Velar Stretch as a Function of Task

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This study examined velar stretch in 20 young, normal adults during the production of /ɑ/, /ɛ/, and /u/, and during blowing. Velar length was measured from cephalometric x-rays in two ways: (1) along the nasal surface of the velum and (2) along the velar midline.

Results show no significant differences in velar stretch between males and females. Using nasal surface measures, there was significantly greater stretch for /u/ and for blowing than for /ɑ/ and /ɛ/. For midline measures, the only differences which reached statistical significance were between blowing and /ɑ/ or /ɛ/, which were not different from each other.

Correlations between need ratio and percentage of stretch were significant as were correlations between percentage of velar stretch (nasal surface measure) and velar height.

Comparisons of the two methods of measuring velar length are presented followed by a discussion concerning the significance of the findings.

Introduction

The velopharyngeal mechanism provides regulation of the amount of air flow into the oral and nasal passages during production of vowels and non-nasalized consonants. Velopharyngeal closure is accomplished primarily by posterior-superior movement of the velum permitting it to contact the posterior pharyngeal wall. In addition, medial movement of the lateral pharyngeal walls is of major importance and, in some individuals, anterior movement of the posterior pharyngeal wall makes a contribution to velopharyngeal closure. The major concern of this paper is with the velar aspect of velopharyngeal closure.

Radiography, in the form of cine- or videofluoroscopy or cephalometric x-rays, provides the most accurate measures of velar structure and function. Measurements related to the velum which are commonly utilized include (1) pharyngeal depth, (2) velar length, (3) size of opening, (4) degree of contact during closure, and (5) velar height. These provide information as to the structural adequacy of the mechanism and its ability to function appropriately in terms of velar movement, velar stretch, and posterior wall movement.

Failure of the individual to achieve adequate closure of the velopharyngeal mechanism will result in speech characterized by excessive nasal emission and nasal quality. It must be emphasized, however, that the degree of closure termed adequate is determined at least partially by the task, e.g. the specific phoneme produced.

The degree of velopharyngeal closure changes for different tasks as indicated by several measures. First, the size of the opening between the velum and the posterior pharyngeal wall will vary for different phoneme productions. Even for normal speakers, complete closure does not always occur (Moll, 1960, 1962; Benson, 1972), particularly in production of the low vowels /ɑ æ/. Different phonemes display varying degrees of closure. Benson (1972) found that 63% of normal adult subjects demonstrated incomplete closure during sustained phonations of /ɑ/ whereas 25% of the subjects demonstrated incomplete closure on /i/ but only 9% on /u/. In measuring the size of the opening, Moll (1962) reported greater gaps for /ɑ/ and /æ/ than for /i/ and /u/.

Second, the extent of contact of the velum with the posterior pharyngeal wall has been investigated. Previous studies have indicated that contact varies as a function of the phoneme produced. For example, Moll (1960, 1962) reported greater contact for the high vowel /i/ than for the low vowel /ɑ/. Thus, contact between the velum and the posterior pharyngeal wall is another measure which indicates differences in velopharyngeal closure.

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A third variable of velopharyngeal function is velar height. This has generally been found to be greater for high vowels than for low vowels. Warren and Hoffmann (1961) reported mean velar heights of 4.10 mm on /p/, 6.50 mm on /u/, and 10.70 mm during blowing. In a study by Moll (1961), velar height was reported to be greater for /i/ and /u/ than for /ɑ/ and /æ/ during CVC productions. Bzoch (1968) found differences in velar height between productions of /pɑ/ and /pu/ and between /pɑ/ and /pi/. Lubker (1968) also reported differences in velar height for vowels both in CV combinations and in isolation, with the velum achieving a significantly greater height for higher vowels than lower vowels. Thus, velar behavior does differ according to the phoneme with these differences demonstrated by the measures of velopharyngeal gap, velopharyngeal contact, and velar height.

Researchers have theorized about the cause of the observed variations in velopharyngeal valving. Velar height varies with tongue height with both structures achieving greater elevation on high than on low vowels (Harrington, 1946; Moll, 1962). Moll and Shriner (1967) hypothosized that differences in velar height could be partially explained by this relationship. They felt that the mechanical linkage between the velum and the tongue by the palatoglossus muscle restricts velar elevation for vowels which are produced with a low tongue position and allows greater velar elevation for vowels which are produced with the tongue high in the oral cavity. Lubker (1968), as a result of a study employing both radiographic and electromyographic measures, did not accept the Moll-Shriner hypothesis but felt that ". . . greater palatal elevation may accompany vowels with high tongue position simply because such elevation is needed to prevent the vowel from being detected as nasal in quality" (p.16).

An increase in the intrinsic length of the soft palate during function, or velar stretch, is an adjustment which occurs in most individuals. This adjustment also allows for compensation of the individual mechanism in which velar movement alone is not adequate to produce closure. In an early study of velar stretch in adult subjects, Graber et al. (1959) found ranges of velar length to be 32 to 49 mm during rest and 45 to 70 mm during productions of /p/, /b/, and /f/. Increases of 16.28 mm or 49.3% have been found for normal adult subjects during CV syllable productions (Bzoch, 1968). Simpson and Austin (1972) reported a mean increase of 7.35 mm or 20.6% stretch from rest to production of /s/ in normal adult subjects. Simpson and Colton (1980), in a study of normal adolescent subjects during production of /s/, found an average stretch of 5 mm or 15.19%. Mourino and Weinberg (1975) determined the velar stretch to be 3.6 mm or 11.98% in 10-year-old children and 1.48 mm or 4.82% in eight-year-old children during production of /s/. Subjects with congenital palatal incompetence exhibited increases of 5 mm from rest to production of /u/ and of 3 mm from /u/ to /s/ (Pruzansky and Mason, 1969). Normal subjects after adenoidectomies have demonstrated a 27.8% stretch from rest to production of /s/ compared to 12.67% stretch preoperatively (Neiman and Simpson, 1975).

Several of these studies (Simpson and Austin, 1972; Neiman and Simpson, 1975; Mourino and Weinberg, 1975) have reported a significant correlation between the amount of velar stretch and the structural characteristics of the mechanism. The amount of stretch is at least partially determined by the anatomical characteristics of an individual mechanism, specifically the relationship between velar length and pharyngeal depth. "Need ratio," which has been used to describe this relationship, may be obtained by dividing pharyngeal depth by velar length at rest. Larger need ratios reflect structures which require greater velar adjustment or compensation in order to achieve adequate closure.

In summary, the velum is a structure which is capable of a variety of behaviors depending upon the particular task as it relates to the structural characteristics of the entire velopharyngeal mechanism.

Previous investigations have shown that the degree of velopharyngeal closure and velar elevation both vary with respect to the task and are greater during the production of high than of low vowels. Velar stretch is an adjustment which varies with respect to the structural characteristics of the velopharyngeal mechanism. It may be hypothesized that velar stretch would also vary with respect to the demands of the task. This study investigated the amount of velar stretch occurring during

productions of /ɑ/, /ɛ/, /u/ and during blowing in normal adult subjects.

Procedures

SUBJECTS. Ten males and 10 females served as subjects for this investigation. All were normal speakers between the ages of 18 and 30. Criteria for subject acceptance were that they be native speakers of the General American Dialect, have normal articulation and resonance balance, and have no history of cleft palate or palatal insufficiency.

CEPHALOMETRIC PROCEDURES. Lateral cephalometric x-rays were taken with a General Electric dental x-ray unit and Wehmer headholder. Cassettes for the film were Rapid (Par Speed).

Prior to the experiment, subjects were instructed to produce /ɑ/, /ɛ/, /u/, and to blow hard after maximum inhalation. Each subject was then seated in the chair and placed in the cephalostat. The five lateral cephalometric x-rays were taken of each subject from a randomized sequence of rest, /ɑ/, /ɛ/, /u/, and hard blowing. The subjects performed two successive five-second trials of each task. The first trial was evaluated for accuracy of production, and exposures were taken midway through the second production.

Distance from the source of the x-ray to the mid-sagittal plane of the subject was 58 inches. Setting for the x-ray was 15 milliamperes, 90 kilovolts, and 21 pulses per second. The distance from the mid-sagittal plane of the subject to the cassette was 20 cm. Radiation dosage was .02 Roentgen for each exposure or a total of .1 Roentgen for the five exposures. This study was reviewed and approved by the Institutional Review Board for the Use of Human Subjects of the University of Illinois.

MEASUREMENT PROCEDURES. Tracings from all of the headplates were made on acetate transparencies, and all measurements were taken from them. Measurements were made for all 10 male and 10 female subjects to the nearest .5 millimeter. The following linear measurements (Figures 1 and 2) were made for all conditions:

1. Velar length:
   a. Nasal surface: Distance from the posterior nasal spine to the tip of the uvula along the nasal surface, bisecting every fifth millimeter.
   b. Midline: Distance from the posterior nasal spine and the tip of the uvula, measured at the midline of the velum.
2. Velar height: Perpendicular distance from the palatal plane to the highest point of velar eminence.
3. Pharyngeal depth: Depth of the nasopharynx measured along the palatal plane from the posterior nasal spine to the posterior pharyngeal wall.

Derived scores included:

1. Need ratio: Computed by dividing pharyngeal depth by velar length at rest.

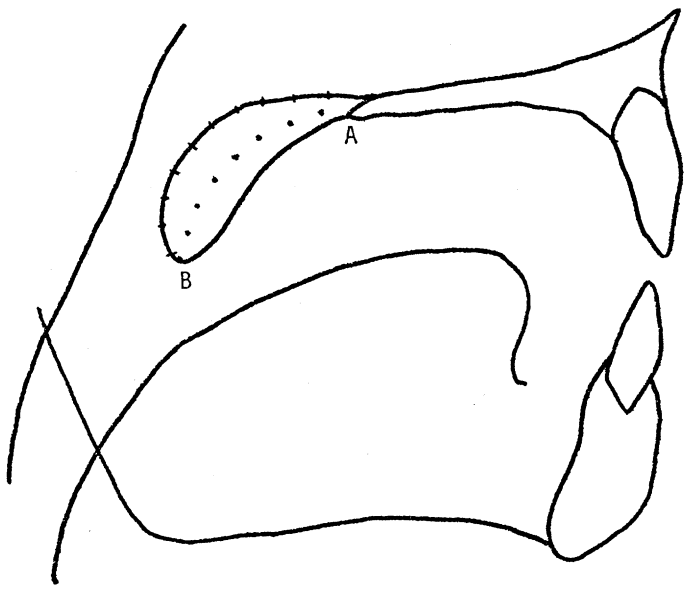

Figure 1. Schematic diagram of nasal surface and midline measurements of velar length (AB) with the velum in rest position.

2. Velar stretch: Increase in velar length computed by subtracting velar length at rest from velar length during a specific task.
3. Percentage of velar stretch: Velar stretch divided by velar length at rest times 100.

Results

In order to assess inter-judge measurement reliability, all x-rays of four randomly selected subjects were retraced and remeasured by one of the investigators (RKS). Coefficients of reliability ranged from .822 to 1.000 with the mean for nasal border measures being .8746 and the mean for midline measures being .9073. Reliability was considered sufficiently high for the purpose of this study.

The means and standard deviations for all the cephalometric measures are presented in Table 1. The raw data from which these figures were derived may be found in Tables 2 and 3. Both nasal surface and midline measurements of velar length were obtained for each subject. These two sets of data were interpreted independently of one another with respect to velar stretch.

To determine whether significant differences occurred between groups, among subjects, and among conditions, analyses of variance were performed on both sets of data (see Table 4). No differences were found between males and females in percentage of velar stretch. Therefore, all subjects were treated as

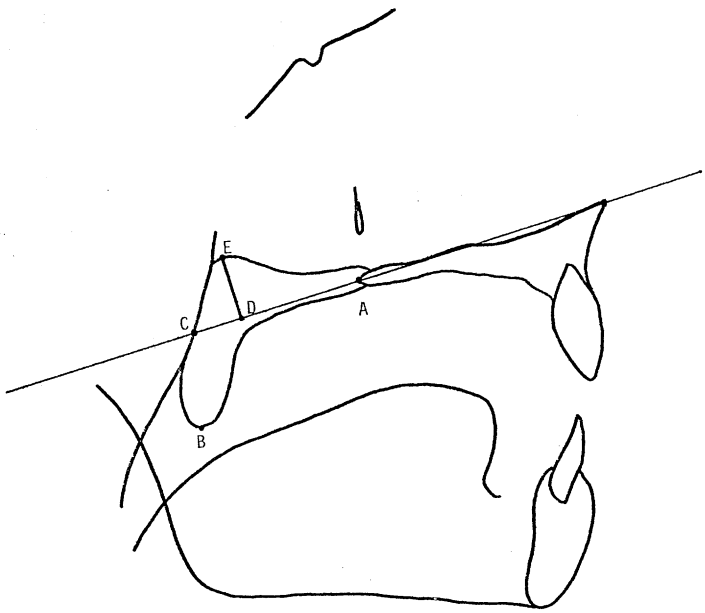

Figure 2. Schematic diagram illustrating measures of velar height (DE) and pharyngeal depth (AC).

TABLE 1. Means and standard deviations (in parentheses) of all nasal border and midline cephalometric measures during rest, /α/, /ε/, /u/ and blowing.

Measure	*Rest*	*/α/*	*/ε/*	*/u/*	*Blowing*
Velar Length	39.1	53.0	53.9	56.3	56.2
Nasal Border (mm)	(3.8)	(4.2)	(3.5)	(4.4)	(4.8)
Velar Stretch	0.0	37.4	39.2	45.2	45.3
Nasal Border (%)		(14.6)	(15.9)	(16.8)	(18.3)
Velar Length	33.3	42.0	41.7	42.9	43.7
Midline (mm)	(4.6)	(4.0)	(2.9)	(2.8)	(3.8)
Velar Stretch	0.0	28.0	27.0	31.2	33.3
Midline (%)		(19.6)	(17.4)	(21.9)	(19.7)
Pharyngeal	30.7	30.6	30.5	30.5	31.7
Depth (mm)	(3.2)	(3.2)	(3.2)	(3.4)	(3.2)
Velar Height	0.0	4.0	5.0	6.9	8.1
(mm)		(2.5)	(3.2)	(3.0)	(2.8)

FIGURE 2. Cephalometric measures for male subjects.

Subject	Task	Velar Length Nasal Border (mm)	Velar Stretch Nasal Border (%)	Velar Length Midline (mm)	Velar Stretch Midline (%)	Velar Height (mm)	Pharyngeal Depth (mm)	Need Ratios Nasal (%)	Need Ratios Midline (%)
Males									
1	Rest	45.5	0.0	39.0	0.0	0.0	31.5	69.23	80.77
	/ɑ/	59.0	29.7	43.5	11.5	4.0	31.5		
	/ɛ/	58.0	27.5	42.0	7.7	4.0	31.5		
	/ʊ/	59.5	30.8	43.0	10.3	8.0	31.5		
	Blow	58.5	28.6	40.0	2.6	10.5	31.5		
2	Rest	42.0	0.0	38.0	0.0	0.0	36.0	85.71	94.74
	/ɑ/	55.0	30.6	45.0	18.4	2.0	36.0		
	/ɛ/	53.0	26.2	41.5	9.2	2.5	36.0		
	/ʊ/	59.0	40.5	39.0	2.6	8.0	36.0		
	Blow	49.5	17.9	45.0	18.4	8.0	34.0		
3	Rest	33.5	0.0	35.0	0.0	0.0	30.0	89.55	85.71
	/ɑ/	50.0	49.3	38.5	10.0	5.0	30.0		
	/ɛ/	52.0	55.2	41.0	17.1	5.5	30.0		
	/ʊ/	54.5	62.7	43.0	22.9	8.0	30.0		
	Blow	54.5	62.7	42.0	20.0	8.5	30.0		
4	Rest	42.5	0.0	40.0	0.0	0.0	33.0	77.65	82.50
	/ɑ/	52.0	22.4	46.5	16.3	2.2	32.0		
	/ɛ/	55.0	29.4	45.5	13.8	5.5	31.0		
	/ʊ/	56.0	31.8	43.5	8.8	5.2	31.0		
	Blow	61.5	44.7	47.0	17.5	7.8	31.0		
5	Rest	44.0	0.0	26.0	0.0	0.0	28.0	63.64	107.70
	/ɑ/	56.0	27.3	40.5	55.8	2.5	28.0		
	/ɛ/	56.0	27.3	39.0	50.0	4.0	28.0		
	/ʊ/	56.0	27.3	44.0	69.2	6.0	28.0		
	Blow	48.5	10.2	39.5	51.9	5.5	28.0		
6	Rest	34.0	0.0	33.0	0.0	0.0	29.0	85.29	87.88
	/ɑ/	52.5	54.4	40.5	22.7	5.5	29.0		
	/ɛ/	56.0	64.7	37.0	12.1	8.5	29.0		
	/ʊ/	58.0	70.6	44.5	34.8	9.5	29.0		
	Blow	56.5	66.2	43.5	31.8	11.5	29.0		
7	Rest	46.5	0.0	35.0	0.0	0.0	34.0	73.12	97.14
	/ɑ/	59.5	27.9	40.5	16.2	8.0	34.0		
	/ɛ/	56.0	20.4	45.5	30.0	6.0	34.0		
	/ʊ/	64.0	37.6	49.5	41.4	9.5	34.0		
	Blow	63.0	35.5	48.0	37.1	9.0	37.0		
8	Rest	36.0	0.0	33.0	0.0	0.0	32.0	88.89	96.97
	/ɑ/	57.0	58.3	43.0	30.3	0.0	32.0		
	/ɛ/	55.0	52.8	45.5	37.9	0.0	32.0		
	/ʊ/	58.0	61.1	40.0	21.2	1.0	32.0		
	Blow	58.0	61.1	46.5	40.9	2.0	32.0		
9	Rest	38.0	0.0	30.0	0.0	0.0	34.5	90.79	115.00
	/ɑ/	58.5	53.9	52.0	73.3	7.0	34.5		
	/ɛ/	60.0	57.9	46.0	53.3	10.5	34.5		
	/ʊ/	65.0	71.1	51.0	70.0	10.5	34.5		
	Blow	63.0	65.8	50.5	68.3	12.0	37.5		
10	Rest	34.0	0.0	28.5	0.0	0.0	32.5	95.99	114.00
	/ɑ/	57.0	67.7	44.5	56.1	7.5	32.5		
	/ɛ/	57.0	67.7	44.0	54.4	8.5	32.5		
	/ʊ/	59.0	73.5	45.5	59.7	11.0	32.5		
	Blow	61.0	79.4	47.0	64.9	12.0	35.0		

FIGURE 3. Cephalometric measures for female subjects.

Subject	Task	Velar Length Nasal Border (mm)	Velar Stretch Nasal Border (%)	Velar Length Midline (mm)	Velar Stretch Midline (%)	Velar Height (mm)	Pharyngeal Depth (mm)	Need Ratios Nasal (%)	Need Ratios Midline (%)
Females									
1	Rest	37.0	0.0	32.0	0.0	0.0	32.5	87.84	101.60
	/ɑ/	58.0	56.8	46.0	43.8	8.0	30.5		
	/ɛ/	56.0	51.4	44.5	39.0	8.5	30.5		
	/ʊ/	54.0	45.9	43.5	35.9	9.0	30.5		
	Blow	61.0	64.9	48.0	50.0	11.0	34.0		
2	Rest	42.0	0.0	38.0	0.0	0.0	24.0	57.14	63.16
	/ɑ/	50.0	19.0	41.5	9.2	0.0	24.0		
	/ɛ/	48.0	14.3	40.0	5.3	1.0	24.0		
	/ʊ/	51.5	22.6	41.0	7.9	2.0	24.0		
	Blow	52.0	23.8	38.0	0.0	5.5	25.0		
3	Rest	41.0	0.0	37.5	0.0	0.0	31.0	75.61	82.67
	/ɑ/	51.0	24.4	41.0	9.3	3.0	31.0		
	/ɛ/	51.5	25.6	43.0	14.7	4.5	31.0		
	/ʊ/	53.0	29.3	42.5	13.3	6.0	31.0		
	Blow	56.0	36.6	45.0	20.0	8.0	33.5		
4	Rest	36.5	0.0	28.0	0.0	0.0	24.0	67.75	85.71
	/ɑ/	46.5	27.4	32.5	16.1	1.0	24.0		
	/ɛ/	47.5	30.1	37.5	33.9	2.0	24.0		
	/ʊ/	50.0	36.9	38.5	37.5	3.0	24.0		
	Blow	50.0	36.9	38.0	35.7	4.5	28.0		
5	Rest	37.0	0.0	23.5	0.0	0.0	30.0	81.08	127.70
	/ɑ/	45.0	21.6	39.0	65.9	0.0	30.0		
	/ɛ/	48.5	31.1	38.0	61.7	0.8	30.0		
	/ʊ/	49.5	33.8	40.5	72.3	3.0	30.0		
	Blow	48.5	31.1	40.0	70.2	4.2	30.0		
6	Rest	38.0	0.0	32.5	0.0	0.0	26.0	68.42	80.00
	/ɑ/	49.0	28.9	38.0	16.9	4.0	26.0		
	/ɛ/	49.0	28.9	37.0	13.8	2.0	26.0		
	/ʊ/	49.0	28.9	36.0	10.8	5.0	24.5		
	Blow	51.5	35.5	39.0	20.0	5.5	30.0		
7	Rest	42.5	0.0	37.5	0.0	0.0	32.0	75.29	85.33
	/ɑ/	51.5	21.2	41.5	10.7	3.5	32.0		
	/ɛ/	55.0	29.4	42.0	12.0	5.5	32.0		
	/ʊ/	58.0	36.5	42.5	13.3	9.0	32.0		
	Blow	59.0	38.8	44.0	17.3	10.5	34.0		
8	Rest	37.5	0.0	31.0	0.0	0.0	30.0	80.00	96.77
	/ɑ/	53.5	42.7	39.5	27.4	11.0	30.0		
	/ɛ/	51.0	36.0	39.5	27.4	11.0	30.0		
	/ʊ/	53.0	41.3	40.0	29.0	11.5	30.0		
	Blow	55.0	46.7	40.5	30.6	10.5	30.0		
9	Rest	39.0	0.0	39.0	0.0	0.0	34.5	88.46	88.46
	/ɑ/	57.0	46.2	46.0	17.9	0.5	34.5		
	/ɛ/	57.0	46.2	43.5	11.5	2.0	34.5		
	/ʊ/	58.0	48.7	45.5	16.7	5.0	36.0		
	Blow	61.0	56.4	48.5	24.4	7.5	35.5		
10	Rest	35.0	0.0	30.5	0.0	0.0	30.5	87.14	100.00
	/ɑ/	48.5	38.6	40.5	32.8	5.0	30.5		
	/ɛ/	57.0	62.9	42.0	37.7	8.0	30.5		
	/ʊ/	61.0	74.3	44.5	45.9	8.0	30.5		
	Blow	57.0	62.9	44.0	44.3	8.5	29.5		

one group (F=1.21, df=1 along the nasal border and F=1, df=1 midline). Individual differences did occur in nasal border measures (F=40.16; df=p < .01) and midline measures (F=9.38; df=3; p < .05).

STRETCH VARIATION BY TASK. The results of this study showed that percentage of velar stretch varied as a function of the task. A Studentized-Range Test was conducted to compare the percentage of velar stretch among tasks. As indicated in Table 5, using nasal surface measures, /u/ and blowing, which were not different from one another, show significantly greater stretch than /ɑ/ and /ɛ/, which also were not significantly different from one another. Also, as shown in Table 5, /ɑ/ and /ɛ/, which were not significantly different from one another on midline measures, resulted in less stretch than blowing. The vowel /u/ did not differ from /ɑ/, /ɛ/, or blowing.

Mean percentages of velar stretch along the nasal border, as indicated in Table 1, were 37.4 mm, 39.2 mm, 45.2 mm, and 45.3 mm for /ɑ/, /ɛ/, /u/, and blowing respectively. Results of midline measures were 28 mm, 27 mm, and 31.2 mm, and 33.3 mm for /ɑ/, /ɛ/, /u/, and blowing. Thus, measures along the nasal border showed more consistent increases in velar stretch. Using either nasal border measures or midline measures, there is a trend for greater stretch to occur as the vowel height is increased, with the greatest stretch occurring during blowing. The amount of stretch during the low vowel /ɑ/ and the mid vowel /ɛ/ was significantly different from blowing for both measures.

CORRELATIONS BETWEEN VELAR STRETCH AND OTHER MEASURES. Need ratio and percentage of velar stretch were significantly correlated (p < .01) for all conditions using either of the two measures (see Table 6). Thus, individuals exhibiting greater need ratios also demonstrated greater percentages of velar stretch for nasal border and for midline measures. Although results of both nasal border and midline measures were significant at the .01 level of confidence, percentages of velar stretch from midline data correlated slightly better with need ratio than did nasal border data.

While not part of the original hypothesis, the correlation between velar height and velar stretch was found to be significant for mea-

TABLE 4. Results of the analysis of variance on nasal border and midline measures.

Sources of Variation	df	SS	MS	F
Nasal Border				
Groups (G)	1	1234.8	1234.8	1.2
Subject/Group	18	18365.0	1020.8	28.9**
Condition (C)	3	994.1	331.4	9.4**
C × G	3	139.2	46.4	1.3
C × S	54	1906.6	35.3	
Midline				
Groups (G)	1	442.7	442.7	< 1
Subject/Group (S)	18	28537.5	1585.4	40.2**
Condition (C)	3	486.5	162.2	4.1*
C × G	3	34.6	11.5	< 1
C × S	54	2131.8	39.5	

* Results exceeded the critical values to the .05 level of confidence.

** Results exceeded the critical values to the .01 level of confidence.

TABLE 5. Results of Studentized-Range Test comparing percentage of velar stretch on /ɑ/, /ɛ/, /u/, and blowing for nasal border and midline measures.

Nasal Border				*Midline*			
/ɑ/	/ɛ/	/u/	Blowing	/ɑ/	/ɛ/	/u/	Blowing
37.4	39.2	45.2	45.3	27.0	28.0	31.2	33.3

TABLE 6. Correlation coefficients of need ratio and percentage of velar stretch on nasal border and midline measures of /ɑ/, /ɛ/, /ʊ/, and blowing.

Task	Nasal Border	Midline
/ɑ/	.7908**	.8978**
/ɛ/	.8249**	.8990**
/ʊ/	.8225**	.8502**
Blowing	.7964**	.9342**

** Correlation coefficient exceeded the critical difference of .5155 at the .01 level of confidence.

TABLE 7. Correlation coefficients of velar height and velar stretch on nasal border and midline measures of /ɑ/, /ɛ/, /ʊ/, and blowing.

Task	Nasal Border	Midline
/ɑ/	.4493*	.1971
/ɛ/	.5174**	.2208
/ʊ/	.4199*	.2151
Blowing	.4032*	.0671

* Correlation coefficient exceeded the critical difference of .4000 at the .05 level of confidence.

** Correlation coefficient exceeded the critical difference of .5155 at the .01 level of confidence.

surements taken on the nasal border for all four tasks (see Table 7). On the other hand, for measurements made at the midline, none of these correlations was significant.

Discussion

The velum is a structure which is capable of a variety of behaviors depending upon the particular task and upon the structural characteristics of the entire velopharyngeal mechanism.

Individual differences occur as demonstrated by cephalometric measures, but differences between males and females were not significant.

Much of the previous research on velar stretch has utilized a midline measure of velar length. In this study, velar length was determined at both the midline and the nasal surface of the velum. Obtaining a midline measure requires that the researcher approximate the curve of the velum with a series of straight lines through the midline. Sometimes, especially when the velum is elevated, it can be difficult to determine the midline. Nonetheless, in this and previous studies, both intra- and inter-tracer reliabilities are very high.

The method of measuring velar length along the nasal border as used in this study appears to be simple and accurate. Dividing the curve of the nasal border into five millimeter segments permits the tracer to follow and measure the curve accurately without using a planimeter.

Although both measures of velar length appear to be reliable, nasal border measures are generally numerically greater than midline measures. This results in a higher percentage of velar stretch and probably accounts for much of the discrepancy between the results of Bzoch (1968), who used nasal surface measures, and other investigators (Benson, 1972; Mourino and Weinberg, 1975; Neiman and Simpson, 1975; Simpson and Austin, 1972; and Simpson and Colton, 1980) who used midline measures.

When nasal surface measures of velar length are used, there is a significant increase in velar stretch between the lower vowels (/ɑ/ and /ɛ/) and the more demanding tasks of /u/ and blowing. As might be predicted, there is a significant correlation between velar height and velar stretch. As velar height increases, velar stretch also increases.

There is also a significant correlation between need ratio and percentage of velar stretch. Each of the subjects had a velopharyngeal mechanism which was functionally adequate since each had normal speech. However, there were variations in the anatomical characteristics of the velopharyngeal mechanisms among subjects as indicated by the wide range of need ratios. To the extent that need ratio reflects the anatomical adequacy of the velopharyngeal mechanism, the less adequate the mechanism the greater the stretch.

Therefore, at least for normal speakers, it would seem that Lubker's statement can be expanded as follows: Greater palatal elevation accompanies vowels with higher tongue position simply because such elevation is needed to prevent the vowel from being detected as nasal in quality. Greater velar stretch also occurs during the production of vowels with high tongue position and during blowing simply to prevent the vowel from being detected as nasal in quality or to prevent nasal air loss. In addition, the amount of velar stretch will also vary as a function of the anatomical characteristics of the individual velopharyngeal valving mechanism.

It remains to be determined whether individuals with inadequate mechanisms follow similar patterns of velar adjustment and, if so, the extent of the adjustment or compensation which either is or can be developed by these individuals.

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