Variations in Velopharyngeal Valving: The Factor of Vowel Changes

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A considerable amount of study regarding "normal" velopharyngeal valving as related to sound production in connected speech is yet to be completed, mainly because of the large number of variables involved in such investigations. Studies have shown that velopharyngeal valving for specific sounds is affected by the phonetic environment of the sound evaluated (*3, 4, 7, 9*). It has also been demonstrated that valving for sustained sounds is considerably different from valving on the same sounds in any connected speech utterance (*9, 10*).

Since additional information is needed and because there are important clinical and theoretical applications for such descriptive information on larger samples, a series of cinefluorographic investigations was designed to describe some relationships between velopharyngeal valving and the production of specific sounds as they occur in syllables in connected speech. The syllable, as described by Stetson (*13*) and, more recently, by Jakobson and Halle (*8*), is considered in these studies to be the basic unit of motor speech production. With this frame of reference, controlled cinefluorographic films were obtained to analyze movement patterns of the organs of speech from the trachea to the lips for 100 normal speaking subjects. Each film contains sets of syllables, a series of consonant-vowel-consonant words, and a sentence containing numerous nasal and oral consonants and a sampling of various types of vowel elements.

This report is the first in the series of reports. The report is limited to an analysis of velopharyngeal valving for five normal subjects producing similar repeated CV syllables under controlled conditions. The vowels /i/, /a/, and /u/ were combined with the labial consonant /p/ to form the CV syllables analyzed.

The questions asked were: a) Do significant differences in measurements of velopharyngeal valving occur as a result of vowel changes in utterances of repeated CV syllables? b) Does the temporal order of a syllable in an utterance affect the measurements of velopharyngeal

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valving in cinefluorographic analysis? c) Does opening in the velopharyngeal port occur on any of the three non-nasal test syllables?

Method

The methods of procedure for this study were the same as previously reported by Sparrow, Brogdon and Bzoch (*12*). Cinefluorographic films of five normal subjects producing utterances of repeated CV syllable sets in varying orders were obtained and analyzed.

SUBJECTS. Criteria for the selection of the speakers were that a) they must be between the ages of 18 and 30 years, b) they must be monolingual speakers using the General American dialect, c) they must have an Angle Class I occlusion, d) they must have no articulation or voice deviations, and e) their hearing acuity must measure between −10 and +10 dB reference average normal hearing for both ears through the speech range.

PROCEDURE FOR OBTAINING FILMS. A Picker fluoroscopic unit with an eight-inch image intensifier, mounting a modified 16 mm Eastman Cine II camera was used. Procedures for radiation control, film selection, and film processing were the same as previously reported (*12*). Positioning and immobilization of the subjects was achieved by an adjustable lucite head positioner equipped with ear rods and a nasion bar. Each subject performed the speech sample task within a 45 to 60 seconds period of time; radiation dosage to each subject for the syllable, word, and sentence series, was less than three roentgens.

Cinefluorographic films were taken at 30 frames per second, since methodological studies had shown this rate to be adequate for the proposed analysis of velopharyngeal valving (*9, 12*). A separate tape-recorded sound track was obtained during the cine recordings.

SPEECH SAMPLES. Each of the five subjects produced three experimental utterances. As shown in Figure 1, an utterance includes three syllable sets produced on one exhalation of breath. A syllable set is comprised of the repetition of seven CV syllables containing the same phonemes. The sequential order of repeated syllables was changed within each of the three utterances to determine whether order was a significant factor affecting velopharyngeal valving. Only those frames describing the middle five syllables of each sequence were traced and analyzed in order to avoid possible artifacts related to velar movements at the initiation and termination of the utterance.

FILM ANALYSIS. All films revealed the mid-sagittal plane of the speaking mechanism from the level of the vocal folds to the lips. Syllable boundaries were determined visually from the films. Each syllable was operantly defined as beginning with the first frame showing bilabial contact and ending on the frame preceding the next bilabial contact. All the mid-sagittal structures were traced for every third frame (*12*).

Each film was projected to life size as determined by an intrinsic

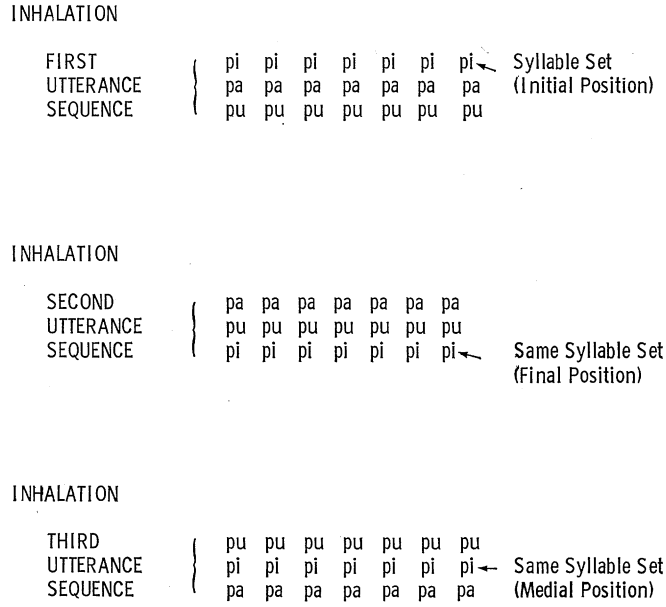

FIGURE 1. Speech sample.

radiopaque marker inserted in the mouth at the start of each film. The outline of structures in the mid-sagittal plane was traced by hand on acetate paper (Dietzgen draft film, .003 with matte surface) for later analysis of related articulatory movements. More than 600 tracings were measured.

RELIABILITY. Inter- and intratracer reliability was established for both the tracing technique and for the seven measures taken in this study. The interreliability of the tracing technique was established by comparing tracings made by four research assistants on 48 frames of film. Analysis by t test was used to determine if there were any significant differences in measurements obtained from these tracings. The intertracer analysis demonstrated sufficiently high reliability. Only one tracer obtained measurements for velar length and height which were significantly different from the other three. The extent of the difference for velar height was 1 mm; the difference for mean length was 2.4 mm with a range from 1.0 to 4.5 mm. Intratracer differences were not significant.

Studies of measurement reliability for the seven measures used were carried out by remeasuring the same tracings. Pearson product moment correlations were .90 and higher for all repeated measures; reliability was considered sufficiently high for the purposes of this study.

MEASURES. The tracing procedure and the measurements used are shown in Figures 2 and 3. The seven measurements of the velopharyngeal area shown in Figure 3 are defined as follows. *The length*

FIGURE 2. Line drawing of a tracing from cinefluorographic frame.

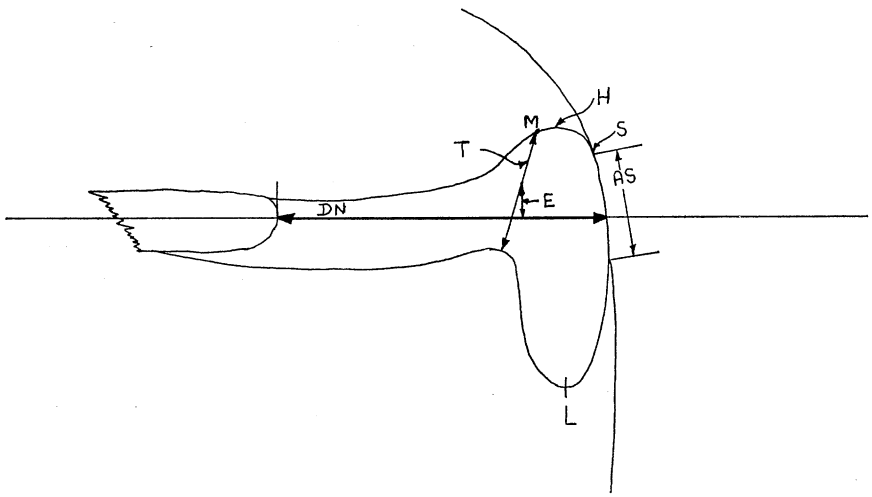

FIGURE 3. Line drawing of a cinefluorographic frame showing the seven measurements made in the study.

of the velum (L) was determined by measuring along the nasal surface of the soft palate from a point above the posterior palatine spine to the mid-point of the uvula. *Thickness* (T) was determined by measuring the distance from the nasal surface at the mid-point of L to the

nearest point on the oral surface. *Amount of seal* (AS) was measured from the superior and inferior points of contact of the velum and the posterior pharyngeal wall. *Height of the velum* (H) was measured from the palatal plane to the highest point of the velum on the nasal surface. *Elevation of the velum* (E) was measured from the mid-point of the thickness measure perpendicular to the palatal plane. *Depth of the nasopharynx* (DN) was measured along the palatal plane from the posterior point of the hard palate to the posterior pharyngeal wall. *Superior point of velopharyngeal contact* (S) was measured perpendicular to the palatal plane.

Results

The results from a separate analysis of variance for each of the seven measures among values for the syllables /pi/, /pa/, and /pu/ revealed no significant differences, except for measurement E (elevation of the velum).

The findings of Tuckey's Significant Difference Test (*11*) of the specific syllable sets show that the difference in palatal elevation among the three syllables was related to differences between /pa/ and /pu/ and differences between /pa/ and /pi/. No significant differences were found between /pi/ and /pu/. These demonstrated a lower palatal position for the low vowel /a/ than for /i/ or /u/; the inference is made then that valving results as a function of syllabic changes in CV combinations. The extent of this difference in palatal elevation is in the range of only 1 mm, however.

The possibility that diminished tidal air at the end of a speech utterance might indirectly affect the palatal position and thereby contaminate the findings of analysis of sets of syllables in utterance sequences was considered. The presentation of each of the three syllables in beginning, medial, and final sections of utterances was included to investigate this possibility. Inspection of the raw data and subgroups' mean and range scores for each syllable by each subject in each position revealed no differences whatever. The evidence from this study indicates there is no difference on velar dimensions as a function of the order of each syllable sets in an utterance.

Table 1 presents data for a comparison of selected measures from rest to the "functional" position. The average distance at rest for the

TABLE 1. A comparison of rest to functional position of mean velar dimensions for five normal speakers. Values are in millimeters.

measure	*rest position*	*functional position*
length	33.00	49.28
thickness	6.30	8.44
depth of nasopharynx	29.50	28.66
amount of velopharyngeal separation	17.90	0.00

five subjects between the velum and the posterior pharyngeal wall was 17.9 mm. During production of the CV syllables this measure was 0 mm for all subjects indicating that the velum was in complete contact with the posterior pharyngeal wall for all frames during function. No velopharyngeal opening occurred on any of the three syllablic elements for any of the subjects.

Comparison of the average velum length measure at rest and in function reveals, as expected, a considerable increase in velar length. This is compatible with previous findings of Graber, Bzoch and Aoba (*5*). The average thickness measure indicates an increase in thickness from rest to the functional position as well. These findings indicate that the palate becomes both longer and thicker, at least in the mid-sagittal plane, during function for speech.

Comparison of the depth of the nasopharynx from rest to functional position indicates that a slight decrease in the depth during function occurs. Since the anterior attachment of the velum is a stable point, apparently there is a slight forward movement of the posterior pharyngeal wall during speech.

Discussion

Previous radiographic studies of velopharyngeal valving for speech have indicated that in certain respects the velum acts as an articulating structure for the production of specific phonemes in normal speech. After the palate is lifted and accomplishes complete velopharyngeal seal, the most striking necessary articulation function of the velum is the action of lowering and/or pulling away from the posterior pharyngeal wall which is requisite for producing the three nasal phonemes in English (*1, 2*).

The position of the velum during complete velopharyngeal valving for speech has been shown to vary slightly in a manner which has been described as oscillating or vibrating (*6, 9, 14*). Apparently these terms have been used to indicate an actual separation of the velum from the posterior pharyngeal wall; the observations may also be related to small differences in measurements from one frame to the next.

The opening and closing of the velopharyngeal port at the beginning and end of utterances and for the production of nasal consonants is an action which logically appears to be directly related to the muscular innervation of the extrinsic (and possibly intrinsic) muscles of the soft palate. However, the small variations in the position of the velum on non-nasal syllables without openings of the velopharyngeal port might be the result of changes either in intraoral air pressure or of mechanical forces related to movements of the mandible, tongue, and suprahyoid musculature. These movements conceivably change the points of attachment of extrinsic muscles running into the velum relative to their points of insertions in the palate. Currently very little research evidence is available to relate possible consistent patterns in these small

movements of the velum as a function of specific non-nasal sound production. However, the findings of this study appear to be similar to and consistent with the previous reports in the literature (*3, 4, 9*). The findings add evidence indicating a frequent pattern of slightly lowered velar position for the syllabic element /a/ as contrasted with either /i/ or /u/ even in controlled utterances of repeated syllables.

In accounting for this finding, the contention can be made that the lowered position of the tongue for /a/ syllable sets exerts a mechanical force on the position of the valving palate. The possibilities of either a decrease in muscle tonus or slightly different levels of intraoral air pressure against the velum must also be considered.

The findings that the velopharyngeal port was completely sealed throughout all of the repeated syllables analyzed seemingly contradicts the findings of several studies (*1, 6, 9, 10*). The question of whether or not velopharyngeal opening occurs in non-nasal parts of speech utterances, and if so, under what conditions, appears to be a basic question of speech physiology needing further investigation.

Considered together, several cinefluorographic investigations of this phenomenon present different findings suggesting that the broad phonemic environment of sounds studied and/or the phonemic structure of syllables analyzed result in different findings. It may be that the CVC structure of the syllable and the nasal sound in the carrier phrase used in the study by Moll (*10*) are the major factors in the different findings of these two studies. Under the conditions of this study no velopharyngeal opening was observed during the production of the syllable sets.

On an applied level, the basic question of whether or not complete velopharyngeal valving is typical or necessary for normal speech production seems, to this investigator, to have real significance. Previous reports in the literature have tended to emphasize the occasional opening of the velopharyngeal port on non-nasal sections of speech utterances. These same studies revealed, however, that complete closure occurred for most sections on non-nasal syllables. Aside from this study, inspection of some 200 cinefluorographic films of normal speakers indicates that a slow rate of utterance of syllables is a factor related to the occasional occurrence of velopharyngeal opening on non-nasal speech elements. This factor also needs to be specified and/or closely controlled in future cinefluorographic studies of the non-nasal open valve phenomenon in normal speech.

Summary

This study was designed to investigate variations in velopharyngeal valving as a function of syllabic changes in repeated CV syllables. A second area of investigation was to determine if the temporal order of a syllable set in an utterance sequence significantly affects the measurement of velopharyngeal opening by cinefluorographic analysis. A third

area of investigation was to determine if any opening in the velopharyngeal port occurs on the three test syllables /pi/, /pa/, and /pu/. Cinefluorographic films were taken of five young adult subjects producing utterances of repeated CV syllable sets in varying order. Hand tracings were made of the frames associated with each syllable and seven measures of the velopharyngeal port were made from each tracing. The findings of this study show: a) the velar position for the syllables with the vowel /a/ is slightly lower than for syllables with either /i/ or /u/; b) the velar dimensions do not vary as a function of the order of syllable sets in an utterance sequence; and c) the velopharyngeal port remains sealed throughout the production of CV syllable sets under the conditions of this study.

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References

1. Ashley, F. L., Sloan, R. F., Hahn, Elise, and Hanafee W., and Miethke, J., Cinefluorographic study of palatal incompetency cases during deglutition and phonation. *Plastic reconstr. Surg., 28,* 347–364, 1961.
2. Ashley, F. L., Sloan, R. F., Hahn Elise, and Hanafee, W., Cinefluorographic studies of deglutition and phonation, a preliminary report. *Amer. J. Surg., 100,* 864–867, 1960.
3. Björk, L., Velopharyngeal function in connected speech, *Acta radiol. Stockh.,* Suppl. *202,* 1961.
4. Calnan, J. S., Movements of the soft palate. *Brit. J. plastic Surg., 5,* 286–296 1953.
5. Graber, T. M., Bzoch, K. R., and Aoba, T., A functional study of the palatal and pharyngeal structures. *Angle Orthod., 29,* 30–40, 1959.
6. Hofmann, F. A., Cineradiographic data reduction of soft palate movement. In S. Pruzansky (Ed.), *Congenital Anomalies of the Face and Associated Structures.* Springfield, Ill.: Charles C Thomas, 337–344, 1961.
7. House, A. S., and Fairbanks, G., The influence of consonant environment upon the secondary acoustical characteristics of vowels. *J. acoust. soc. Amer., 25,* 105–113, 1953.
8. Jabokson, R., and Halle, M., *Fundamentals of Language.* Mouton and Co., 1956.
9. Moll, K. L., Cinefluorographic techniques in speech research. *J. speech hearing Res., 3,* 227–241, 1960.
10. Moll, K. L., Velopharyngeal closure on vowels. *J. speech hearing Res., 5,* 30–37, 1962.
11. Snedecor, G. W., *Statistical Methods.* The Iowa State University Press, 1956.
12. Sparrow, Sara S., Brogdon, B. G., and Bzoch, K. R., The effect of filming rate and frame selection in cinefluorographic velopharyngeal analysis. *Cleft Palate J., 1,* 419–429, 1964.
13. Stetson, R., *Motor Phonetics: A Study of Speech Movements in Action.* 2nd Ed., Amersterdam, North Holland, 1951.
14. Warren, D. W., and Hofmann, F. A., A cineradiographic study of velopharyngeal closure. *Plastic reconstr. Surg., 28,* 656-669, 1961.