Videoendoscopic Feedback in Training Velopharyngeal Closure

RALPH L. SHELTON, Ph.D.
KAREN BEAUMONT, M.S.
WILLIAM C. TRIER, M.D.
MONTIE L. FURR, D.D.S., M.S.D.
Tucson, Arizona 85721

Each of two adolescents with *velopharyngeal closure deficits* was taught to position him or herself on an *endoscope* attached to a *television camera* and to observe the velopharyngeal port during the production of syllables and other units. The *videoendoscope* was then used as a *training* apparatus, and each subject was given practice attempting to increase velopharngeal closure while producing vowels and syllables. Videorecordings of each subject made without feedback before, during, and after the training period were played to panels of observers who were to rate closure during each utterance, and the data obtained indicated that the subjects more frequently approximated complete closure as the study progressed but that improved performance was not established on an automatic level. Suggestions are made for the refinement and further investigation of *videoendoscopic closure training.*

Videoendoscopic feedback displaying velopharyngeal closure has been studied as a possible training technique for influencing velopharyngeal closure (Shelton et al., 1975). In that study, normal subjects utilized laryngeal fixation and modification of gag to influence non-speech velopharyngeal closure. The purpose of the current report was to explore videoendoscopic feedback in closure training for persons with velopharyngeal closure deficits. The training required each of two subjects to attempt voluntary closure while producing syllables that could be produced with the endoscope in the mouth. Each subject was to observe velopharyngeal movements by use of the videoendoscope as they occurred.

Procedure

Instrumentation. As described by Shelton et al. (1975) a National Taub Oral Panendoscope (hereafter referred to as endoscope) was coupled to a Sony AVC 3200 videocamera and AVF 3200 viewer, and the image was displayed to the subject during orientation and training trials by means of a television set which was placed within the subject's view. Sessions and probes were recorded on videotape. In the current study, an isolation transformer was used to increase subject protection relative to any electrical hazard that might be present.[1] A Sampson 7301 tripod was added to the system to provide stability and safety for the camera and ease of camera manipulation in obtaining an image. The tripod was adjusted so that the subject had to sit up straight with the neck slightly ex-

Dr. Shelton is affiliated with the Speech and Hearing Sciences Department, University of Arizona, Tucson, Arizona. Karen Beaumont is employed by School District Number One, Tucson, Arizona. Dr. Trier is affiliated with the Departments of Surgery and Dental Ecology, University of North Carolina, Chapel Hill, North Carolina. Dr. Furr is Secretary/Treasurer, Charles E. Tweed Foundation for Orthodontic Research, Tucson, Arizona.

This paper was presented at the poster session of the 1976 meeting of the American Cleft Palate Association, San Francisco.

The research reported was supported by Public Health Service Research Grant DE03350 from the National Institute of Dental Research, U.S. Department of Health, Education, and Welfare.

[1] The endoscope used in this study is no longer acceptable for use with human subjects at the University of Arizona because it requires placement of an electric bulb in the mouth. We are now using endoscopes that employ fiber optic cables for illumination.

tended. The subject moved onto the scope with the mouth moderately open and the scope just above or touching the tongue. A mirror taped to the front of the television camera aided the subject in this positioning. Visualization was sometimes facilitated when the tripod was positioned so that the shaft of the scope was angled slightly downward. The field of view was not sufficiently wide to allow both sides of the pharynx to be observed simultaneously.

Subjects. Subject 1 was a male, aged 17 years, 3 months, who was born with a cleft of the soft and hard palate. He had undergone pharyngeal flap surgery at age 15 years and 10 months. The surgery preceded the initiation of this study by 19 months. Hypernasality and audible nasal escape of air were evident in the boy's speech. However, no more than 1.5 cm. of water displacement in one wing of a U tube was observed when escape was measured from both nares simultaneously. Nares open/nares closed quotients of 0.73 and 0.60 were obtained for blowing and inhalation as measured with a Hunter manometer. On repeated administrations of the 43-item *Iowa Pressure Articulation Test,* the boy made only 10 or 11 correct responses, and his spontaneous speech was often unintelligible to us even after we were well acquainted with him. Videoendoscopy showed that the boy closed the velopharyngeal port on the right side of the pharyngeal flap. The port on the boy's left side remained open although movement toward closure was sometimes observed. The boy's hearing was within normal limits although for the frequencies 250–8000 Hz, the left ear thresholds of 20 to 25 dB (ISO) were 15 to 25 dB poorer than those observed in the right ear.

Subject 2 was a 12-year-old girl who was referred by a school speech pathologist because of suspected palatopharyngeal insufficiency. Her spontaneous speech was marked by hypernasality and audible nasal escape of air. However, she was able to speak essentially normally with conscious effort. Her spontaneous conversation (as when we were driving her home) was often of poor intelligibility. Her *Iowa Pressure Articulation Test* scores on repeated testing ranged from 37 through 39 correct responses, and she produced as much as 6 cm. of water displacement in one wing of a U tube manometer that was coupled to both nares. Her hearing was normal.

Endoscopic observation showed a prominent bulge on the posterior wall of the girl's pharynx in the region of velopharyngeal closure (Figure 1). This appeared to represent a prominent bony structure in the region of the

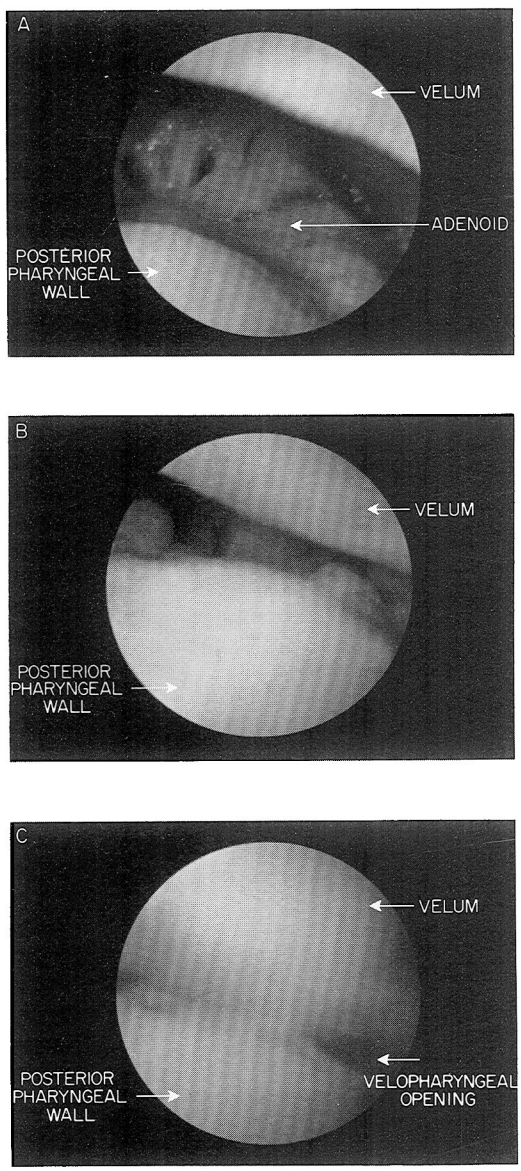

FIGURE 1. Videoendoscopic photographs of subject 2. *A* shows the subject at rest, *B* during blowing, and *C* during /pa/. The bulge on the posterior wall of the pharynx (which is particularly evident in *B*), is presumed to reflect a vertebral defect.

first cervical vertebra—perhaps a deformity (Osborne, Pruzansky, and Koepp-Baker, 1971). However, the family declined to have cephalometric studies included in the project.[2] Endoscopic observation indicated that the soft palate sometimes contacted the bulge on the posterior pharyngeal wall but that ports usually remained open on each side of that contact. The contact observed was produced during stop consonants and was not produced during isolated vowels.

Training. Early in training, each subject learned to tolerate the endoscope, to position him or herself on the scope both with and without television feedback, and to recognize the movement toward closure that was the goal of the training. Recognition was taught by describing variations in closure to the subject as the subject observed his or her own ongoing orientation trials. Sometimes replay was used to compare trials on which movement toward closure varied. The study of each subject included: orientation, baseline, training, training session probes, and post-treatment probes. Television feedback was provided only during orientation and training. During baseline, probe, and post-treatment probes, the subjects produced random arrangements of the following 21 items which are arranged here according to categories used in data analysis:

Vowels	Consonant Vowel (CV) Syllables	
/ɑ/	/pɑ/	/bɑ/
/æ/	/pæ/	/bæ/
/ʌ/	/pʌ/	/bʌ/

Vowel Consonant (VC) Syllables		Consonant Vowel Consonant (CVC) Syllables	
/ɑp/	/ɑb/	/pɑp/	/bɑb/
/æp/	/æb/	/pæp/	/bæb/
/ʌp/	/ʌb/	/pʌp/	/bʌb/

These consonants and vowels were used because they could be produced with the endoscope in the mouth; plosives were made by closing the lips around the endoscope shaft. Training involved random arrangements of the 12 items underlined in the list presented above. Performance was probed on the 21-item set to allow us to observe whether learned performance generalized to untaught items.

Subject 1 received 15 training sessions. In each session, from two to four sets of 12 items were administered (a total of 46 sets of 12 training items were presented). After each production, the boy moved off the scope, and the light controller was turned to its lowest setting. All training was directed to the boy's left velopharyngeal port which we considered to function poorly. During most training trials, each subject was given additional descriptive information regarding the magnitude of the movements produced. The speech pathologist who provided the training was free to provide this information at her discretion.

Subject 2 received only six training sessions. For each of the first four sessions, two sets of the 12 training items were directed to the left side of the velopharyngeal port and two to the right side. During several baseline and training sessions, the subject's performance was observed during blowing and simultaneous blowing and phonation. Shprintzen, McCall, and Skolnick (1975) had reported that subjects who produced better closure during blowing than speech could be helped to improve speech performance by a procedure that encouraged generalization from blowing to speech. While our subject usually appeared to approximate closure more nearly during blowing than in production of isolated syllables, we observed that she came ever closer to closure during production of strings of syllables such as /pap, ap, ap, pap/. While connected speech is not possible with the endoscope in the mouth, strings of syllables can be produced. We decided to use syllable strings in the last two training sessions. In those sessions, the left side was trained with a set of the 12 single syllables and then with a set of 21 syllable strings. This was then repeated for the right side.

Larynx displacement. We used a second camera and videorecorder to study displacement of the larynx during training and probe trials because there is a danger that efforts to drive

[2] The services were presented to each family as experimental. Parents signed informed consent releases which included the statement: Dental x-rays expose the subject to a small amount of radiation. The radiation exposure will be less than that used by the dentist to perform a full-mouth x-ray examination. Each subject was paid a small hourly salary for participation in the study.

the velopharyngeal port more vigorously may result in hyperfunctional use of the larynx (McWilliams, Bluestone, and Musgrave, 1969; Tash et al., 1971). Informal inspection of the tapes did not show fixation or displacement of the larynx to be a problem in this study, and data from the larynx tapes are not reported. Nevertheless, because of the high incidence of laryngeal voice disorders in the cleft palate population, the larynx should be monitored in therapy directed to the velopharyngeal port.

Data analysis. The videotapes of each baseline, probe, and post-treatment session were played in random order to nine or ten judges who were trained for the task. Photographs of each subject were used to show the velopharyngeal port open, moderately closed, and almost completely closed. Judges were instructed to use a five-point scale to rate the smallest aperture observed at any moment during each syllable. On that scale, 1 represented maximum opening, 2 wide opening, 3 moderate opening, 4 slight opening, and 5 closed. Judges were to rate each aperture against photos of maximum opening. This served to adjust for the fact that the aperture was sometimes partially closed when a trial began. Judges used the scale just described to rate the syllable strings as well as the isolated syllables. However, for the syllable strings, they were instructed to assign a value that reflected variability in closure approximation from one segment of a string to another. The judges were given rating practice by presenting them with training trial tapes that were not used in the assessment of the treatment.

The random order in which tapes of the second subject were presented to the judges tended to present early tapes first, and the judges found scale value 4 for that subject to be relatively wide. They reported that, had a scale value of 6 been available, they would have used the value 5 more often. This suggests that the rating procedure may have worked against the demonstration of improvement for subject 2. Consequently, an additional analysis of a subset of tapes from subject 2 was performed. We identified three random arrangements of the 21 single syllable items that had been recorded both before and after treatment with subject 2. Each arrangement had been used pre- and post-treatment to assess closure on either the subject's left or right side. That is, a pre-treatment left side recording was not paired with a post-treatment right side recording or the reverse. Two television sets were placed side by side, and an item from one tape was played to the judges and then the same item was played from the second tape. The four judges, who did not know the order in which the tapes had been obtained, were instructed to report whether the closure image on the television to their left showed an opening less than,

TABLE 1. Mean velopharyngeal closure ratings for subject 1 during baseline, probe, and post-treatment sessions. Mean standard deviations for the ratings are also reported.*

	Baseline				*Treatment session probes*			*Post-treatment probes*		
	7/16	*7/17*	*7/22 (1st)*	*7/22 (2nd)*	*7/26*	*8/2*	*8/12*	*8/13*	*8/14*	*8/15*
	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*	$\bar{X}$ *SD*
Vowels	2.8 .61	2.3 .50	2.5 .57	2.4 .50	1.5 .82	2.0 .52	2.2 .60	2.3 .53	2.9 .55	2.6 .53
Vowel-consonant syllables	2.9 .62	2.3 .68	3.3 .55	2.7 .50	1.6 .64	3.3 .74	3.0 .62	2.7 .65	2.9 .55	2.7 .36
Consonant-vowel syllables	3.0 .79	2.3 .63	2.9 .72	2.9 .39	2.2 .49	4.3 .52	4.0 .64	3.9 .55	3.6 .66	3.7 .31
Consonant-vowel-consonant syllables	3.0 .79	2.6 .66	3.2 .42	2.7 .67	2.2 .46	4.0 .41	3.8 .67	3.8 .55	3.5 .56	3.7 .39
All production units combined	2.9 .70	2.4 .64	2.9 .62	2.8 .47	2.0 .54	3.6 .57	3.4 .64	3.3 .57	3.3 .59	3.3 .38

* A standard deviation for the ratings made by the set of judges was computed for each vowel or syllable studied. The standard deviations reported here are averages based on the standard deviations for each unit in each production category.

greater than, or equal to that shown on the right-hand television. Assignment of tapes to each television was randomized.

Judge Reliability

The reliability of the judges is reflected in the standard deviations reported in the data tables. A standard deviation of 0.00 indicates perfect judge agreement whereas a standard deviation of 0.50 usually means judges split with five choosing one scale value and four an adjacent value. For the second subject, 315 single syllables (including isolated vowels) were rated by each of nine judges. For 23 of the syllables, the judges assigned three of the available five values to the performance, and for 48 syllables all judges agreed. For the remaining 244 syllables, judges agreed within one scale value. We conclude that the judges were adequately reliable to detect any treatment effect of sufficient magnitude to be worth noting.

Results

Data for subject 1 are reported in Table 1. For each date, ratings across the three vowels were averaged to provide a vowel score; and similar averages were obtained for the other production categories. A comparison of the baseline and post-treatment probe data indicates higher ratings after treatment for all contexts combined and for the CV and CVC syllables. Closure was not uniform across the duration of a syllable but tended to peak with consonants. A contextual effect is evident in Table 1 in that relatively small ratings are associated with the isolated vowels.

We conclude that, for some of the contextual categories studied, subject 1 used more extensive movements after treatment was initiated. The improvement probably involved use of movements available to the subject prior to the onset of the study. Certainly any improved performance that was observed was not established on an automatic level (Shelton, 1963), and informal observation indicated no improvement in his spontaneous speech. Also, the *Iowa Pressure Articulation Test* scores were the same after treatment as before. Table 1 is based on the list of twenty-one syllables presented earlier. We did not differentiate between the syllables used in training and those used only for generalization testing

TABLE 2. Mean velopharyngeal closure ratings for subject 2 during baseline, probe, and post-treatment sessions. Mean standard deviations for the ratings are also reported. These data are for the 21 items listed in the text, and they represent observations of the left and right sides of the subject's velopharyngeal port.

	Baseline						*Treatment probe*		*Post-treatment probes*							
	7/21		*7/22*		*7/23*		*7/31*		*8/6*		*8/7*		*8/8*			
	left	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*	*left*	*right*		
	X SD	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*	*X SD*		
Vowels	2.4	2.5	2.6	2.6	2.6	2.5	3.0	2.9	2.7	2.9	3.2	3.1	3.4	3.3	3.0	
	.32	.40	.31	.35	.44	.30	.35	.14	.32	.27	.30	.27	.28	.42	.35	
Vowel-consonant syllables	2.9	2.7	3.1	3.2	3.4	3.5	3.3	3.0	3.4	3.4	3.7	3.5	3.5	3.5	3.4	
	.42	.44	.21	.32	.34	.44	.37	.18	.34	.39	.46	.35	.46	.41	.48	
Consonant-vowel syllables	2.9	3.1	3.0	3.3	3.4	3.1	3.5	3.1	3.6	3.7	3.9	3.8	3.5	4.0	3.6	
	.32	.49	.26	.27	.27	.37	.45	.33	.51	.37	.28	.43	.46	.30	.37	
Consonant-vowel-consonant syllables	3.2	2.9	3.5	3.3	3.2	3.3	3.4	3.1	3.6	3.9	3.8	3.6	3.4	3.9	3.8	
	.47	.31	.38	.43	.19	.42	.39	.35	.41	.38	.36	.35	.52	.31	.27	
All production units combined	2.9	2.9	3.1	3.2	3.2	3.2	3.3	3.1	3.4	3.6	3.7	3.6	3.5	3.7	3.5	
	.39	.41	.29	.34	.29	.40	.39	.27	.40	.38	.36	.36	.45	.35	.37	

because inspection of the data did not show any systematic difference between those two item categories. This was also true for subject 2 (Table 2).

Data for subject 2 are reported in Tables 2 and 3. Table 2, like Table 1, reports mean ratings and mean rating standard deviations for subsets of the single syllables. Some of the utterances show a tendency toward higher ratings for the post-treatment observations.

Table 3 reports data for the syllable strings. This information is presented to contrast ratings for syllable strings with the ratings for single syllables (Table 2). The initial ratings of the syllable strings were comparable in magnitude to post-treatment ratings of the single syllables. The syllable string data thus indicated that, for this subject, syllable strings appeared to provide better approximation to closure or closure itself than did isolated syllables. The syllable string data also showed a context effect in that ratings tended to be higher for strings loaded with consonants than for those that consisted primarily of vowels. The lowest ratings were obtained for a string that contained a nasal consonant.

The side-by-side television comparison of pre- and post-treatment single syllables showed greater closure approximation after treatment. Each judge's assessment of each tape pair was analysed in terms of the percentage of post-treatment syllables that surpassed the corresponding pre-treatment syllables in closure approximation. From 76 to 100 per cent (mean = 86%) of the comparisons showed smaller openings in the post-treatment syllables. We interpret these data to indicate that treatment did have an effect.

Discussion

Miyazaki, Matsuya, and Yamaoka (1975) reported success in improvement of velopharyngeal closure by persons who practiced closure as they observed it through a fiberoptic nasopharyngoscope. However, their article did not specify how practice was performed or report measures reflecting improvement made. Investigation of biofeedback in training velopharyngeal closure is sufficiently promising to warrant further study, and various instruments could be used in this research. However, treatment should be carefully described and its assessment quantified. At the present time, a clinician cannot advise a patient that training similar to that used in the study reported here is likely to resolve a velopharyngeal closure problem.

In future research, we would attempt to rank-order utterances including syllables, blowing plus phonation, and syllable strings

TABLE 3. Mean velopharyngeal closure ratings for subject 2 performing syllable strings.* Mean standard deviations for the ratings are also reported.

	8/1		*8/6*		*8/7*		*8/8*	
	left	*right*	*left*	*right*	*left*	*right*	*left*	*right*
	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$	$\bar{X}SD$
Consonant emphasis	3.8 .34	3.8 .28	4.5 .43	3.6 .45	3.3 .27	3.4 .49	4.1 .30	4.0 .05
Vowel emphasis 1	—	—	3.9 .31	2.9 .50	2.8 .42	2.8 .47	3.2 .27	3.1 .35
Vowel emphasis 2	—	—	4.1 .31	3.2 .52	3.2 .42	2.9 .49	3.5 .44	3.1 .31
Consonant-vowel	—	—	4.2 .27	3.7 .45	3.8 .27	3.8 .45	3.8 .44	4.0 .10
Vowel-nasal consonant-vowel	—	—	3.0 .47	2.3 .67	2.7 .67	2.4 .68	2.7 .50	3.0 .47

* The following syllable strings were studied: consonant emphasis— /pap ap ap pap/, /pæp æp æp pæp/, /pΛp Λp Λp pΛp/, /pap pa pa pap/, /pæp pæ pæ pæp/, /pΛp pΛ pΛ pΛp/, /bab ab ab bab/, bæb æb æb bæb/, /bΛb Λb Λb bΛb/, /bab ba ba bab/, /bæb bæ bæ bæb/, bΛb bΛ bΛ bΛb/, and /bap ap ap bap/; vowel emphasis 1— /a a a ap/, /æ æ æ æp/, /Λ Λ Λ Λp/; vowel emphasis 2— /a ab a/, /æ æp æ/; consonant vowel— /pa a pa/, /bæ æ bæ/, /pΛ Λ pΛ/; vowel-nasal consonant-vowel— /a ma a/. Only consonant emphasis strings were recorded the first time strings were used; the /a ma a/ string was not used in training.

in terms of the closure observed on each item. Training would then start with items that gave the best performance; and when specified criteria were achieved, training would be switched to items lower on the continuum. Rate used to produce syllable strings could be varied. Also, the subject would be instructed to produce the maximum closure possible throughout a syllable including the vowel portion. We would add use of a bilabial fricative to the contexts employed with the endoscope. That would afford the subject some experience in the production of high pressure continuants.

If a subject improved performance during an item with visual feedback, he would be asked to maintain that performance during trials where less direct forms of feedback were employed. These would include muscle sense, air pressure-flow recordings, and information from the instructor. *Muscle sense* is used here as knowledge of muscle activity. This knowledge is less precise than kinesthesis or position sense. It would appear to be an error to ask a subject to attend to visual and muscle cues simultaneously in that Klein and Posner (1974) have demonstrated by means of tracking studies that "kinesthetic cues seem to be ignored when visual cues are present." They concluded that vision dominates kinesthesis at least when attention is involved.

Acknowledgments: The authors wish to thank the following persons for contributions to this study: Anita F. Johnson, Marie Vergari, Barbara Major, Lori Linaker, Dennis Ruscello, Susie Morris, Kathy Perkins, Robert Heyman, Amy Thompson, Mindy Kirchbaum, Chris Gastel, Gail Brodie, Carl Coelho, Jan Aratani, Jan Cox, Judy Alexander, and Karen Phil.

References

KLEIN, R. M. and POSNER, M. I., Attention to visual and kinesthetic components of skills, *Brain Research, 71,* 401–411, 1974.

MCWILLIAMS, B. J., BLUESTONE, C. D. and MUSGRAVE, R. H., Diagnostic implications of vocal cord nodules in children with cleft palate, *Laryngoscope, 79,* 2072–2080, 1969.

MIYAZAKI, T., MATSUYA, T. and YAMAOKA, M., Fiberscopic methods for assessment of velopharyngeal closure during various activities. *Cleft Palate J., 12,* 107–114, 1975.

OSBORNE, G. S., PRUZANSKY, S., and KOEPP-BAKER, H., Upper cervical spine anomalies and osseous nasopharyngeal depth, *J. Speech Hearing Res., 13,* 14–22, 1971.

SHELTON, R. L., Therapeutic exercise and speech pathology, *Asha, 5,* 855–859, 1963.

SHELTON, R. L., PAESANI, A., MCCLELLAND, K. D. and BRADFIELD, S. S., Panendoscopic feedback in the study of voluntary velopharyngeal movements, *J. Speech Hearing Dis., 40,* 232–244, 1975.

SHPRINTZEN, R. J., MCCALL, G. N., and SKOLNICK, M. L., A new therapeutic technique for the treatment of velopharyngeal incompetence, *J. Speech Hearing Dis., 40,* 69–83, 1975.

TASH, E. L., SHELTON, R. L., KNOX, A. W. and MICHEL, J. F., Training voluntary pharyngeal wall movements in children with normal and inadequate velopharyngeal closure, *Cleft Palate J., 8,* 277–290, 1971.