

Fiberscopic Examination of Velopharyngeal Closure in Normal Individuals

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Data on the velopharyngeal mechanism in normals is essential as reference information in the study of disorders. Velopharyngeal closure in normal individuals has been investigated with lateral X-ray procedures (1, 3, 13), ultrasonic method (9), and the frontal projection method (2). They reported the differences among various activities of velopharyngeal function.

The fiberscope, (10, 19, 20) developed previously, enables us to observe the entire velopharynx. Fiberscopic studies of velopharyngeal movement patterns and the degree of variability needs to be pursued in a manner similar to that in studies of the normal. Thus, a fiberscopic examination in normal individuals was performed as a preliminary study to learn the structure and function of the velopharyngeal system.

Method and Apparatus

The method and the apparatus were given in the previous paper (10).

Subject

Seven normal adult volunteers, four males and three females, were selected as the subjects.

Sample

To study velopharyngeal closure, the volunteers were instructed in the prerequisite functions of swallowing, blowing, voiced blowing, non-nasal consonants /p, b, t, d, k, g, s and z/ phonation and vowels /a, i, u, e and o/ production, and for velopharyngeal opening the nasal consonants /m

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This paper was presented at the 15th annual convention of the Japan Society of Oral Surgery in Nagoya, October, 1970, and the 25th annual convention of the Japan Society of Oral Medicine in Tokyo, April, 1971, and the 2nd annual convention of the Japan Society of Cleft Palate in Tokyo, April, 1971, and the 2nd International Cleft Palate Congress in Copenhagen, August, 1973, and was supported, in part, by a grant from the Ministry of Education, Japan. Some of the material in this paper has been published in the Japan Journal of Oral Surgery, Volume 19, No. 1, 1973.

and *n*/ phonation. The consonants were chosen to represent various manners of consonant production (fricatives, plosives and nasals), and voiced and unvoiced ones. They were followed by an isolated vowel /*a*/, making syllables such as /*pa*/ and /*ba*/.

Blowing task was performed by use of a carnival blower which needs continuous oral air pressure of 12–13 cmH₂O. Voiced blowing was performed by combining /*u*/ with soft blowing.

Results

The velopharyngeal movements in normals were as follows (Figure 1). The shape of the velopharynx at rest was elliptical, being longer than wide. Velopharyngeal closure was achieved during swallowing, blowing and non-nasal consonants phonation, but it was not always done during vowel production.

The velopharynx moved prominently in swallowing. The closure was constrictive, and the entire pharyngeal wall and surrounding structure moved toward the midline.

A significant difference existed between complete closure in swallowing and complete closure in blowing. Complete closure in blowing was chiefly achieved by posterior movement of the velum and medial movement of lateral pharyngeal walls. It showed a point of contact or an osculating plane between the velum, lateral and posterior walls. Velopharyngeal closure in voiced blowing was achieved in the same manner as in blowing.

During non-nasal consonants phonation it closed completely. Its movement was similar to blowing, in which the entire pharyngeal walls exhibited the point of contact or an osculating plane.

Four subjects exhibited complete closure in all vowels production. Three

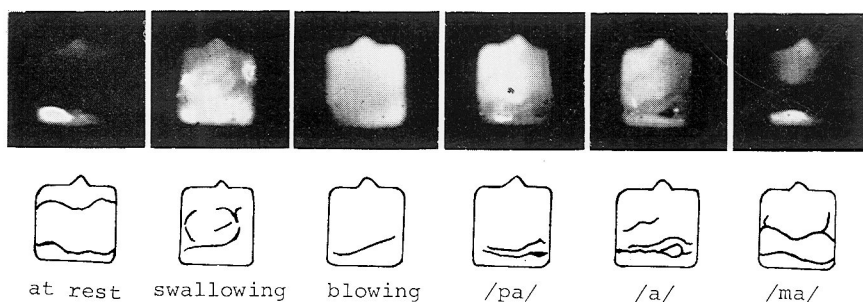


FIGURE 1. Velopharyngeal movements in normal individuals.

Velopharyngeal mucous membrane was brightly illuminated when velopharyngeal closure was achieved completely or almost completely.

Velopharyngeal movement on swallowing was different from on blowing and phonation.

Velopharyngeal opening on /*a*/ was estimated as large as 3 × 3 mm. Nasality was not observed.

On /*ma*/, a intermediate opening between the relaxed position and complete closure remained necessary for normal nasal resonance.

persons exhibited a small opening with the movement on /a/, and complete closure on the other vowels. The modality of closure in vowels production was similar to consonants phonation. Concerning detail, however, the movements in low vowels /a and o/ differed from high vowels /i and e/. Velopharyngeal modality in /a/ was characterized with medial movement of the lateral walls, but in /i/ little or no medial movement of lateral walls was seen.

Velopharyngeal movement in nasal consonants exhibited constant opening that was an intermediate position between the relaxed position and complete closure.

Discussion

Concerning the effects of speech rate to the velar activity, the following is known. The amount the velum swings from the position of rest to that of syllable production decreases consistently as the rate of the production increases. The velum fell short of the position it would attain if enough time were available (17). Moll (14) stated that for /t/ syllables produced at rates of one and two per second, the velopharyngeal port alternately opened and closed, opening for the pause between syllables and closing for the syllable productions. In these reports, an interval of more than three seconds was left between the examined sounds so that the velum descended appreciably in the present study.

Machida (7) reported that some cleft palate cases exhibited greater velopharyngeal closure in connected speech than in isolated phonation, but in other cases, the closure was inadequate in connected speech. Because of the complexity of connected speech, in this study swallowing, blowing and isolated phonation were studied.

Since puffing and sucking can be performed without velopharyngeal closure by utilization of lingual-palatal contact, (13, 15, 16) these tasks were not investigated in this study.

Calnan (5) observed the velopharyngeal activities in swallowing by a patient who lost part of the nose and cheek through removal of a maxillary tumor, and concluded that the sphincter closure on swallowing was quite distinct from the palate flap valve action on speech. Moll (12, 13) wrote that few differences were noted between swallowing and speech of normal subjects concerning forward movement of the posterior pharyngeal wall and Passavant's ridge, but that velar movements were greater during swallowing than during speech. The present study confirms these reports in that the velopharyngeal movements in swallowing appear to be much greater than that in blowing and phonation. Velopharyngeal movements in swallowing may be physiologically different from blowing and phonation.

Bloomer (4) observed blowing in a patient who had a maxillary tumor removed and said that the activity of blowing resembled speech in rela-

tion to velopharyngeal function. On the contrary, Moll (12, 13) concluded that blowing produced approximately two to three millimeters of greater velar elevation than that observed during speech production for normal subjects. And he grouped the movement of blowing into three categories: (1) Subjects show more anterior movements of the wall in blowing than in speech. (2) The velum contacts the wall with more force during blowing than in speech, causing the wall to buckle forward above the site of contact. (3) No appreciable differences between pharyngeal wall activities during speech and blowing.

In a cineradiographic study on normal subjects, Warren et al. (18) concluded that there was a statistically significant difference in elevation of the soft palate in blowing than in different sounds.

In the present study the velopharyngeal closure in blowing was similar to that in consonants (plosives and fricatives).

In the phonation of explosive, nasal consonants and vowels, mentioned above, Calnan (5) noted that soft palate movements did not differ in type, but might in amplitude, and that there was a firm closure by the levator palatini, with little contribution of the posterior or lateral walls in explosive consonants. Minifie (9) measured the extent of lateral pharyngeal wall movements using ultrasound, and found that the lateral wall moved 5 mm toward the midline in the bilabial voiced consonant context. During consonants production pharyngeal wall movements appeared to be dependent on the adjacent vowels.

In the present study, velopharyngeal closure by movement of the soft palate, lateral and posterior walls on consonants production was similar to closure on blowing, and the movement of soft palate, lateral and posterior walls did not differ on various consonants of fricatives and plosives. Complete velopharyngeal closure is important to produce efficient oral air pressure on blowing and non-nasal consonants.

Moll (11) summarized that in normal individuals there were no significant differences between the effects of non-nasal consonant contexts on closure during vowel phonation, but there was a tendency for less closure on isolated vowels than on those in non-nasal consonant contexts. He wrote percentages of velopharyngeal opening, /i/ 14%, /æ/ 38% and /a/ 37%, which indicated greater velopharyngeal opening on the low than on the high vowels.

The finding of the present study that there was no velopharyngeal opening on /i/, may be based on the small numbers of subjects or on the difference between the Japanese /i/ and English /i/. The fact that a small velopharyngeal opening was observed on only /a/, may be due to the fact that /a/ doesn't influence oral air pressure and nasal resonance.

Calnan (5) noted that on /AH/ the salpingopharyngeus reduced the transverse diameter by $\frac{1}{3}$, but closure was not complete, while on /EH/ the levator moved more actively. Astley (2) noted that the lateral walls showed a pronounced inward shift, maximum at about the level of the

palate, when they touched together (shape of an hour-glass) on /ah/. Minifee et al. (9) concluded that during production of the high vowels /i/ and /u/ there was generally little, if any, inward movement of the lateral pharynx, and sometimes there was outward movement. During the low vowels /æ/ and /ɑ/ the lateral pharyngeal wall moved substantially toward the midline.

In the present study, on /i/ little or no medial movement of lateral pharyngeal walls was observed, and velopharyngeal closure was strictly complete, and the tongue moved anteriorly. This phenomenon may make the oropharyngeal cavity large enough to produce impedance on high vowels.

In the present study velopharyngeal opening on /ma/ was intermediate between the relaxed position and complete closure, making nasal resonance needed to nasal consonants.

During nasal consonants, some low level activity was seen in electromyographic studies by Harris (6) and Mimura (8). Moll et al. (14) stated that the velum remained two to five millimeters above the rest position even during a sustained nasal sound and that the nasal consonants could not be produced in the rest position since the resonance characteristics of the oral side-branch seemed important to nasal consonant production. This situation is different from the level to which the velum elevates as completely as possible.

Summary

Velopharyngeal closure in seven normal individuals during various activities was observed by a fiberoptic method. The closure was complete on swallowing, blowing, non-nasal consonants and vowels other than /a/. On nasal consonants, velopharyngeal movement was intermediate between complete closure and the relaxed position.

At present, the analysis of velopharyngeal closure in normals has been made as a preliminary study to cleft palate cases in future.

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