

# Acoustic attributes of preadolescent voices

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The purpose of this study was to investigate acoustic attributes of the voices of preadolescent children as a function of sex and age. Voice samples of the sustained vowel /a/ were obtained from 180 children, 15 males and 15 females at ages five, six, seven, eight, nine, and ten years. Measurement of fundamental frequency was obtained to determine sex-related differences and age-related trends. This acoustic analysis revealed that a male/female difference in fundamental frequency emerged by age seven, and that fundamental frequency decreased significantly in male children only, between age five and age ten.

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## INTRODUCTION

There are well-defined anatomic differences between the vocal mechanisms of adult males and females, as well as acoustic and perceptual differences between their vocal productions (Negus, 1949; McGlone and Hollien, 1963; Hollien and Shipp, 1972; Fant, 1973; Monsen and Engebretson, 1977; Singh and Murry, 1978). However, the nature of the process by which these sex-related vocal differences develop needs further clarification.

It is commonly asserted in the literature that prior to adolescence there are no significant differences in the vocal mechanisms or vocal productions of boys and girls (Murphy, 1964; Luchsinger and Arnold, 1965; Kaplan, 1971). Despite these assertions, there is some anatomic and perceptual evidence which supports the existence of sex-related vocal differences, prior to puberty. For example, Crelin (1973), suggested that sexual differences in laryngeal growth appear by the third year.

Perceptual differences between the voices of male and female children have also been demonstrated. Several studies have shown that listeners can judge the sex of child speakers with some degree of accuracy from brief voice samples (Weinberg and Bennett, 1971; Bennett and Weinberg, 1979), but the correlates of maleness and femaleness in children's voices are relatively unexplored.

Numerous studies have investigated average fundamental frequency in children of various ages prior to adolescence. The results of these studies together with pertinent information concerning sample size and methodology are summarized in Table I. It is difficult to draw conclusions concerning sex-related differences and age-related trends due to differences in procedures and the lack of comparisons for the entire preadolescent age range. However, the available data does not suggest significant differences in  $f_0$  prior to age ten (Cornut, Riou-Bourret, and Louis, 1971; and Kent, 1976).

The present study was designed to obtain frequency

patterns of a substantial sample of male and female children, aged five to ten, and to investigate both sex-related differences and age-related trends as a function of fundamental frequency ( $f_0$ ). One vowel (/a/) was selected for study in order to focus on sex and age comparisons rather than vowel differences.

## I. METHOD

### A. Speakers

Voice samples were drawn from children in the Gainesville, Florida schools, grades kindergarten-5th, and were obtained by another experimenter for a related study (Brown *et al.*, 1978). Each child was required to produce a sustained phonation of the vowel /a/, monitored by a VU meter, at a relatively stable intensity for five seconds. Children were encouraged to use a normal speaking voice and training and practice trials were given as needed. Each voice sample was judged by two phonetically trained listeners and vowel productions judged by both to be other than /a/ were eliminated. The final experimental population included 180 children, fifteen males and fifteen females at each age between five and ten years.

### B. Acoustic measurements

Measures of fundamental frequency ( $f_0$ ) were obtained by two different procedures. The first measure was obtained by processing the initial 3 s of the samples through an optical oscillograph (Honeywell, 1508C) at a chart speed of 1000 mm/s. The oscillograph recorded 1/10 s time markers. The number of fundamental pulses for each 1/10-s period were tabulated, averaged, and converted into measures of Hz.

The second measure of  $f_0$  was obtained by submitting the voice samples to analysis via a fast Fourier transform program. This program sampled and analyzed a 500-ms. portion of the voice at a rate of 20 000 samples per second. The sampling point was within the 3-s segment analyzed on the oscillograph. A bandwidth resolution of 19.6 Hz with an amplitude of 100 dB was selected as being most efficient and appropriate. A computer plotting representing a frequency by ampli-

TABLE I. Summary of  $f_0$  values reported for males and females, aged 5–10.

Age	$f_0$ Reported (Hz)			#Ss	Speech sample	Analysis technique	Study
	Male	Female	Combined				
5th year			288.7	5	two sentences	spectrogram	Eguchi and Hirsh (1969)
	252.4	247.6		15M 15F	spontaneous speech sampled	Honeywell visicorder	Weinberg and Bennett (1971)
			283	10F 11M	repeated sentences	oscillograph	Chevrie-Muller (1971)
			265	10F 10M			
	279 282	279 283	281	? ?	repeated sentences	sonograph	Cornut, Riou-Bourret, Louis (1971)
6th year			271.2	5	two sentences	spectrogram	Eguchi and Hirsh (1969)
	247.4	247			spontaneous speech samples	Honeywell visicorder	Weinberg and Bennett (1971)
*avg of 61–82 mos.		248.8		10	responses to pictures	Honeywell visicorder	McGlone and McGlone (1972)
	261			38			
		256		22	long vowels	$f_0$ indicator	Vuorenkoski <i>et al.</i> (1978)
	293 269	276 272	277	? ?	repeated sentences	sonograph	Cornut, Riou-Bourret, Louis (1971)
7th year	294	281		15M 15F	reading passage	oscillogram from phonograph recording	Fairbanks (1950)
			262.5	5	two sentences	spectrogram	Eguchi and Hirsh (1969)
*ages 6 & 7	238.2			26M 21F	brief sentences	Honeywell visicorder	Bennett and Weinberg (1979)
	291 282	293 278	286		repeated sentences	sonograph	Cornut, Riou-Bourret, Louis (1971)
8th year	297	288		15M 15F	reading passage	oscillogram from phonograph recording	Fairbanks (1950)
			261	5	two sentences	spectrogram	Eguchi and Hirsh (1969)
		275.8		10	reading passage (same as Fairbanks (1950))	Honeywell visicorder	McGlone and McGlone (1972)
	259	253		28 32	long vowel	$f_0$ indicator	Vuorenkoski <i>et al.</i> (1978)
	289 279	294 281	286	? ?	repeated sentences	sonograph	Cornut, Riou-Bourret, Louis (1971)
9th year			262.5	5	two sentences	spectrogram	Eguchi and Hirsh (1969)
10th year	210.2			6	Rainbow passage	phonellograms	Hollien and Malcik (1962) Negro Boys
	235.4			6	Rainbow passage	phonellograms	Hollien, Malcik, and Hollien (1965) Southern White Boys
	226.4			6	Rainbow passage	phonellograms	Hollien and Malcik (1967) Northern White Boys
			261.9	5–6	two sentences	spectrogram	Eguchi and Hirsh (1969)
	247			32	Long vowel	$f_0$ indicator	Vuorenkoski <i>et al.</i> (1978)
	256		28				

tude display of the spectrum was obtained for each child. The first prominent peak to appear on the plotting was assumed to be the fundamental frequency. The actual  $f_0$  could, however, fall between the frequencies being sampled (every 19.6 Hz). To check for this possibility and to obtain the most accurate measurement, the value of the fourth harmonic was divided by four. When there was a discrepancy between the two values, the latter measure was accepted as the more accurate.

## II. RESULTS

Two measures of  $f_0$  were obtained for each child. The Pearson product-moment correlation between the two sets of measures was  $r = 0.82$  ( $N = 150$ ). The values reported here are those obtained from FFT analysis.

The average  $f_0$  for males and females at the six age levels are reported in Table II. A two-way analysis of variance was performed to test for the main effects of sex and age. The main effect of sex was found to be significant ( $F = 17.6$ ,  $df = 1$ ,  $168$ ,  $p < 0.001$ ), indicating that the average  $f_0$  of female children aged five to ten was significantly different from the average  $f_0$  of male children of the same age. A Scheffé test was performed between the average  $f_0$  of boys and girls at each age to determine the age at which the significant difference in  $f_0$  between males and females begins to emerge. The difference between mean  $f_0$  for male and female children was significant at ages seven, eight, nine, and ten.

The main effect of age was also significant ( $F = 2.3$ ,  $df = 5$ ,  $168$ ,  $p < 0.05$ ). A critical value for determining the age groups which differed significantly from each other was computed by the Neuman-Keuls Multiple Range Test. The average  $f_0$  at age five and age six was found to differ significantly from the average  $f_0$  which occurred between ages six and nine.

An examination of the data in Table II suggested that the developmental trends for the two sexes differed, and that the decline in  $f_0$  for the group as a whole was due primarily to the change in male voices. To investigate this *post hoc* hypothesis that only male children show a decrease in  $f_0$  between age five and age ten, one-way analyses of variance were performed on the male and female data separately. No significant difference in  $f_0$  between age five and age ten was found for female children, but the effect of age on  $f_0$  was significant for males, ( $F = 3.6$ ,  $df = 5$ ,  $84$ ,  $p < 0.05$ ). Significant differences between age six and ages eight, nine, and ten, were revealed by the Neuman-Keuls Multiple Range Test. The difference

TABLE II. Mean, standard deviation and range of  $f_0$  measures for children at six ages.

Age	Males			Females		
	$f_0$	S.D.	Range	$f_0$	S.D.	Range
5	247.5	27.9	186-313	257.7	28.7	202-306
6	262.5	31.1	228-332	254.3	22.7	210-313
7	234.2	17.9	199-264	261.7	35.8	195-303
8	235.6	28.5	195-313	264	24.6	215-306
9	230.4	13.1	211-254	246.7	22.4	210-281
10	228.9	33.8	173-293	253.7	19.8	234-303

between age five and ages nine and ten approached significance.

## III. DISCUSSION

This study suggests that a significant difference between the average  $f_0$  of preadolescent male and female children begins to emerge by age seven or eight. This finding is in contrast to a number of previously reported investigations (Fairbanks, 1950; Cornut *et al.*, 1971; Kent, 1976). The male/female difference was directly attributable to a decline in  $f_0$  for male children only, beginning around age seven. No systematic age-related change was apparent for girls, suggesting that the decrease in  $f_0$  between childhood and adulthood occurs primarily after the age of ten for females. Similar results are reported by Vuorenkoski *et al.*, (1978), who found a decrease in  $f_0$  for males between ages eight and ten, but no corresponding change for females during the same period.

There is no clearcut explanation for differential changes in  $f_0$  between boys and girls during this age period. It is possible, however, that physical changes occur in young girls. Crelin (1973) suggested that sexual differences in laryngeal size and thyroid angle begin to appear by the third year. It may be that these differences are sufficiently great by age seven or eight to account for the decline in  $f_0$  observed in the male sample. It is also possible that cultural stereotypes of "maleness" and "femaleness" might encourage young boys to adapt a lower pitch than would be optimum for their phonatory apparatus.

As stated earlier, a male/female difference in  $f_0$  among five-to-ten-year-old children has not been previously reported. A male/female difference could not have emerged from the present investigation had not a representative sampling of both males and females over a range of ages been studied. The tendency of other investigators to study combined groups of preadolescent children, or to study only one sex, may have prevented the observation of sex-related differences in  $f_0$  prior to this study. In addition, sex-related differences in  $f_0$  may have been masked by the great variability which exists among children's voices at all of the ages studied. This variability has also been noted by other investigators with the suggestion that future studies of children's voices use large samples to maximize the validity of conclusions (Bennett and Weinberg, 1979).

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