A Study of Velopharyngeal Competence in Children with Repaired Cleft Palates

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There is a lack of agreement among surgeons who close palatal clefts regarding choice of surgical procedure and age of the child at which surgery is performed. At the present time there is no uniform or standard method of evaluating velopharyngeal competency that is universally accepted. It would be helpful if a simple, yet reliable and valid, means could be found by which results for different surgeons using different techniques and for children of different ages could be compared. One such possible means might be the use of a pressure gauge to test blowing and sucking abilities of their patients. The purpose of the present study was to describe the performances of a group of children who have cleft palates on measures of nasality and pressure tasks, compare those performances with those of normal children, and investigate the interrelationships among the measures employed.

Hypernasality has been reported by several investigators (*2*, *3*, *5*, *7*, *9*, *10*) to be characterized by the reinforcement of certain resonance areas. There has not been general agreement, however, as to which frequencies are reinforced. Formant frequencies and amplitudes were measured from sound spectrograms in this study for the purpose of locating possible areas of reinforcement of the cleft palate speakers.

Procedure

SUBJECTS. Twenty-eight children with repaired complete unilateral clefts of the lip and palate constituted the experimental group. Their ages ranged from four years, eight months, to ten years, six months. The mean age was seven years, one month. All had received surgery to close the cleft lip within the first month of life, and all received V-Y surgical techniques at approximately one year of age. Dr. William McEvitt performed all the operations in Detroit medical hospitals. Of the total of 54 children that qualified for inclusion in the experimental group, the 28 subjects selected were those who had not moved from the area and who were willing to cooperate. There were 18 boys and 10 girls. Six had received no speech training, five had received less than six months of training, 14 had received from four

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months to three years of speech correction, and three had received more than three years of speech training. The mean period of training was 1.5 years. Sixteen were given speech lessons only at the public schools, and six received therapy at Children's Hospital in Detroit.

A control group was also used for the investigation. The age range for the control group was the same as for the experimental group, and the mean age was six years, 11 months. There were 15 boys and 13 girls. All the children were normal speakers with no voice or articulation disturbances.

PRESSURE AND SUCTION MEASUREMENTS. A set of two Emerson gauges was used to obtain sucking and blowing measures. One gauge was designed for use with adults and the other for use with children. The former is calibrated according to millimeters of mercury, and reads from zero to 120 millimeters on each scale. The blowing (positive pressure) scale is numbered clockwise and the suction (negative pressure) scale counter-clockwise. The gauge for children is calibrated according to centimeters of water, and reads from zero to 60 on each scale. This latter gauge was used for all the children of the experimental group and for three children in the control group. When it was found that most of the normal-speaking children could exceed the 60 cm point on the children's instrument, the instrument for adults was used. The measurements of the two gauges were later equated on the basis of 1 cm of water equalling 1.36 mm of mercury. The gauges are connected to removable mouthpieces by plastic tubes, also easily removed for sterilizing.

Four measures were obtained from each child. These were: a) blowing, b) blowing with nostrils occluded, c) suction, and d) suction with nostrils occluded. All subjects carried out the tasks in the above order.

The tester demonstrated the task to the child before each step of the process, and the child was given one trial effort. Five trials were then allowed for each of the four measures, and the highest score was chosen from the five.

Ratio scores were derived for both positive pressure and suction. If velopharyngeal closure were complete, as was hypothesized and tested by Chase (*1*), the child should be able to blow or suck with equal force whether the nostrils were open or occluded. Thus, the ratio of pressure with nostrils occluded to pressure with nostrils open should be approximately *one* to *one*, or 1.00. If there were gross velopharyngeal incompetency, the child should be able to blow or suck with much greater force by keeping the nasal canal closed at the nostrils than with the canal open.

RECORDING. Recordings were made with the microphone, subject, and experimenter situated in a sound-treated room, and with a tape recorder situated in an adjacent control room. An Electro-Voice 666 Super-Cardioid Microphone was used, along with an Ampex 351 tape recorder. The mouth-to-microphone angle and distance was kept constant. Four cue-cards were shown to the child, each containing a drawing of a mouth in position for the production of a particular vowel sound, and a drawing of an object, the name of which contained that vowel sound. The vowels and the objects pictured were the /i/ as in *bee*, /u/ as in *shoe*, /æ/ as in *cat*, and /ɑ/ as in

bottle. The child was instructed to name first the object and then to repeat the vowel sound contained in the name. Practice was given until the child produced both responses for each card without any help from the tester.

When the child responded to the cue-cards correctly, the responses were recorded. The cue-cards were presented in random order to each child. The examiners listened to the recordings to determine whether each vowel produced rhymed with the name of the object on the card. If it did not, the child was again shown the picture and was asked to repeat the name of the picture and the sound contained. Next, the subject was instructed to precede the name of each object pictured with the carrier phrase "I see the _____". These sentences were subsequently used for the basis of judgments of nasality.

Spectrographic Analysis. In the spectrographic analysis of the vowels, the original tape recordings were played on the original recording apparatus. After each spectrogram was made, but before it was removed from the instrument, the display was inspected and the section points were located. On all of the sections, frequency and amplitude measures were made for the fundamental and for the three lowest formants. The formant amplitude was defined as that of the strongest component, or the arithmetic mean of two equal components, expressed in decibels above the baseline of the section.

Linear measurement of the frequency of each formant was made to the nearest 0.1 mm, with reference to the frequency of the harmonic of the calibration tone nearest to the formant being measured. The linear measurement was then converted to frequency and rounded to the nearest multiple of five cps.

Ratings of Nasality. Nine judges were employed; all were graduate students in speech correction at Wayne State University, and staff members at the speech and hearing clinic. Recordings of sentences from the combined two groups were randomized and dubbed on a single tape. There were four consecutive utterances for each speaker, with a one-second interval between them. After the fourth utterance, there was a five-second pause, during which the judges recorded their evaluations. They were given instructions to judge only nasality, and to consciously prevent articulation skills from affecting their judgments. They were to rate the nasality on a five point scale: *one*, representing a normal voice; *two*, representing a very mild degree of nasality; *three*, representing moderate hypernasality; *four*, representing a moderately severe hypernasal voice; and *five*, representing a severe hypernasality.

Statistical Procedures. There were eight sets of data, one for each of the four vowels from each of the two groups. Each set contained the following 11 variables: blowing ratio; suction ratio; rating of nasality from sentences; frequency of the fundamental; frequencies of each of the first three formants; amplitude of the fundamental; and amplitudes of each of the first three formants.

Values for each set, or for each vowel spoken by each of the two groups of subjects, were correlated to determine whether any pair of variables varied together. Correlation coefficients were computed for every possible combination of variables. A significant correlation would indicate that either the two variables were measuring the same phenomenon or that they were both affected in like manner by a third variable. A high negative correlation, for example, between F_3 (the frequency of formant 3) and A_3 (the amplitude of formant 3) of the vowel /i/ might suggest that both were indicators of a degree of hypernasality, and that this nasality was portrayed by an increase of one variable and by a decrease of the other. Correlation coefficients were computed on a Gate Program Computer. For this experiment, a value of .47 was necessary for significance at the 1% level of confidence, and a value of .36 was necessary for significance at the 5% level. In all, 880 correlation coefficients were obtained.

Next, in order to determine whether there were significant differences between the normal group and the cleft group with respect to any of the 11 variables, an analysis of variance was done. Each variable for each vowel from the cleft group was compared with the corresponding variable for the same vowel from the normal group. In order for the difference to be significant at the 1% level, the F value had to be 7.12 or greater. A value of 4.03 was required for significance at the 5% level.

Past spectrographic studies have shown there to be a roll-off in amplitude toward the higher frequencies of vowels. Because of this roll-off, it is possible that differences in amplitudes of a given formant between two speakers or groups of speakers may be due to a difference in frequency of the formants. In other words, if formant three of the vowel /i/ in the cleft group is found to differ significantly from the same formant in the normal group's /i/, and if the frequencies of the formant differ between groups, the amplitude of the formant having the high frequency would be expected to be less, due to the roll-off. To correct for this effect of frequency of a formant upon amplitude of the same formant, an analysis of covariance was carried out.

Whenever a correlation coefficient significant at the 5% level or higher was obtained between the amplitude and frequency of a given formant, it was considered possible that the frequency of the formant was affecting the amplitude of the formant. If either of the two significantly correlated variables, amplitude and frequency, was found to differ significantly (by the analysis of variance) from the same variable in the other group, an analysis of covariance was applied to eliminate statistically the effect of frequency upon amplitude. Formulae used in the analysis of covariance were those outlined by Lindquist (*6*). The F value from the analysis of covariance, in order to be significant at the 1% level, had to be 7.14 or higher, and at the 5% level, 4.02.

Results

Within-Group Correlations. Significant correlation coefficients are listed in Table 1. At the 1% level of confidence, no significant relationships

TABLE 1. Significant correlation coefficients between pairs of the eleven measures for the normal group (N), and the cleft group (Cl) for each of the four vowels. All coefficients are significant at the 5% level; nonsignificant coefficients are not reported. Measures are positive pressure ratios (P), suction ratios (S), judges ratings (J), frequencies (F_0, F_1, F_2, F_3), and amplitudes (A_0, A_1, A_2, A_3).

Variables	/i/		/æ/		/ɑ/		/u/	
	N	Cl	N	Cl	N	Cl	N	Cl
P and F_1							.42	
P and A_3	.40							
S and F_1				−.38				
S and A_1						−.44		
J and A_1		.38						
J and A_2		−.42	−.60					
J and F_1			.39					
J and F_3				.42		.42		
F_2 and F_3	.47	.50	.69	.84	.47	.58	.38	.48
F_0 and F_1	1.00	.56			.49			
F_0 and F_3					.36	.37		
A_0 and A_3						−.38		
A_2 and A_3	.58	.70					.54	.57
A_0 and A_1	1.00	.65			−.49			.37
A_0 and A_2			−.53				−.48	
A_0 and F_0			−.45	−.39	−.55			.41
A_1 and F_1				−.52				
A_2 and F_2						−.66		−.65
A_0 and F_1							−.44	−.59
A_2 and F_3		.46						
A_1 and F_0					.44			
A_1 and F_2				−.36		−.42		

were found among pressure scores, suction scores, and judges' ratings of nasality, or between any one of these variables and the frequencies or amplitudes of the formants. Correlations discussed in the following three sections are all significant at the 5 % level, having an r of .36 or greater.

Positive Pressure Scores and Formants. Significant relationships were found in only two instances, both in vowels of the normal group. These were between pressure scores and F_1 for /u/ (r = .42) and between pressure scores and A_3 for /i/ (r = .40). The correlations in both cases were positive. Since pressure scores did not differ significantly between the two groups, as determined by an analysis of variance, no conclusions regarding the nature of hypernasality could be drawn from these correlations.

Suction Scores and Formants. A significant relationship between suction scores and formant frequencies was discovered in only one case, that being the vowel /æ/ of the cleft group. A negative correlation of .38 obtained between F_1 and suction scores, indicating that poor velopharyngeal function resulted in, or was accompanied by, a lowering of F_1 for that vowel. Likewise, in only one case did suction scores and formant amplitudes vary

together. For /ɑ/ for the cleft group, a negative correlation of .44 was found between A_1 and suction scores. For this vowel alone, poorer velopharyngeal action as revealed by suction ability was accompanied by a decrease in amplitude of the first formant.

Judges' Ratings and Formants. There was a positive correlation of .38 between A_1 and judges' ratings for the vowel /i/ of the cleft group. For the same vowel (/i/ of the cleft group) and for /æ/ of the normal group, negative correlations of .42 and .60 respectively, were found between A_2 and judges' ratings of nasality. That is, the ratings of nasality increased as A_2 decreased. Since this occurred in one vowel in the two groups, it would be difficult to draw any conclusions from these correlations.

A positive correlation of .39 was found between F_1 and judges' ratings in the normal group's /æ/. For the vowels /æ/ and /ɑ/ of the cleft group, positive correlations of .42 and .42 existed between F_3 and judges' ratings. These findings would support those of DeLattre (*3*), which indicated that as hypernasality increases, the position of F_3 is raised. In the present study, this obtained only on the two more open vowels.

Suction Scores, Pressure Scores, and Judges' Ratings. No significant correlations were found among these three variables.

Relationships among Formant Frequencies. Significant correlations were found between F_0 and F_1 of /i/ from both groups of subjects. In the normal group, in every case F_1 coincided with F_0, so the r was a positive 1.00. In the cleft group, there were a few exceptions to this, but generally the fundamental was so high that it was undistinguishable from F_1. The r between F_0 and F_1 for this group was plus .56. This fusing of formant one with the fundamental has been found in past research with children (*7*). A like positive correlation (.49) occurred between F_0 and F_1 on /ɑ/ of the normal group.

F_0 and F_3 varied together in both groups on the vowel /ɑ/. The correlation coefficients, both positive, were .36 and .37 respectively. It would seem significant that, with this one exception, F_0 did not vary with F_3.

Relationships among Formant Amplitudes. Similarly, in only one case did A_0 vary significantly with A_3; this was for /ɑ/, cleft group. There were other interesting correlations; however, several of which were significant at the 1% level. A_2 and A_3 varied concomitantly in /i/ and in /u/ in both groups. For /i/, for the normal group, the obtained rs were .58 and .57. All four correlations were positive. For these two closed vowels, as A_2 was attentuated, A_3 was also attenuated.

Formant Frequencies and Amplitudes. At the 5% level of confidence, several isolated correlations were found between formant amplitudes and frequencies. Since the relationships occurred only in one vowel from one group, and since both negative and positive correlations were found between the same two variables on different vowels, generalizations from these data would be highly speculative and would contribute little to the purpose of this study.

BETWEEN-GROUP DIFFERENCES. The preceding discussion was concerned with within-group relationships. In order to determine which measurements found real differences between the groups, an analysis of variance was performed. However, to permit a graphic portrayal of a comparison between the two groups with respect to formant frequencies and amplitudes, means of these scores were calculated.

Differences in Means. The means of the frequencies and amplitudes of the formants are listed in Table 2 and illustrated in Figure 1.

These patterns, reproduced from ones drawn on semi-logarithmic paper, show the frequencies and amplitudes in much the same manner as they appear on a section portrayal of the sound spectrograph. Figure 1 shows the means for all 28 subjects in each group. The vowels are arranged on the page in the conventional manner, with front vowels to the left and high vowels toward the top of the sheet. Broken lines represent the normal subjects and solid lines represent the cleft subjects. It is apparent, in Figure 1, that the differences in amplitude and frequency were minor and few. The only formant frequency that differed significantly between the groups was F_3 of the vowel /u/. As can be seen at the upper right-hand corner of the figure, the attenuation on formants two and three of the cleft group for this vowel was very great, and for this reason the frequencies were exceedingly difficult to locate. On several spectrograms the amplitudes of the peaks of these higher frequencies approached those of the voice level peaks, hence the difference found between groups on F_2 of /u/ is not considered highly reliable.

There were significant differences in amplitude on some of the formants, however. A_2 and A_3 of the vowel /i/ differed significantly between the two groups. As seen in Table 4, the F value for A_2 of /i/ was 11.21, and the F value for A_3 of /i/ was 10.00. Both values were significant at the 1 % level. A_3 of /u/ of the cleft group was significantly more attenuated ($F = 7.60$) than was the corresponding variable of the control group. A_2 of /u/ did

TABLE 2. Mean scores for frequencies and amplitudes of the fundamental and first three formants, for normal subjects (N) and cleft subjects (Cl) for four vowels. Values are cycles per second. Amplitude in db re baseline of section.

Variables	/i/		/æ/		/ɑ/		/u/	
	N	*Cl*	*N*	*Cl*	*N*	*Cl*	*N*	*Cl*
F_0	307	289	285	271	278	256	302	289
F_1	307	309	844	798	1108	1192	414	374
F_2	3403	3346	2672	2976	1869	1907	1612	1656
F_3	4393	4703	3718	3739	3431	3307	3375	3039
A_0	50.6	50.3	44.0	46.1	43.6	46.3	48.6	49.7
A_1	50.6	50.0	47.2	45.2	47.2	45.2	49.6	50.6
A_2	33.2	26.4	38.6	35.4	39.4	39.0	25.6	20.3
A_3	31.8	25.6	32.3	31.1	28.0	25.3	16.0	10.3

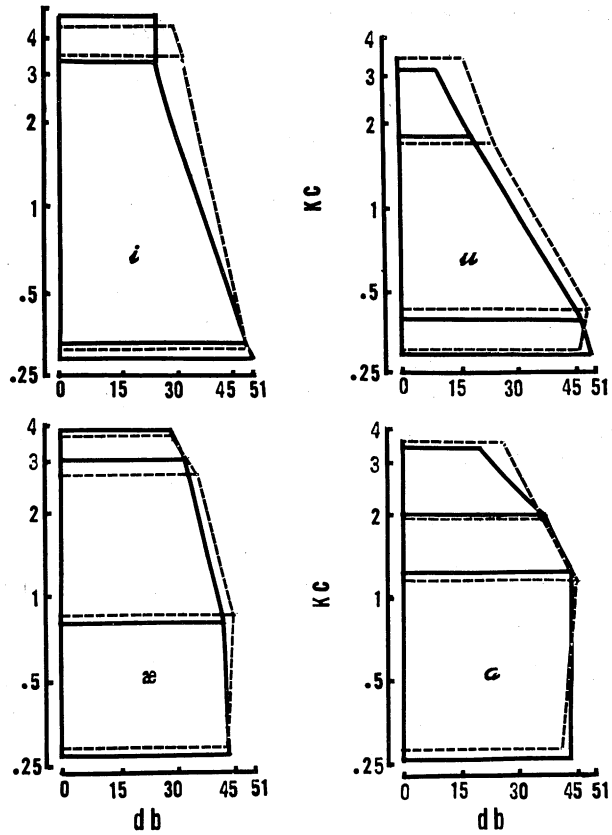

FIGURE 1. Mean amplitudes and frequencies of the fundamental and first three formants of vowels produced by all speakers. Broken lines represent the normal group and solid lines represent the cleft group. Amplitude in db re baseline of section.

not meet the 5% level requirement of 4.03, but the F value of 3.63 approached significance. Whereas differences between the groups on /u/ with respect to frequencies of the higher formants were questionable, it was evident that these formants were being attenuated considerably more than those of the same vowel spoken by normal subjects. The cleft group attenuated A_1 significantly more than did the normal group (F of 4.81 significant at 5% level). It seems likely that raising the tongue to form the two high vowels /i/ and /u/ caused them to be produced nasally by the children with cleft palates, and, as DeLattre has postulated, the higher formants were attenuated. None of the formant amplitudes differed significantly on the vowel /æ/.

Because of the relatively few spectrographic findings that differentiated between the normal children and those with repaired cleft palates, and because the mean judges' ratings indicated a mild hypernasality among the children with cleft palates, the ten cleft subjects rated by the judges as

having the greatest amount of hypernasality were compared with the ten normal subjects judged as having the least amount of nasality. Table 3 lists the mean amplitudes and frequencies of the fundamental and first three formants for these two groups of ten subjects each, and Figure 2 portrays these means in the same manner. The solid lines again represent the cleft subjects.

In order to observe the changes occurring when the extremes from each group were selected for comparison, the reader can examine each vowel on Figure 2 separately. The difference between A_2 and A_3 of the vowel /i/ was greatly increased when the ten from each group were compared. In the total group, the mean difference in A_2 between the groups was 6.8 db. The difference between the groups of ten each was 12.7 db. With respect to A_3, the difference was increased from 6.3 db to 13.8 db. In both formants the differences were approximately doubled. The direction of the change indicated that greater hypernasality resulted in, or was accompanied by, greater attenuation of these higher formants. In other words, the ten most hypernasal subjects, A_0 and A_1 were changed less than 1 db when the ten were compared.

On the /æ/ vowel diagrams (Figures 1 and 2, lower left-hand corner) it is again noted that the differences between A_2 and A_3 doubled. The between-groups difference in A_2 increased from 3.21 db for the total groups to 8.5 db for the ten subjects at either extreme of the nasality scale. The difference in A_3 increased from 1.2 db to 4.0 db. In /æ/, as in /i/, the direction of the change indicated that greater attenuation of the higher two formants was a concomitant of greater hypernasality.

On the two back vowels, however, the direction of the change reversed, especially on A_3. A_3 of /ɑ/, instead of being attenuated more by the extremely hypernasal ten subjects, was attenuated less by them and more by the group of ten least nasal speakers. Instead of the effects of the selection

TABLE 3. Mean scores for frequencies and amplitudes of the fundamental and first three formants, for the ten cleft subjects judged as having the greatest hypernasality, and for the ten normal subjects judged as having the least nasality. Values are cycles per second. Amplitude in db re baseline of section.

Variables	/i/		/æ/		/ɑ/		/u/	
	N	*Cl*	*N*	*Cl*	*N*	*Cl*	*N*	*Cl*
F_0	295	308	274	290	266	262	277	303
F_1	295	328	763	730	1104	1124	389	364
F_2	3353	3281	2635	2850	1724	1999	1349	1712
F_3	4265	4494	3591	3880	2832	3516	3266	3142
A_0	50.8	50.9	42.8	46.2	43.3	47.2	49.0	50.3
A_1	50.8	51.0	47.1	46.4	46.5	44.5	50.3	50.8
A_2	34.3	21.6	41.1	32.6	40.3	36.5	24.9	18.6
A_3	34.9	21.1	34.0	30.0	29.4	28.0	13.9	12.9

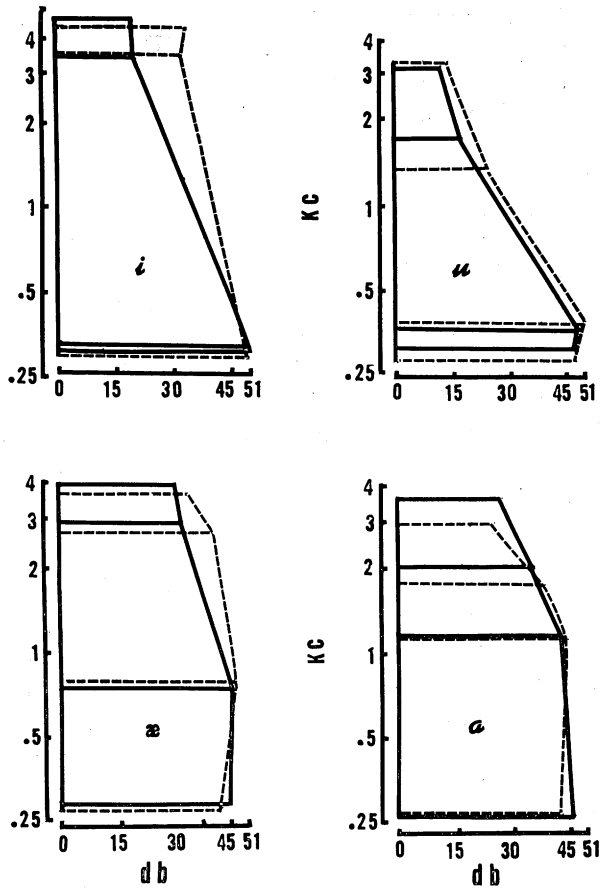

FIGURE 2. Mean amplitudes and frequencies of the fundamental and first three formants of vowels produced by the ten cleft subjects judged as having the greatest hypernasality and the ten normal subjects judged as having the least nasality. Broken lines represent the control group and solid lines represent the cleft group. Amplitude in db re baseline of section.

of ten being to double the difference between the total groups of A_3, it nearly halved the difference, from 2.7 db to 1.4 db. This pattern continued on the /u/ vowel.

Analysis of Variance and Analysis of Covariance. Table 5 lists the *F* values obtained from an analysis of variance on each variable. The purpose of the analysis of variance was to determine whether there were significant between-group differences on scores on any of the 11 variables previously mentioned. From the analysis of variance, no significant differences were found between groups on pressure scores. Differences significant at the 1 % level were found on suction scores and on judges' ratings of nasality. The *F* value from a comparison of suction scores was 13.2, surpassing the required 7.1 at the 1 % level. The *F* value from the analysis of judges' ratings between the groups was 39.6, well above the required 7.1.

TABLE 4. *F* values from analysis of variance on positive pressure scores, suction scores, judges' ratings, and frequency and amplitude of the fundamental and first three formants, for differences between normal and cleft groups on four vowels. Values are cycles per second. Amplitude in db re baseline of section. *F* values with asterisks are significant at the 5% level (values of 7.12 or higher are significant at the 1% level).

Variables		*Vowels*			
		/i/	/æ/	/ɑ/	/u/
Positive Pressure	1.43				
Suction	13.17*				
Judges' ratings of nasality	39.69*				
F_0		2.12	1.77	3.75	1.17
F_1		0.01	0.35	2.29	1.63
F_2		0.48	1.98	0.09	0.13
F_3		3.90	0.03	0.76	6.39*
A_0		0.00	3.75	5.94*	3.00
A_1		0.27	1.75	4.78*	4.81*
A_2		11.21*	3.73	0.05	3.58
A_3		10.00*	0.91	3.63	7.60*

TABLE 5. Correlation coefficients and *F* values from analysis of variance and analysis of covariance for the normal group (N) and the cleft group (Cl). Coefficients and *F* values with asterisks are significant at the 5% level (*F* values of 7.12 or higher are significant at the 1% level).

Variables	*Correlation Coefficients*				*Analysis of Variance*				*Analysis of Covariance*
	Group	*r*	*Group*	*r*	*Variable*	*F*	*Variable*	*F*	*F Values*
A_0 and F_0 for /æ/	N	−.45*	Cl	−.39*	A_0	3.8	F_0	1.8	1.54
A_1 and F_1 for /æ/	N	−.08	Cl	−.52*	A_1	1.8	F_1	0.4	3.12
A_0 and F_0 for /ɑ/	N	−.55*	Cl	−.20	A_0	6.0*	F_0	3.8	2.98
A_2 and F_2 for /ɑ/	N	−.26	Cl	−.66*	A_2	0.1	F_2	0.1	0.16
A_0 and F_0 for /u/	N	−.01	Cl	+.41*	A_0	3.0	F_0	1.2	3.48
A_0 and F_1 for /u/	N	−.44*	Cl	−.59*	A_0	3.0	F_1	1.6	1.08
A_2 and F_2 for /u/	N	−.29	Cl	−.65*	A_2	3.6	F_2	0.1	3.81

To determine whether between-group differences in formant amplitudes might have resulted because of the decay in amplitude accompanying a rise in frequency of the formants, an analysis of covariance was carried out. This was done for all amplitudes in which significant or nearly significant correlation coefficients were found, and for which significant analysis of variance *F*'s were obtained. The results indicated that in all cases where correlations between a formant's amplitude and frequency were significant, formant amplitude differences found to be significant in the analysis of

variance were due to these correlations. No significant *F*'s were found between formant amplitudes in the analysis of covariance. (See Table 5.)

The Fisher test for homogeneity of variance (*4*, p. 163) was applied to the two groups on the suction and judges' ratings scores, as well as on F_3 of /u/. The groups were found to be homogeneous with respect to F_3 of /u/ but not with respect to nasality judgments. The difference between the groups on F_3 of /u/ was significant at the 5% level. Due to the lack of homogeneity of variance on nasality judgments, it could be assumed, according to Lindquist (*6*, p. 86), that the differences originally found to be significant at the 1% level was really significant at the 2% level, or a non-parametric test of variance could be applied. The latter was done for this variable. The Mann-Whitney test (*8*, pp. 116–119) found the difference to be significant at the 1% level.

Thus, the two groups did, in fact, differ from each other with respect to F_3 on /u/ (the reliability of which has already been questioned); on A_2 and A_3 of /i/; A_1 of /ɑ/; A_1 of /u/; and on suction scores and judges' ratings of nasality. If the latter two variables were valid indicators of velopharyngeal function, scores of one should correlate highly with scores of the other. The correlation coefficient between these variables on the cleft group was .35, just slightly short of the .36 necessary for significance at the 5% level.

Discussion

Pressure and Suction Scores. One of the purposes of this study was to investigate interrelationships among various measures of velopharyngeal competency. Judgments of sophisticated listeners have proven in other studies to be reliable measures of hypernasality. In the present study, there was also a high correlation among the judges' ratings. These ratings were used as a basis for evaluating the positive pressure and suction ratios, and the correlations between judges' ratings and those measurements were not significant. The lack of correlation should not, in the opinion of this investigator, be interpreted to mean that poor velopharyngeal closure during blowing or sucking was not an index of hypernasal speech in these subjects. It was found that the children were reluctant to blow their hardest, especially those in the cleft group; many of whom reported a concern over the effect of hard blowing on their eardrums. Many of the children in the control group obtained widely varying scores on their various attempts on the pressure test, probably due to this fear of blowing too hard. Even though a sustained effort was required before a given pressure score was accepted, the pressure scores were difficult to determine with any exactness, for it was difficult for the children to sustain a given amount of pressure.

The suction phase of the experiment did not present the difficulties of the pressure test, however. The scores for each child were more consistent and the children did not reveal any fear toward this part of the test. The direction of the air stream during sucking assists in the closure of the Eustachian tube orifice. Whereas hard blowing tends to force open this

orifice and increase the pressure in the middle ear, sucking tends to close the salpinx. Thus, the children were able to suck with full force without ill effects. The children were also able to sustain a given suction force for a longer period of time. The correlation between suction scores and nasality judgments was nearly significant at the 5 % level, indicating that these two measures of velopharyngeal competency were more probably measuring the same thing than were blowing scores and judges' ratings of nasality.

The significant between-group differences on both suction scores and nasality judgments, together with the nearly-significant correlation for the cleft group between these two types of measures, would suggest that the suction device is a more reliable index of velopharyngeal action for speech than is the blowing device. This finding agrees with that of Chase (*1*) who, using the same instruments, also found suction scores to be better measures than blowing scores. This finding would indicate that several clinical tools presently employed to evaluate velar closure, using blowing pressure as the basis for the assessment, may not be serving the purpose as well as would a suction test.

Spectrographic Analysis. The high correlation between judges' ratings and F_3 in the vowels /æ/ and /ɑ/ in the cleft palate group substantiates DeLattre's contention that hypernasality tends to elevate the position of F_3. In the present study, however, this occurred only on these two more open vowels. The almost complete absence of significant correlations between pressure and suction scores and spectrographic measures is an important finding, since all three types of measures have been used to assess velopharyngeal competency.

Among formant frequencies and amplitudes, the only correlation that was consistent throughout the four vowels was that between F_2 and F_3. Considering the number of correlation coefficients obtained in the study, those found to be significant were comparatively few.

The results of the analysis of variance and analysis of covariance showed that the spectrograms failed to differentiate between the groups significantly, with the exceptions of F_3 of /u/ and A_2 and A_3 of /i/. Yet the panel of judges assessed the cleft palate group as having very significantly greater hypernasality than the normal group. Even though the mean rating for the cleft palate children was half-way between *mild* and *moderate* hypernasality, greater spectrographic differences were expected than those actually obtained.

It was noted by the researchers who first used the sound spectographic technique that hypernasality was displayed by certain areas of reinforcement that lay between the more prominent formants (*7*). A study of the sectioned patterns of vowels from speakers in both groups of the present study failed to find this characteristic of hypernasality. Had the hypernasality been more marked in the cleft subjects, these areas of reinforcement might have been found. It is possible that the instrument may be

modified in such a way as to more adequately portray mildly excessive hypernasality.

One of the most significant observations made in the present study concerns the articulation patterns of the cleft palate children. In the instructions given to judges, they were asked to evaluate the degree of nasality of the voice and not to confuse the articulation with the voice quality in making their estimates of nasality. All the judges reported that this was a very difficult task, since most of the children with cleft palates were clearly distinguishable from the normal-speaking children by their defective articulation, particularly due to their difficulty with the sibilant sounds. It is possible that to some extent the judges' ratings of nasality were higher than they would have been without the effects of faulty articulation, and that even the relatively mild hypernasality found among the cleft subjects was exaggerated by the judges.

The judges agreed it would have been much easier to evaluate the children's speech as a whole, including articulation, inflection, and voice quality. A complete assessment would include at least these three aspects of a child's speech. The observation concerning articulation has special meaning in connection with the age of palatal repair. Due to the very early closure effected on these children, they learned to use their palates before any appreciable speech was learned. The surgical procedure used on all the children gave them long, mobile palates, and as a result their voices have been only very mildly hypernasal. On the other hand, maxillary development may have been hindered somewhat, with resulting crowding of the tongue, making it difficult for the children to form the channel necessary for sharp, clear sibilant sounds. Past research is not adequate for one to make an assumption concerning the amount of crowding that would have taken place had the closure been performed at two years, four years, or six or ten years of age. While orthodontia later corrects the crossbite, the correction comes after the sibilant sounds have been learned and practiced for several years.

Summary

There were not significant correlations between pressure scores and any of the other variables. The r of .35 found between judges' ratings and suction scores was just short of the .36 required for significance at the 5% level. Suction scores correlated significantly with only two of the 32 vowel formant measurements. Nasality judgments were significantly correlated with F_3 (frequency of formant 3) of /æ/ and /ɑ/. For both vowels, the correlation was positive, indicating that as hypernasality increased, so did F_3 on these vowels. There were very few correlations among formant frequency and amplitude measurements.

Blowing scores did not differ significantly between the groups, but very significant between-group differences were found on suction scores and judges' nasality ratings. Children in the experimental group were found to

have a mean rating of 2.6, with a rating of *two* representing very mild nasality and *three* representing moderate nasality. The mean rating for children in the control group was 1.2, with *one* signifying a normal voice.

Differences between spectrographic vowel patterns of the two groups were few. F_3 of /u/ was the only formant frequency that differed significantly between the groups, and A_2 (amplitude of Formant 2) and A_3 of /i/, and A_1 of /ɑ/ and /u/ were the only formant amplitudes that differed significantly.

When the ten experimental subjects with the greatest hypernasality were compared with the ten least nasal control subjects, spectrographic differences were more meaningful. A_2 and A_3 of /i/, for example, were attenuated to a much greater degree by the ten most hypernasal subjects.

Suction scores were more valid indices of velopharyngeal competency than were blowing scores, although neither correlated significantly with judges' ratings of nasality. Due to the relatively mild hypernasality of the children with cleft palates, characteristics of nasality were not prominent on the spectrograms. Although articulation was not studied, all judges reported it was easier to distinguish the children with cleft palates from the normal children on the basis of their articulation than on the basis of voice quality.

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