The Effect of Cleft Palate on Oral Port Constriction during Fricative Productions

WILLIAM H. CLAYPOOLE, D.M.D., M.S.
DONALD W. WARREN, D.D.S., Ph.D.
DORIS P. BRADLEY, Ph.D.
Chapel Hill, North Carolina 27514

Inadequate closure of the palatal mechanism is usually considered the primary problem in cleft palate speech. Although closure of the velopharyngeal port is important, a linear relationship between velopharyngeal opening and speech performance has not been demonstrated (*1*, *11*). Other factors such as nasal airway resistance, lingual, glottal and lateral pharyngeal wall adjustments, auditory acuity, respiratory effort, malocclusion and the degree and duration of oral port constriction all modify the quality and intelligibility of speech when the palatal mechanism is inadequate (*3*, *5*, *6*).

The production of fricative sounds is of particular interest to clinicians because these consonants are often distorted by speakers with cleft palate (*2*, *8–12*). Although palatal incompetency undoubtedly contributes to the problem it is conceivable that anterior deformities associated with clefting provide additional difficulties for the speaker. Since anterior dental spacing and malocclusion are usually present, the speaker may modify labial and lingual function to maintain an adequate oral port opening. Studies of normal fricative productions have indicated that the anterior constriction usually is well controlled (*4*, *5*). If the cleft speaker is unable to maintain an adequate oral airway, intraoral pressure would drop unless respiratory effort is increased (*16*). Increased respiratory airflow in the presence of velopharyngeal inadequacy results in greater nasal emission of air and oral airway turbulence, both of which modify speech performance.

The purpose of the present study was to determine whether oral port closure in cleft subjects differs from normals during fricative sound pro-

---

Dr. Claypoole was National Institute of Health Postdoctoral Fellow in the Department of Orthodontics, School of Dentistry, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina and is presently Part-Time Assistant Professor of Orthodontics, University of North Carolina School of Dentistry.

Dr. Warren is Professor and Chairman, Department of Dental Ecology, University of North Carolina School of Dentistry.

Dr. Bradley is Associate Professor of Dental Ecology, University of North Carolina School of Dentistry.

Supported in part by USPHS Grant RR-05333 and by National Institute of Dental Research Grants DE-42642-01 and DE-03533 and DE-02668.

Presented at the 30th Annual Meeting of the American Cleft Palate Association, Phoenix, Arizona, April 14, 1972.

ductions and to analyze any differences observed in terms of anterior dental spacing and articulation errors.

Methods

The subjects studied included ten normals ages 8 to 18 years, ten cleft palate subjects with adequate velopharyngeal closure (C.P.A.) ages 9 to 17 years, and ten cleft palate subjects with inadequate velopharyngeal closure (C.P.I.) ages 7 to 25 years. Velopharyngeal adequacy was deter-

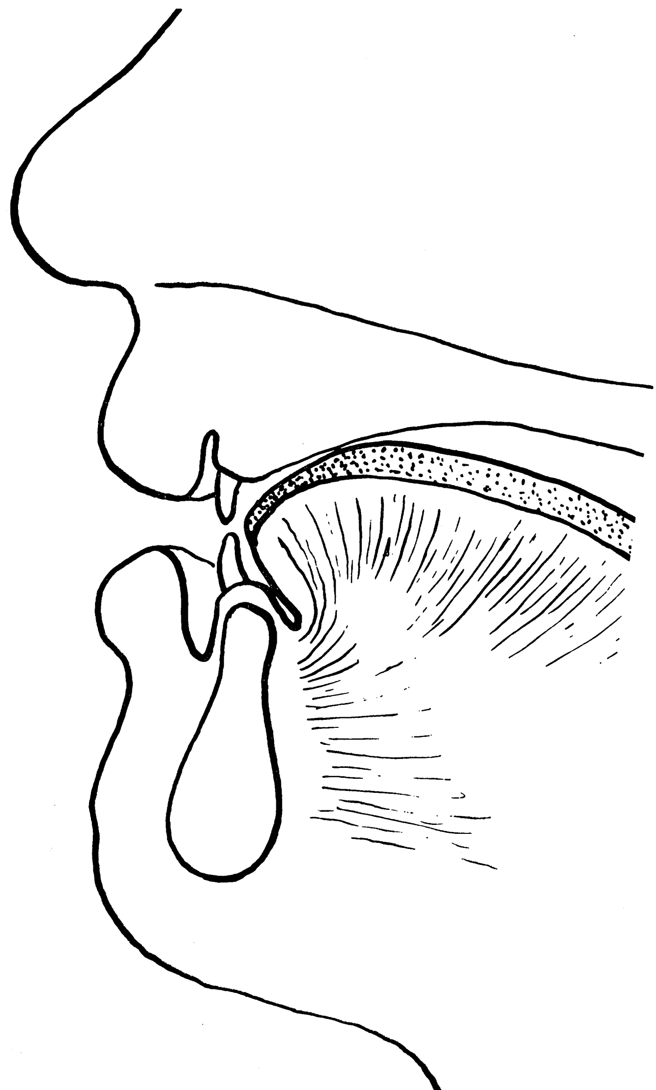

FIGURE 1. Oral port constriction during the production of /s/ or /z/.

mined by an aerodynamic technique which has been reported in detail previously (*13, 14*). This technique provides an estimate of velopharyngeal orifice area utilizing the respiratory parameters of pressure and airflow during sound productions. A calculated velopharyngeal orifice area of 20 mm^2 or more during the production of plosives /p/ and /b/ was considered inadequate closure.

Oral port area is defined as the opening formed by the complex interaction of the lips, tongue, teeth and anterior palate during fricative sound productions (Figure 1). It was measured in the same manner as velopharyngeal orfice area. Placement of one catheter in the oral cavity and a second in an oral mask provided a record of differential air pressure across the oral port. Figure 2 shows the catheter which has been molded to fit around the most distal upper tooth. Airflow was measured by a pneumotachograph connected to the face mask and pressure was measured with a differential pressure transducer. An orifice area equation was used to calculate oral port area from the pressure and airflow measurements. Figure 3 is a schematic illustration of the equipment used for oral port determination.

Anterior dental spacing was determined with the subject in centric occlusion. Using a Boley Gauge and measuring in a plane perpendicular to the occlusal plane the area of anterior spacing was obtained for each

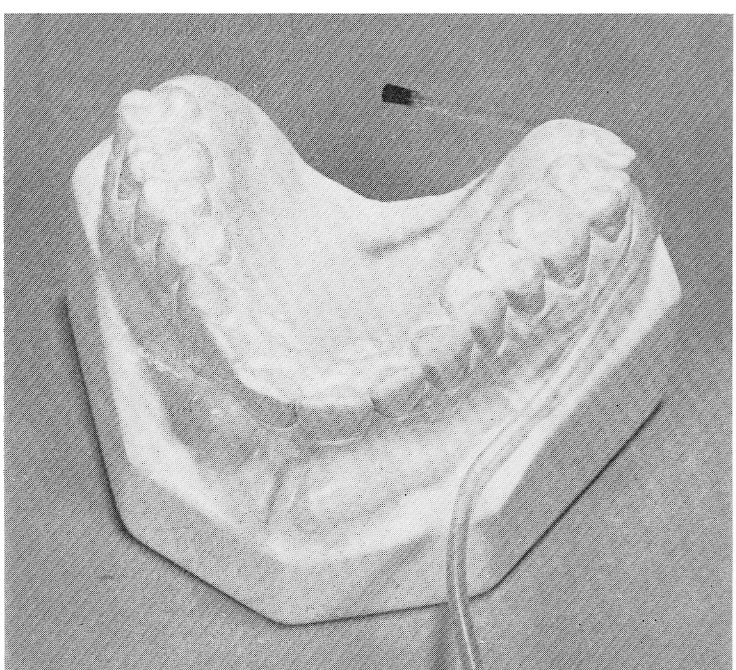

FIGURE 2. The oral catheter, molded to fit around the most distal maxillary tooth.

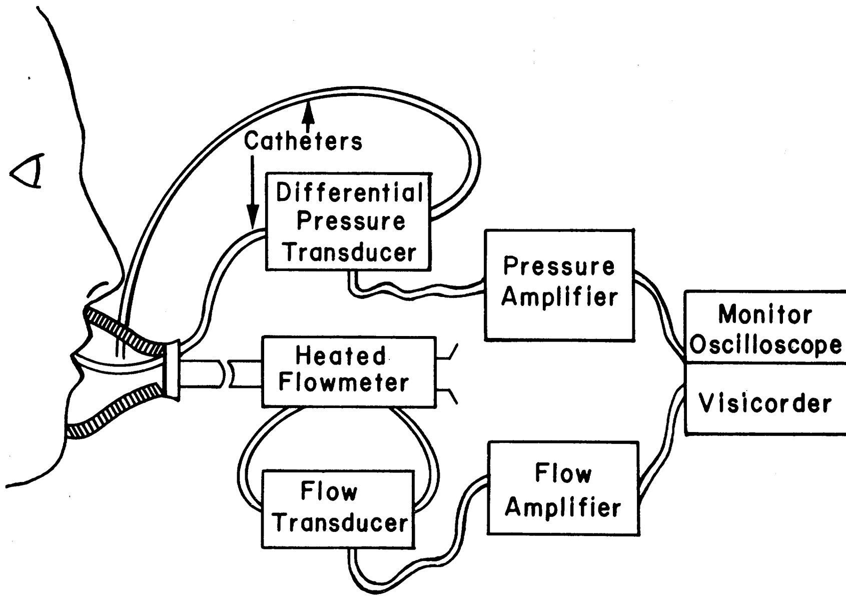

FIGURE 3. Diagrammatic representation of the instrumentation used.

subject. The only spaces calculated were those present anterior to the mesial surface of the first premolar or the deciduous first molar on one side and the mesial surface of the corresponding teeth on the other side of the arch. If the first premolars or deciduous first molars were not present then the mesial surface of the next most distal tooth was used as a measurement point.

Articulation was tested in connected speech. Each subject read a list of sentences which contained all the phonemes of English. Errors were identified by a speech pathologist with only the fricative misarticulations being used for analysis purposes.

The data obtained in this study provided quantitative measurements of the area of oral port constriction obtained at peak intraoral pressures during the production of /s/ and /z/ and /f/ and /v/ (Figure 4). Using this procedure, the smallest area for each sound is not always obtained. However, the method does allow uniform comparisons among subjects. The speech sample used for calculating oral port area consisted of fricatives produced as isolated sustained sounds and in carrier phrases. The patients practiced the sounds and phrases prior to testing to establish a speech effort level and utterance rate that represented a normal conversational level.

Results and Discussion

Figure 5 demonstrates that oral port constriction in the adequate closure group is similar to normals. The inadequate closure group has gener-

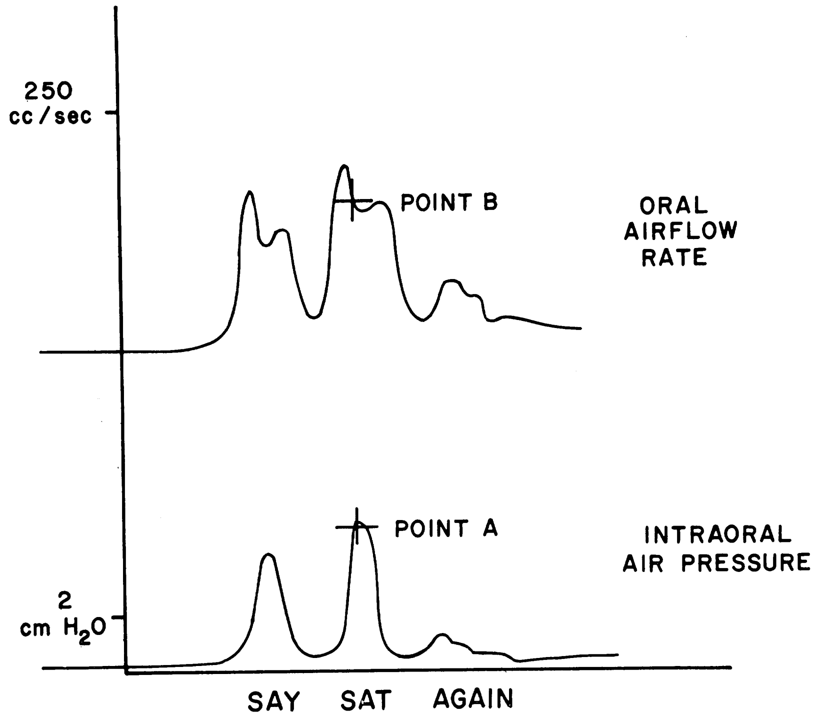

FIGURE 4. Area of opening, computed at the point of highest pressure during ricative sound production.

ılly larger oral port areas than the normal and adequate closure groups. The range of oral port areas for fricatives in carrier phrases is 0.9–9.8 mm^2 for the normal group, 0.9–6.7 mm^2 for the adequate closure group and 0.5–54.7 mm^2 for the inadequate subjects. Seven of the ten C.P.I. subjects had much larger oral port areas than any of the normal and C.P.A. subjects. Quantitative values for the areas of oral opening for normal subjects compare favorably with the values obtained by Hixon (*4*) and Klechak (*5*). The data indicate that the size of the oral port varies very little within speakers but does vary among speakers.

Phonetic context appears to influence oral port area to some extent (Table 1). Although areas for the isolated sustained fricatives are larger in each instance than for the same sounds in carrier phrases, only a few differences were sizable. When the fricatives were divided into voiced and voiceless cognate pairs for analysis, the voiceless sustained sounds in both cleft palate and normal groups had slightly larger oral port areas. This compares favorably with previous findings which indicated that voiceless fricatives often differ from other sound productions in terms of physiological requirements for production (*17–19*).

Table 2 compares anterior dental spacing, articulation errors and oral

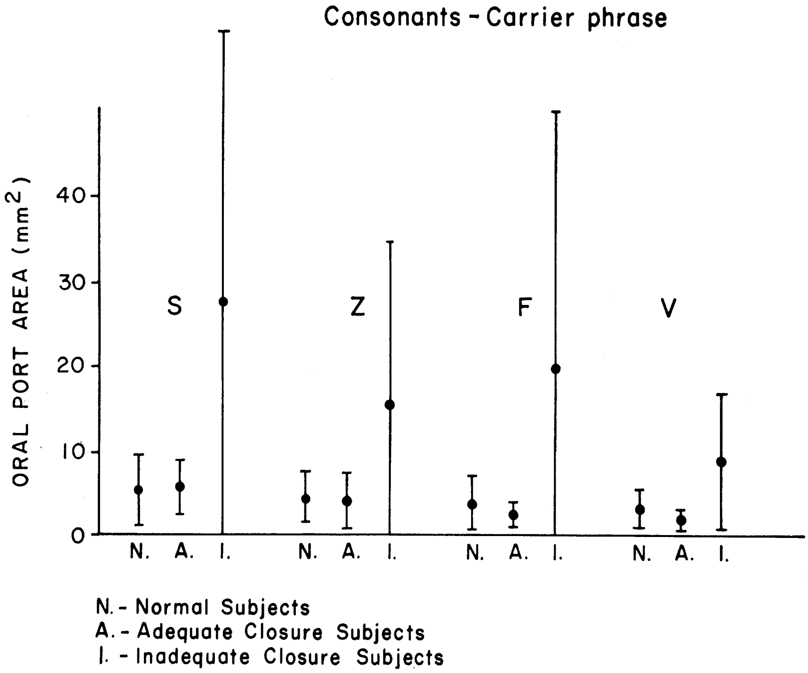

FIGURE 5. Mean areas and standard deviations of oral port constriction (mm^2) for cleft palate and normal subjects.

TABLE 1. The mean areas (mm^2) of oral port constriction between cleft palate and normal subjects.

consonants	*S*		*Z*		*F*		*V*	
	I.S.	*C.*	*I.S.*	*C.*	*I.S.*	*C.*	*I.S.*	*C.*
Normal								
Mean	9.8	5.2	6.2	4.4	8.6	3.7	6.0	3.4
Standard deviation	4.1	4.2	2.0	2.7	4.0	3.0	3.1	2.2
C.P.A.								
Mean	6.7	5.6	5.9	4.2	8.5	2.4	5.6	1.9
standard deviation	3.4	3.4	2.7	3.3	3.4	1.6	2.3	1.1
C.P.I.								
Mean	28.1	27.6	19.9	15.2	19.8	19.7	9.4	8.7
standard deviation	39.0	31.7	29.9	19.4	31.6	30.3	7.8	8.2

I.S.—Isolated sustained.
C.—Carrier phrase.
C.P.A.—Cleft palate with adequate velopharyngeal closure.
C.P.I.—Cleft palate with inadequate velopharyngeal closure.

TABLE 2. Summary of the parameters studied for normal, C.P.A. and C.P.I. speakers.

type	*anterior space (mm²)*	*articulation errors**	*mean oral port areas (mm²)***
Normal			
D.C.	45	0	6.3
T.T.	3	0	5.1
A.T.	4	0	5.3
P.F.	12	0	0.9
S.B.	0	0	9.8
D.J.	6	0	2.4
S.W.	6	0	3.8
R.W.	0	0	3.3
T.L.	0	0	2.1
B.D.	0	0	2.8
mean	7.6	0	4.2
C.P.A.			
S.W.	34	0	3.1
D.J.	23	36	3.5
K.C.	5	0	5.6
L.P.	30	0	3.4
J.W.	45	4	6.7
D.M.	17	24	4.6
S.S.	18	16	0.9
T.M.	23	24	2.2
W.J.	24	22	1.6
D.W.	40	5	3.7
mean	25.9	13.1	3.5
C.P.I.			
W.S.	53	9	32.8
D.P.	76	1	0.5
W.G.	0	29	2.6
D.F.	7	41	40.8
S.E.	46	36	5.3
L.M.	109	30	54.7
J.E.	71	38	4.5
M.B.	0	21	11.4
M.L.	19	35	13.4
L.E.	38	30	12.3
mean	41.9	27.0	17.8

C.P.A.—Cleft palate with adequate velopharyngeal closure.
C.P.I.—Cleft palate with inadequate velopharyngeal closure.
*—Forty-three possible articulation errors.
**—Mean oral port areas for fricatives in carrier phrases.

TABLE 3. Cleft palate misarticulation summary.

	S	*Z*	*F*	*V*
C.P.A.				
mean errors	4.6	5.8	1.3	1.4
s.d.	4.6	6.0	2.3	2.4
C.P.I.				
mean errors	8.3	10.9	3.8	4.1
s.d.	4.0	5.3	3.0	2.8
possible errors	11.0	15.0	9.0	9.0

port size for the three groups studied. Mean anterior spacing was 7.6 mm^2 for the normal subjects, 25.9 mm^2 for the C.P.A. subjects, and 41.9 mm^2 for the C.P.I. subjects. The mean number of articulation errors was zero for the normal group, 13.1 for the C.P.A. group and 27.0 for the C.P.I. group. Combined mean areas of oral port constriction for fricatives in carrier phrases were 4.2 mm^2 for the normal subjects, 3.5 mm^2 for the C.P.A. subjects, and 17.8 mm^2 for the C.P.I. subjects. Mean number of articulation errors for all individual fricative sounds was substantially larger for the subjects with palatal inadequacy (Table 3). The /s/ and /z/ sounds were misarticulated more frequently in both cleft palate groups than the /f/ and /v/ cognate pairs and most of the articulation errors noted were anterior distortions.

Further analysis of the data failed to reveal any discernible relationship between oral port size, anterior dental spacing and articulation errors within any of the groups. This probably demonstrates individual differences in ability to compensate. For example, the two patients in the C.P.I. group with the largest anterior dental spaces demonstrated markedly different mean articulation scores and oral port areas. Also of interest is the finding that two C.P.I. subjects with oral port areas greater than 40 mm^2 demonstrated anterior spacing of 109 mm^2 in one case and 7 mm^2 in the other.

The data do suggest, however, that individuals with adequate closure can obtain normal oral port constriction in spite of dental spacing. This is probably accomplished through lingual adjustments. However, the high incidence of fricative misarticulations in spite of normal port areas suggests that lingual compensatory movements may have some undesirable effects on speech performance.

The group with inadequate palatopharyngeal closure was very inconsistent in its performance. Three of the subjects demonstrated oral port openings greater than 30 mm^2 and three subjects had constrictions slightly larger than 10 mm^2. It is apparent that with palatal incompetency lingual efforts to close anterior spaces are more difficult to achieve. There are a number of reports (*2*, *7*) indicating that the dorsum of the tongue is frequently elevated in patients with palatal insufficiency. If this occurs, it would be difficult for the speaker simultaneously to effect anterior and posterior lingual adjustments. The high frequency of articulation errors in this group seems to support this thesis.

The effects of inadequate oral port constriction on pressure and airflow associated with sound productions may be significant. Studies of simulated cleft palate speech (*15, 16*) have demonstrated that even slight opening of the oral port for fricative sounds reduces oral pressures unless respiratory effort is increased. Nasal emission of air is also greatly influenced by the degree of oral port constriction especially in the presence of palatopharyngeal incompetency. The simulated speech studies showed that an increase in oral port opening of 10 mm^2 reduces nasal emission of air by 45% when respiratory effort stays constant. However, respiratory effort approximately doubles in patients with incompetent palatopharyngeal closure (*19*). It should also be noted that some cleft speakers tend to close the oral port too much during fricative productions. This would produce high oral port impedance and result in greatly increased nasal emission of air and possibly more nasal voice quality.

Summary

In this study, ten normal, ten cleft palate subjects with adequate closure, and ten cleft palate subjects with inadequate closure were studied in order to determine the area of oral port constriction, anterior dental spacing and articulation errors during the production of fricative sounds. The results indicate that oral port size does not differ markedly between normal and C.P.A. groups but that C.P.I. subjects have generally larger oral port areas. In the case of those subjects with adequate closure, the data demonstrate that normal oral port constriction is achieved despite anterior dental spacing. However, the compensatory movements necessary to obtain this appear to have an undesirable effect on sound production.

reprints: *Dr. Donald W. Warren*
Department of Dental Ecology
School of Dentistry
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina 27514

References

1. Brandt, Sara and Morris, H. L., The linearity of the relationship between articulation errors and velopharyngeal competence. *Cleft Palate J., 2,* 176–183, 1965.
2. Bzoch, K. R., Categorical aspects of cleft palate speech, in *Communicative Disorders Related to Cleft Lip and Palate,* ed. by K. R. Bzoch (Boston: Little, Brown, and Co., 1971), 109–129.
3. Claypoole, W. H., Oral port constriction during fricative productions in normal and cleft palate subjects (unpublished thesis, University of North Carolina, 1971).
4. Hixon, T., Turbulent noise sources for speech. *Folia Phoniat., 18,* 168–182, 1966.
5. Klechak, T. L., Anterior open bite and oral port constriction (unpublished thesis, University of North Carolina, 1971).

6. Lubker, J. F. and Schweiger, J. W., Nasal airflow as an index of success of prosthetic management of cleft palate. *J. Dent. Res., 48,* 368–375, 1969.
7. McDonald, E. T. and Koepp-Baker, H., Cleft Palate speech: an integration of research and clinical observation. *J. Speech Hear. Dis., 18,* 43–47, 1951.
8. Shelton, Ralph, Brooks, Alta and Youngstrom, K. A., Articulation patterns of palatopharyngeal closure. *J. Speech Hear. Dis., 29,* 390–408, 1964.
9. Spriestersbach, D. C., Moll, K. L., and Morris, H. L., Subject classification and articulation of speakers with cleft palates. *J. Speech Hear. Res., 4,* 362–372, 1961.
10. Starr, Clark, Dental and occlusal hazards to normal speech production, in *Communicative Disorders Related to Cleft Lip and Palate,* ed. by K. R. Bzoch (Boston: Little, Brown, and Co., 1971), 66–76.
11. Subtelney, Joanne D. and Subtelney, J. D., Intelligibility and associated physiological factors of cleft palate speakers. *J. Speech Hear. Res., 2,* 355–360, 1959.
12. Van Demark, D. R. and Van Demark, Ann A., Misarticulations of cleft palate children achieving velopharyngeal closure and children with functional speech problems. *Cleft Pal. J., 4,* 31–37, 1964.
13. Warren, D. W., Velopharyngeal orifice size and upper pharyngeal pressure-flow patterns in normal speech. *Plast. and Reconstr. Surg., 33,* 148–162, 1964.
14. Warren, D. W., Velopharyngeal orifice size and upper pharyngeal pressure-flow patterns in cleft palate speech: a preliminary study. *Plast. and Reconstr. Surg., 34,* 15–26, 1964.
15. Warren, D. W. and Devereux, J. L., An analog study of cleft palate speech. *Cleft Pal. J., 3,* 103–114, 1966.
16. Warren, D. W. and Ryon, W. E., Oral port constriction, nasal resistance, and respiratory aspects of cleft palate speech: an analog study. *Cleft Pal. J., 4,* 38–46, 1967.
17. Warren, D. W. and Mackler, S. B., Duration of oral port constriction in normal and cleft palate speech. *J. Speech Hear. Res., 11,* 391–401, 1968.
18. Warren, D. W. and Wood, M. T., Respiratory volumes in normal speech: a possible reason for intraoral pressure differences among voiced and voiceless consonants. *J. Acoust. Soc. of America, 45,* 466–469, 1969.
19. Warren, D. W., Wood, M. T., and Bradley, D. P., Respiratory volumes in normal and cleft palate speech. *Cleft Pal. J., 6,* 449–460, 1969.