, a 23.1-dB decrease was found from the frequency of 320 Hz to 2240 Hz. The difference was 2 dB between 2240 Hz and 4000 Hz, so a flat region was also found between these frequencies. A 25.5-dB intensity difference was observed between 4000 Hz and 8000 Hz. In the girls with cleft, a 20.6-dB decrease was found from the frequency of 320 Hz to 2240 Hz. The difference was 8.9 dB between 2240 Hz and 4000 Hz. It is much bigger than 2 dB of the normal girls in this region. Thus, there was not a flat region observed in this range of girls with

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