A Comparative Study of the Speaking Fundamental Frequency Characteristics in Children with Cleft Palate

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Descriptions of the speaking characteristics of cleft palate persons have been primarily concerned with the articulatory (*21, 30*) and resonance aspects (*18, 21, 26*) of speech production with limited attention directed toward phonation. Information that is available regarding phonation has been confined to subjective descriptions of voice quality (*5, 25*) and to speculation about the effects of velopharyngeal coupling on vocal pitch and intensity (*7, 21*). Cobb and Lierle (*5*), for example, reported that there was a general lack of pitch variation and vocal intensity in the cleft subjects they studied. Ritchie (*25*) stated that a "flat monotone" intonation pattern is typical of voices of persons with clefts. Breathiness and hoarseness (*2, 19*) as well as harshness (*1*) are some of the voice quality disorders that have been reported for this group. In addition, research has suggested that changes in vocal pitch may influence the perception of harshness (*8, 11*) as well as to hoarseness (*11, 31*), further emphasizing the need for objective evaluation of the fundamental frequency characteristics of these speakers.

Curtis (*7*) has suggested that insufficient velopharyngeal closure may also affect intensity and fundamental frequency. He speculated that because of greater energy absorption accompanying nasalization, the cleft palate speaker cannot produce as much vocal intensity as would be the case if he could attain velopharyngeal closure. To maintain a given level of intensity, the speaker must expend a greater amount of respiratory effort and hence increase subglottic pressure. Based on the data of several investigators (*13, 15, 29*), Curtis suggested that this increase in subglottic pressure will involuntarily tend to raise the speaker's mean voice frequency for all intensity levels as well as limit the lower end of the frequency range.

There may be additional reasons why fundamental frequency differences are possible between cleft and noncleft speakers. Some cleft

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speakers use compensatory movements in an effort to improve misarticulation or hypernasality (*19, 28*). Because of the anatomical relationship between the tongue and the larynx, it seems reasonable to assume that any compensatory activity involving the tongue, such as tongue carriage (*4*) or tongue-palate valving (*3*), could potentially affect the extent and rate of movement of the larynx, thus altering frequency parameters (*14*).

Objective information regarding fundamental frequency characteristics in cleft speakers relative to noncleft speakers is needed to validate reports in the literature that pitch differences between the groups do exist. The purpose of this study was to obtain information about the speaking fundamental frequency characteristics of children with repaired cleft palates.

Method

SUBJECTS. Two groups of 12 children each were subjects in this study. The cleft lip and/or palate group consisted of nine males and three females between the ages of 7 years and 8 years, 11 months. All cleft subjects had palatal surgical repair initiated between the ages of 12 and 27 months. An attempt was made to match noncleft control subjects to cleft subjects as closely as possible for age, height, and weight factors. The medians and ranges for both groups are presented in Table 1. All children passed an audiometric sweep-frequency screening test (20 dB, ISO) in the better ear for 500–4000 Hz. No child with a known neurological or laryngeal pathology was included.

RECORDING PROCEDURE. Subjects were seen individually for the administration of an articulation test and a manometric examination. After this, a speech recording was made. The Iowa Pressure Articulation Test (*23*) was administered to all subjects. Manometric quotients were obtained using the standard technique described by Morris (*22*). A Hunter Oral Manometer, Model 360, with bleed valve in use was employed to measure air pressures, both positive and negative, in ounces per square

TABLE 1. Medians and ranges for age, height, and weight for 12 cleft and 12 noncleft groups.

group	*subject physical characteristics*		
	age (in months)	*height (in inches)*	*weight (in pounds)*
cleft			
median	94.0	49.0	56.5
range	86.0–106.0	45.0–55.0	49.0–65.0
noncleft			
median	97.0	50.0	54.5
range	89.0–107.0	47.5–56.5	42.0–67.0

TABLE 2. Manometric quotients and percent of correct responses on the Iowa Pressure Articulation Test for 12 cleft and 12 noncleft groups.

group	*mean manometric quotient*		*mean articulation score (per cent correct responses)*
	positive pressure	*negative pressure*	
cleft	.84	.73	68.5
noncleft	.97	.98	91.7

inch. Included in Table 2 are the scores for both the Iowa Pressure Articulation Test and the manometric quotients for each group.

Speech samples were recorded on magnetic tape using an Ampex 601 recorder and associated directional microphones (Electro-Voice 664, Altec Model 20, and Shure Model 36F). Subject availability required that recordings be made in a variety of settings. The experimenter judged environmental sound levels at each location as being low ambient noise. The subject was given a copy of a standard prose reading passage (*10*) and was instructed to read the passage silently. When he indicated that the task was completed, he was asked to read it aloud until the experimenter felt the child could perform the task adequately. The subject was then positioned with the microphone at a distance of 12 inches from the lips and an optimum record level was determined. The child was then given the following instructions and a recording was made. "Read the passage aloud as you have just done. Read it as you would to your class in school".

FUNDAMENTAL FREQUENCY ANALYSIS. An Ampex Model 351-2 tape recorder (7½ inches per second) was used to play back the experimental recordings for analysis. The speech signal was led into a high pass filter (Krohn-Hite Variable Filter Model 314 R) with a high pass cut-off at 140 Hz to eliminate 60 Hz noise present on some recordings. The output from the filter was passed into a Honeywell Galvanometer Amplifier Model T6GA-100 which in turn was connected to a Honeywell Visicorder Model 1108 which was used to display the speech signal. A paper speed drive of 40 inches per second enabled a display of sufficient amplitude and wavelength to be measured easily. The standard phonellographic technique (*6*) was employed for measurement of the speech wave trace. Average periodic values were the basic data in a computer program[1] used to analyze all fundamental frequency measures. The number of complete waveforms for each measured segment was recorded on IBM punch cards for computer processing. The program is designed to determine a frequency distribution of the mean period values from each segment and results in values for mean fundamental frequency in Hz, standard deviation and total range in semitones as well as a melody

[1] Montgomery, A., Melody plot program for grouped data: a computer program. Purdue University, 1967. A copy of this program, *Program Melody for Grouped Data*, is on file at the University of Wisconsin Computing Center, W. Dayton Street, Madison, Wisconsin.

plot. The program was run on the CDC 3600 computer at the University of Wisconsin Computing Center.

Results

FUNDAMENTAL FREQUENCY DISTRIBUTION MEASURES. The means and ranges of the mean fundamental frequency in Hz for the cleft and noncleft groups are presented in Table 3. The average fundamental frequency level of the cleft group (251.7 Hz) was somewhat higher than the average fundamental frequency level of the noncleft group (241.5 Hz), however, this difference between the two groups was less than one semitone and was not statistically significant.

The means and ranges of the fundamental frequency standard deviations for the cleft and noncleft groups are also presented in Table 3. The standard deviation values for the noncleft group are slightly higher (3.0 semitones) than that value obtained for the cleft group (2.7 semitones). The mean difference was not significant at the .05 level of significance.

The computer output for the grouped frequency data provided a plot of the frequency distribution of average period expressed in semitone intervals (upper and lower limits, 987.8 Hz to 32.7 Hz). The corresponding center frequencies in Hz of the interval were also listed. Total range was calculated by finding the difference between the highest and lowest semitone intervals in which the highest and lowest fundamental frequencies fell. Group means and ranges for total range in semitones for both subject groups are shown in Table 3. Mean total range values of 33.9 semitones for the cleft group and 30.8 semitones for the noncleft group were found. Although the cleft group obtained a higher mean value for total range, the difference between the groups was not statistically significant.

The functional or 90% range was determined by finding the difference between the semitone interval at the 5th centile of the distribution and the 95th centile of the distribution. Group means for functional range for both groups are presented in Table 3 in which it is observed that the mean of the functional range for the noncleft group (9.6 semi-

TABLE 3. Group means and ranges for fundamental frequency in Hz, standard deviation, total range and functional range in semitones for 12 cleft and 12 noncleft subjects.

group	*fundamental frequency characteristics*			
	mean (in Hz)	*SD (in S.T.)*	*total range (in S.T.)*	*functional range (in S.T.)*
cleft				
mean	251.7	2.7	33.9	7.6
range	211.4–301.2	1.5–3.8	21.0–42.0	4.0–11.0
noncleft				
mean	241.5	3.0	30.8	9.6
range	214.0–263.4	2.3–4.4	21.0–44.0	6.0–14.0

tones) was higher than that of the cleft group (7.6 semitones). A t test was used to analyze the significance of difference in mean number of semitones. The obtained t was not significant. Although the range measure differences were not statistically significant, it can be noted (see Table 3) that the cleft group had a greater mean total range (33.9 semitones) than the noncleft group with a mean value of 30.8 semitones; whereas, the noncleft group (9.6 semitones) had a greater functional range than the cleft group (7.6 semitones).

FUNDAMENTAL FREQUENCY INFLECTION MEASURES. Group means and ranges for number of upward and downward inflections for both cleft and noncleft groups are presented in Table 4. An inflection is defined as an uninterrupted change in vocal frequency that exceeds one semitone in extent (*8*). Note that this definition refers only to change in acoustic signal and is not to be interpreted as implying a perceptual unit such as linguistic intonation. Average number of upward inflections obtained were 145.8 and 90.3 for the cleft and noncleft subjects, respectively. Similarly ordered mean values of 154.7 and 104.8 for the two groups were obtained for number of downward inflections. Both of these differences were found to be significant at the .01 level.

Group means and ranges for extent of upward and downward inflections in semitones for both groups are shown in Table 4. It is observed that the average extent of upward inflections was greater for the noncleft subjects (3.5 semitones) than for the cleft subject (2.9 semitones). The same relation was found for the extent of downward inflections with the noncleft group obtaining a mean of 3.8 semitones. The t value for the difference between groups on the extent of upward inflections was significant at the .01 level. For extent of downward inflections, the obtained t value was significant at the .05 level.

Discussion

The results of the distribution measures and those of the inflectional measures suggest somewhat different though not necessarily contradictory

TABLE 4. Group means and subject ranges for number and extent of upward and downward inflections for cleft and noncleft subjects.

group	*inflection measures*			
	number of inflections		*extent of inflections (in semitones)*	
	upward	*downward*	*upward*	*downward*
cleft				
mean	145.8	154.7	2.9	3.2
range	77–236	86–249	2.3–3.9	2.4–4.6
noncleft				
mean	90.3	104.8	3.5	3.8
range	83–129	80–140	3.0–4.0	3.4–4.3

conclusions about pitch usage in the cleft palate speakers. Results of the distribution measures, which are statistical representations of the basic vocal period data, failed to support an hypothesis of difference between the cleft and noncleft speakers. It would appear, then, that cleft and noncleft speakers, as represented by the present sample, do not use different pitch levels and do not differ in the dispersion and range of vocal periods produced. However, the inflectional measures, which more closely represent the dynamic aspect of vocal production by maintaining information about vocal period sequencing, were found to be different in the two groups. It is these latter measures that will be the focus of the discussion.

Interpretation of inflectional data based on fundamental frequency measurement is made difficult because descriptions of perceptual correlates of fundamental frequency are limited. However, some investigators (*17, 24*) have suggested that there is a relation between pitch variability, extent of inflections, and vocal effectiveness. These researchers report that there is a tendency for voices judged as less effective to exhibit less average variability as shown by fundamental frequency standard deviations and inflectional measures. The cleft subjects in this study used a significantly smaller extent of inflection than their matched controls. If restricted variation contributes to judgments of vocal ineffectiveness (*17*), it seems reasonable to hypothesize that the less variability in pitch usage for the cleft sample may contribute to the over-all perceptual differences noted in voice quality in some cleft palate speakers.

The cleft palate children had a significantly greater number of both upward and downward inflections. If the time spent in phonation for the cleft group was longer than that for the noncleft group, the probability of finding a greater number of inflections would be increased. A post-hoc analysis of reading time and over-all reading rate for the two groups was performed to test the plausibility of this explanation. The analysis revealed that the cleft group, with a mean reading time of 49.6 seconds and a range of 28 to 77 seconds, had a reading time almost twice as long as the noncleft group, with a mean of 29.3 seconds and a range of 22 to 44 seconds. Consequently, the cleft group had a smaller word per minute rate (105.4 wpm; range of 60.6 to 166.8 wpm) than the noncleft children (164.8 wpm; range of 123.0 to 212.4 wpm). The difference between the means for the reading rate measure was significant at the .01 level of significance. An inspection of the computer output showed that the cleft subjects also had a greater number of data points, confirming that these subjects spent a longer period of time in actual phonation. The significant differences found for the inflectional data as well as the differences observed for rate and phonation time imply that certain prosodic elements of speech, at least pitch variation and duration, were differentiating features of the speech of the cleft and noncleft children in this study.

Analyses by Lieberman (*16*) directed at isolating the acoustic correlates of stress and intonation in normal speakers may aid in inter-

preting the present data. He reported that particular changes in fundamental frequency, intensity, and time are all cues to the perception of the supra-segmental aspects of our language and hypothesized the existence of a normal synchronized pattern of activity involving the respiratory and laryngeal muscles which forms a basic "breath-group" that characterizes the intonation of a language. An apparent implication of Lieberman's hypothesis is that the integrity of both the respiratory and phonatory mechanisms of a speaker is necessary for normal intonation patterning to take place. In compensating for inadequate velopharyngeal closure, the cleft speaker may find it necessary to place greater demands on the respiratory and phonatory mechanism than the normal speaker. These assumptions may provide partial explanation for the differences found in the inflectional data for the cleft group.

The effects on the speaking fundamental frequency and intensity characteristics for velopharyngeal compensation have been discussed by Curtis (*7*). He suggested that the dynamic intensity range and vocal pitch range of a speaker with insufficient velopharyngeal closure would likely be reduced significantly. His argument, based on an inferred relation between subglottic pressure and insufficient velopharyngeal closure, contends that due to increases in subglottic pressure for all intensity levels, pitch may be higher than average. This may result in the limiting of the lower end of the pitch range.

In light of Curtis' discussion, an informal inspection of the present data was made to determine if differences exist between groups of subjects demonstrating two levels of velopharyngeal closure. The cleft group was dichotomized into two "closure" groups based on the values of the manometric quotients. No systematic trends in the data were found for any of the fundamental frequency measures obtained in the study. Although no apparent differences were found between the two "closure" groups, it should be noted that these observations are based on the measures of only six subjects per group. The heterogeneity of the cleft palate sample may account for the lack of discrete differences between these "closure" groups. Perhaps with a larger sample the differences in fundamental frequency characteristics would be more evident.

Table 5 presents the fundamental frequency measures (mean fundamental frequency, standard deviation, total range, functional range, and extent of upward and downward inflections obtained from this and other pertinent studies). The age, height, and weight characteristics for both the cleft and noncleft groups were all comparable to those of the studies cited. Values obtained for all measures of fundamental frequency for the subjects in the present study are similar to those found by Fairbanks and his associates (*9, 10*) except for measures of mean fundamental frequency and total range. The mean fundamental frequency for both the cleft and noncleft subjects (251.7 and 241.4 Hz, respectively) is considerably lower than the mean for the subjects in the same age group. It is noted that the later studies of fundamental frequency (*12, 20*) also

TABLE 5. Comparison of fundamental frequency measures from previous studies. Measures include mean fundamental frequency (f.f.) in Hz, standard deviation, total range, functional range, and extent of upward and downward inflections in semitones for seven- and eight-year-old males and females (*9*, *10*) cleft and noncleft subjects, mongoloid males (M.O.B.) (*20*) and ten-year-old males (*12*).

investigators	*subjects*	*N*	*mean f.f.*	*SD*	*total range*	*functional range*	*extent of inflections*	
							upward	*downward*
Fairbanks *et al.* (*10*)	7 year old males	15	294.0	2.2	19.6	7.2	3.0	3.6
	8 year old males	15	297.0	2.0	19.4	7.8	3.0	3.8
Fairbanks *et al.* (*9*)	7 year old females	15	281.0	2.0	20.6	7.4	2.8	3.4
	8 year old females	15	288.0	2.8	20.0	6.6	3.0	3.6
present study	clefts	12	251.7	2.7	33.9	7.6	2.9	3.2
	nonclefts	12	241.4	3.0	30.8	9.6	3.5	3.8
Michel and Carney (*20*)	M.O.B.	8	235.7	3.0	16.6	10.0	—	—
Hollien and Malcik (*12*)	10 year old males	12	230.9	3.2	—	10.1	—	—

have found lower fundamental frequencies than earlier studies for similarly aged subjects. This tendency is consistent with fundamental frequency literature for adult males and females.

Summary

The purpose of this study was to obtain information about the speaking fundamental frequency characteristics of children between the ages of seven years and eight years, eleven months, with repaired palatal clefts. Oral reading samples were tape recorded for a group of 12 cleft palate children and a group of noncleft children matched for age, height, and weight characteristics. The tape recorded speech samples were analyzed for: a) mean fundamental frequency, b) fundamental frequency standard deviation, c) total range, d) functional range, and e) the melody plot from which number and extent of upward and downward inflections were obtained. No significant differences were found between groups on measures of mean fundamental frequency, fundamental frequency standard deviation, total range, or functional range. The cleft group had a significantly greater number of both upward and downward inflections, while the noncleft group had a greater extent of inflection.

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