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ACOUSTIC CHARACTERISTICS OF EUROPEAN-AMERICAN AND LATIN-AMERICAN MALE ADULTS DURING ORAL READING AND SUSTAINED PHONATION OF VOWELS

A Thesis

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Heather Sonner-Ward

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ABSTRACT

Previous research has shown that differences exist in acoustic characteristics as well as in physical characteristics between ethnic groups. Few studies have been conducted in this area of voice research. The Hispanic ethnic group has received considerably less attention than the African-American and European-American groups. If the Hispanic population continues to grow as expected, this group will become a large percentage of the American population. In order to properly identify, diagnose and treat voice disorders in this population it is imperative to know the different parameters of a normal voice.

The purpose of this study was to determine whether differences exist in acoustic and physical characteristics between Latin-American male adults, a large subgroup of the Hispanic population, and European-American male adults. In particular, this study compared speaking fundamental frequency during oral reading, fundamental frequency of a sustained vowel, semitone range, and formant frequency. Ten Latin-American and ten European-American male adults, ages 18 to 35 years, performed both oral reading and sustained vowel tasks. The European-American subjects were age-matched to the Latin-American subjects. The height and weight of the subjects were not matched. However, height and weight were measured and compared to ascertain whether these physical characteristics have any correlation to acoustic differences.

The results showed significant differences in physical measurements and acoustic characteristics between the European-American and Latin-American ethnic groups. The Latin-American group was significantly shorter in standing height and sitting height. The Latin-American group was lower in weight, although not significantly. Semitone range was significantly smaller in the Latin-American group than in the European-American group. The second formant frequency of the vowel /u/ was significantly lower in the Latin-American group than in the European-American group.

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CHAPTER I

OVERVIEW OF STUDY

INTRODUCTION

Proper identification, diagnosis and treatment of voice disorders requires a knowledge of the acoustic characteristics of normal voice. Previous research has suggested that these characteristics vary across groups (Awan & Mueller 1996; Hudson & Holbrook, 1982; Wheat & Hudson, 1988). Therefore, acoustic characteristics that are normal among European-Americans should not be assumed to be normal among other groups (Agin, 1992).

Over the last fifty years, few studies have been conducted that examine the acoustic characteristics of non-European-American ethnic groups (Agin, 1992). Some data are available on acoustic characteristics of voice for the African-American ethnic group. There are significantly less data available regarding the Hispanic ethnic group.

The Bureau of the Census (1993) defines Hispanic as those whose origin is from Mexico, Puerto Rico, Cuba, Central America, South America, Spain or Dominican Republic. Origin is further defined as ancestry, nationality group, lineage, or the country of birth of that person, the person's parents or ancestors before their arrival in the United States. Furthermore, an Hispanic person may be of any race. The 1990 United States Bureau of the Census (1992) divides the Hispanic population into the following subgroups: Mexican, Puerto Rican, Cuban, Central American, South

American and Other Hispanic. The "Other" subgroup consists of persons from Spain or persons whose families have been in the United States for several generations. The Mexican subgroup makes up the largest subgroup in the United States at 64.3% of the Hispanic population, with the Central and South American subgroups at 13.4%, the Puerto Rican subgroup at 10.6%, the Other subgroup at 7%, and the Cuban subgroup at 4.7%.

The lack of acoustic data for Hispanics is of concern given the expected growth of this population. According to the Population Bulletin (Martin & Midgley, 1994), the Hispanic ethnic group constituted 10% of the population in the United States in 1993. By the year 2050, the Hispanic population is expected to rise to 18% if there is no immigration and to 22% if immigration is 880,000 per year. If these predictions are correct, by 2050 the Hispanic population will be the second largest ethnic group in the United States, behind non-Hispanic whites at 52-61% of the population. With the Hispanic group becoming such a large portion of the population, it will become increasingly important to have the appropriate clinical resources available for this population. In order to properly screen, diagnose and treat voice disorders in the Hispanic population, it is imperative to understand the acoustic characteristics of this group.

REVIEW OF THE LITERATURE

To date, few studies have been conducted that examine the acoustic differences between European-Americans and Hispanics. However, there is evidence that acoustic differences do exist between ethnic groups. Such evidence can be found in the literature comparing the acoustic characteristics of African-Americans to those of European-Americans. Studies examining the acoustic differences between Hispanics and European-Americans are relatively rare, but there have been several studies that compare physical characteristics between Hispanics and European-Americans. If physical differences in size can be related to differences in acoustics, then these studies lend support to the hypothesis that there is a difference in the acoustic characteristics of Hispanic and European-American voices.

Normative Vocal Characteristics

In order to properly diagnose and treat voice disorders, it is necessary to understand the acoustic characteristics of normal voice. The majority of acoustic data have been collected from European-American individuals. Some of the most commonly measured acoustic characteristics are speaking fundamental frequency (SFF), fundamental frequency (F_o) of a sustained vowel and formant frequency. Few research studies have been designed specifically to obtain normative acoustic data for the European-American population; however, several studies have reported acoustic characteristics for normal voices of unspecified ethnicity.

Speaking Fundamental Frequency

Fundamental frequency is the "lowest component frequency of a periodic wave" (Nicolosi, Harryman, & Kresheck, 1989, p. 109). Speaking fundamental frequency (SFF) in oral reading has been reported by several researchers. Normative data for male adults only will be reported in this chapter.

In 1940, Curry obtained the SFF for six 10-year-old, six 14-year-old and six 18-year old males. The 18-year-old subjects were all college freshmen at the time of the recording. Although Curry does not state the ethnicity of these subjects, Hollien and Malcik (1962) stated that Curry's subjects were all northern white males. Each subject read the first paragraph of "The Rainbow Passage". The reading samples were recorded phonographically. A phonophotic technique plotted pitch curves from which the frequency measurements were obtained. Mean SFF for the 18-year-old subjects was 137.1 Hz (see Table 1).

Snidecor (1943) reported the mean and median pitch of adult males. A rigid screening for speaking and oral reading was administered to 25 adult males. These subjects were judged to have "superior" voices as judged by staff members at the Department of Speech at the State University of Iowa. An individual was excluded from the study if he presented any deviation from "superior" articulation and voice. Eight individuals met this criteria. Specific age and ethnicity were not reported by the author. Each subject read the first paragraph of "The Rainbow Passage" four times. Seven trained observers selected the best of the four readings; the other three readings were discarded. Snidecor used twelve trained judges to rank the eight subjects' best readings by general effectiveness of the performance. The two lowest ranked subjects were eliminated leaving the top six subjects as participants in the study.

Table 1

Mean Speaking Fundamental Frequency of Normal Male Adults During Oral Reading

Author(s)	Date	Age Range (years)	SFF (Hertz)	Number of Subjects	Reading Passage	Frequency Range (Hertz)
Curry	1940	17:-18:5	137.1	6	Not specified	Not specified
Snidecor	1943	adult	132	25	Rainbow	Not specified
Michel	1968	Over 18	110.6	10	Rainbow	Not specified
Hollien and Shipp	1972	20-29	119.5	25	Rainbow	Not specified
Hollien and Jackson	1973	17:9-25:8	129.4	157	Apology for Idlers	Not specified
Horii	1975	26-79	112.5	4	Rainbow	84 to 151
Fitch	1990	21-26	112.9	6	Rainbow	Not specified

The phonophotographic technique was employed to determine SFF. This technique produces a photograph of the fundamental sound wave from which SFF could be calculated. The mean SFF from these six subjects was 132 Hz (see Table 1).

Michel (1968) compared the SFF of individuals with normal and disordered voice. Ten male speakers over the age of 18 and in good general and vocal health were selected as normal speakers. Ten subjects with clinically harsh voices were also selected, but will not be discussed here. Neither the exact ages nor ethnic group were reported for these subjects. The subjects were recorded reading "The Rainbow Passage" once using a normal voice and once using a vocal fry. The Fundamental Frequency Indicator was used to extract the fundamental frequency. The mean SFF of the ten normal subjects using normal voice was 110.6 Hz (see Table 1).

Hollien and Shipp (1972) reported the mean SFF during oral reading for adult males ages 20 to 89 years. The subjects were divided into seven equal age groups. Each group contained 25 subjects and spanned approximately ten years, with the first age group being 20-29 years, the second age group being 30-39 years and so forth. The ethnic origin of the subjects was not reported; however, individuals with a foreign dialect, individuals with a pronounced regional dialect and professional voice user were excluded from the study. Each subject read the first paragraph of "The Rainbow Passage". The Fundamental Frequency Indicator was used to extract SFF. The mean SFF of the group ages 20-29 was 119.5 Hz (see Table 1).

Hollien and Jackson (1973) sought to obtain normative SFF data for young adult males. All subjects were male students at the same university, had no history of vocal pathology, no history of vocal training, used a Southern dialect and were between the ages of 17:9 and 25:8 years of age. The authors did not note the ethnic origin of the subjects. One hundred fifty-seven subjects were recorded reading R. L. Stevenson's "Apology for Idlers". This passage is approximately three minutes in length. SFF was extracted using the Fundamental Frequency Indicator. The mean SFF of the 157 subjects was 129.4 Hz (see Table 1).

Horii (1975) recorded 65 adult males between the ages of 26 and 79 years reading the first paragraph of "The Rainbow Passage". Ethnic origin was not reported, nor did Horii provide a further breakdown of this large age group. A peak-picking method was used to extract fundamental frequency. The mean SFF was 112.5 Hz (see Table 1). Horii also provided the minimum and maximum SFF produced within the reading passage. The frequencies ranged from 84 Hz to 151 Hz (see Table 1).

Fitch (1990) examined the consistency of fundamental frequency of a sustained vowel, SFF, and perturbation of repeated vocal samples. Six males and six females between the ages of 21 and 26 years with no history of vocal or respiratory problems, no professional voice use, no consistent loud or prolonged voice use, and no swallowing problems were chosen as subjects. Ethnic origin was not provided by the author. Each subject performed two readings of the "The Rainbow Passage" and two to three productions of the vowels /i/, /u/, /ɑ/ and /æ/. Visi-Pitch was used to analyze all data. SFF was extracted from "The Rainbow Passage". The test and retest mean SFF were identical, 112.9 Hz (see Table 1).

Few of these studies report the specific ethnic group of the subjects. However, Baken (1987) refers to Snidecor's (1943), Hollien and Jackson's (1973), Curry's (1940), Michel's (1968), Horii's (1975) and Hollien and Shipp's (1972) subjects as "normal Caucasian adults".

In summary the mean SFF of male adults has been reported to range from 110.6 Hz and 137.1 Hz (see Table 1). All of the subjects studied had no diagnosed vocal pathology or other impairment that would affect the voice. Therefore it is assumed that all subjects had "normal" voice. Hollien and Jackson (1973) report the only study with a sample size large enough to be generalized to the overall population. However, the number of studies reported over time supply us with a general idea of the appropriate range of SFF.

Sustained Vowel Fundamental Frequency

As previously described, in 1990 Fitch compared the consistency of the mean fundamental frequency (F_o) of the vowels /i/, /u/, /ɑ/ and /æ/ during two time-delayed trials. The Visi-Pitch was used to extract the F_o from the middle four seconds of each sustained vowel. The test and retest mean F_o of the sustained vowels were 132.6 Hz and 140 Hz, respectively. Both figures are reported in Table 2.

Table 2

<u>Mean Fundamental Frequencies of Normal Male Adults</u>

Author(s)	Date	Age Range (years)	F_o (Hertz)	No. of subjects
Fitch	1990	21-26	132.6	6
Fitch (retest)	1990	21-26	140	6
Mayo	1990	18-30	129.86	30
Mayo and Manning	1994	19:1-30:0	124.7	20
Walton and Orlikoff	1994	18-57	107.55	50
Mayo and Grant	1995	18-30	117.21	30

Mayo (1990) examined the F_o of 60 African-American and 60 European-American adults between the ages of 18 and 30 years, with an equal number of males and females. Each subject sustained the vowels /ɑ/, /i/, /u/, and /æ/ at a comfortable pitch for five seconds each, while maintaining a loudness level between 70 dB and 75 dB SPL. This task was repeated three times for each vowel. The MacSpeech Lab was used to analyze the acoustic data. The average F_o of the European-American males across the four vowels was 129.84 Hz (see Table 2).

Walton and Orlikoff (1994) performed a study to examine whether trained and untrained listeners could distinguish Black and White speakers through perceptual cues only. Fifty Black and 50 White male speakers between the ages of 18 and 57 years with no speech or hearing impairments were chosen for this study. All subjects were inmates at a correctional facility. Each subject produced the vowel /ɑ/ for at least six seconds at a comfortable pitch and loudness level. One second from the middle of the sample was analyzed using the Computerized Speech Lab. Mean F_o for the White subjects was 107.55 Hz (see Table 2).

Mayo and Manning (1994) compared fundamental frequency and formant frequency between African-American and European-American adult males. Twenty African-American and twenty European-American males between the ages of 18 and 30 years were chosen as subjects. All subjects were nonsmokers, had no professional voice experience and were required to pass a hearing, speech, voice and language screening. Each subject sustained the vowel /ɑ/ for five seconds, while maintaining an intensity level between 70 dB and 75 dB SPL. Three trials were recorded. The middle three seconds of the vowel were analyzed using MacSpeech Lab. It was not reported which of the three trials were analyzed or if an average of the three trials was used. The mean F_o of the vowel /ɑ/ for the European-American subjects was 124.7 Hz (see Table 2).

Mayo and Grant (1995) compared fundamental frequency, perturbation and formant frequency between African-American and White-American males. Thirty African-American and 30 White-American males between the ages of 18 and 30 years were chosen as subjects. All subjects had no history of professional voice use, were judged to speak Southern Standard English and were required to pass a hearing, speech, voice and language screening. Each subject produced three trials of the vowel

/ɑ/ at a comfortable pitch for five seconds and maintained an intensity level between 70 dB and 75 dB SPL. CSpeech was used to analyze F_0 of the vowel. The middle one second of the sample was analyzed to obtain fundamental frequency. The mean F_0 for the White-American subjects was 117.21 Hz (see Table 2).

In summary, mean F_0 of a sustained vowel for normal White-American speakers has been reported to range from 107.55 Hz to 140 Hz. Mean F_0 values for the vowel /ɑ/ are reported in Table 2.

Formant Frequency

"A formant is a resonance of the vocal tract" (Pickett, 1980, p. 45). Normative data for formant frequencies have been gathered for subjects of unspecified ethnic origin (Eguchi & Hirsh, 1969; Hillenbrand, Getty, Clark, & Wheeler, 1995; Peterson & Barney, 1951) and for Caucasian subjects (Mayo & Grant, 1995; Mayo & Manning, 1994; Walton & Orlikoff, 1994)

Peterson and Barney (1951) reported the formant frequencies for 76 speakers, including 33 men, 28 women and 15 children. Neither the specific ages nor ethnic group were reported for these subjects. Some of the subjects spoke a foreign language before learning English and two of the speakers were not born in the United States. Most of the women and children were from the Middle Atlantic area. The majority of the male subjects spoke General American English.

Each subject read two randomized lists of 10 monosyllabic words: heed, hid, head, had, hod, hawed, hood, who'd, hud and heard. First and second formant frequencies were obtained through an estimation of a "weighted average of the frequencies of the principal components in the formant" (Peterson & Barney, 1951, p. 180). Mean first formant frequencies of the adult males for /i/, /u/ and /ɑ/ were 270 Hz, 300 Hz and 730 Hz, respectively. Mean second formant frequencies of the adult males for /i/, /u/, and /ɑ/ were 2290 Hz, 870 Hz, and 1090 Hz, respectively (see Table 3).

Roberts (1966) examined the pronunciation of vowels of Negro and White speakers. She sought to discover if the race of a speaker could be identified through perceptual cues only. Roberts (1966) examined the voices of 20 Negro and 20 White subjects enrolled in the tenth through the twelfth grade. Each subject was given a list of monosyllabic words with each of the 16 vowels and diphthongs represented twice. The subject was asked to read the word silently, then pronounce the vowel only aloud. Brüel and Kjaer Audio Frequency Spectrometer was used to extract the first and second formant frequencies from the vowels /æ/, /u/, /ɛ/, /ɔ/, /ɝ/, /ʊ/,and /ʌ/. The mean first and second formant frequencies of the 12 White male subjects for the vowel /u/ were 250 Hz and 1250 Hz, respectively (see Table 3).

Bryden (1968) performed a study to examine whether untrained listeners could distinguish Negro and White speakers through perceptual cues only. Ninety-one Negro and White adults between the ages of 17 and 65 years were selected as subjects. Each speaker was perceptually identified as either Negro of White after listening to a recorded reading passage. A spectrographic analysis was performed on

Table 3

Mean Formant Frequencies in Hz of Normal Male Adults

Author(s)	Date	Ages years	No. of Subjects	Vowel /i/ Hertz		Vowel /u/ Hertz		Vowel /ɑ/ Hertz	
				F1	F2	F1	F2	F1	F2
Peterson and Barney	1951	adult	33	270	2290	300	870	730	1090
Roberts	1966	10th-12th grade	12	--	--	250	1250	--	--
Bryden	1968	17-65 years	10	319	2076	400	1353	--	--
Eguchi and Hirsh	1969	adult	5	288	2217	344	1256	--	--
Walton and Orlikoff	1994	18-57 Years	50	--	--	--	--	662	1181
Mayo and Manning	1994	adult	20	--	--	--	--	683.2	1162.2
Hillenbrand, et al.	1995	adult	45	342	2322	378	997	768	1333
Mayo and Grant	1995	adult	30	--	--	--	--	637	1072

F1 = first formant frequency
F2 = second formant frequency
-- = no data available

the acoustic data of those subjects who were consistently identified in the correct racial group.

The first and second formant frequency of 10 White male speakers, who had been identified by listeners as White at least 95% of the time, was obtained. The vowel /i/ and /u/ was extracted from the sentences. "I will say beet" and "I will say boot", respectively. Spectrographic analysis was completed using the Kay Electric Company Sona-Graph Model 6061-A. Mean first formant frequency of the White males for /i/ and /u/ were 319 Hz and 400 Hz, respectively. The mean second formant frequency of the White males for /i/ and /u/ were 2076 Hz and 1353 Hz, respectively (see Table 3).

Eguchi and Hirsh (1969) investigated formant frequency as well as several other acoustic characteristics. Subjects included five girls and five boys ages three-to-ten, five boys and five girls ages 11-to-13, five adult men and five adult women. The ages of the adults were not specified, nor was the ethnic group provided for any of the subjects.

Each subject produced two sentences containing the phonemes /i/, /æ/, /u/, /ɛ/, and /ɑ/. Each sentence was spoken five times within the same session. The steady state portion of each vowel was identified and analyzed with the Sound-Spectrum Analyzer. The five samples of each vowel were averaged to provide mean first and second formant frequencies. Mean first formant frequencies of the adult male subjects for the vowels /i/ and /u/ were 288 Hz and 344 Hz, respectively. Mean second formant frequencies of the adult male subjects for the vowels /i/ and /u/ were 2217 Hz and 1256 Hz, respectively (see Table 3).

As previously discussed, Walton and Orlikoff (1994) examined the ability to distinguish Black and White speakers through perceptual cues only. In addition to reporting mean F_o, they also extracted first and second formant frequencies. Mean first and second formant frequencies for the vowel /ɑ/ were 662 Hz and 1181 Hz, respectively (see Table 3).

Mayo and Manning (1994) compared the F_o and formant frequencies of a sustained vowel between African-American and European-American male adults using procedures described previously. The mean first and second formant frequencies for the vowel /ɑ/ were 683.2 Hz and 1162.2 Hz, respectively (see Table 3).

In 1995, Mayo and Grant analyzed the formant frequencies of African-American and White-American adult males. Each subject sustained the vowel /ɑ/ during three trials. The procedures have been discussed in more detail earlier in this chapter. Cspeech was used to analyze the middle three seconds of each vowel. Mean first and second formant frequencies of the vowel /ɑ/ were 637 Hz and 1072 Hz, respectively (see Table 3).

Hillenbrand, Getty, Clark and Wheeler (1995) replicated and extended Peterson and Barney's 1951 study. They reported formant frequencies for a total of 139 subjects. The subject group consisted of 45 men, 48 women and 46 ten-to-12 year old boys and girls. Eighty-seven percent of the subjects grew up on Michigan's lower peninsula. The remainder of the subjects were from the upper midwest United States. Each subject participated in an extensive screening process.

Each subject read a list of 16 monosyllabic words. The list of words all began with /h/ and ended with /d/, with the vowel being the only difference. Twelve vowels and 4 diphthongs of the English language were used. Each subject was allowed ample practice before recording. Formant frequencies were calculated using a hand measuring technique. The mean first formant frequencies of /i/, /u/ and /ɑ/ were 342 Hz, 378 Hz, and 768 Hz, respectively. The mean second formant frequencies of /i/, /u/ and /ɑ/ were 2322 Hz, 997 Hz and 1333 Hz, respectively (Table 3).

As previously described, Mayo (1990) examined the formant frequency of African-American and European-American adults. MacSpeech Lab was used to analyze the formant frequencies of the vowels /ɑ/, /i/, /u/ and /æ/. Mayo did not report the formant frequencies for the individual vowels. He reported an average of the four vowels. The mean first and second formant frequencies for the European-American male adults across the four vowels were 488.65 Hz and 1499.47 Hz, respectively.

In summary, several studies have reported mean formant frequency values for a variety of vowels. A summary of the data on the formant frequencies of normal voice for the vowels /i/, /u/ and /ɑ/ is provided in Table 3.

Comparison of African-American and European-American Groups

Several studies have suggested a difference in the acoustic characteristics of voice between European-American and African-American ethnic groups. Acoustic characteristics such as fundamental frequency, formant frequency, jitter, shimmer, harmonics-to-noise ratio, and voice onset time have been compared between African-Americans and European-Americans (Awan & Mueller, 1996; Hollien & Malcik, 1962; Hudson & Holbrook, 1982; Mayo & Grant, 1995; Mayo & Manning, 1994; Ryalls, Zipprer, & Baldauff, 1997; Sapienza, 1997; Walton & Orlikoff, 1992; Wheat & Hudson, 1988).

Fundamental Frequency

Fundamental frequency is one of the primary acoustic parameters used to study voice characteristics. Much of the research that has compared African-American and European-American groups has included some measure of fundamental frequency.

Continuous speech. Hollien and Malcik (1962) found a difference in fundamental frequency between southern Negro males and northern white males in oral reading. They obtained measures of central tendency of pitch and pitch variability for six ten-year-old, six fourteen-year-old and six eighteen-year-old southern Negro males. These data were age matched to similar data obtained for northern white males (Curry, 1940, 1946). The results of the comparison revealed that the Negro group had a lower median fundamental frequency and earlier onset of pubertal voice change compared to the white group. Median fundamental frequency differed between the two groups for all age groups. However, the ten-year-old and fourteen-year-old groups showed a much larger difference between the groups than did the eighteen-year-old group. Hollien and Malcik suggested this was due to a pubertal voice change found in the Negro group that had not yet occurred in the white group. The eighteen-year-old subjects in both groups had reached vocal maturity; thus, differences in median fundamental frequency were present, yet less pronounced.

Hudson and Holbrook (1982) provided data on the acoustic characteristics of adult Blacks that support Hollien and Malcik's (1962) findings. They obtained measures of fundamental frequency from a reading passage for 200 Black men and women between the ages of 18 and 29 years and compared these measures to a previous study by Fitch and Holbrook (1970) of 200 White subjects of similar age, height and weight. This comparison showed that the Black subjects had a slightly lower fundamental frequency than did the White subjects. Hudson and Holbrook found a greater mean frequency range for both Black gender groups when compared to Whites.

Wheat and Hudson (1988) obtained fundamental frequency data from 100 six-year-old Black children during spontaneous speech. They then compared these data to previously obtained data from White boys and girls ages four-to-six and eight-to-ten (Gilbert & Campbell, 1980). The ages of the groups compared were not perfectly matched; however, the design and process of obtaining fundamental frequency were comparable between these two studies. Comparison of the two data sets showed that the Black children exhibited a lower mean speaking fundamental frequency than did the White children.

The studies by Hudson and Holbrook (1982), Wheat and Hudson (1988) and Hollien and Malcik (1962) compared data obtained at different times by different investigators. This form of investigation is valuable, yet is by nature vulnerable to violations of validity. Awan and Mueller (1996) obtained data on White, Hispanic and African-American kindergarten subjects from the same geographic location as well as during the same time frame. This study showed that African-American kindergartners use a slightly lower mean speaking fundamental frequency than do White kindergartners and a significantly lower mean speaking fundamental frequency than do Hispanic kindergartners during a continuous speech task.

Sustained vowels. The previously discussed studies have measured continuous speech. Steinsapir, Forner and Stemple (as cited in Walton & Orlikoff, 1994) obtained measures of fundamental frequency from samples of sustained vowels. They compared 41 Black and 79 White children ages three-to-six years on acoustic characteristics. Each child sustained the vowels /ɑ/, /u/ and /i/. No differences were found in mean fundamental frequency between the two groups. Mayo (1990) and Sapienza (1997) found similar results in African-American and European-American adults in a sustained vowel task. Walton and Orlikoff (1994) also found no significant difference in mean fundamental frequency of sustained vowels between these two groups. However, they did find that 91.6% of trained and untrained listeners perceptually judged the African-American group to have a lower pitch.

Summary. The research to date shows that the African-American group consistently produces a lower fundamental frequency in connected speech than does the European-American ethnic group. However, no difference has been shown in the fundamental frequency of sustained vowels between these two groups.

Formant Frequency

Formant frequency is a resonance characteristic of the vocal tract. Therefore, formant frequency is dependent on the shape of the oral-pharyngeal tract. The length of this tract as well as the location and amount of the constriction will affect the formant frequency of vowels (Pickett, 1980).

In 1990 Mayo compared formant frequencies of 60 African-American and 60 European-American adults between 18 and 30 years. The two groups were matched for age, sex, physical stature, education, socioeconomic status and dialect. Each subject sustained the vowels /a/, /i/, /u/ and /æ/. Mayo reported that the African-American group showed significantly lower mean formant frequencies for all vowels than did the European-American group. Similar results were shown in subsequent studies by Mayo and Grant (1995) and Mayo and Manning (1994).

Although three studies have shown significantly lower formant frequencies in African-Americans as compared to European-Americans, all researchers do not agree with this finding. Roberts (1966) obtained the first and second formant frequencies and peak formant amplitudes of the vowels /æ/, /u/, /ɔ/, /ɛ/, /ɔ/, /ɝ/, /ʊ/ and /ʌ/ from Black and White adolescents enrolled in the tenth through the twelfth grade. She found no significant differences in mean formant frequencies between groups. Roberts did, however, find that the Black group had lower relative mean formant amplitudes. Bryden (1968) reported similar findings using the vowels /i/ and /u/. Walton and Orlikoff (1994) also compared Black and White adults and found no significant difference in formant frequency using the vowel /ɑ/.

Other Parameters

Several researchers have compared the ability to identify speakers as African-American or European-American through perceptual cues only. Other researchers have sought to differentiate these two groups through the acoustic measures of jitter, shimmer, harmonics-to-noise ratio and voice onset time.

Roberts (1966) performed a study to test whether trained listeners could distinguish between Black and White speakers by listening to isolated vowels and diphthongs. The vowels and diphthongs were extracted from a list of stimulus words. The trained listeners were able to distinguish between the Black and White speakers with 83% accuracy. Lass, Tecca, Mancuso and Black (1979) found that listeners could identify speakers as Black or White at a rate higher than chance (approximately 55%) by listening to a half second sample extracted from a vowel prolongation. The ability to identify ethnic group increased with longer speech samples. When the length of the sample was increased to the sentence level, the same listeners were able to identify ethnic group with approximately 75% accuracy. Walton and Orlikoff (1994) also found that listeners, both trained and untrained, could identify an adult speaker as Black or White by listening to a one second vowel production with 60% accuracy.

In an attempt to explain listeners' ability to discriminate between the Black and White groups, Walton and Orlikoff (1994) examined various acoustic parameters. They investigated two indexes of perceived roughness: shimmer, the "cycle to cycle variations in amplitude of glottal pulses" (Nicolosi et al., 1989, p. 237), and jitter, the "cycle to cycle variation in the periods of glottal cycles" (Nicolosi et al., p. 136). They found that the Black group had significantly higher shimmer and higher jitter values than did the White group. Steinsapir and his colleagues (as cited in Walton & Orlikoff) found similar results with children ages three to six. They found that Black children exhibited higher jitter values than did White children during a vowel prolongation task.

Walton and Orlikoff (1994) also analyzed the degree of hoarseness. This parameter was evaluated by measuring the harmonics-to-noise ratio, "the extent to which noise replaces the harmonic structure in the spectrogram" (Yumoto, Sasaki, Okamura, 1984, p. 2). Walton and Orlikoff found that Black adults had significantly higher shimmer values, significantly higher jitter values and significantly lower harmonics-to-noise ratios than did White adults.

Voice onset time (VOT) is the "measure of time between a supraglottal event and the onset of voicing" (Kent & Read, 1992, p. 234). Ryalls, Zipprer and Baldauff (1997) have reported the only research comparing VOT between African-American and Caucasian groups. Twenty subjects produced six stop consonants combined with three vowels for a total of fifty-four individual VOT measures. For both groups, prevoicing of voiced stops was frequently observed; however, African-American speakers had larger negative average VOT values for voiced stops than did their Caucasian counterparts.

Summary

SFF, F_o of a sustained vowel, frequency range, formant frequency, perceptual identification, jitter, shimmer, harmonics to noise ratio, and voice onset time (VOT) have been compared between the African-American and European-American ethnic groups. Research has consistently shown that there is a difference in the fundamental frequency of continuous speech between these two groups, but no difference in the F_o of a sustained vowel has been reported. Several researchers have shown that listeners can distinguish African-American and European-American speakers with perceptual cues only. Although the data comparing jitter, shimmer, harmonics-to-noise ratio and VOT are limited, the research to date shows that a difference does exist between African-American and European-American groups on these parameters. Formant frequencies have also been compared between the two groups, with mixed results.

The majority of research suggests that differences do exist in some acoustic characteristics between the African-American and European-American groups. However, research has yet been unable to discern the reason behind the difference.

Comparison of Hispanic and European-American Ethnic Groups

There are very limited data available on the acoustic characteristics of voice for the Hispanic racial group. Awan and Mueller (1996) compared the acoustic characteristics of White, African-American and Hispanic kindergartners. Subjects were selected from a speech, language and hearing screening for kindergartners at a University clinic. All subjects used English as the primary language and were required to pass a perceptual voice and hearing screening. A total of 105 subjects were chosen: 35 White, 35 African-American and 35 Hispanic subjects. Each child produced a two-to-three minute speech sample. The sample was elicited through a picture description task using the "Cookie Theft" picture. To further elicit conversation, subjects were also asked questions about daily routines and favorite activities. The speech sample was recorded for later analysis using the Computerized Speech Lab. The study showed that the Hispanic group had a slightly higher average SFF than did the White group. Although no difference was found in analysis of pitch sigma, the Hispanic kindergartners produced a significantly smaller semitone range than did the White and African-American kindergartners.

It is generally accepted that Puerto Rican and Mexican students have a higher incidence rate of vocal nodules and hoarseness than do Caucasians (Kayser, 1995). If this higher incidence of pathology is caused by a difference in physiology, it could possibly result in an acoustic difference as well.

In summary, research on acoustic characteristics of the Hispanic voice is limited. However, the current data suggest that a difference in acoustic characteristics of voice may exist between Hispanic and European-American ethnic groups.

Physical Differences Between Hispanic and European-American Ethnic Groups

In addition to differences in acoustic characteristics, physical differences have been suggested between Hispanic and European-American ethnic groups. Researchers have shown differences in height, weight, total body fat and leg length (Greaves, Pahl, Baronowski, Gruken & Seale, 1989; Kautz & Harrison, 1981; Malina, Brown, & Zavaleta, 1987; Pawson, Martorell, & Mendoza, 1991; Stern, Patterson, Mitchell, Haffner, & Hazuda, 1990).

Height

Malina et al. (1987) found that Mexican-American youth ages 9 to 17 are shorter in height and sitting height than their American Black or American White counterparts. They found that average sitting height ratios were slightly higher in Mexican-American males as compared to White males and significantly higher as compared to Black males. The difference in stature appears to be in the lower extremities. Mexican-American males have shorter leg lengths than either American White or American Black males.

Weight

In addition to total height, researchers have shown that Hispanic adults have greater trunk fat, greater weight for height, greater estimated total body fat and a higher prevalence for being overweight than U.S. White adults (Pawson et al., 1991; Greaves et al., 1989). Kautz and Harrison (1981) showed that younger Mexican-American children aged 48 to 56 weeks have a higher body weight and greater body fat than Anglo-American children of the same age. Stern et al. (1990) suggested that weight tables derived from non-Hispanic whites may not be suitable for obtaining appropriate weight ranges for Mexican-Americans.

Summary

In summary, there does appear to be a difference in physical characteristics between European-Americans and Hispanics. Research suggests that the Hispanic ethnic group is shorter in overall height, with shorter lower extremities and slightly taller trunk height than the European-American ethnic group. Several studies also show that Hispanics are more likely to be overweight than the European-American group.

Relationship between Physical Characteristics and Acoustic Characteristics

If there is a relationship between physical and acoustic characteristics, than the differences shown in physical characteristics between Hispanic and European-American ethnic groups could help support the hypothesis that there are also acoustic differences. The data concerning whether physical or physiological data are correlated to acoustic characteristics are controversial. Several researchers contend that physical characteristics are directly related to acoustic characteristics (Lass, 1980; Lass, Almerino, Jordan & Walsh, 1980; Lass, Beverly, Nicosia & Simpson, 1978; Laver &

Trudgill, 1979; Van Bezooijen, as cited in Kunzel, 1989). However, others have found no correlation (Cohen, Crystal, House & Newberg, 1980; Gunter & Manning, 1982; Kunzel, 1989). Laryngeal size, vocal tract length, vocal fold length, body height, body weight and body type have been compared to the acoustic characteristics of speech.

Laryngeal Size

Hollien (1960) used lateral radiography to measure laryngeal size. He compared a total of 24 male and female adults ranging in age from 18-29. The subjects were divided into the following four groups: six males with very low pitched voices, six males with very high pitched voices, six females with very low pitched voices, and six females with very high pitched voices. The subjects within each group were similar in average pitch and pitch range. An effort was made to make the differences in average pitch and pitch range between groups as extreme as possible. Upon comparing the measures of laryngeal size and vocal pitch, Hollien found a significant inverse correlation between pitch level and laryngeal size.

Vocal Tract Length

Theoretically, longer vocal tracts produce lower formant frequencies than do shorter ones (Titze, 1994). Laver and Trudgill (1979) reported that a taller man will tend to have a longer vocal tract and larger vocal folds, causing him to have a lower range of formant frequencies and fundamental frequencies.

Vocal Fold Length

Titze (1994) reported that longer vocal folds should produce lower fundamental frequencies than do shorter vocal folds. "In broad terms, the fundamental frequency of any sound-producing device is inversely related to its size" (Titze, p. 169). This has also been shown to be true in humans. A male infant will have a fundamental frequency of approximately 500 Hz. Fundamental frequency will drop with age and size to approximately 125 Hz (Kent, 1976).

Height and Weight

Several studies have provided data comparing perceptual acoustic characteristics to body height and weight. Lass and Davis (1976) examined the ability of 30 normal hearing people to judge the height and weight of males and females by listening to recorded speech samples only. The listeners were asked to assign each speaker's recorded voice to a height and weight range using a multiple choice format. They found that the ability to judge height was significantly higher than chance for both men and women. The ability to judge weight was significantly higher than chance for men only. In 1978, Lass et al. found that naive listeners were able to estimate the height and weight of males and females using vocal cues only. Forty listeners were asked to estimate the height and weight of 30 male and female speakers using recorded speech samples. The average difference between listener estimations and actual measurements was 0.80 inches for height and 3.48 pounds for weight. In a similar study, Lass (1980) found listener estimations and actual measurements varied on average 0.88 inches for height and 1.18 pounds for weight. Lass, DiCola, Beverly, Barbera, Henry and Badali (1979) set out to discover if listeners could identify a speaker's height and weight with reduced linguistic information. Each of the 28 male and female speakers recorded speech samples of isolated vowels, monosyllabic words, bisyllabic words and sentences. Twenty-four judges were able to estimate the height of the speakers within 0.41 inches and weight within 1.44 pounds regardless of linguistic level.

In their study of adolescent voices, Andrews and Summers (1991), examined the relationship of habitual levels of pitch to height and weight at various ages. Weight was significantly related to habitual pitch in children ages five to nine-and-one-half, but height was more significantly related to habitual pitch in children ages nine-and-one-half to thirteen.

Other researchers have found no correlation between a subject's weight and their acoustic characteristics (Cohen et al., 1980; Kunzel, 1989). Cohen et al. (1980) reanalyzed data from a study by Lass and his colleagues (Lass, DiCola, et al., 1979). Cohen showed that the results of Lass' study were based on a two-fold averaging process using group averages. Cohen and his colleagues analyzed the individual listener estimates and found that they were far less reliable than the group listener estimates reported by Lass, DiCola, et al. (1979). Gunter and Manning (1982) reported that neither height nor weight could be reliably estimated by listeners.

As opposed to the perceptual studies performed by many of his colleagues, Kunzel (1989) compared the actual values of estimated height and weight to the average fundamental frequency of 105 men and 78 women between the ages of 19 and 61 years. No correlation was found between the average fundamental frequency and height or weight.

Body Type

Several studies have shown that listeners are able to correctly identify a person's Kretschmerian body type when presented with voice cues only (Bonaventura, as cited in Kunzel, 1989; Fay & Middleton, 1940; Moses, 1940). Laver and Trudgill (1979) state that "exceptions to the general rule of our ability to attach a particular size and physique to a given voice are sufficiently rare to take us aback when they occur" (p.9). Van Bezooijen (as cited in Kunzel) also found similar results. However, no single acoustic parameter or group of acoustic parameters have been directly correlated with the identification of physical characteristics (Gunter & Manning, 1982; Lass et al., 1980).

Summary

The relationship between physical and acoustic characteristics continues to be controversial. However, agreement has been shown in some areas. Theory suggests, and most researchers agree, that the following parameters are inversely related to fundamental frequency: laryngeal size and vocal fold length. Formant frequency has also been shown to be inversely related to vocal tract length. The relationship between acoustic characteristics, both perceptual and actual, and height or weight remains unknown.

Summary of the Review of the Literature

Research has shown that there are differences in acoustic characteristics between African-American, European-American and Hispanic ethnic groups. African-American and European-American groups have been studied significantly more than the Hispanic group. Acoustic differences have been shown between European-American and Hispanic kindergartners (Awan & Mueller, 1996). Studies have shown that Hispanics are shorter in height, longer in sitting height, higher in weight and higher in body fat than either the European-Americans or African-Americans. Research, although not conclusive, suggests that there is a correlation between measures of body size and acoustic parameters. In summary, the differences shown between Hispanics and European-Americans in physical attributes and in acoustic parameters help support the hypothesis that there is a difference in the acoustic characteristics of Hispanic and European-American voices.

PURPOSE

The purpose of this study is to provide normative data regarding the acoustic characteristics of the Latin-American adult male voice. Additionally this study investigates the differences in acoustic characteristics of European-American and Latin-American male voices. The specific acoustic characteristics to be examined are

SFF, F_o of the sustained vowel /ɑ/, semitone range and average formant frequencies at one frequency level using three different vowels. The following questions are asked:

1. Is there a difference in standing height, sitting height or weight between European-American and Latin-American male adults?

   It is hypothesized that the Latin-American subjects are shorter in standing height and shorter in sitting height than the European-American subjects. This hypothesis is based on previous research (Malina et al., 1987).

2. Is there a difference in the average speaking fundamental frequency between European-American and Latin-American male adults during oral reading? If so, is this difference related to differences in physical size?

   It is hypothesized that the SFF of the Latin-American subjects during oral reading is higher than that of the European-American subjects. This hypothesis is based on both linguistic and physical criteria.

3. Is there a difference in the fundamental frequency between European-American and Latin-American male adults during a sustained vowel task? If so, is this difference related to differences in physical size?

   It is hypothesized that the F_o of a sustained vowel of the Latin-American subjects is higher than that of the European-American subjects. This hypothesis is based on both linguistic and physical criteria.

4. Is there a difference in semitone ranges between European-American and Latin-American male adults during oral reading? If so, is this difference related to differences in physical size?

It is hypothesized that the Latin-American subjects would exhibit smaller semitone ranges during oral reading than would the European-American subjects. This hypothesis is based on the findings of Awan and Mueller (1996).

5. Is there a difference in average formant frequencies between European-American and Latin-American adults during a sustained vowel task? If so, is this difference related to differences in physical size?

It is hypothesized that the formant frequency values for the Latin-American subjects would be higher than those for the European-American subjects. This hypothesis is based on the concept that the Latin-American group is shorter in height than the European-American group. A difference in height could result in differences in formant frequency since this measure is directly related to vocal tract length.

CHAPTER II

METHODS

SUBJECTS

Description of Subjects

For this study, Latin-American was defined as any individual of Mexican, South American, Central American, Puerto Rican, or Cuban descent. Ten non-black Latin-American (mean age = 25:1 years) and ten European-American (mean age = 25:0 years) male adults either currently attending or graduated from the University of Tennessee at Knoxville were selected as volunteers for this study. The Latin-American subjects were selected first. The ten European-American subjects were then age-matched (plus or minus 10 months) to the Latin-American subjects. All subjects met the following criteria for inclusion:

(1) bilateral hearing within normal limits as determined by a 20 dB HL hearing screening at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz (ASHA, 1990) administered by the principal investigator;

(2) English as the native language for European-American subjects and Spanish as the native language for the Latin-American subjects;

(3) minimum of two years speaking English as the primary language in either a work or academic setting;

(4) no diagnosed or suspected current or past communication disorders as reported by the subject and interpreted by a certified speech-language pathologist;

(5) no voice disorder at the time of the experiment as judged perceptually by a certified speech-language pathologist;

(6) membership in either the non-black Latin-American or European-American ethnic group with both biological parents identified as Latin-American for Latin-American subjects and European-American for European-American subjects;

(7) chronological age between 19:00 and 34:11 years; and

(8) no known chronic upper respiratory infections within the last year as reported by the subject through questionnaire.

Twenty-five subjects were screened for this study. Five subjects were disqualified: two Latin-American subjects failed to meet the criteria for hearing, one European-American subject was found to have abnormal voice quality and two European-American subjects were not an appropriate age match. All subjects were non-smokers and were not taking any medications at the time of the study.

Subject Recruitment

Names and addresses of Latin-American students ages 19 - 35 years were provided by the University of Tennessee Data Enrollment department. Letters were sent requesting their participation in this study. Latin-American subjects also were recruited from the St. John's XXIII Center, a Catholic church located at the University of Tennessee, Knoxville, as well as from the University of Tennessee International House. Permission was granted to recruit subjects from both these facilities. Latin-American and European-American subjects were recruited from an introductory psychology course taught at the University of Tennessee, Knoxville. Permission to recruit subjects from this class was granted and a sign-up sheet for the study was posted. Subjects recruited from the introductory psychology class received class extra credit upon completion of the study. All other subjects received $10.00 compensation.

<u>Subject Personal Data Form</u>

A written questionnaire was completed by all subjects to determine their ethnic background and provide a brief physical history. The questionnaire was completed by each subject and collected prior to initiation of data collection. Any vague answers were clarified through verbal questions by the principal investigator. The questions elicited information about personal health, ancestry and prior voice problems (see Appendix A).

PROCEDURES

Data collected included physical measures and acoustic recordings. All data were collected by the principal investigator, a female European-American adult.

Physical Measurements

Height

Positioning and points of measurement followed procedures described by the U.S. Health Examination Survey (Malina, Hamill, & Lemeshow, 1974). Height was measured as the distance from the top of the head to the standing surface. All subjects were measured with shoes off. The head was held with eyes looking directly forward (Frankfort plane) and posture erect. Feet were placed together with arms held in a relaxed position at the sides.

Subjects were measured for height using a measuring device attached to a wall. The measuring device was positioned vertically on the wall four feet from the floor and calibrated using a tape measure. The measuring device remained attached to the wall until all subjects' measurements were acquired. The permanent position of the measuring device aided in alleviating inconsistencies in the measurement of height. Each subject stood with his back to the measuring device with both heels touching the edge of a piece of masking tape permanently attached to the floor one inch parallel from the wall. A standard carpenter's square was placed squarely on the back of the subject's head to achieve a ninety degree angle with the wall. Height was measured in inches.

Sitting Height

Positioning and points of measurement for sitting height also followed procedures from the U.S. Health Examination Survey (Malina et al., 1974). Each subject was seated with knees and feet together, feet at right angles to the lower legs and lower legs at right angles to the thighs. Elbows were positioned at the sides with forearms at right angles to the upper arm and hands resting on the thighs. Sitting height was measured as the distance from the sitting surface to the top of the head.

A measuring device was permanently positioned to the back of a straight-backed chair. The measuring device was calibrated using a tape measure and remained attached to the chair until all subjects' measurements were acquired to aid in alleviating inconsistencies in the measurement. Each subject sat in the chair as described above. A standard carpenter's square was placed squarely on the subject's head to achieve a ninety degree angle to the measuring device. A level was used in conjunction with the carpenter's square to aid in obtaining an accurate measure.

Weight

Subjects were measured for weight using a Health-o-meter scale by Continental. The scale was calibrated with a 50 pound lead weight each time the scale was moved. Each subject was weighed with shoes and outerwear off.

Reliability

To measure intrajudge reliability of standing height, sitting height and weight, 100% (20/20) of the subjects were remeasured by the principal investigator. Each subject was measured twice on each measuring device, once before recording and then again after recording. The Pearson product moment correlation coefficients for standing height, sitting height and weight were 0.998, 0.970 and 0.999, respectively.

Recordings

Equipment

Each subject was recorded while standing in an Industrial Acoustics 1203 double-walled sound-treated booth with a mounted Shure 533SB microphone positioned six inches from the lips at an angle of 90 degrees. Acoustic data were recorded on Maxell digital audio tapes (DAT) using a SONY PCMR500 DAT recorder. The recorded acoustic data were analyzed using the Computerized Speech Lab (CSL) (Kay Elemetrics, Pine Brook, NJ) and the Multi-Dimensional Voice Program (MDVP) (Kay Elemetrics, Pine Brook, NJ).

Tasks

Each subject completed a total of five vocal tasks. One task involved oral reading while the other four tasks required sustained vocalizations.

Oral Reading. According to Baken (1987), an oral reading task is preferable to spontaneous speech when measures of fundamental frequency are being obtained for purposes of comparison between groups. Horii (1975) found that using samples consisting of the same phonetic structure as opposed to samples of the same duration for analysis significantly reduces error when comparing average speaking fundamental frequency (SFF) estimates between two groups. While oral reading has been shown to yield slightly higher SFF values than does spontaneous speech, the increase in this measure is consistent across individuals. Thus, Baken recommends an oral reading task. A logical choice for a reading sample is "The Rainbow Passage". Not only is the passage phonetically balanced, but it also is widely used in research and assessment. Normative data on average SFF obtained from readings of "The Rainbow Passage" could be of practical importance to clinicians.

Each subject counted from one to ten in order to set the input level of the recorder to avoid clipping. The subject read "The Rainbow Passage" once silently (see Appendix B). Each subject was then recorded reading the passage aloud. The passage was repeated until fluency was achieved. Fluency was defined as three or fewer whole or part-word repetitions, omissions or perceptually noticeable intra-sentence pauses. The fluency of each passage was remeasured by the principal investigator at a later date to ensure accuracy. All passages (20/20) were in 100% agreement for fluency. Additionally, a second judge measured four (20%) randomly selected recording for fluency. Interjudge reliability was 100%.

Sustained Vowels. Each subject was recorded while vocalizing /ɑ/ for five seconds at a comfortable pitch and loudness level. During the next three tasks, the subject was asked to match one pitch, the musical note C, one octave below middle C (130.8 Hz). This pitch was provided from an electronic keyboard. Each subject sustained the vowels /i/, /u/ and /ɑ/. All subjects were able to match the pitch within ± 3 Hz, except for two Latin-Americans and three European-Americans. Two of the subjects' pitches ranged from 117 Hz to 125 Hz, another two of the subjects' pitches ranged from 113 Hz to 130 Hz. The last of these five subjects varied from 105 Hz to 114 Hz. During each production, the subject was asked to monitor a sound level meter (Realistic Sound Level Meter no. 33-2050) and keep his intensity level between 50 dB and 66 dB. The subject was allowed sufficient practice for each task.

Data Measurements

Oral Reading

Average SFF and semitone range were obtained from the reading of "The Rainbow Passage" using MDVP. Analysis of the passage was limited to the second through the fifth sentences.

The sampling rate was set at 50,000 Hz with the maximum duration set at 25 seconds. Using cursors, the data were trimmed to include only the second through the fifth sentences of the passage. During analysis, sudden spikes in fundamental frequency above 400 Hz were sometimes observed during the production of voiced consonants. Since these sudden four octave jumps were not likely physiologically and could not be heard in the audio recording, these spikes were trimmed from the data. The data were analyzed using the Running Speech Analysis command. The Show Results command provided the average SFF, highest F_o, lowest F_o and the phonatory range in semitones (see Appendix C for example). Phonatory range was reported in semitones because this measure is related linearly to the perception of pitch.

Reliability

To measure intrajudge reliability of SFF and semitone range, 100% (20) of the subjects' recordings were reanalyzed by the principal investigator two weeks after the initial analysis. The Pearson product moment correlation coefficients for SFF and semitone range were 0.993 and 0.787, respectively. Inconsistencies in the placement and removal of erroneous fundamental frequencies spikes in the test and re-test conditions may have contributed to the lower reliability scores for semitone range. Further examination of the reliability data revealed that mean semitone range for the European-American group was 15.7 semitones in the test condition and 15.7 semitones in the retest condition. The mean semitone range for the Latin-American group was 11.8 semitones in the test condition and 11.9 semitones in the retest condition. To further test the intrajudge reliability of the parameter semitone range, an additional *t*-test was performed This *t*-test showed that the mean semitone range of the test data was not significantly different from that of the retest data ($p = 0.4814$). Comparison of the correlational and *t*-test analyses suggests that while semitone ranges for individuals varied between the test and retest conditions, this variation was not systematic, thereby canceling any statistical differences. Thus, the measures of semitone range were considered reliable.

To measure interjudge reliability of SFF and semitone range, 20% (4/20) of the subjects' recordings were reanalyzed four weeks after the initial analysis. The Pearson product moment correlation coefficients for SFF and semitone range were 0.992 Hz and 0.912 Hz, respectively.

Sustained Vowels

Average Fundamental Frequency. The F_o of the sustained /ɑ/ was obtained using MDVP. Using cursors, the data were trimmed to include only the middle three seconds of each sample. This segment was used for analysis to avoid the natural rise in pitch at the beginning of a sample and the decline in pitch at the end of a sample.

The sampling rate was set at 50,000 Hz with the maximum duration set for eight seconds. The data were analyzed using the Sustained Phonation command. The Show Results command provided the F_o in Hertz.

Formant Frequency. Formant frequencies for /i/, /ɑ/ and /u/ were obtained using CSL. The sampling rate was set at 16,000 Hz with the maximum length set for eight seconds. The cursor was placed on the data point that most closely approximate the mid-point of the data. The data from each of the three tasks were analyzed using a Fast Fourier Transform (FFT) with a pre-emphasis of 0.9 and frame length 1024 ms. Linear Predictive Coding (LPC) was used to provide a spectral envelope and to calculate formant frequencies and bandwidths. The following LPC parameters were used: filter order = 18, pre-emphasis = 0.9 and framelength = 30 ms.

Reliability

Intrajudge reliabilities for sustained vowels were measured using the Pearson product moment correlation coefficient. The F_o of the sustained vowel /ɑ/ and formant frequencies of the vowels /i/, /u/ and /ɑ/ were reanalyzed for 100% (20/20) of the subjects by the investigator two weeks after the initial analysis. The Pearson product moment correlation coefficient for mean F_o of a sustained vowel was 0.989. The Pearson product moment correlation coefficients for the first formant frequency of the vowels /i/, /u/ and /ɑ/ were 0.990, 0.980 and 0.856, respectively. The Pearson product moment correlation coefficients for the second formant frequency of the vowels /i/, /u/ and /ɑ/ were 0.961, 0.991 and 0.912, respectively.

Interjudge reliabilities for sustained vowels were measured using the Pearson product moment correlation coefficient. The F_0 of the sustained vowel /ɑ/ and formant frequencies of the vowels /i/, /u/ and /ɑ/ were reanalyzed for 20% (4/20) of the subjects four weeks after the initial analysis. The Pearson product moment correlation coefficient for mean F_0 of a sustained vowel was 0.999. The Pearson product moment correlation coefficients for the first formant frequency of the vowels /i/, /u/ and /ɑ/ were 0.928, 0.996 and 0.903, respectively. The Pearson product moment correlation coefficients for the second formant frequency of the vowels /i/, /u/ and /ɑ/ were 0.992, 0.982 and 0.990, respectively.

CHAPTER III

RESULTS

The purpose of this study was to provide normative data regarding the acoustic characteristics of Latin-American voices. An additional purpose was to investigate the differences in acoustic characteristics of European-American and Latin-American male voices. Four acoustic measurements were obtained. Three physical characteristics were measured for each subject in order to ascertain whether these physical traits vary between groups and whether these physical characteristics correlate to possible acoustic differences.

PHYSICAL MEASUREMENTS

The first question posed was "Is there a difference in standing height, sitting height or weight between European-American and Latin-American male adults?

Descriptive Statistics

The mean (*M*), standard deviation (*SD*), range, skewness and kurtosis for standing height, sitting height and weight of the European-American and Latin-American groups are reported in Table 4. Kurtosis and skewness are considered normal at 0.0. A high negative kurtosis value yields a peaked, or leptokurtic distribution. A high positive kurtosis value yields a flattened, or platykurtic distribution. A large negative skewness value represents a negatively skewed distribution. A large positive skewness value represents a positively skewed

Table 4

Descriptive Statistics for Standing Height, Sitting Height and Weight (*N* = 20)

	European-American	Latin-American
Standing Height in Inches		
Mean	70.256	68.233
SD	1.256	1.678
Range	67.88-73.00	64.86-70.88
Skewness	0.498	-0.624
Kurtosis	3.459	1.061
Sitting Height in Inches		
Mean	36.375	35.095
SD	1.403	1.192
Range	34.88-38.75	34.00-85.25
Skewness	0.841	2.380
Kurtosis	-0.935	6.611
Weight in Pounds		
Mean	190.125	164.575
SD	22.457	34.449
Range	150-230	122.50-238.00
Skewness	0.172	0.966
Kurtosis	0.645	1.040

distribution (Bentler, 1995). Each subject's standing height, sitting height and weight measurements are found in Appendix D.

Correlations

Cliff (1987) reported that strong correlations between independent variables can cause computational problems when analyzing multivariate data. Therefore, Pearson product-moment correlation coefficients were calculated to determine whether correlations exist between standing height, sitting height or weight. Results of this procedure indicated three positive correlations. These correlations are summarized in Table 5. The strongest significant positive correlation was between standing height and sitting height ($p = 0.003$). Sitting height and weight showed the next strongest positive correlation ($p = 0.017$). Standing height and weight was the least strong of the physical correlations, yet showed a significant positive correlation ($p = 0.044$).

Table 5

Correlation Matrix for Standing Height, Sitting Height and Weight ($N = 20$)

	Standing Height	Sitting Height	Weight
Standing Height	1.00	0.589**	0.391*
Sitting Height		1.00	0.475*
Weight			1.00

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Multivariate Analysis of Variance

A multivariate analysis of variance (MANOVA, 2 levels of ethnicity) was performed to determine whether the two ethnic groups differed simultaneously on standing height, sitting height and weight. A significant main effect was shown for ethnicity (Wilks' Lambda (λ) = 3.424, $p = 0.043$). The results are summarized in Table 6.

F ratios were calculated for each dependent variable. A significant difference was shown in standing height between the European-American group and the Latin-American group ($F = 9.330, p = 0.007$). A significant difference was also shown between groups for sitting height ($F = 4.884, p = 0.041$). Although a difference was found in weight between the two ethnic groups, this difference was not significant ($F = 3.860, p = 0.065$). The results of the MANOVA are summarized in Table 7.

Comparison of Means

Two-tailed t-tests were calculated to determine the direction of the differences found in physical measurements between the European-American and Latin-American ethnic groups (see Table 8). The mean standing height of the European-American group, 70.256 inches, was significantly higher than the mean standing height of the Latin-American group, 68.233 inches ($p = 0.007$). The mean sitting height of the European-American group, 36.375 inches, was also significantly higher than that of the Latin-American group, 35.095 inches ($p = 0.041$). The mean weight for the European-American group, 190.125 pounds, was greater than that of the Latin-

Table 6

Multivariate Analysis of Variance for the Main Effects of Ethnicity on the Simultaneous Effects of Dependent Variables of Standing Height, Sitting Height and Weight ($N = 20$)

Source of Variation	Degrees of Freedom	Wilks' Lambda	Significance Level
Ethnicity	3	3.424	0.043

Table 7

Multivariate Analysis of Variance for the Main Effects of Ethnicity on the Dependent Variables of Standing Height, Sitting Height and Weight ($N = 20$)

Dependent Variable	Sum of Squares	Degrees of Freedom	F	Significance Level
Standing Height	20.503	1	9.330	0.007
Sitting Height	8.192	1	4.834	0.041
Weight	3264.013	1	3.860	0.065

Table 8

Mean Standing Height, Sitting Height and Weight for European-American and Latin-American Male Adults ($N = 20$)

Source of Variation	European-American Mean	Latin-American Mean	Degrees of Freedom	Significance Level
Standing Height	70.258	68.233	1	0.007
Sitting Height	36.375	35.095	1	0.041
Weight	190.125	164.575	1	0.065

American group, 164.575 pounds. This difference approached significance ($p = 0.065$). The mean standing height and mean sitting height of the two ethnic groups are depicted in Figure 1. Figure 2 shows mean weight for European-American and Latin-American groups.

Summary

In answer to the first question, the Latin -American ethnic group differs from the European-American ethnic group on standing height, sitting height, and weight. Specifically the Latin-American ethnic group was significantly shorter than the European-American ethnic group in standing and sitting height. The mean weight of the Latin-American ethnic group was lower than the mean weight of the European-American ethnic group. This difference approached significance.

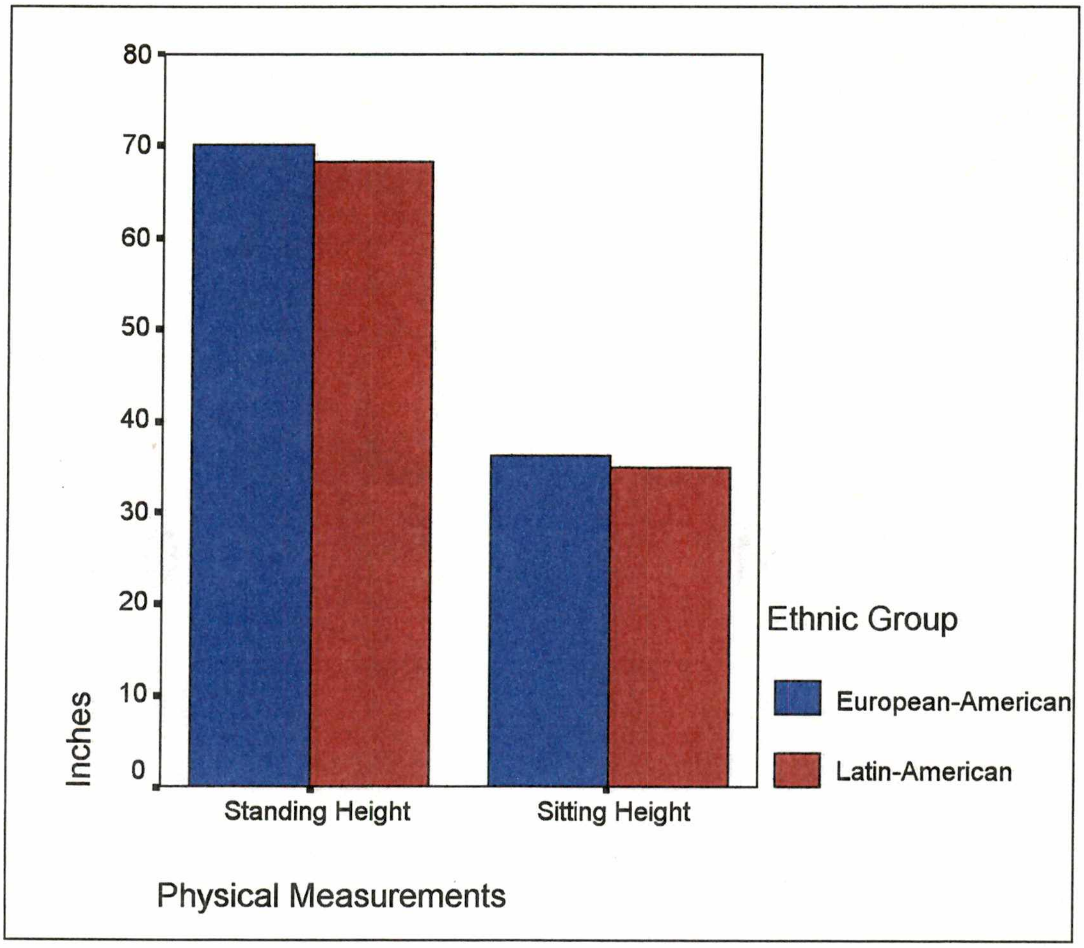

Figure 1: Mean standing height and mean sitting height of European-American and Latin-American male adults.

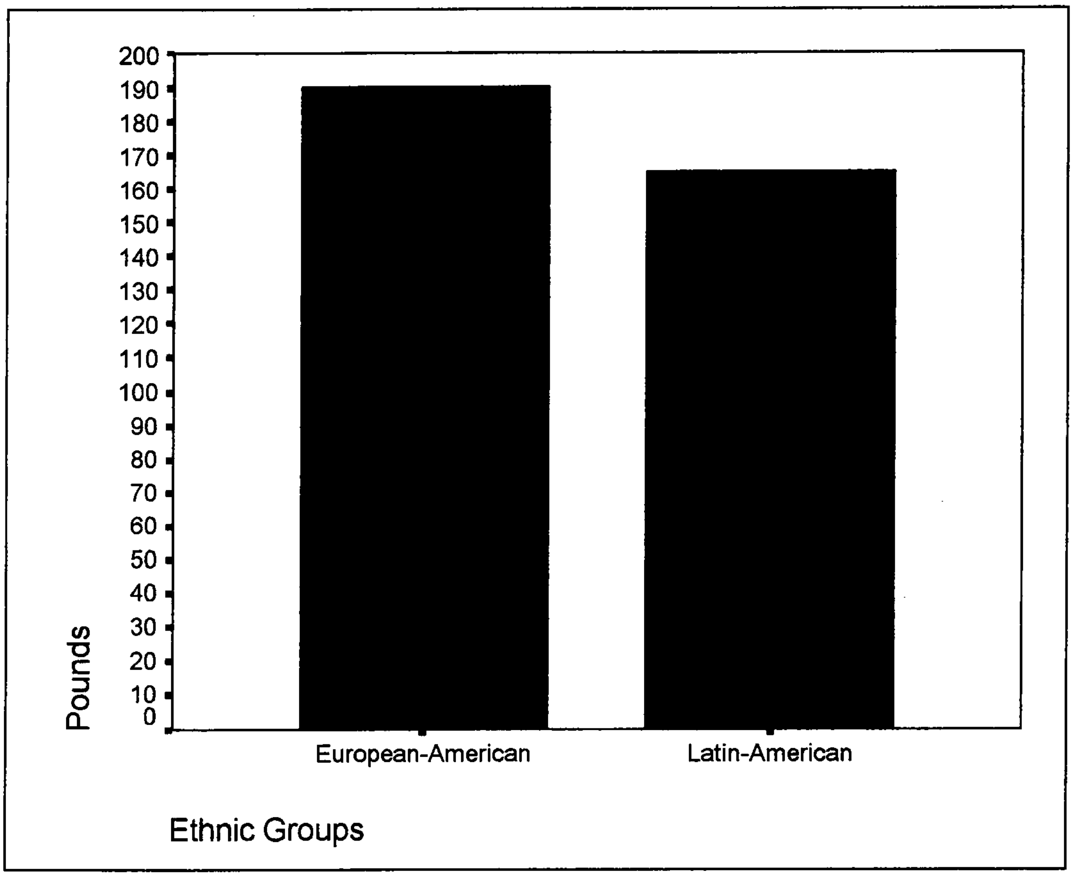

Figure 2: Mean weight of European-American and Latin-American male adults.

FUNDAMENTAL FREQUENCY VARIABLES

Research questions two, three and four asked if a difference exists in SFF, in F_o of a sustained vowel or in semitone range between European-American and Latin-American male adults. In addition, if differences do exist, are they related to differences in physical size?

Descriptive Statistics

The mean (*M*), standard deviation (*SD*), range, skewness and kurtosis for the European-American and Latin-American groups are reported in Table 9. Each subject's individual SFF, F_o and semitone range measurements are found in Appendix E.

Correlations

Pearson product-moment correlation coefficients were performed to determine whether SFF, F_o of a sustained vowel or semitone range were significantly correlated to sitting height or weight within each ethnic group. Due to the strong correlation between sitting and standing height (see Table 5), only sitting height was used in this analysis. The results of this procedure indicated no significant correlation between SFF, F_o of a sustained vowel or semitone range with either sitting height or weight in both ethnic groups. These results are summarized in Table 10.

Table 9

Descriptive Statistics for Speaking Fundamental Frequency (SFF), Fundamental Frequency (F_0) of the Sustained Vowel /ɑ/ and Semitone Range ($N = 20$)

	European-American	Latin-American
SFF		
Mean	115.331	112.876
SD	13.662	11.640
Range	102.58-148.93	92.20-128.94
Skewness	1.850	-0.194
Kurtosis	4.007	-0.371
F_0		
Mean	116.078	113.197
SD	15.316	12.152
Range	97.40-144.06	95.83-139.84
Skewness	0.0433	0.830
Kurtosis	-0.757	2.061
Semitone Range		
Mean	15.7	11.8
SD	3.368	2.700
Range	8-19	8-17
Skewness	-1.442	0.645
Kurtosis	2.118	0.259

Table 10

Correlations for Speaking Fundamental Frequency (SFF), Fundamental Frequency (F_o) of a Sustained Vowel, and Semitone Range to Sitting Height and Weight by Group ($N = 20$)

	European-American		Latin-American	
	Sitting Height	Weight	Sitting Height	Weight
SFF	-0.121	0.074	-0.051	-0.210
F_o	-0.262	-0.100	0.035	-0.246
Semitone Range	0.106	-0.093	-0.315	-0.217

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Multivariate of Analysis of Variance

Simultaneous Effects

A three-way MANOVA (2 levels of ethnicity x sitting height x weight) was performed to discover whether ethnicity, sitting height and weight differ simultaneously on three dependent variables: SFF, F_o of a sustained vowel and semitone range. Strong correlations among independent variables, or colinearity, can cause computational problems when analyzing multivariate data (Cliff, 1987). Due to the strong correlation between standing height and sitting height, standing height was not included in this MANOVA. There was no significant main effect for ethnicity ($\lambda = 0.396, p = 0.758$), sitting height ($\lambda = 0.456, p = 0.718$) or weight ($\lambda = 0.469,

$p = 0.710$). No significant two-way interactions were found. The results are summarized in Table 11.

As reported earlier, the European-American group differed from the Latin-American group on the dependent variables of standing height and sitting height. These two groups also differed highly on the dependent variable of weight. Thus, ethnicity was highly related to all three physical variables. This colinearity may have lead to erroneous computation in the previous three-way MANOVA. To test for possible computational errors, physical measures were removed from the analysis. A one-way MANOVA (2 levels of ethnicity) was performed to discover whether ethnic group varied simultaneously on SFF, F_o of a sustained vowel and semitone range. Upon removal of the physical variables, large changes in significance level for main effect of ethnicity can be observed. The two ethnic groups were found to differ simultaneously on SFF, F_o of a sustained vowel and semitone range at a level approaching significance ($p = 0.063$) (see Table 12). Independent Effects

Based on the nearly significant group difference on the simultaneous parameters of SFF, F_o of the sustained vowel and semitone range, separate F ratios were calculated for each of these dependent variables. The results are summarized below and in Table 13.

There was no significant difference in SFF between European-Americans and Latin-Americans ($F = 0.187$, $p = 0.670$). There was no significant difference shown

Table 11

Multivariate Analysis of Variance for the Main Effects and 2-way Interactions Among the Factors Ethnicity, Weight and Sitting Height on the Simultaneous Dependent Variables Speaking Fundamental Frequency, Fundamental Frequency of a Sustained Vowel and Semitone Range ($N = 20$)

Source of Variation	Degrees of Freedom	Wilks' Lambda	Significance Level
Main Effects			
Ethnicity	3	0.396	0.758
Sitting Height	3	0.456	0.718
Weight	3	0.469	0.710
2-way Interactions			
Ethnicity x Sitting Height	3	0.413	0.747
Ethnicity x Weight	3	0.338	0.798
Sitting Height x Weight	3	0.480	0.703

Table 12

Multivariate Analysis of Variance for the Main Effects of Ethnicity on the Simultaneous Dependent Variables of Speaking Fundamental Frequency, Fundamental Frequency of a Sustained Vowel and Semitone Range ($N = 20$)

Source of Variation	Degrees of Freedom	Wilks' Lambda	Significance Level
Ethnicity	3	2.972	0.063

Note. Physical factors removed.

Table 13

Multivariate Analysis of Variance for the Main Effects of Ethnicity on the Dependent Variables of Speaking Fundamental Frequency (SFF), Fundamental Frequency of a Sustained Vowel (F_o) and Semitone Range ($N = 20$)

Source of Variation	Sum of Squares	Degrees of Freedom	F Ratio	Significance Level
SFF	30.145	1	0.217	0.647
F_o	41.509	1	0.217	0.670
Semitone Range	76.050	1	8.163	0.010

Note. Physical factors removed.

between the two ethnic groups for F_o of the sustained vowel ($F = 0.217, p = 0.647$). A significant main effect of ethnicity was discovered between groups on semitone range ($F = 8.163, p = 0.010$) (see Table 13).

Speaking Fundamental Frequency

A two-tailed *t*-test showed there was no significant difference on SFF between ethnic groups ($p = 0.670$) (see Table 14). The mean SFF of the European-American group was slightly higher (115.333 Hz) than the mean SFF of the Latin-American group (112.876 Hz). Upon inspection of the raw SFF data (see Figure 3) an outlier in the European-American group can be observed. When the outlier and his Latin-American age-match were removed from the data, the mean SFF was slightly lower

Table 14

Mean Speaking Fundamental Frequency (SFF), Fundamental Frequency of a Sustained Vowel (F_0) and Semitone Range for European-American and Latin-American Male Adults ($N = 20$)

Source of Variation	European-American Mean	Latin-American Mean	Degrees of Freedom	Significance Level
SFF	115.332	112.876	1	0.670
F_o	116.078	113.197	1	0.647
Semitone Range	15.7	11.8	1	0.010

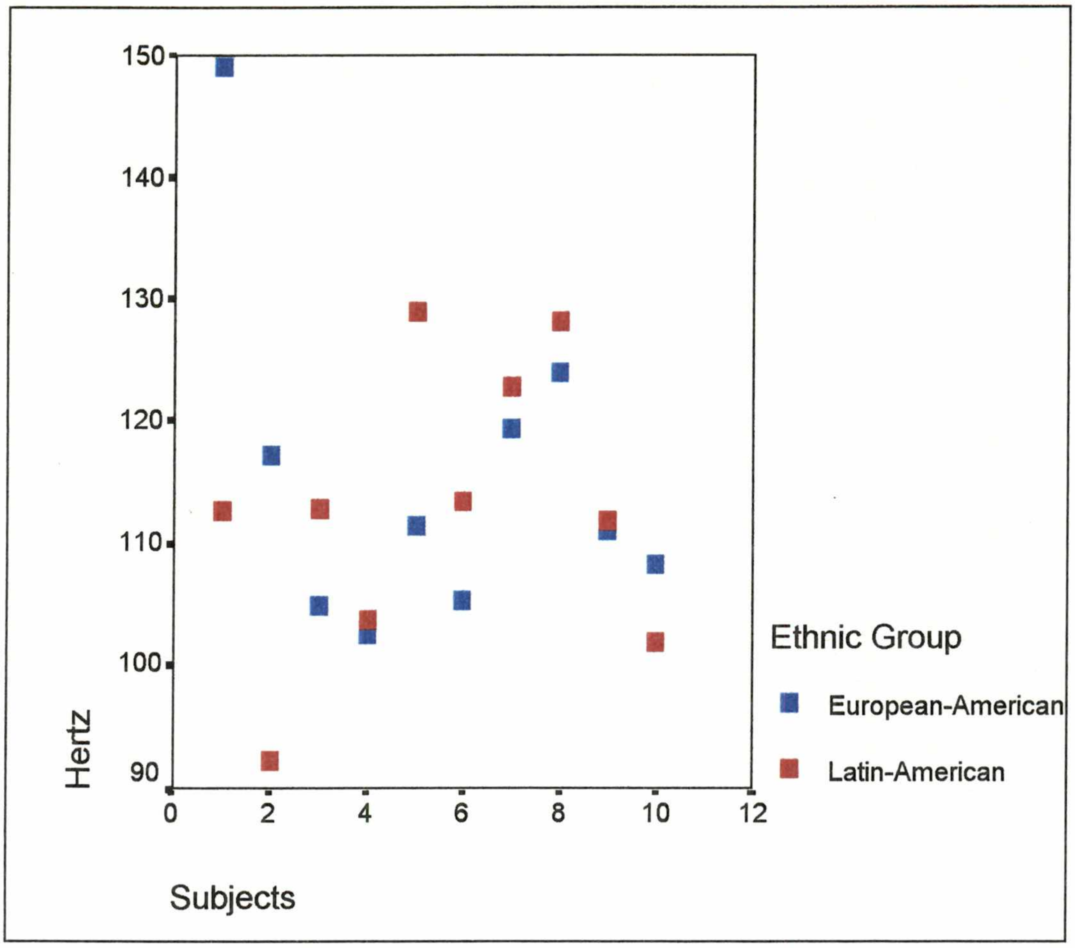

Figure 3: Speaking fundamental frequency of European-American and Latin-American male adults.

for the European-American group (111.598 Hz) than for the Latin-American group (113.884 Hz). This difference was not significant.

Fundamental Frequency of a Sustained Vowel

A two-tailed *t*-test indicated no significant difference in mean F_0 of a sustained vowel between ethnic groups ($p = 0.647$) (see Table 14). The mean F_0 of a sustained vowel was slightly higher in the European-American group than in the Latin-American group. As with SFF, the raw F_0 data revealed an outlier in the European-American group (see Figure 4). When the outlier and his Latin-American age-match were removed from the data, the mean F_0 of a sustained vowel was slightly lower, yet still not significantly different between the European-American group (112.970 Hz) and the Latin-American group (114.788 Hz).

Semitone Range

A two-tailed *t*-test indicated a significant difference in semitone range between ethnic groups. The semitone range of the Latin-American group (11.8 semitones) was significantly smaller than the European-American group (15.7 semitones) ($p = 0.010$) (see Table 14). This difference is graphically depicted in Figure 5.

Summary

No significant difference was found in SFF or F_0 of a sustained vowel. In summary the semitone range of the Latin-American group was significantly lower than

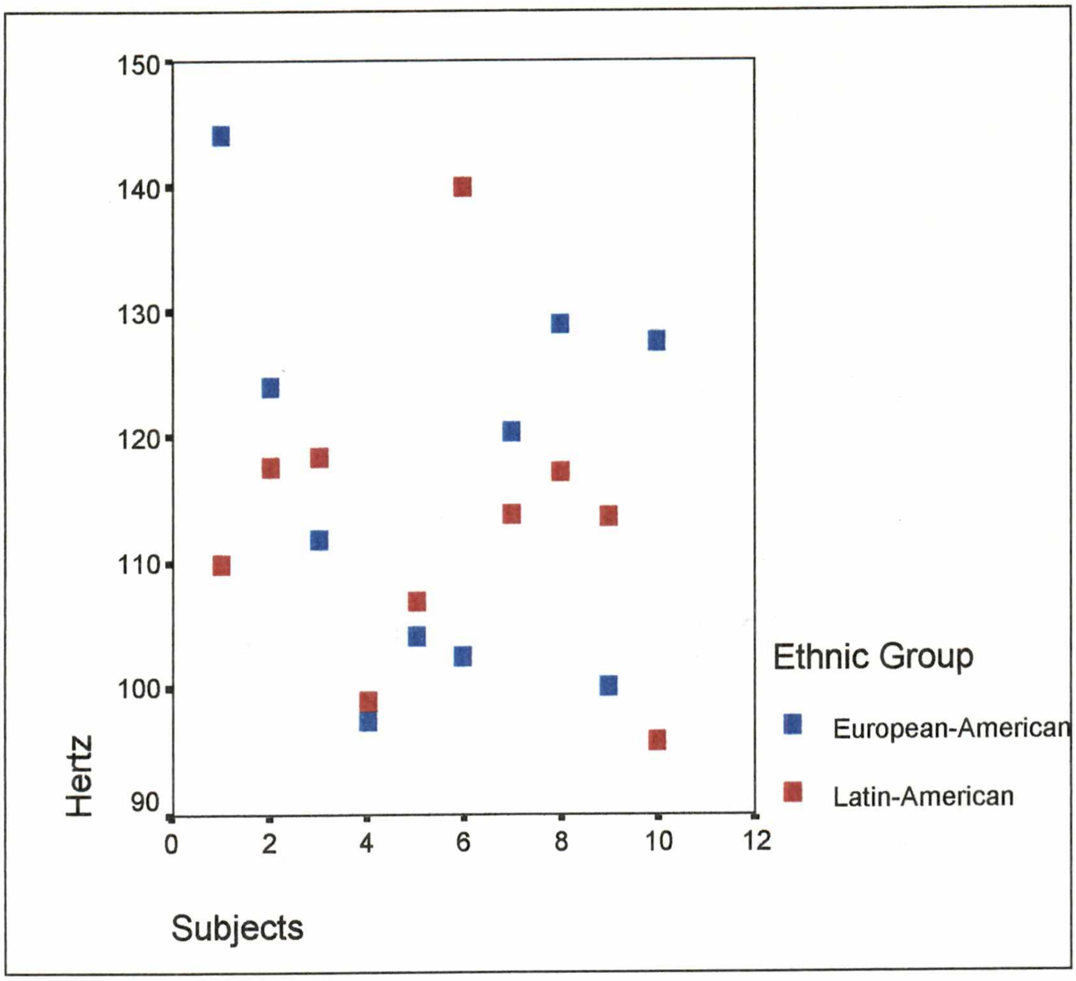

Figure 4: Fundamental frequency of a sustained vowel of European-American and Latin-American male adults.

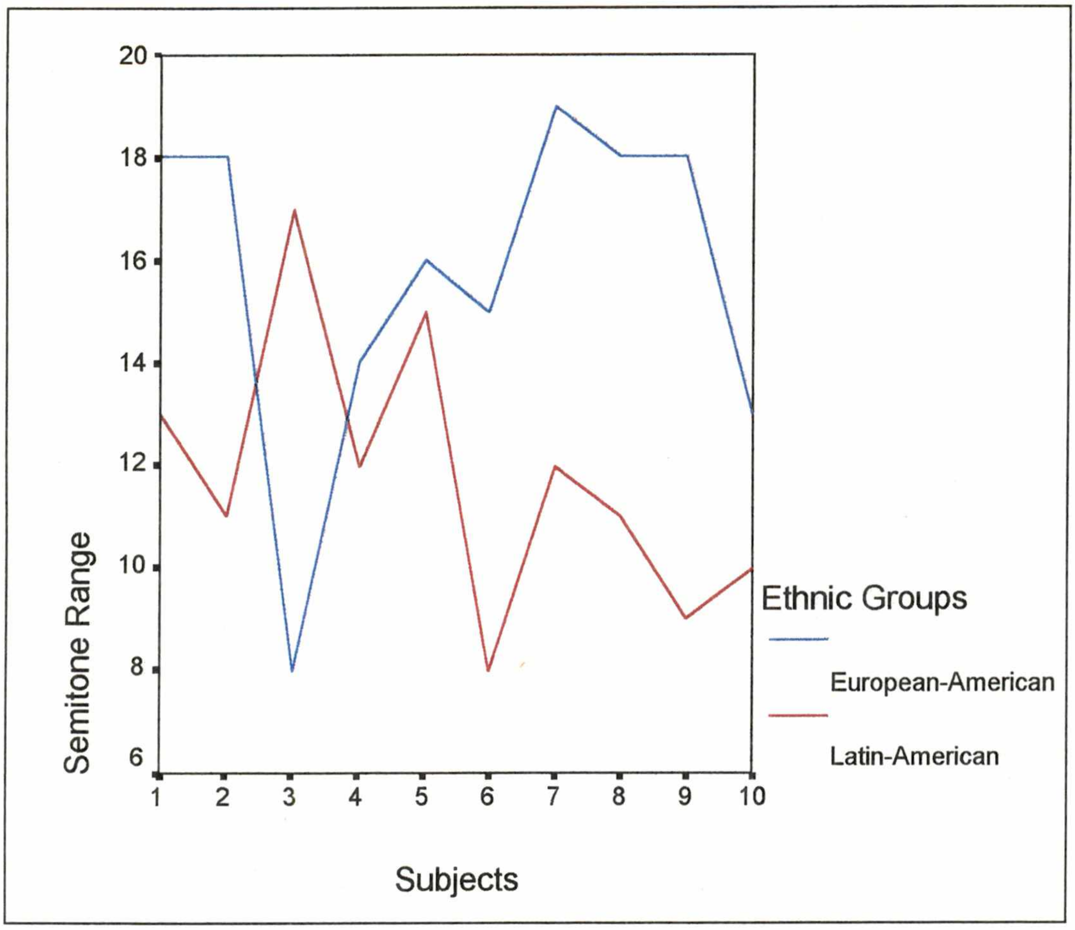

Figure 5: Semitone range of European-American and Latin-American male adults.

that of the European-American group. No correlations were found between SFF, Fo of a sustained vowel, semitone range and any of the physical characteristics.

FORMANT FREQUENCY

The final question posed was "Is there a difference in average formant frequencies between European-American and Latin-American adults during a sustained vowel task? If so, is this difference related to differences in physical size?"

Descriptive Statistics

The mean (*M*), standard deviation (*SD*), range, skewness and kurtosis for F1 and F2 frequency of the vowels /i/, /u/ and /ɑ/ are summarized in Table 15. Each subject's data are reported in Appendix F.

Correlation Analysis

Pearson product-moment correlation coefficients were calculated to determine whether the frequencies of F1 and F2 of the vowels /i/, /u/ and /ɑ/ were significantly correlated to sitting height or weight (see Table 16). Results of this procedure indicated a significant correlation between F1 frequency of the vowel /ɑ/ and sitting height and between F2 frequency of the vowel /i/ and weight in the European-American group only. These correlations are depicted in Figure 6 and Figure 7, respectively. The other four formant frequencies in the European-American group had no significant correlation to sitting height or weight. No significant correlations were found within the Latin-American group between formant frequency and sitting height or between formant frequency and weight.

Table 15

Descriptive Statistics of First Formant Frequency (F1) and Second Formant Frequency (F2) of the Vowels /i/, /u/ and /ɑ/ ($N = 20$)

	Parameter	European-American	Latin-American
Vowel /i/			
F1	Mean	311.300	292.139
	SD	27.538	23.595
	Range	263.12-347.80	264.13-325.98
	Skewness	-0.467	0.344
	Kurtosis	-0.935	-1.836
F2	Mean	2164.182	2199.354
	SD	137.996	185.026
	Range	1897.35-2351.45	1953.24-2550.44
	Skewness	-0.547	0.613
	Kurtosis	0.070	-0.100
Vowel /u/			
F1	Mean	304.237	297.578
	SD	37.808	38.253
	Range	245.07-354.88	251.14-360.32
	Skewness	-0.195	0.668
	Kurtosis	-1.296	-0.719
F2	Mean	1195.122	1018.125
	SD	154.277	220.721
	Range	968.68-1427.60	641.13-1415.82
	Skewness	-0.265	0.082
	Kurtosis	-1.222	0.125
Vowel /ɑ/			
F1	Mean	593.328	531.772
	SD	75.899	79.970
	Range	458.66-722.89	417.21-679.13
	Skewness	-0.083	0.277
	Kurtosis	0.133	-0.217
F2	Mean	1182.098	1204.942
	SD	70.030	122.582
	Range	1056.85-1296.60	1060.83-1483.26
	Skewness	-0.113	1.309
	Kurtosis	-0.062	2.161

Table 16

Correlations for Formant Frequencies to Sitting Height or Weight by Ethnic Group ($N = 20$)

	European-American		Latin-American	
	Sitting Height	Weight	Sitting Height	Weight
Vowel /i/				
F1	-0.101	-0.325	-0.422	-0.284
F2	-0.299	-0.656*	-0.143	-0.212
Vowel /u/				
F1	-0.200	0.002	-0.117	0.039
F2	0.089	0.470	-0.139	0.206
Vowel /ɑ/				
F1	-0.698*	-0.053	-0.027	-0.304
F2	-0.580	0.271	-0.196	0.212

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

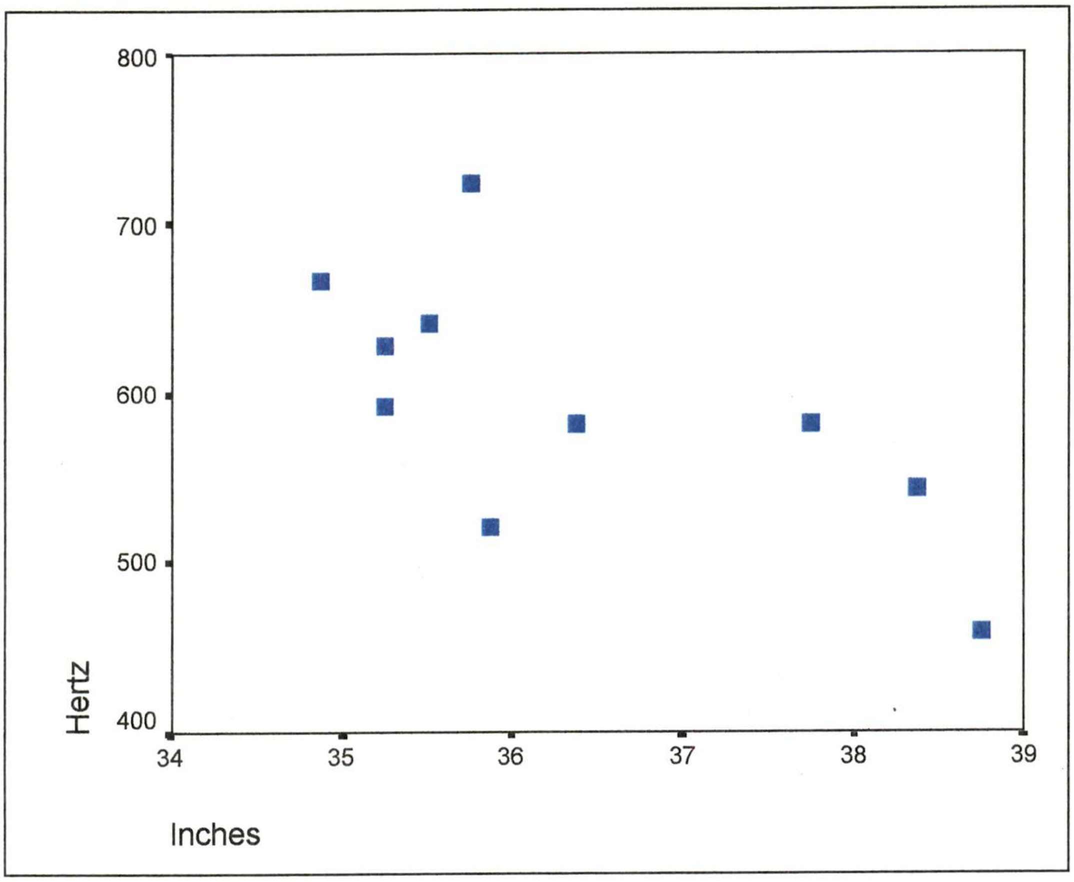

Figure 6: F1 frequency of the vowel /ɑ/ of the European-American group as a function of sitting height.

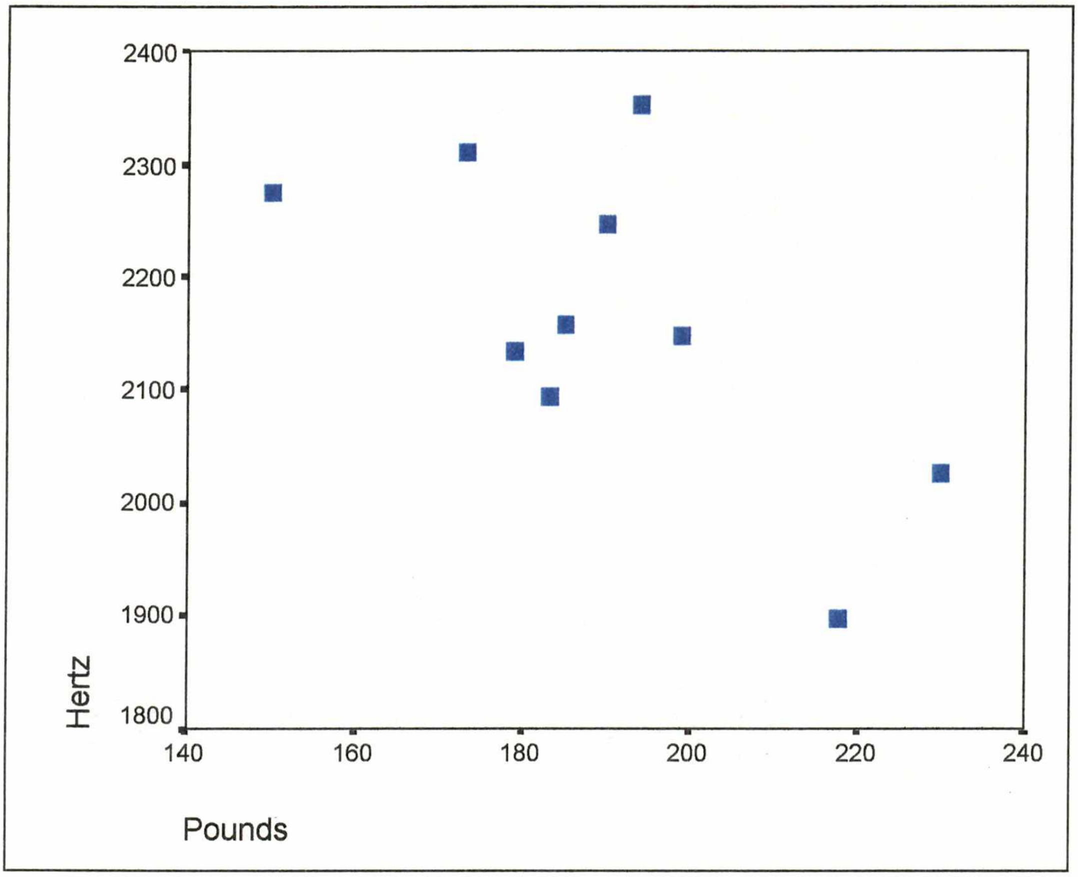

Figure 7: F2 frequency of the vowel /i/ of the European-American group as a function of weight.

Repeated Measures Analysis of Variance

A repeated measures analysis of variance (ANOVA) was performed to determine the effects of ethnicity, sitting height, weight, vowel (repeated measure), and formant (repeated measure) on formant frequency (see Table 17). No significant main effects were observed. An unexpected significant within subjects interaction was found between vowel and weight for formant frequency ($F = 4.490, p = 0.019$). A significant interaction was not found between any of the other variables.

Formant frequency is known to vary by vowel and by formant. Yet this interaction was not found to be significant ($p = 0.267$). Because the physical measurements were highly correlated with ethnicity, inclusion of these variables in the above analysis may have introduced computational errors due to multicolinearity. Therefore, a repeated measures ANOVA was performed to discover the effects of ethnicity, weight, vowel and formant on formant frequency. Sitting height was removed from the analysis because it is more closely correlated with ethnicity than is weight. Since a significant interaction was observed between weight and vowel, this variable was retained in the analysis.

With the removal of sitting height, a significant difference of formant frequency was found between vowels ($F = 337.240, p < 0.001$), between formants ($F = 1920.538, p < 0.001$) and between the interaction of vowel and formant ($F = 604.201, p <0.001$). Source filter theory predicts such results (Fant, 1970).Thus,

Table 17

Analysis of Variance Computed for the Between Subjects Effects and Within Subjects Effects Among the Factors of Ethnicity, Sitting Height, Weight, Vowel and Formant With Repeated Measures on Vowel and Formant on the Dependent Variable Formant Frequency ($N = 20$)

Source of Variation	Sum of Squares	Degrees of Freedom	F Ratio	Significance Level
Between Subjects Effects				
Ethnicity	54154.086	1	1.820	0.196
Sitting Height	44832.585	1	1.507	0.237
Weight	4812.573	1	0.162	0.693
Within Subjects Effects				
Vowel	17456.785	2	1.152	0.329
Vowel x Weight	68053.863	2	4.490	0.019
Vowel x Sitting Height	12076.775	2	0.797	0.460
Vowel x Ethnicity	10782.087	2	0.711	0.499
Formant	75967.089	1	3.673	0.073
Formant x Weight	9665.793	1	0.467	0.504
Formant x Sitting Height	7489.503	1	0.362	0.556
Formant x Ethnicity	580.922	1	0.028	0.869
Formant x Vowel	18444.337	2	1.375	0.267

with the removal of sitting height, the repeated measures ANOVA generated reasonable results.

In this second repeated measures ANOVA, a significant difference was found in the interaction of vowel, formant and group ($F = 4.753$. $p = 0.015$). As in the previous analysis, significant interactions were found involving weight. The interactions of vowel and weight and of vowel, formant and weight were significant ($F = 4.483, p = 0.019, F = 4.753, p = 0.015$, respectively). The results are summarized in Table 18.

Analysis of previous data correlating formant frequency and weight by ethnic group revealed no significant relationships between these two variables, with one exception: F2 frequency of the vowel /i/ was significantly correlated with weight for the European-American group. This correlation likely contributed to the significant interactions involving weight as a predictor of formant frequency in this repeated measures ANOVA.

Comparison of Means

The above repeated measures ANOVA indicated that for a specific vowel and formant, group nearly significantly predicted formant frequency. To provide more specific information, two-tailed *t*-tests for equality of means were calculated between ethnic groups for F1 frequency and F2 frequency of the vowels /i/, /u/ and /ɑ/. F2 frequency of the vowel /u/ for the European-American group, 1195.122 Hz, was significantly higher than that of the Latin-American group, 1018.125 Hz ($p = 0.026$).

Table 18

Analysis of Variance Computed for the Within Subjects Effects Among the Factors Ethnicity, Weight and Vowel with Repeated Measures on Vowel on the Dependent Variable Formant Frequency ($N = 20$)

Source of Variation	Sum of Squares	*df*	*F* ratio	Significance Level
Vowel	400395.84	2	26.736	<0.001
Vowel x Weight	67138.924	2	4.483	0.019
Vowel x Ethnicity	13100.095	2	0.875	0.426
Vowel x Formant	485123.35	2	38.361	<0.001
Formant	737899.85	1	37.069	<0.001
Formant x Weight	5266.973	1	0.265	0.614
Formant x Ethnicity	18.849	1	0.001	0.976
Vowel x Formant x Weight	57589.352	2	4.554	0.018
Vowel x Formant x Ethnicity	60103.929	2	4.753	0.015

F1 frequency of the vowel /ɑ/ was also higher in the European-American group (593.328 Hz) than in the Latin-American group (531.772 Hz) ($p = 0.094$). This difference approached significance. Likewise, a nearly significant difference was found between the two groups for F1 frequency of the vowel /i/ ($p = 0.112$). No significant difference was found between the two groups for F1 frequency of the vowel /u/, nor for F2 frequency of the vowels /i/ and /ɑ/. The results are summarized in Table 19. Figure 8 depicts F1 frequency of the vowels /i/, /u/ and /ɑ/ for both ethnic groups. Figure 9 depicts F2 frequency of the vowels /i/, /u/ and /ɑ/ for both ethnic groups.

Summary

In summary, a significant difference was found between the Latin-American and European-American ethnic groups for F2 frequency of the vowel /u/. The difference between ethnic groups for F1 frequency of the vowel /i/ and /ɑ/ approached significance. No systematic correlations were found between the six formant frequencies and sitting height or weight.

SUMMARY OF ANALYSES

There were four significant differences found between the Latin-American and European-American ethnic groups:

1. the Latin-American group was significantly shorter in standing height than the European-American group;
2. the Latin-American group was significantly shorter in sitting height than the European-American group;

Table 19

Mean First (F1) and Second (F2) Formant Frequencies of the Vowels /i/, /u/ and /ɑ/ for European-American and Latin-American Male Adults (*N* = 20)

Source of Variation	European-American Mean	Latin-American Mean	*df*	Significance Level
Vowel /i/				
F1	311.300	292.1390	18	0.112
F2	2164.182	2199.354	18	0.636
Vowel /u/				
F1	304.237	297.578	18	0.700
F2	1195.122	1018.125	18	0.052
Vowel /ɑ/				
F1	593.328	531.772	18	0.094
F2	1182.098	1204.942	18	0.615

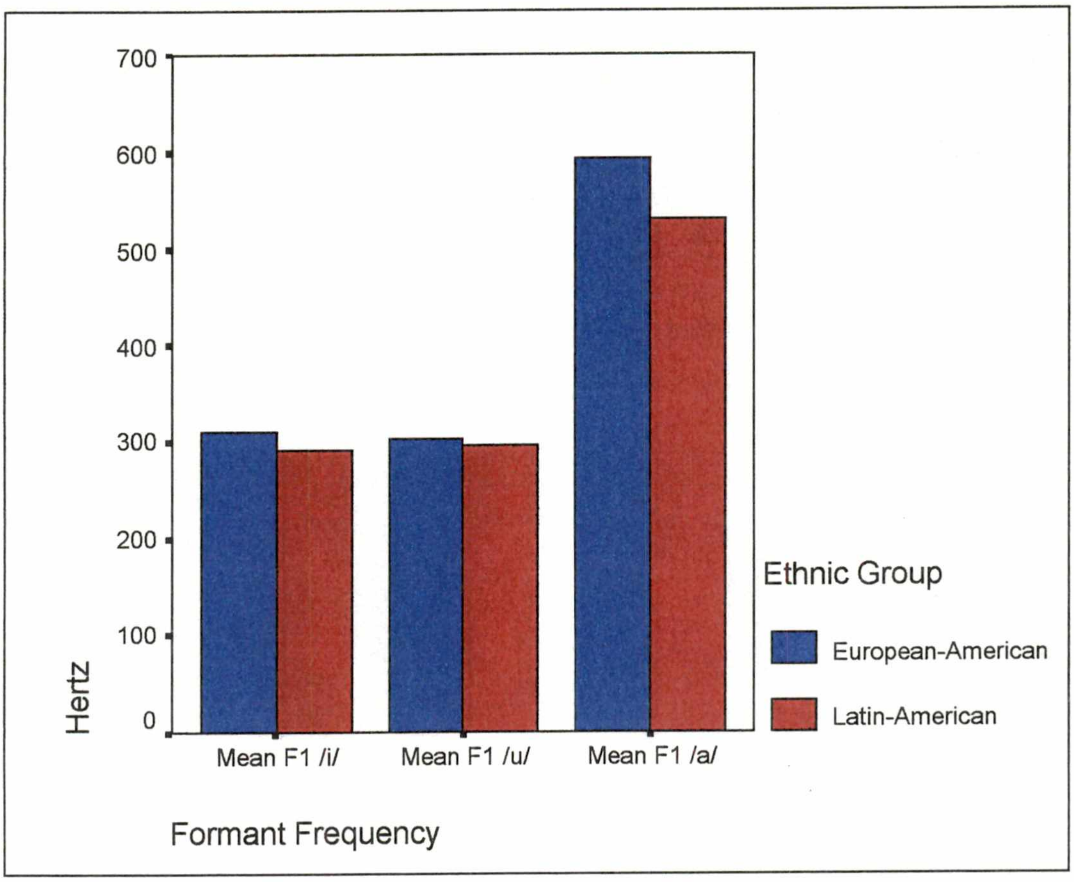

Figure 8: Mean first formant frequency (F1) of the vowels /i/, /u/ and /ɑ/ comparing European-American and Latin-American male adults.

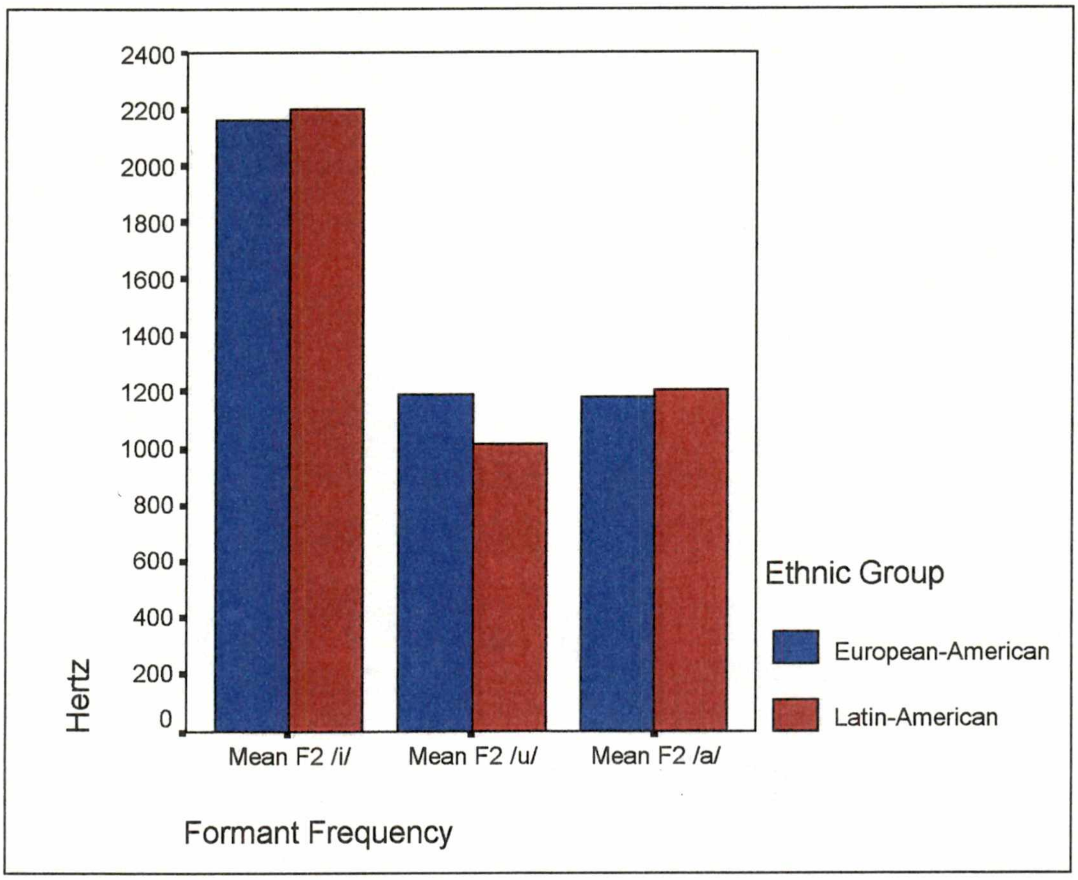

Figure 9: Mean second formant frequency (F2) of the vowels /i/, /u/ and /ɑ/ comparing European-American and Latin-American male adults.

3. the Latin-American group showed a significantly smaller semitone range than did the European-American group;
4. the formant frequency of the vowel /u/ for the Latin- American group was significantly lower than that of the European-American.

Other differences were found that approached significance. The Latin-Americans were lower in weight than the European-American group ($p = 0.065$). F1 frequency of the vowels /i/ and /ɑ/ were slightly lower, yet not statistically significant the Latin-American group than in the European-American group ($p = 0.111$, $p = 0.094$, respectively).

The Latin-American group was found to have slightly lower values for SFF and F_0 of a sustained vowel than the European-American group. The differences were not significant. An outlier was observed in the data of the European-American group. When the outlier and his Latin-American age-match were removed from the data, the Latin-American group became slightly higher in SFF and F_0 of a sustained vowel than the European-American group. This difference was not significant.

CHAPTER IV

DISCUSSION

The primary purpose of this study was to provide normative data for the acoustic characteristics of normal Latin-American male voices. Additionally, this investigation sought to determine whether differences in acoustic characteristics exist between European-American and Latin-American male voices. Physical measurements of standing height, sitting height, and weight were included in this research in order to determine whether any observed acoustic differences between the two groups might be related to physical differences.

While Latin-American subjects were found to be significantly shorter in standing height and sitting height than European-Americans, they did not differ significantly on the acoustic parameters of SFF and F_0 of a sustained vowel, nor was there a correlation between these acoustic measures and physical measures. The Latin-American group used a significantly smaller semitone range during oral reading than did the European-American group; however, semitone range also was not correlated to any physical variables. No significant difference was found between the two groups when formant frequency of all three vowels and both formants were examined simultaneously. However, F2 frequency for the vowel /u/ was found to be significantly higher in the Latin-American group than in the European-American group. No systematic correlations were observed between formant frequency and the physical variables.

TESTS OF THE HYPOTHESES

Physical Measurements

This study sought to determine whether Latin-Americans differ from European-Americans on the physical parameters of standing height, sitting height, or weight. It was hypothesized that the Latin-American subjects would be shorter in both standing height and sitting height. Weight differences were not predicted.

The Latin-American ethnic group was significantly shorter in standing and sitting height than the European-American ethnic group. These results are in agreement with those of Malina et al. (1987). These researchers found that 17-year-old Mexican-American youths are shorter in standing height and sitting height than 17-year-old White youths. The current study also found that the Latin-American subjects were also lighter in weight. This difference approached significance.

Previous research has shown that physical differences exist between Mexican-American and European-American subjects. Less is known about differences between other Latin-American subgroups and European Americans. In this study, 4 of the 10 Latin-American subjects belonged to the Mexican-American subgroup. Thus, it is possible that this subgroup accounted for most of the observed differences between the Latin-American group and the European-American group. Further research using specific, non-Mexican-American subgroups is needed.

Fundamental Frequency Measures

It was hypothesized that the SFF of the Latin-American subgroup would be higher than that of the European-American subgroup. This hypothesis was based on both linguistic and physical criteria. Previous research (Awan & Mueller, 1996) found that the SFF of Hispanic kindergartners was higher than that of White kindergartners. However, this difference was not significant. Awan (personal communication, February 4, 1998) felt that any observed differences between these groups of kindergartners would likely be linguistic in nature. It is also possible that physical differences could exist between the two groups. If the Latin American group was found to be shorter than the European-American group, they may exhibit a higher SFF due to correspondingly shorter vocal folds.

Mean SFF of both ethnic groups was consistent with previously obtained normative data (110.6 Hz - 137.1 Hz) (see Table 1, p. 8). Mean F_o of the sustained vowel /ɑ/ of both ethnic groups was also consistent with previously reported normative data (107.55 Hz - 140 Hz) (see Table 2, p. 11).

Mean SFF and mean F_o of the sustained vowel /ɑ/ in the present study were slightly higher for the European-American ethnic group than for the Latin-American group. However upon inspection of Figures 3 and 4, the data reveal an outlier in the European-American group. This difference was not significant. When the outlier and his Latin-American age-match were removed from the data, the mean SFF and mean F_o of the sustained vowel /ɑ/ were slightly higher for the Latin-American group than in the European-American group, although not statistically significant. The limited size of this study does not compensate for outliers in the data. It also does not provide sufficient power to conclude that no differences exists between these populations on the parameters of SFF and F_o.

In summary, no significant differences were found in SFF or F_o between Latin-Americans and European Americans. No significant correlations between SFF or F_o and the physical measurements were observed.

Semitone Range

This study sought to determine whether Latin-American subjects differed from European-American subjects on the parameter of semitone range. It was hypothesized that the Latin-American group would exhibit smaller semitone ranges during oral reading than did the European-American group. This hypothesis was based on the findings of Awan and Mueller (1996) for semitone range in Hispanic and White kindergartners. These authors found the Hispanic kindergartners used a significantly reduced semitone range compared to their White counterparts. Any observed differences were hypothesized to be linguistic in nature. It was hypothesized that physical variables would not correlate to semitone range.

The semitone range of the Latin-American ethnic group was significantly smaller than that of the European-American ethnic group. There was no correlation between semitone range and any of the physical characteristics measured. Therefore, the difference found in semitone range between ethnic groups is suspected to be linguistic in nature.

Previous research provides some possible explanations for this difference. Stockwell and Bowen (1965) suggest that prosodic differences may be found between the two languages. They found that the English language contains four pitch contours, whereas the Spanish language contains only three. In addition the pitch contours in the English language cover a broader range of pitch than do the pitch contours in the Spanish language.

In contrast, Kelm (1995) reported that the range of pitch did not differ significantly between native speakers of Spanish and native speakers of English. However, he found that the English speakers vacillated more within this range than did the Spanish speakers. Kelm found that both groups of speakers used a reduced pitch range when speaking in a non-native language. Both groups of speakers appeared to transfer the intonational patterns of their native language to that of their non-native language. Wennerstrom (1994) found similar results. He found that non-native speakers did not use pitch to signal meaningful contrasts as they would in their native language. The results of these studies suggest that the difference found in the semitone range in the present study's Latin-American speakers is related to speaking a non-native language.

Backman (1978) compared eight Spanish speaking subjects, just beginning to learn English, to four native English speaking subjects. Backman found that 78% of the utterances of the non-native speakers had inappropriate intonation and that the range of pitch was smaller. However, three months later, the same speakers showed complete improvement in 15% of their utterances and partial improvement in 19% of their utterances, suggesting that the semitone range of non-native English speakers is directly related to the amount of time speaking English. To test this hypothesis, the Latin-American data from the current study were analyzed to determine whether semitone range is correlated with the number of years speaking English. No significant correlation was found. The raw data are listed in Appendix G.

The current study found a reduced semitone range during oral reading for Latin-American subjects as compared to European-American subjects. Is this difference perceptually significant? 't Hart (1981) examined the perceptual sensitivity to differences in the amount of change in fundamental frequency of sustained pitches. He found that individuals, regardless of musical ability, were able to distinguish differences of more than three semitones. While these results cannot be generalized to continuous speech, they provide some evidence that the differences in semitone range observed in this study may be perceptually significant.

Formant Frequency

This investigation sought to determine whether Latin-Americans and European-Americans differed systematically on the parameter of formant frequency. It was hypothesized that the formant frequency values for the Latin-American group would be higher than those for the European-American group. This hypothesis was based on the concept that the Latin-American group was shorter in height than the European-American group. A large difference in height could result in differences in formant frequency since this measure is directly related to vocal tract length.

According to previously reported normative data (see Table 3), the mean first formant frequencies of the vowels /i/ and /u/ and the mean second formant frequencies of the vowels /i/, /u/ and /ɑ/ for both ethnic groups are within expected limits. The first formant frequency of the vowel /ɑ/ falls below the range reported for normal voices (see Table 3) for the European-American and Latin-American groups by 43 Hz and 105 Hz, respectively.

There was no significant difference between the Latin-American group and the European-American group when formant frequency was analyzed without regard to vowel or formant, suggesting that there was no systematic raising of these frequencies for the Latin-American group. There was, however, a significant interaction between vowel, formant, and group on the dependent variable of formant frequency ($p = .015$), suggesting that formant frequency values do differ between these groups for specific vowels and formants. Inspection of mean formant frequency values for each vowel and each formant revealed no pattern of lowering across all vowels. Only one significant difference was found between the two groups. The frequency of F2 for the vowel /u/ was significantly lower for the Latin-American group than for the European-American group. F1 frequency for the vowels /i/ and /ɑ/ for the Latin-American group were lower than those of the European-American group. These differences approached statistical significance (p =0.112, p = 0.094, respectively).

No systematic correlations were found between the physical variables and formant frequency. There was one unexpected significant finding regarding the relationship between physical variables and formant frequency, however. A significant interaction was found between vowel and weight for formant frequency. Analysis of correlational data for each vowel and formant computed by group indicated no significant correlations between weight and formant frequency with the exception of the F2 frequency of the vowel /i/ for European-American subjects. Formant frequency for this group was found to vary inversely with weight. This relationship would be expected if formant frequency were related to physical size. Given that all other formant frequencies did not follow this same pattern, it is difficult to draw such a conclusion from the data.

The significantly and nearly significantly lower formant frequency values for the Latin-American group reported above are contrary to those expected based on the observed physiological differences between the two groups. It is the author's suggestion that these differences are linguistic in nature. Were these differences physiologic in nature, not only would we expect them to be in the opposite direction, but we would also expect them to occur across all vowels and formants. A systematic correlation between formant frequency and physical measures would be expected. No such correlation was observed. These differences might better be explained by differences in tongue position. Specifically, lower first formant frequency values for the Latin-American group on the vowels /i/ and /ɑ/ might be explained by a higher tongue constriction on these vowels. Likewise, the significantly lower formant frequency for the Latin-American group on the vowel /u/ might be explained by a more posterior constriction on this vowel. These hypotheses are consistent with the source-filter theory proposed by Fant (1970).

The findings of this study are similar to previous research. It has been reported that Spanish is an extremely stable language whereas English is extremely variable (Mendez, 1982). Guirao and Borzone de Manrique (1975) also found that English vowels were more variable than Spanish vowels. F1 and F2 of the five Spanish vowels were much more concentrated than that of the English vowels. Examination of the data provided by Guirao and Borzone de Manrique showed that the mean F2 of the Spanish vowel /u/ was lower than that of the English vowel /u/. Stockwell and Bowen (1965) provided information as to why this difference might exist. They reported that the Spanish vowel /u/ is high, back, and rounded through-out whereas the English vowel /u/ begins with little or no rounding and only becomes rounded toward the end. Source filter theory predicts that the longer the vocal tract the lower the formant. Rounding of the lips serves to lengthen the vocal tract. In addition, when the tongue is held further back in the mouth, the second formant frequency tends to lower.

Summary

In summary, there was a significant difference found in standing height, sitting height, semitone range and F2 of the vowel /u/ between European-American and Latin-American male adults. It is suspected that the acoustic differences are linguistic in nature, and not related to physiological differences. No systematic correlations were found between the acoustic characteristics and the physical characteristics. The significant difference between the two groups observed in only one of six formant frequencies suggest that this difference is due to tongue positioning rather than vocal tract size.

PRACTICAL IMPLICATIONS

The normative data for acoustic characteristics currently available is predominantly based on European-American individuals. However, the United States is historically and presently a melting pot of cultures. According to the U.S. Census Bureau (1997), 51 ethnic groups and five racial groups are represented in the United States,. If normative data are expected to encompass all individuals that are served in the United States, it is necessary to understand the differences between these ethnic groups.

Toward this end, this study represents a first effort to provide normative data for the Latin-American population. Additionally, this study sought to determine whether a difference exists between Latin-American and European-American male adults. In order to properly identify, diagnose and treat voice disorders it is necessary to understand what constitutes normal voice in various ethnic groups. This study is a first step toward providing normative data for this rapidly growing population.

METHODOLOGICAL CONSIDERATIONS

Limitations of the Study

This study was limited by sample size, gender restriction to males only, and heterogeneous composition of the ethnic groups. Each of these limitations will be described below.

Sample Size

The major limitation of this study was the small sample size ($N = 10$ for each group). Small sample size contributed to problems with power and outlier effects.

Power. This study did not find significant differences between Latin-Americans and European Americans on numerous acoustic variables: SFF, Fo of a sustained vowel, and most of the formant frequencies. However, this study lacks the statistical power to conclude that differences between these two populations on these variables do not exist. Cohen (1962) recommends a sample size of 13 in each group to achieve a power of .80 when large differences are suspected. For medium differences, he recommends a sample size of 32 for this same power level. If a medium difference in these acoustic parameters is expected, a sample size of at least 30 in each group would be needed before such conclusions regarding lack of difference between these two groups could be drawn.

Outlier Effects. Outliers present special problems when working with small samples. First, it is difficult to determine whether an observed "outlier" in a small data set would be an outlier in a larger data set or in the population. Thus, it is risky to remove such outliers from the data analysis in cases of small *N* unless there is converging evidence in the literature that it is in fact a true outlier. Second, in large data sets, outliers have much less effect on statistical calculations than they do in small data sets. Inappropriate rejection or non-rejection of the null hypothesis can result when a single outlier is present in small sample.

In this study, a single outlier was identified in the European-American group. The SFF for this individual was 148.93 Hz, nearly 2.5 standard deviations above the mean for this European American group (115.33 Hz). However, Curry (1940), reported a mean SFF for 17 to 18.5 year old males of 137.1 Hz (Curry, 1940). The age of the outlier was 19 years. It may be that this individual is not truly an outlier, but is simply within normal limits for his age. Thus, it was not possible to safely remove this individual from the study.

Gender

Another limitation of the sample is gender. This study examined the acoustic characteristics of European-American and Latin-American males only. The findings of this study cannot be generalized to females of either population.

Composition of the Ethnic Groups

Comparing ethnic groups provides a limitation in itself. Both the European-American group and the Latin-American group are heterogeneous within themselves. The genetic and linguistic background of the European-American group represents contributions from a variety of European sources. The Latin-American ethnic group also represents a wide variety of genetic and linguistic backgrounds.

European-American Group. The subjects designated as European-American in this study are those who reported themselves, as well as reported their parents, to be among this ethnic group. The European-American subjects in this sample were reared in the southeast United States, except for two. One European-American subject was reared in Pennsylvania and one in Illinois.

Latin-American Group. The subjects designated as Latin-American in this study are those who reported themselves and their parents as being of Mexican, South American, Central American, Puerto Rican or Cuban descent. The Latin-American subjects in this sample were reared in Mexico, South America, Central America, California and New York. The Latin-American subjects also differed in the length of time speaking English. Two of the Latin-American subjects learned English at approximately the same time as they learned their native language, Spanish (see Appendix G). The other eight had learned English after they had become fluent in Spanish. All subjects had spoken English as the primary language in a work or academic setting for at least two years.

Strengths of the Study

Subjects

The subjects were age-matched between ethnic groups. Furthermore, the subjects were similar in educational background. All subjects were current or former students at the University of Tennessee, Knoxville. Subjects' physical measurements were not matched between groups. However, the physical measurements were obtained and accounted for through statistical analysis.

Acoustic Measures

Many previous studies have compared fundamental frequency data or formant frequency data. One strength of this study is that measures of both fundamental frequency and measures of formant frequency were obtained. These measures allow for analysis of pitch characteristics and vocal tract configuration.

Reliability

Another strength of this study rests in the reliability of the measurements. All physical and acoustic measures were found to be highly reliable in test and re-test measures.

IMPLICATIONS FOR FUTURE RESEARCH

To the author's knowledge, the SFF, Fo of a sustained vowel, semitone range and formant frequency data presented in this study represent the only normative data available for Latin-American male adults. This study also represents the only direct comparison of acoustic characteristics between European-American and Latin-

American male adults. Yet this study is only preliminary in nature. Further research in this area is needed.

This present study should be expanded in several ways. First, the number of subjects in each group should be increased to at least 30. Second, female subjects for each group must be included. Third, SFF and semitone range should be obtained from spontaneous speech. Fourth, other acoustic measures such as jitter and shimmer should be examined.

Although it is suspected that the acoustic differences found in this study are linguistic in nature, this hypothesis has not been proven. A comparison of Latin-American subjects who speak English as their native language, Latin-American subjects who speak Spanish as their native language and European-American subjects who speak English as their native language could help determine whether this difference is physiologic or linguistic. A further exploration would involve both spontaneous speech and read speech. It has been shown that a difference exists in fundamental frequency between spontaneous speech and read speech (Baken, 1987).

Additionally, a study of maximum phonation range between European-American and Latin-American subjects is also needed. Maximum phonation range, when properly elicited, is dependent on the physiological constraints of the vocal mechanism and is independent of linguistic influences. Such a study could help determine whether the reduction in semitone range observed in this study for the Latin-American group is linguistic in nature or due to a reduction in phonational range.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The following is a review of the results of the present study in regards to the five hypotheses posed.

The hypothesis for research question one was that Latin-American adult males will be significantly shorter in standing height and sitting height than European-American adult males. Latin-American adult males will differ from European-American adult males on the parameter of weight. The direction of the difference was not predicted. A significant difference was found in standing height and sitting height between European-American and Latin-American adults. The Latin-American group was significantly shorter in both measures of stature than the European-American group. Although the Latin-American group was lower in mean weight than the European-American group, this difference was not significant, but did approach significance.

The hypothesis for the second research question was that during oral reading, mean SFF of Latin-American adult males will be higher than that of European-American adult males. No significant difference was found in SFF between the European-American and Latin-American ethnic groups.

The hypothesis for the third research question was that during a sustained vowel task, mean F_o will be higher for Latin-American adult males than for European-

American adult males. No significant difference was found in F_0 of a sustained vowel between the European-American and Latin-American ethnic groups.

The hypothesis for the fourth research question was that semitone range during oral reading will be reduced for Latin-American adult males as compared to European-American adult males. The Latin-American ethnic group was significantly smaller in semitone range than the European-American ethnic group.

The hypothesis for the final research question was that formant frequency values measured from sustained vowels will be systematically higher for Latin-American adult males as compared to European-American adult males. The Latin-American group was significantly lower in F2 frequency of the vowel /u/ than the European-American group. F1 frequency of the vowels /i/ and /u/ approached significance, however no significant difference was shown in the other three formant frequencies. A systematic lowering of formant frequencies for the Latin-American group was not observed.

CONCLUSIONS

Previous research has shown that acoustic differences do exist between ethnic groups. As reported earlier there are 51 ethnic groups and five racial groups represented in the United States. The Hispanic population is currently growing rapidly. Within the next 50 years the Hispanic population will become the second largest ethnic group in the United States. This will place them just behind non-Hispanic whites in number. If we, as a profession, are to serve this rapidly growing ethnic group appropriately, we must have normative data for this population. This research is a small, yet imperative, first step towards providing valuable normative data for this important segment of our population.

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APPENDICES

APPENDIX A: SUBJECT PERSONAL DATA FORM

Biographical Information

Name ________________________________ Telephone ______________
Date of birth __________________________ Place of Birth ______________

Briefly describe where you have lived (city and state only) and how long you lived there.____

____

Ethnic group (please circle one)
European   Hispanic (non-black)   Hispanic (black)

Father's ethnic group (please list) ______________________________

Father's native language (please list) ______________________________

Mother's ethnic group (please list) ______________________________

Mother's native language (please list)______________________________

Primary spoken language (English, Spanish, etc.) ______________________

List any secondary languages. ______________________________

Have you spoken English for at least two years as your primary language in either a work or academic setting?   Yes   No

Have you ever received speech or language services?   Yes   No
If yes, please provide brief description including type and length of service.

____

____

Do you currently or have you ever smoked? Yes   No
If yes, when and for how long? ______________________________

____

Have you had any chronic upper respiratory problems within the last year? Yes   No
If yes, please provide a brief description. ______________________

____

____

Are you currently taking any medications? If so, please list.

____

APPENDIX B: THE RAINBOW PASSAGE

When the sunlight strikes the raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Throughout the centuries men have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation. To the Hebrews it was a token that there would be no more universal floods. The Greeks used to imagine that it was a sign from the gods to foretell war or heavy rain. The Norseman considered the rainbow as a bridge over which the gods passed from earth to their home in the sky. Other men have tried to explain the phenomenon physically. Aristotle thought that the rainbow was caused by reflection of the sun's rays by the rain. Since then physicists have found that it is not reflection, but refraction by the raindrops which causes the rainbow. Many complicated ideas about the rainbow have been formed. The difference in the rainbow depends considerably upon the green of the first, the result is to give a bow with an abnormally wide yellow band, since red and green lights when mixed form yellow. This is a very common type of bow, one showing mainly red and yellow, with little or no green or blue.

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APPENDIX C: MDVP ANALYSIS RESULT FILE FORMAT

Running Speech

Sampled Data:	not named
Signal Level:	29040
Sampling Rate:	50000
Time Range:	0.00000 sec
	5.43320 sec

Average Fundamental Frequency	Fo = 213.045 Hz
Average Pitch Period	To = 4.950 ms
Highest Fundamental Frequency	Fhi = 346.500 Hz
Lowest Fundamental Frequency	Flo = 129.132 Hz
Standard Deviation of Fo	STD = 47.623 Hz
Phonatory Fo-Range in semi-tones	PFR = 18
Length of Analyzed Sample	Tsam = 5.433 s
Degree of Voice Breaks	DVB = 48.271%
Number of Voice Breaks	NVB = 14

Institution	UTK
Patient's name:	Subject 1
Patient's age:	21 years 3 months
Patient's sex:	M

Sustained Phonation

Sampled Data:	not named
Signal Level:	32506
Sampling Rate:	50000
Time Range:	0.00000 sec
	2.15640 sec

Average Fundamental Frequency	Fo = 280.444
Average Pitch Period	To = 3.566 ms
Highest Fundamental Frequency	Fhi = 288.517
Lowest Fundamental Frequency	Flo = 273.000
Standard Deviation of Fo	STD = 2.775
Phonatory Fo-Range in semi-tones	PFR = 2
Fo-Tremor Frequency	Fftr = 4.545 Hz
Amplitude Tremor Frequency	Fatr = 1.258 Hz
Length of Analyzed Sample	Tsam = 2.156
Absolute Jitter	Jita =23.338 us
Jitter Percent	Jitt = 0.654%
Relative Average Perturbation	RAP = 0.396%
Pitch Perturbation Quotient	PPQ = 0.373%
Smoothed Pitch Perturb. Quotient	sPPQ = 0.592%
Fundamental Frequency Variation	vFo = 0.989%
Shimmer in dB	ShdB = 0.091 dB
Shimmer Percent	Shim = 1.056%
Amplitude Perturbation Quotient	APQ = 0.707%
Smoothed Ampl. Perturb. Quotient	sAPQ = 1.914%
Peak-Amplitude Variation	vAm = 10.020%
Noise to Harmonic Ratio	NHR = 0.0635
Voice Turbulence Index	FTRI = 0.503%
Soft Phonation Index	SPI = 17.5653
Fo Tremor Intensity Index	FTRI = 0.503%
Amplitude Tremor Intensity Index	ATRI = 1.283%
Degree of Voice Breaks	DVB = 0.000%
Number of Voice Breaks	NVB = 0
Number of Sub-harmonic Segments	NSH = 0
Number of Unvoiced Segments	NUV = 0
Number of Segments Computed	SEG = 68
Total Pitch Periods Detected	PER = 602

Institution	UTK
Patient's name:	Subject 1
Patient's age:	21 years 3 months
Patient's sex:	M

APPENDIX D: RAW DATA FOR PHYSICAL MEASUREMENTS

Subject	Standing Height (inches)	Sitting Height (inches)	Weight (pounds)
European-American			
1	73	36.375	217.75
2	70.625	35.75	199
3	69.75	35.25	183.25
4	70.825	37.75	230
5	70	35.5	185
6	70.25	38.375	179
7	70.375	37.75	173.25
8	69.875	35.875	150
9	67.875	34.875	194
10	70	35.25	190
Latin-American			
1	67.75	35.125	238
2	66.625	34	136
3	70.875	35.125	132.25
4	68.75	35.25	185
5	67.625	34.5	148.5
6	68.875	35.25	170
7	64.825	34.375	150.25
8	68.25	34.325	122.5
9	69.75	38.25	190.75
10	69	34.75	172.5

APPENDIX E: RAW DATA FOR FUNDAMENTAL FREQUENCIES

Subjects	SFF (Hz)	Fo (Hz)	Semitone Range (semitones)
European-American			
1	148.933	144.056	18
2	117.212	123.993	18
3	104.884	111.81	8
4	102.58	97.396	14
5	111.518	104.035	16
6	105.316	102.51	15
7	119.428	120.375	19
8	124.059	128.919	18
9	111.13	100.13	18
10	108.258	127.558	13
Latin-American			
1	112.66	109.921	13
2	92.204	117.523	11
3	112.807	118.32	17
4	103.806	98.881	12
5	128.94	106.876	15
6	113.445	139.835	8
7	122.872	113.81	12
8	128.107	117.289	11
9	111.942	113.682	9
10	101.981	95.832	10

APPENDIX F: RAW DATA OF FORMANT FREQUENCIES

	F1 /I/ (Hz)	F2 /I/ (Hz)	F1 /u/ (Hz)	F2 /u/ (Hz)	F1 /ɑ/ (Hz)	F2 /ɑ/ (Hz)
European-American						
1	323.44	1897.35	317.24	1284.11	581.18	11179.24
2	295.89	2147.61	245.07	1067.25	722.89	1197.88
3	347.8	2094.74	346.77	1246.96	591.48	1248.54
4	263.12	2027.19	284.3	1299.46	458.66	1128.09
5	326.98	2158.39	354.88	1310.68	640.98	1244.29
6	331.15	2133.76	337.76	1265.02	543.	1155.59
7	338.48	2310.45	259.37	1091.39	581.08	1126.
8	285.68	2274.02	275.07	990.07	520.12	1056.85
9	284.36	2351.45	297.8	1427.6	665.79	1296.6
10	316.4	2246.86	324.11	968.68	628.1	1187.9
Latin-American						
1	274.27	2063.36	284.81	1146.68	434.58	1298.43
2	267.73	2092.79	251.14	992.79	417.21	1164.23
3	276.75	2288.94	319.74	1055.27	588.84	1206.19
4	325.98	2213.82	356.34	1171.8	490.63	1262.1
5	318.11	2550.44	310.09	1415.82	569.16	1483.26
6	278.09	1953.24	287.12	846.5	476.88	1144.26
7	309.81	2411.21	360.32	1166.96	593.84	1060.83
8	319.03	2007.91	258.47	641.13	538.71	1106.9
9	264.13	2158.09	268.87	902.03	528.74	1105.52
10	287.49	2253.74	278.88	842.27	679.13	1217.7

APPENDIX G: LATIN-AMERICAN SUBJECTS; DESCENT

Latin-American Subjects	Descent	Age (Years: Months)	Years Speaking English	Semitone Range
1	Mexican	21:8	Simultaneous English & Spanish	13
2	Mexican	25:5	20	11
3	Mexican	20:5	Simultaneous English & Spanish	17
4	South America	19:6	Simultaneous English & Spanish	12
5	Panama	20:5	4	15
6	Argentina	27:2	10-12	8
7	Colombia	30:9	7-8	12
8	Mexican	34:10	7	11
9	Venezuela	23:1	5	9
10	Chile	27:10	2	10

VITA

Heather Sonner-Ward was reared in southern Illinois and east Tennessee. She entered the University of Tennessee, Knoxville in the fall of 1987. During her undergraduate career she was awarded music scholarships and served on several student government committees. She received her Bachelors of Science degree with honors in Marketing in spring of 1991. Following graduation Heather worked in management for four years.

She returned to the University of Tennessee in 1995 to acquire undergraduate classes in Speech-Language Pathology. She entered the Speech-Language Pathology graduate program in 1996. During this time she served as President of the local NSSLHA chapter and worked as a graduate assistant. She graduated with a Master of Arts in May of 1998 with departmental honors.

Heather's clinical interests include neurogenic disorders, dysphagia and voice. She will begin her clinical fellowship year in the Nashville area.