Variations in Velopharyngeal Valving: The Factor of Sex

DOROTHY McKERNS, Ph.D.
KENNETH R. BZOCH, Ph.D.
Gainesville, Florida

This report is the second in a series of studies of normal velopharyngeal valving for speech using the data and the general methods of procedure previously described by Bzoch (*2*).

It has been considered important for the planning of rehabilitation of velopharyngeal insufficiency to know the expected site of velar contact along the pharyngeal wall, the height to which the velum elevates relative to the palatal plane, the amount of tissue making contact, and whether or not there is a relationship between velar length and pharyngeal depth in normal velopharyngeal function for speech. The definition of systematic variations in these elements of normal velopharyngeal valving can provide essential information about the total process for the more effective design of speech appliances and operative procedures. Inspection and comparison of our cinefluorographic films of 100 young adults suggested that a consistent difference in velar configuration and motion existed for male as compared to female subjects. It seemed therefore that there might be definable variations in velopharyngeal valving existing as a factor of sex. The purpose of this study was to test that hypothesis by the detailed measurement and analysis of films on 40 subjects.

Previous Descriptions of Velar Configuration. In its functional or closed position, the velum, as seen in lateral x-ray pictures, assumes a certain configuration resulting from the height to which it elevates (relative to palatal plane), the place on the pharyngeal wall where it touches, the extent of contact, the area on its surface which makes the seal, and the position of the uvula relative to the posterior pharyngeal wall. It has been recognized that velar configuration as it is revealed in lateral x-rays is the result of the balance of muscle forces exerted upon the velum in achieving closure (*10*). However, configuration as an entity defined by the foregoing contributing elements has not been a subject of previous study.

Velar configuration in adults has been referred to, incidental to the main points of papers, by Podvinec (*9*), Ricketts (*10*), Hagerty and associates (*6*), and Green (*5*). The uvula was described as angled well forward in these

Dr. McKerns is Postdoctoral Fellow and Dr. Bzoch is Chairman, Department of Communicative Disorders, Shands Teaching Hospital, University of Florida.

This study was supported in part by Research Grant HD 00163-05.

reports. The high point on the velar surface seen when in the closed position for speech has been called the "levator eminence" and defined as the point of insertion of the levator muscles (*5*, *14*). Green (*5*) has called the configuration of the velum in closure "comma-like" with the levator eminence forming the apex. Ricketts (*10*) has described the velum in closure as being a "hooking action". Beyond these descriptions, velar configuration *per se* or the possible significance of variations from basic configurations have not been studied.

Description of Sex Difference in Velar Configuration. One basic configuration having been described, observed deviations from it have been assumed to be in accordance with individual differences. However, it seems that not one but two basic configurations exist and that the difference is related to sex. Pilot studies showed that it was possible to tell male from female subjects on the basis of judgment of the pattern of motion in movement toward closure and the configurations of the velum in closure during connected speech. The difference is manifested in a different orientation of levator eminence to uvula so that the configuration of the velum for females has the appearance more of a right angle within the pharynx and that for males an acute angle as shown in Figure 1. In this figure, the arrows indicate the perceived directions of movement toward closure and during phonetic adjustments. Note that in the male the configuration fits well the descriptions of velopharyngeal valving in the literature, while in the female the configuration could be described as "squared-off" rather than comma- or hook-like.

Method

The following questions were formulated in order to structure a detailed study based on measurement data from the film library: 1. Can it be shown by an angular measurement that the basic orientation of the velum to the pharynx is different in the sexes? 2. Can it be established that there are differences in the sexes on the following measures: a) site on the pharyngeal wall at which the inferior point of contact falls relative to palatal plane? b)

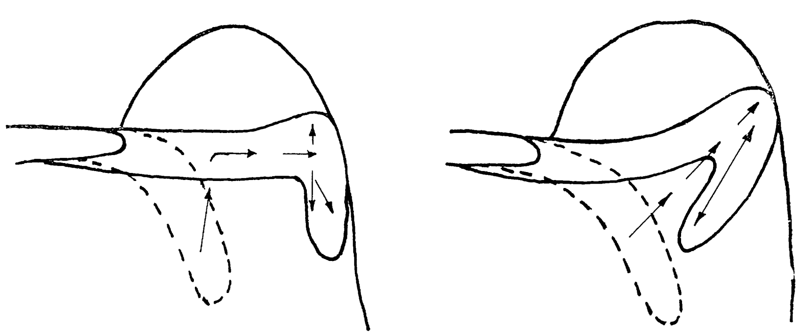

FIGURE 1. "Squared-off" female and "acute" male velar configurations. Broken lines show velum at rest. Arrows show directions of movement.

height of elevation above the palatal plane? c) amount of contact? d) distance of the uvula from the pharyngeal wall? e) velar length? 3. If differences on the foregoing measures exist, will discretely different configurational patterns be manifested? 4. Can differences in configuration be accounted for on the basis of the ratio between velar length and pharyngeal depth? 5. If it is assumed that there is an optimal distance which can most effectively be spanned by the velum, and closure is effected above, on, or below palatal plane accordingly, was the distance significantly changed as revealed by the difference between the depth of the nasopharynx along palatal plane and the depth from PNS to midpoint of closure?

SUBJECTS. From the library of films available 40 normal subjects (20 males and 20 females) were chosen for this study. All were between the ages of 19 and 32. The subjects had been filmed previously, in random order with regard to sex, just as they came in for their appointments. The films to be used here were therefore taken in order from subject number one on. The only criterion for rejecting a film as a subject of study was lack of sufficient clarity for tracing.

SPEECH SAMPLE. The total speech sample filmed consisted of nine consonant-vowel (CV) "syllable" sets, a list of 13 words, and a sentence. For this analysis, one frame for each subject was chosen from the syllable sets containing the consonants /p/, /t/, or /k/ and the vocalic element /i/ as illustrated previously by Bzoch (*2*). Any frame within these syllables was used if it provided sufficient clarity for tracing. Pilot studies had shown that under these conditions, the selection made was representative of the velopharyngeal configuration for each of the 40 subjects.

RELIABILITY. The reliability of tracing technique was determined by a tracing-retracing procedure separated by considerable periods of time. In no instance was there any change in the features such that the outcome of the results would have been affected. When the original data were compared with retracings of the same frame for 12 subjects, the following correlation coefficients were obtained: amount of contact, .927; height of elevation, .950; angle ABC, .989; velar length, .993; depth of the nasopharynx along palatal plane, .970; and depth of the nasopharynx to midpoint of closure, .938.

The accuracy of the tracings used was confirmed with the assistance of an independent experienced tracer in a re-checking procedure.

MEASUREMENTS MADE. Figure 2 illustrates the lines drawn for palatal plane and for measurement of depth of the nasopharynx along palatal plane and from posterior nasal spine to the midpoint of closure.

The length of the velum was measured according to the procedure described by Graber, Bzoch, and Aoba (*4*). In this procedure, velar length in the functional position for speech is determined by measuring along the superior curvilinear border from the posterior nasal spine to the midpoint of the uvula.

The amount of contact is the distance in millimeters spanned by the velar

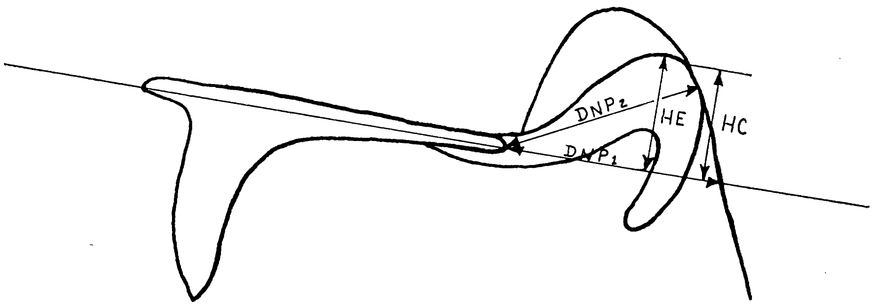

FIGURE 2. A drawing of the hard and soft palates illustrating four of the measurements taken. DNP1: the measurement of depth of the nasopharynx along palatal plane from posterior nasal spine (PNS) to the posterior pharyngeal wall. DPN_2: the depth of the nasopharynx from PNS to the midpoint of the tissue making closure. HE: height of elevation, the distance along a line perpendicular to palatal plane to the highest point of the velum on the nasal surface. HC: height of closure, the perpendicular distance from the palatal plane to the superior point of contact.

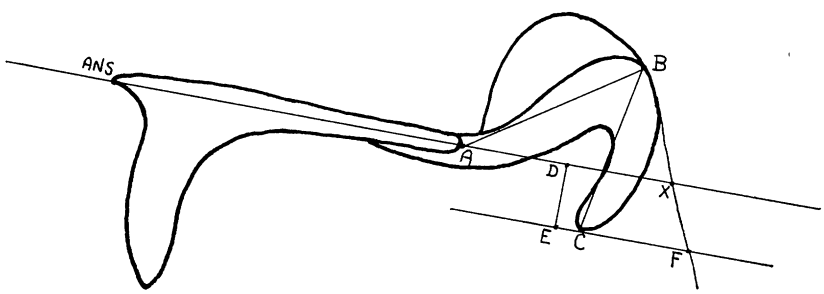

FIGURE 3. Drawing of the hard and soft palates showing palatal plane and the points used to construct ∠ABC and the lines EC and EF for the calculation of "Ratio EC:EF". ANS: anterior nasal spine. Palatal plane is the line drawn from ANS through PNS (point A) to the posterior pharyngeal wall to point X. AB: line drawn from PNS to superior point of velar contact with posterior pharyngeal wall. BC: line drawn from superior point of contact to midpoint of the uvula. AX: depth of the nasopharynx along palatal plane. D: one-half the measurement of AX: EF: an arbitrary line drawn parallel to AX from a line dropped from point D perpendicular to AX, going through point C to the posterior pharyngeal wall at point F.

tissue contacting the pharyngeal wall, measured along the pharyngeal wall from the superior point of contact to the inferior point of contact.

The height of elevation is the measurement in millimeters of a line perpendicular to the palatal plane to the highest point on the superior surface of the velum in the closed position. The height of closure is the perpendicular distance from the palatal plane to the superior point of contact. These measurements are illustrated in Figure 2 also.

Angle ABC (∠ABC) was devised as a way of defining the basic orientation of velum to pharynx. It was formed by lines from the PNS to the superior point of contact and from the superior point of contact to the inferior point of the uvula. The construction of this angle is illustrated in Figure 3.

The ratio EC:EF has been calculated in an attempt to show the orientation of the uvula to the posterior pharyngeal wall. An arbitrary line was drawn from the midpoint of the measurement of the depth of the nasopharynx along palatal plane (point D in Figure 3) perpendicular to the palatal plane. This line intersects another line drawn parallel to the palatal plane at the level of the inferior point of the uvula at point E. The distances EC (the distance from point E to the midpoint of the uvula) and EF (the distance from point E to the back wall of the pharynx) were measured in millimeters and the ratio between them calculated.

Findings

On the basis of differences in measurements of ∠ABC, the orientation of the velum to the pharynx is different between the sexes. The difference is significant beyond the .00003 level, using a Mann-Whitney *U* test. The range for males was 50° to 84°, with a mean of 69.7°, SD 9.28. For females the range was 75° to 102°; the mean was 88.1°, SD 7.33. The mean measurement for females was thus 18.4° larger than for males. No females were found to have angle measurements in the 50–74° range and no males were found in the 85–102° range. Fifteen of the 20 male subjects were in the 50–74° category, and 16 of the 20 female subjects were in the 85–102° category. Five males and four females were in the 75–84° range as shown in the frequency distribution curve in Figure 4.

There are other differences between the sexes on the following measures:

a) Relationship of Inferior Point of Contact to Palatal Plane. Five males had the inferior point of contact on, and twelve males above, the palatal plane. Only three male subjects had it below. In contrast, only 3 females had the inferior point of contact above palatal plane, and 17 had it below palatal plane.

b) Height of Elevation. The mean of this measurement for males (10.05 mm) is almost double the mean for females (5.9 mm). The range for males was 3 to 16 mm, and for females, 1 to 10 mm. The SD for males was 3.66, and for females, 2.2. On the basis of a Mann-Whitney *U* test the difference is significant beyond the .0003 level.

c) Amount of Contact. The mean of this measure in females is almost twice what it is in males. The range for females is from 5 to 15 mm, with a mean of 9.5 mm, SD, 2.74. For males the range is from 3 to 9 mm; the mean is 5.7 mm, and SD, 1.41. These findings are significantly different from zero beyond the .00005 level, using a Mann-Whitney *U* test.

d) Distance of Uvula from Pharyngeal Wall (Ratio EC:EF). The tip of the uvula is angled significantly farther away from the posterior pharyngeal wall in males. The proportion of the distance EF taken up by the distance EC in males ranged from 18 to 57 %, with a mean of 43.3 and SD, 11.4. The range for females was from 50 to 75 %; the mean was 68.9, and SD, 7.6. The possibility that these differences would have occurred by chance was nil as shown by a Mann-Whitney *U* test.

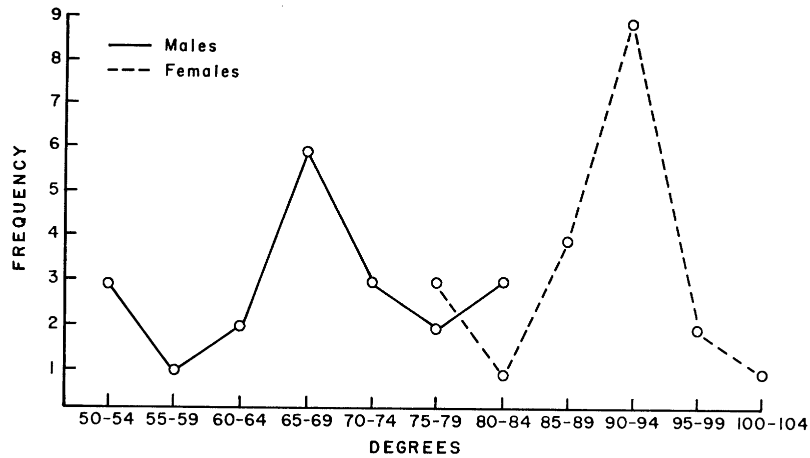

FIGURE 4. Frequency distribution curve for ∠ABC. This angle defines the basic orientation of the velum in the functional position for speech.

e) Velar Length in Function. On this measure, for males the range was from 38 to 61 mm, the mean was 47.8, and the SD was 5.97. For females, the range was from 36 to 46 mm, the mean was 41 mm and the SD was 3.22. A Mann-Whitney *U* test showed these measurements to be significantly different from zero beyond the ∠.00003 level.

The differences found on the foregoing measures are manifested in discretely different configurational patterns. Table 1, in which subjects are organized according to their measurements of ∠ABC, shows that the male subjects have the smaller measurement for ∠ABC, a smaller mean amount of contact, a site of closure predominantly above palatal plane, and greater heights of elevation and closure. As the measurement of ∠ABC increases, the mean amount of contact increases, the site of the inferior point of closure becomes below palatal plane, and the heights of elevation and closure are reduced.

Differences in configuration cannot be accounted for on the basis of the ratio between velar length and pharyngeal depth. An analysis of co-variance was made by constructing an estimated linear model to define the effect of sex on ∠ABC and the effect of depth-to-length ratio on ∠ABC. Depth of the nasopharynx was defined as the distance from the posterior nasal spine to the midpoint of closure as this was the actual distance spanned. The equations calculated showed that the t for sex was 6.13 and was significant at the ∠.001 level for its contribution to ∠ABC. The t for the velar length: pharyngeal depth ratio was .84 and not significant for ∠ABC. The angle assumed by the velum in closure is therefore not determined by the ratio of the length of the velum to the distance to be spanned (depth of the nasopharynx) but is determined on some other basis which appears to be related to sex.

A Wilcoxon Matched-Pairs Signed-Ranks Test showed that the difference

TABLE 1. Organization of subjects by measurements of angle ABC. (As angle size increases, means for amount of velar contact increase and means for heights of elevation and closure decrease, suggesting a downward and backward pull on the velum.)

∠ABC (degrees)	*subject*	*amount of contact (mm)*	*relationship of interior pt. contact to palatal plane*			*height elev. (mm)*	*height closure (mm)*	*velar length (mm)*
			above	*on*	*below*			
A. all subjects are males								
50–54	18	6	x			16	16	61
	22	6	x			16	13	57
	47	6	x			8	7	39
55–59	57	3	x			9	6	45
60–64	31	5	x			10	10	48
	40	5	x			10	9	38
65–69	25	7		x		8	7	48
	55	5	x			9	8	44
	59	6	x			11	11	48
	60	4	x			14	14	50
	95	6	x			15	14	51
	81	7		x		9	8	51
70–74	49	8	x			9	9	48
	58	6			x	7	3	46
	24	7	x			16	12	57
means		5.8				11	9.1	
B. asterisks indicate females; the remainder are males								
75–79	29	6		x		11	8	51
	21	4		x		6	5	43
	38*	5	x			8	8	44
	56*	5	x			9	7	46
	62*	6	x			10	8	38
80–84	42*	8			x	7	5	39
	20	7		x		7	6	44
	30	9			x	7	4	48
	39	7			x	3	3	40
means		6.3				7.5	5.8	
C. all subjects are females								
85–89	23	7			x	7	3	44
	27	8			x	5	3	38
	50	8			x	3	2	41
	88	7			x	8	6	42
90–94	17	15			x	7	7	44
	19	14			x	6	6	43
	26	10			x	7	6	40

TABLE 1.—*Continued*

∠*ABC* (*degrees*)	*subjects*	*amount of contact* (*mm*)	*relationship of interior pt. contact to palatal plane*			*height elev.* (*mm*)	*height closure* (*mm*)	*velar length* (*mm*)
			above	*on*	*below*			
C. all subjects are females—*Continued*								
	43	8			x	4	3	35
	51	12			x	3	1	44
	54	11			x	5	5	45
	61	9			x	6	5	36
	69	9			x	7	6	45
	93	9			x	6	6	40
95–99	36	11			x	4	4	39
	46	11			x	5	4	40
100–104	45	11			x	1	0	38
means		9.7				5.3	4.1	

in the two measurements of depth of the nasopharynx, that is, one along palatal plane and the other from PNS to midpoint of closure, was significant for males at the 1% level but not significant for females. There was a difference in these measurements for only 8 females, the mean being −.3 mm. There was a difference in the two measures in 16 of the males, the mean being −1.65 mm. Thus, the majority of males minimized the distance to be spanned by this difference in the site of closure from palatal plane.

Discussion

The finding of differences in the amount of contact and height of elevation in the sexes is not in agreement with the results of Björk and Nylén (*1*), who reported finding no significant differences on these measures in their Swedish-speaking subjects. No other studies have reported measurements on a sex basis. Mazaheri, Millard, and Erickson (*8*), however, reported in a study of 10 normal American-speaking subjects a site of closure lower than might have been expected on the basis of Calnan's earlier prediction that the usual site in adults would be above palatal plane (*3*). They found the height of velopharyngeal closure was below palatal plane in 80% of their subjects. Eight of the 10 normal subjects in this study were females. Although the authors made no significance of this in interpreting their findings, this may have been an influence, and would be consistent with our finding of a lower site of closure relative to palatal plane in females. On the other hand, the site of closure we found most often in males would approximate the site Calnan had designated as the "infantile" at the basi-occipital level, essentially the upper limit of the nasopharynx.

Warren and Hofmann (*13*) had suggested that shorter palates might have to rise higher to achieve closure. The finding reported here, that the difference between the depths of the nasopharynx measured along palatal plane and at actual site of closure is significant only for males, is evidence against this idea since we find that males usually have significantly greater velar length. This, together with the finding that the ratio of the length of the velum to the depth of the nasopharynx does not influence the orientation of the velum in closure (as this is defined by ∠ABC) suggests that this question asked about structural differences has not been the relevant one.

There could, however, be other significant structural differences. There could be differences in the points of insertion of the levator palatini, palatoglossus, and palatopharyngeus muscles resulting from differences in skull size, orientation of skull to cervical column, or oral and pharyngeal dimensions. The acuteness of ∠ABC in the male pattern could be the result of an orientation of levator palatini to palatoglossus which would lead to the diagonal alignment of the superior point of contact and the tip of the uvula. In the female pattern, the insertions of levator palatini and palatopharyngeus at the same point in the velum could cause the corresponding vertical orientation of the superior point of contact and tip of the uvula as these muscles acted as direct antagonists.

It could also be possible that the two different orientations of the velopharyngeal mechanism are the end products of two different mechanisms of interactions. It may be that in those persons having the male pattern, the palatopharyngeus muscles are caused to move medially, perhaps in accordance with mechanisms proposed earlier by Harrington (*7*) and Strong (*12*). Levators and palatoglossus could then act antagonistically to cause the hooking action. In those individuals having the female pattern, movement of palatopharyngeus muscles could be posteriorward so that they become the direct antagonists of the levator muscles, thus causing the tip of the velum to be directed downward and causing closure to occur at the level of palatal plane with a concomitant decrease in height of elevation above palatal plane.

The different velar orientations and configurations could have some special significance to the acoustic and oral-nasal air flow output during speech. The differences in the measurements of the variables contributing to the configurations could represent physiological adjustments in one sex or the other to compensate for the basic difference in fundamental frequency compounded by differences in the oral and pharyngeal cavities in order to achieve comparable phonetic results. Schwartz (*11*) has presented evidence recently for a difference in intranasal intensity patterns between the sexes in a direction compatible with our finding of a greater amount of velopharyngeal contact in females.

Conclusions

a) The mechanism for velopharyngeal valving, as it is visualized with lateral cinefluorography, has been found to differ for males and females in every measure studied. Control for sex as a variable should be a part of future studies of the velopharyngeal mechansim. b) The basic orientation of velum to pharynx is different for the sexes, and configuration of the velum in outline is concomitantly different according to specific patterns. The basic orientation of the velum to pharynx in males can be described in terms of an acute angle, and that of females more approximately in terms of a right angle. Velar length is greater in males, the height of elevation is greater, the amount of contact is less, and the inferior point of contact is most usually above palatal plane. The reverse of these findings is usual in the female pattern. These differences are not due to chance and are not explainable on the basis of a velar length to pharyngeal depth ratio. c) The establishing of the basic pattern of configuration for experimental subjects under controlled conditions could be a useful technique to use in the further study of variations within velopharyngeal valving for the definition of anatomic or physio-acoustic relationships.

Summary

This study was designed to investigate variations in velopharyngeal valving as a function of sex. The possibility of a difference in basic orientation of the velum to the pharynx with concomitant differences in height of elevation, site of contact, amount of contact, velar length, and distance of the tip of the uvula from the pharyngeal wall was studied by means of lateral cinefluorography during connected speech production. Subjects were 40 normal young adults, 20 of each sex. An angle labeled ∠ABC was constructed from lines drawn from PNS to the superior point of contact, and from superior point of contact to midpoint of the uvula to be used to define basic orientation of velum to pharynx. It was found that measurement of this angle in males ranged from 50° to 84° with a mean of 69.7°, while for females it ranged from 75° to 102° with a mean of 88.1°. In males, as well as the more acute measurement of ∠ABC, there was found to be a smaller mean amount of contact, a site of closure above palatal plane, a greater mean height of elevation, height of closure, velar length, and greater distance of the tip of the uvula from the pharyngeal wall resulting in a total velar configuration which could be designated "acute". For the females, the greater measurement of ∠ABC was accompanied by lower heights of elevation and closure, a greater amount of contact in which the inferior point extended below palatal plane, and an apparent pulling back of the tip of the uvula toward the pharyngeal wall, resulting in a total velar configuration which could be called "squared-off". The different configurations cannot be accounted for on the basis of the ratio between velar length and pharyngeal depth but are determined on some other basis which appears to be related to sex.

Different muscle insertions in the sexes, possibly arising from differences in skull to cervical column, or differences in oral and pharyngeal dimensions were proposed as factors which could contribute to the differences. It was

suggested further that there could be different mechansims of actions of the muscles effecting closure with palatopharyngeus movement being toward the midline in the male pattern and predominantly posteriorward in the female.

It was concluded that sex as a variable should be considered in future studies of velopharyngeal valving and that the identification of basic configurations and variations from them during changing speech conditions could be a useful technique for the further definition of anatomic or physio-acoustic relationships.

reprints: *Dr. Dorothy McKerns*
Department of Communicative Disorders
Shands Teaching Hospital
University of Florida
Gainesville, Florida

References

1. Björk, L., and B. Nylén, The function of the soft palate during connected speech. *Acta Chir. Scand., 126,* 434–444, 1963.
2. Bzoch, K. R., Variations in velopharyngeal valving: the factor of vowel changes. *Cleft Palate J., 5,* 211–218, 1968.
3. Calnan, J. S., Diagnosis, prognosis, and treatment of "palato-pharyngeal incompetence", with special reference to radiographic investigations. *Brit. J. plastic Surg., 8,* 265–282, 1955.
4. Graber, T. M., K. R. Bzoch, and T. Aoba, A functional study of the palatal and pharyngeal structures. *Angle Orthod., 29,* 30–40, 1959.
5. Green, R. I., The radiology of speech defects. *Radiography, 27,* 331–338, 1961.
6. Hagerty, R. F., M. J. Hill, H. S. Pettit, and J. J. Kane, Soft palate movement in normals. *J. speech hearing Res., 1,* 325–330, 1958.
7. Harrington, R., A study of the mechanism of velopharyngeal closure. *J. speech hearing Dis., 9,* 325–345, 1944.
8. Mazaheri, M., R. Millard, and D. M. Erickson, Cineradiographic comparison of normal to noncleft subjects with velopharyngeal inadequacy. *Cleft Palate J., 1,* 199–209, 1964.
9. Podvinec, S., The physiology and pathology of the soft palate. *J. Laryngol. Otology, 66,* 452–461, 1952.
10. Ricketts, R. M., The cranial base and soft structures in cleft palate speech and breathing. *Plastic reconstr. Surg., 14,* 47–61, 1954.
11. Schwartz, M. F., Relative intra-nasal sound intensities of vowels. *Speech Monog., 35,* 196–200, 1968.
12. Strong, L. H., Muscle force components in the occlusive mechanism of the nasopharynx. *Anat. Rec., 103,* 510, 1949.
13. Warren, D. W., and F. A. Hofmann, A cineradiographic study of velopharyngeal closure. *Plastic reconstr. Surg., 28,* 656–659, 1961.
14. Westlake, H., and D. Rutherford, *Cleft Palate,* p. 61. Englewood Cliffs, N.J.: Prentic-Hall, Inc., 1966.