Oral Manometer Ratios: Some Clinical and Research Implications

W. H. MOORE, JR., Ph.D.
RONALD K. SOMMERS, Ed.D.
Auburn, Alabama 36830

One of the instruments used either independently or in conjunction with cineofluorography and/or other devices to assess velopharyngeal competency in cleft palate speakers is the oral manometer. This instrument has been used for both clinical and research purposes by a number of investigators (*1*, *2*, *5*, *6*, *7*, *8*, *10*, *11*, *13*, *14*, *15*). Keeping the bleed valve open to allow for a steady reduction in air pressure is thought to be a better predictor of speech skills in cleft palate speakers (*1*, *7*, *14*) than using the instrument with the bleed valve closed.

The technique for using the oral manometer has been described by Morris (*7*). However, precise information relative to using the equipment has not been available from research evidence. In general, the procedure under both conditions has been to instruct the subject to "blow into the instrument until told to stop". For the first attempt the subject's nares are unoccluded, and a reading is made using the pressure gauge on the instrument. The second attempt is then made by the subject while the examiner mechanically occludes the subject's nares, and again a reading is made. A ratio is then determined between the air pressures attained by the subject under the non-occluded and occluded conditions. If the ratio is less than 1.00, the supposition is that the subject cannot prevent nasal escape by closing his velopharyngeal port.

Evidence to support the assertion that ratios from the manometer are capable of discriminating between good and poor cleft palate speakers has been provided by recent investigators (*1*, *10*, *11*, *13*, *14*). Ratios of less than 0.89 appear to be suggestive of velopharyngeal inadequacy and to relate to reduced intelligibility while those above .090 seem to be associated with good or superior cleft palate speech (*11*, *13*, *14*).

Although most research evidence reported suggests that gross differences in the ratios obtained will differentiate between cleft palate speakers having poor and good speech intelligibility, evidence to link oral manometer ratios to the degree of hyper-nasality present in cleft palate speech has not been overwhelming. Van Demark (*13*) reported a low ($r = 0.30$), but significant,

W. H. Moore, Jr. is Assistant Professor and Chief of Research Laboratories, Speech Pathology and Audiology, Auburn University, Auburn, Alabama. Dr. Ronald K. Sommers is Professor and Coordinator, Speech Pathology and Audiology, Kent State University, Kent, Ohio.

correlation between oral manometer ratios and degree of hyper-nasality in 154 cleft palate subjects. Although Van Demark (*15*) reported that his subjects improved their articulation skills and reduced their hyper-nasality, concomitant improvements in manometer ratios failed to materialize. Shelton, et al. (*8*) did not find a significant correlation between oral manometer ratios and articulatory skills when nasal escape was judged as an error of articulation.

Sherman (*9*) reported a low ($r = 0.34$), but significant, relationship between defectiveness of articulation and nasality in her cleft palate subjects. A recent investigation by Moore and Sommers (*4*) indicated the order of perceived hyper-nasality and articulatory defectiveness to be in close agreement. Considering the results from both investigations, it would appear reasonable to assume that if oral manometer ratios can differentiate between the speech intelligibility of cleft palate speakers, such measurements should also identify those having greater or lesser degrees of perceived hyper-nasality since the two factors seem interrelated.

The purpose of the present investigation was to determine the reliability and validity of the oral manometer under bleed/no-bleed conditions when the criterion was to determine the degree of hyper-nasality in cleft palate speakers. More specifically, the questions under investigation were:

1. Do the oral manometer ratios of cleft palate speakers vary significantly from the bleed to the no-bleed conditions?
2. Can reliable measures of the performances of cleft palate subjects be obtained over repeated trials under the two conditions?
3. What interactions occur when the two conditions are compared to level of hyper-nasality?
4. Do ratios obtained relate significantly to listeners' judgments of hyper-nasality?
5. Are there combinations of consonant/vowel syllables that relate more highly than others to manometer ratios?

Method

SUBJECTS. Sixteen subjects with repaired clefts of the palate served as the experimental subjects. Fourteen were males and two were females. These subjects were judged by the senior experimenter to demonstrate hyper-nasality in their spontaneous speech prior to testing. The Iowa Pressure Test was also administered. Judgments of perceived hyper-nasality on each of the items, on a seven point equal-appearing intervals scale, yielded a mean of 5.89, standard deviation of 3.77 and a range of 3.91–6.89. No individual with an obturator or pharyngeal flap was included in the experimental sample. Subjects ranged in age from 4.8–13.5 years, with a mean age of 9 years and median age of 7 years.

Experimental tasks. Oral manometer pressures with the nares occluded and unoccluded were obtained under bleed and no-bleed conditions. A Hunter Oral Manometer, Model No. 360, was used for these measurements.

Pressure values were measured over five trials for both occlusion conditions under the bleed and no-bleed conditions. Trials within occlusion conditions were separated by thirty seconds, while three minutes separated both the occlusion and bleed conditions. Pressure values were recorded at the end of a three-second interval. Oral manometer ratios for each of the trials were computed by dividing the occluded pressure value into the un-occluded pressure value. The mean ratio was computed by dividing the average occluded pressure value into the average un-occluded pressure value over the five trials for the two bleed conditions.

In the first speech task each subject imitated the examiner's production of the following vowels: /ɑ/, /ɔ/, /u/, /æ/, /ɛ/, and /i/. Following this the the 43-Item Iowa Pressure Test (*5*) was administered. In the third speech task, each subject imitated vowel-consonant-vowel (VCV) syllables. The following vowels were employed, each in the initial and final position in the syllables: /ɑ/, /æ/, /ɔ/, /ɛ/, /u/, and /i/. Each vowel was combined with the following consonants in the order noted: /l/, /w/, /r/, /j/, /h/, /g/, /d/, /b/, /k/, /t/, /p/, /dʒ/, /tʃ/, /v/, /ð/, /ʒ/, /z/, /f/, /θ/, /ʃ/, and /s/. The production of VCV syllables was counterbalanced so that half of the subjects produced the VCV syllables progressing from high to low vowels, while half of the subjects produced the VCV syllables progressing from low to high vowels. The order of the consonants was held constant for each vowel context.

Reliability. Intraclass correlations (*16*), based upon the oral manometer ratios obtained from sixteen subjects on each of five trials for the bleed and no-bleed conditions, yielded identical correlations of 0.93. Audio-tapes of the subjects' responses for each of the three speech tasks were judged, item by item, for severity of hyper-nasality by two clinically certified speech pathologists. A seven-point equal appearing intervals scale was used with one representing no perceived hyper-nasality (i.e., normal nasality) and seven representing severe perceived hyper-nasality. The intraclass correlation (*16*) between the average ratings of the first and second judges was 0.99 on the first speech task, 0.85 on the second task, and 0.90 on the VCV syllables.

Results

Analyses of variances, tests of trend, tests of significant differences between variances for dependent samples, and correlational procedures were utilized in data analysis.

Oral Manometer Ratios. A two-factor analysis of variance for repeated measurements (*16*) of the trials and bleed conditions was completed. This analysis yielded a non-significant main effect for Trials, $F(4, 60) = 0.37$, $p > .83$; a non-significant main effect for the Bleed/No-Bleed conditions, $F(1, 15) = 0.52$, $p > .51$; and a non-significant Trials $\times$ Bleed interaction effect, $F(4, 60) = 1.12$, $p > .35$.

Although a non-significant Trials $\times$ Bleed interaction effect was demon-

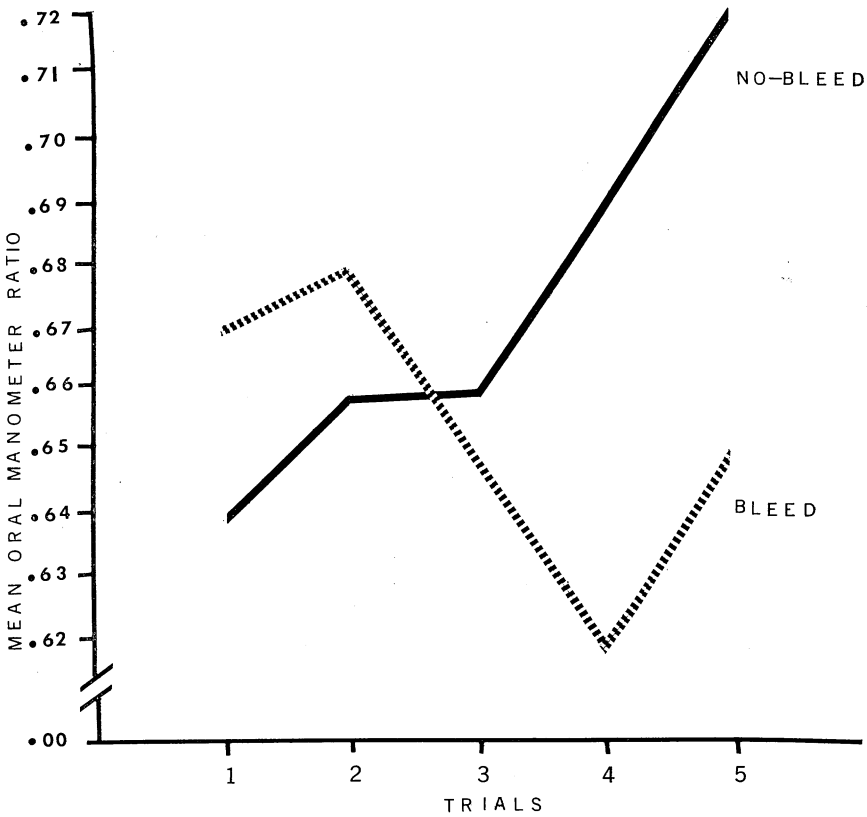

FIGURE 1. Mean oral manometer ratios for no-bleed and bleed conditions across five trials.

strated by the analysis of variance, visual inspection of the Trials × Bleed means (Figure 1) appeared to indicate important trends across trials within each of the bleed conditions. To analyze these apparent trends one-way analyses of variance for the two bleed conditions across trials (*16*) were completed along with tests of trends (*16*). A test of linearity on the oral manometer ratios for the no-bleed condition across the five trials yielded a linear mean square of .064, which is significant beyond the .05 level of confidence ($F = 4.03$, $df = 1, 60$). The total variation between trials for the no-bleed conditions was .070. Of this total, .064 or 92 per cent is accounted for by the linear trend. Neither the quadratic ($F = .05$, $df = 1, 60$), nor the cubic trend ($F = .01$, $df = 1, 60$) components were found to add significantly to the predictability of the linear trend. However, for the bleed condition, neither the linear ($F = .65$, $df = 1, 60$), quadratic ($F = .05$, $df = 1, 60$) nor the cubic ($F = 1.05$, $df = 1, 60$) trend components were found to be significantly predictive of the trials variation. The total variation between the bleed trials was .037. Of this total, .013 or 35 per cent is accounted for by

TABLE 1. Oral manometer ratios for no-bleed and bleed conditions across five trials, mean ratio for each subject, mean ratio of five trials, variances and standard deviations

subject	*no-bleed*						*bleed*					
	trial						*trial*					
	1	*2*	*3*	*4*	*5*	*mean*	*1*	*2*	*3*	*4*	*5*	*mean*
1	.29	.17	.11	.30	.50	.28	.20	.25	.23	.16	.23	.21
2	.75	.74	.52	.74	.81	.70	.60	.32	.43	.60	.53	.48
3	.73	.61	.76	.83	1.10	.80	.73	1.14	1.05	.44	1.07	.88
4	.40	.36	.40	.44	.50	.43	.27	.30	.20	.54	.42	.33
5	.67	.63	.68	.72	.51	.64	.60	.50	.69	.74	.64	.64
6	.47	.50	.45	.55	.67	.53	.68	.55	.74	.48	.41	.56
7	.60	.71	1.06	.79	.80	.78	.54	.71	.73	.64	.54	.62
8	.83	.72	.98	1.05	.78	.87	1.00	.76	.63	.95	.93	.93
9	.38	.50	.38	.35	.33	.38	.36	.20	.20	.43	.16	.26
10	.55	.38	.58	.81	.51	.55	.87	.77	.63	.57	.67	.70
11	.67	1.00	.80	.68	1.08	.82	1.04	.92	.92	.93	.89	.94
12	.93	1.12	1.04	.85	.89	.96	.73	.90	.79	.71	1.00	.96
13	.93	.75	.77	.68	.71	.76	.71	.72	.79	.75	.60	.71
14	.77	.92	.92	.83	1.00	.87	.96	.86	.80	.54	.92	.81
15	.33	.66	.36	.55	.44	.45	.44	.83	.60	.44	.71	.59
16	.92	.78	.70	.93	.88	.83	.94	1.15	1.00	.93	.73	.95
mean	.64	.66	.66	.69	.72		.67	.68	.65	.62	.65	
variance	.047	.060	.075	.043	.056		.067	.090	.071	.046	.071	
standard deviation	.217	.245	.274	.208	.237		.259	3.01	.266	.215	.266	

the linear trend; .001 or 3 per cent is accounted for by the quadratic trend; and .021 or 57 per cent is accounted for by the cubic trend.

VARIANCE BETWEEN TRIALS AND STABILITY OF SUBCLASSIFICATIONS OF ORAL MANOMETER RATIOS. Table 1 represents the oral manometer ratios for the bleed and no-bleed conditions across the five repeated trials together with the means, variances and standard deviations. The differences between the variances for the combinations of the five trials for the bleed and no-bleed conditions were analyzed with tests for significance of difference between variances for dependent samples (*3*). None of the differences between variances were found to be significant when tested at the .05 level of confidence, thus indicating homogeneity of variance within bleed conditions across repeated trials.

Spriestersbach, Moll, and Morris (*11*) have suggested the need for subclassifying cleft palate individuals on the basis of oral-breath pressure ratios when studying articulation skills. Their classification system subclassifies subjects according to manometer ratios with bleed as follows: High = 1.00 to 0.90, marginal = 0.89 to 0.51, and low = 0.50 to 0.00. In-

spection of Table 1 for the no-bleed condition indicates, relative to trial one, that 11 subjects, or 68.75 per cent of the 16 subjects, demonstrated changes in oral manometer ratios over trials 2–5 of such magnitude that they moved from one subclassification to another. Of these 11 subjects, 7 or 63.63 percent changed from a lower to a higher subclassification. Performances under the bleed condition (Table 1) also indicated that 11 subjects, or 68.75 per cent of the subjects demonstrated changes from their trial one oral manometer ratios great enough to move them into another subclassification. Of these 11 subjects, 7 or 63.63 per cent of the subjects changed from a higher to a lower subclassification. One subject (subject number 3) in the bleed condition obtained oral manometer ratios over the five trials associated with high, marginal, and low subclassification categories.

Correlation Analyses. Pearsonian correlational procedures were employed to analyze the relationships between the oral manometer ratios for each of the five trials and the mean oral manometer ratio across trials for the two bleed conditions with the mean scale values of perceived hypernasality of the following variables: vowels in isolation, Iowa Pressure Articulation Test, vowel contexts, and consonants within vowel contexts. Correlations between the mean scale values of hyper-nasality were reported previously (*4*).

As revealed in Table 2, none of the oral manometer ratio measurements was found to be significantly correlated with perceived hyper-nasality of the vowels produced in isolation. Ratios for trial four under the bleed condition were the only manometer measurements found to be significantly correlated with mean scale values of perceived nasality for the Iowa Pressure Articulation Test. Of the six significant correlations between oral manometer ratios and vowel contexts contained in Table 2, all were associated with trial four under either the bleed or no-bleed conditions.

Table 3 represents the significant correlations between the oral manometer ratio measurements and consonant manner of production within vowel contexts. Oral manometer ratios with bleed for trial four were found to be significantly correlated with fricatives/affricatives in five of the six vowel contexts investigated. Three vowel contexts containing plosives were found to be significantly correlated with oral manometer ratios with bleed on trial four. Five vowel contexts containing plosives and/or fricatives/affricatives were found to be significantly correlated with oral manometer ratios with no-bleed on trial four. Glides and /h/ in /æ/ contexts were found to be significantly correlated with no-bleed oral manometer ratios for trial four.

The expected negative correlations between oral manometer ratio measurements and mean scale values of perceived hyper-nasality are reported in Tables 2 and 3. These negative correlations indicated that as oral manometer ratios decreased, mean scale values of perceived hyper-nasality increased and vice versa. The means, standard deviations and ranges of the variables used in the correlational analyses with the five bleed and no-bleed oral manometer trials are presented in Table 4.

TABLE 2. Correlation matrix between oral manometer ratios and isolated vowels, Iowa pressure articulation test, and vowel contexts. Only significant correlations are reported.

oral manometer ratio	*isolat. vowels*	*Iowa press. test*	*vowel contexts*					
			/ɑ/	/æ/	/ɔ/	/ɛ/	/u/	/i/
bleed trial								
1								
2								
3								
4		−.53	−.51	−.62	−.56	−.57		
5								
mean				−.50				
no-bleed trial								
1								
2								
3								
4				−.60	−.52			
5								
mean								

Critical value of r at the .01 level of confidence = .62 (n = 16).
Critical value of r at the .05 level of confidence = .50 (n = 16).

Discussion

Taken at face value, the results of the bleed/no-bleed conditions seem highly similar since the statistical analyses did not confirm the existence of significant differences between the five oral manometer ratios nor significant differences between the mean oral manometer ratios for bleed (mean = 0.65) and no-bleed (mean = 0.67) conditions. Furthermore, the Trials × Bleed interaction was not significant. Considered alone, these findings would appear to indicate that bleed and no-bleed ratios across trials are quite similar. However, further analyses using tests for trends (*16*) revealed important components within bleed conditions. Tests of linear trend showed a linear progression across trials for the no-bleed condition. This finding did not obtain for the bleed condition. None of the trend components investigated (linear, quadratic, or cubic) were found to be significantly predictive of the trial variation under the bleed condition.

The progressively higher ratios observed under the no-bleed condition may represent a "practice" or "learning" effect of subjects' increasing tendency to impound air pressure in the oral cavity by maintaining lingual-palatal contact, an explanation offered by previous investigators (*7*, *10*). On the other hand, the lack of linearity and regression of oral manometer ratios under the bleed condition may reflect a fatiguing effect related to the greater demands that are placed on the velopharyngeal valving mechanism when subjects are required to blow into an open-system with bleed.

The intraclass correlations across trials for both bleed conditions were

TABLE 3. Correlation matrix between oral manometer ratios and consonant manner of production within vowel contexts. Only significant correlations are reported (G = glides and /h/, P = plosives, F = fricatives/affricatives)

oral manometer ratio	*VCV syllables*																	
	/ɑ/			/æ/			/ɔ/			/ɛ/			/u/			/i/		
	G	*P*	*F*	*G*	*P*	*F*	*G*	*P*	*F*	*G*	*P*	*F*	*G*	*P*	*F*	*G*	*P*	*F*
bleed trial																		
1			−.53															
2																		
3																		
4			−.57		−.66	−.62		−.62	−.57		−.57	−.65			−.50			
5																		
mean					−.55													
no-bleed trial																		
1					−.51													
2																		
3			−.59					−.55										
4			−.63	−.62	−.57	−.54			−.53									
5																		
mean																		

Critical value of r at the .01 level of confidence = .62 (n = 16).
Critical value of r at the .05 level of confidence = .50 (n = 16).

TABLE 4. Means, standard deviations, and ranges for vowels in isolation, vowel contexts, and consonants within vowel contexts (G = glides, P = plosives, F = fricatives/affricatives)

variable	*mean*	*standard deviation*	*range*
vowels in isolation	2.68	1.32	1.25–6.08
vowel context			
/ɑ/	4.65	1.25	1.33–6.40
/æ/	5.04	1.49	2.00–6.57
/ɔ/	4.42	1.27	1.21–6.24
/ɛ/	4.99	1.29	3.05–6.83
/u/	5.52	1.25	3.24–6.86
/i/	6.09	.63	4.81–6.86
consonants within vowel contexts			
/ɑ/			
G	3.16	1.30	1.00–5.60
P	4.64	1.87	1.00–6.58
F	5.45	1.41	1.70–7.00
/æ/			
G	4.04	1.58	1.00–6.50
P	4.80	1.91	1.00–6.75
F	5.62	1.42	2.20–6.90
/ɔ/			
G	2.84	1.23	1.00–4.50
P	4.03	1.73	1.17–6.58
F	5.41	1.51	1.35–7.00
/ɛ/			
G	3.83	1.67	1.60–6.90
P	4.61	1.85	2.00–6.75
F	5.79	1.10	3.70–6.90
/u/			
G	4.69	1.67	2.30–6.90
P	5.23	1.72	1.83–6.83
F	5.98	1.17	3.25–7.00
/i/			
G	5.34	1.31	2.90–6.90
P	6.13	.83	4.33–7.00
F	6.39	.49	5.40–6.95

computed to be 0.93. These intraclass correlations appear to indicate that there is high reliability across trials for both bleed and no-bleed oral manometer ratios. However, when oral manometer ratios were examined in regard to subclassification categories suggested by Spriestersbach, Moll and Morris (*11*), two-thirds of the subjects under both bleed conditions were found to change subclassification categories. The paradox appeared to be that the high reliability of oral manometer ratios was not reflected in high degrees of subject stability, since large percentages of subjects in the present study changed subclassifications.

Only one oral manometer ratio measurement, ratios with bleed on trial

four, was found significantly correlated with mean scale judgments of perceived hyper-nasality for the 43-Item Iowa Pressure Articulation Test. Of the six significant correlations obtained between oral manometer ratios and judgments of perceived hyper-nasality for vowel contexts, four were observed under the bleed condition for trial four and two were observed under the no-bleed condition for trial four. Mean oral manometer ratios with bleed were found to be significantly correlated with vowel contexts containing /æ/; however, no other significant correlations between vowel contexts and mean oral manometer ratios were revealed.

Correlational analyses between oral manometer ratios and consonant manner of production within vowel contexts yielded 18 significant correlations. The probability that some of these significant relationships found between VCV syllables and trial scores under the bleed and no-bleed conditions could have been accounted for by chance was studied. Of 18 significant relationships, six were significant at or beyond the .01 level (chance alone would indicate that approximately two would have been determined). The remaining 12 significant relationships were significant at or beyond the .05 level (again, by chance alone 11 could have been significant). All six of the relationships determined to be significant at the .01 level occurred when trial four scores under the bleed or no-bleed conditions were compared to the VCV syllables. Seven of 12 relationships found to be significant at the .05 level were also related to trial 4 bleed and no-bleed scores. Thus, some consistency of findings appear in the data, and these may tend to reflect the fact that the relationships determined between trial 4 scores under the bleed and no-bleed conditions are not the results of chance occurrences.

Seventeen of the significant correlations between oral manometer ratios and consonant manner of production within vowel contexts were associated with plosive or fricative/affricative consonant manner of production. Only one significant correlation was found between glides and the glottal fricative /h/ and oral manometer ratios. Glides and /h/ in /æ/ contexts were found to be significantly correlated with no-bleed oral manometer ratios for trial four. Ten significant correlations were associated with fricative/affricative consonant manner of production. Oral manometer ratios with bleed on trial four were found to be significantly correlated with five vowel contexts containing fricatives/affricatives of the six vowel contexts investigated. These findings appear to be of particular importance since both plosives and fricatives/affricatives have been found to be perceived as significantly more nasal than glides and the glottal fricative /h/ (*4*). The greater degrees of hyper-nasality for these consonant classifications may relate to the greater demands placed upon the valving function during speech production (*12*).

Since subjects' oral manometer ratios under all the bleed and no-bleed conditions were lowest on trial four of the bleed condition and this condition was most highly related to the speech tasks under investigation, some possible implications for the clinical use of this instrument can be inferred. If the oral manometer is used to assist in evaluating velopharyngeal competence

either in clinical work or research, our results suggest that the bleed condition should be used and that subjects should undergo a four-trial examination. This appears to be a more valid indicator of the presence of excessive hyper-nasality when some VCV syllables are produced. Information derived from the oral manometer without the bleed valve does not relate well to judgments of hyper-nasality. Our data tend to support the belief that cleft palate subjects do indeed somehow compensate by impounding air pressure, thus reducing the validity of the obtained measurements if nasality is the criterion. It is conceivable that a four-trial assessment may tend to fatigue the subject, thus inducing a state of reduced muscle tonus which may approximate more closely that associated with normal speech. The suggestion is, therefore, that a four trial sequence is most efficacious in the use of the oral manometer with the bleed valve functional if the goal is to detect fine degrees of excessive nasality presumed to relate to inadequate velopharyngeal valving.

Summary

The effects of repeated measurements of oral manometer ratios for bleed and no-bleed conditions were investigated. Analysis of variance failed to reveal statistically significant differences for the trials, bleed, or interaction effects. However, tests of trends revealed a linear progression for oral manometer ratios in the no-bleed condition across trials. This finding did not obtain for the oral manometer ratios under the bleed condition. These findings are discussed in terms of a "practice" effect under the no-bleed condition and a fatiguing effect under the bleed condition as a possible explanation for the current findings.

Although high reliability and homoscedasticity was demonstrated between trials within the two bleed conditions, high degrees of intrasubject stability for the recommended ratio subclassifications was not shown.

Oral manometer ratios under the bleed condition on trial 4 were more highly related to the three speech tasks under investigation than any other oral manometer ratio measurement investigated. In evaluating velopharyngeal competency with the oral manometer, our current results suggest that the bleed condition be used and subjects undergo a four-trial examination.

Acknowledgements: The authors wish to express their appreciation to Dr. Raymond S. Rosedale, Sr., Mrs. Betty Ricker, Canton, Ohio, the Speech Pathology and Audiology Staff of the Goodwill Rehabilitation Center, Canton, Ohio, and the Speech Pathology and Audiology Staff of the Litchfield Rehabilitation Center, Akron, Ohio, for making subjects available; Miss Iris C. Ripley, Dr. Harold Hartley, and Mr. James Foulk for their assistance in data collection procedures.

reprints: *W. H. Moore, Jr.*
Speech Pathology and Audiology
Auburn University
Auburn, Alabama 36830

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