The Relationship between Pharyngeal Wall Movements and Exchangeable Speech Appliance Sections

RALPH L. SHELTON, Ph.D.
ARTHUR F. LINDQUIST, D.D.S.
ALBERT W. KNOX, Ph.D
VIRGINIA L. WRIGHT, M.A
WILLIAM B. ARNDT, Ph.D
MARY ELBERT, M.A
KARL A. YOUNGSTROM, Ph.D
Kansas City, Kansas 66103

Reduction in size of the pharyngeal section[1] of prosthetic speech appliances has been thought to result in the development of pharyngeal wall movements during speech (*1*, *2*). However, our cinefluorographic comparisons of posterior pharyngeal wall movements before and after pharyngeal section reduction did not show increase in movements (*8*). This did not disprove the section reduction hypothesis but rather indicated that the conditions under which section reduction will influence wall movements are limited. Those conditions remain to be identified. We have reviewed and discussed literature pertaining to this topic elsewhere (*8*).

The current study describes a new procedure for manipulating pharyngeal sections and reports data obtained from three subjects under several pharyngeal section conditions. The study procedure permitted repeated observations of a subject under each of the conditions used. The dependent variable measures included articulation test scores, oral sound pressure level (SPL) and nasal sound level (SL), nasal air pressure, and cinefluorography of the posterior pharyngeal wall.

Dr. Shelton is with the Speech Department of the University of Arizona. Dr. Lindquist is in private dental practice in Prairie Village, Kansas. Dr. Knox is with the Audiology and Speech Pathology Department of the Veterans Administration Hospital, Kansas City, Missouri. Dr. Arndt is with the Psychology Department at the University of Missouri at Kansas City, Missouri. Virginia Wright and Mary Elbert are with the Speech Department at the University of Kansas Medical Center. Dr. Youngstrom is with the Radiology Department at the University of Kansas Medical Center. This work was supported by Public Health Service Research Grant No. DE 02004, Research Career Development Award DE 31669 from the National Institute of Dental Research and by the Research and Education Committee, Veterans Administration Hospital, Kansas City, Missouri.

[1] The term, section or pharyngeal section, replaces the term, bulb, used previously in this study series.

The first purpose was to describe each subject's performance on each dependent variable under the following conditions: (a) while wearing an optimally fitted pharyngeal section; (b) while wearing no appliance; and (c) while wearing each of two or more adaptation sections smaller than the optimally fitted section. For this portion of the study, all data for a given subject were gathered at the beginning of the study on a single day.

The second purpose of the study was to determine whether the subjects showed evidence of maintained closure while wearing a smaller section, or of improved closure over time with the smaller section or with no appliance. For this portion of the study, each subject first wore the optimal section for a period of time and then the next section in his set. If he appeared to show adaptation to that section, he wore his third section. This was continued until all sections had been either tried or rejected on the basis of evidence gathered.

Procedure

SUBJECTS. Three children served as subjects in this study. The first was a girl (C158), age 12 years, 3 months, who had a Peabody Picture Vocabulary Test (PPVT) standard score of 86. Her Veau class IV cleft had been repaired surgically with a Vomer flap procedure at 18 months and with Wardill pushback palatoplasty at 23 months. She had worn a speech appliance for seven years and eight months before the appliance used for this study was built. The second subject (C156) was a boy, age 8 years, 3 months, whose PPVT standard score was 123. His Veau class III cleft had been repaired surgically in another city. He had worn a speech appliance for nine months prior to this study. The palate of the third subject (C157) was intact and moved but was too short to contact the posterior wall of the pharynx. This was a girl, age 7 years, 3 months, whose PPVT standard score was 87. She had worn a speech appliance for two years and ten months prior to this study. Like the other subjects, without a speech appliance she was unintelligible. Table 1 reports cinefluorographic data regarding each subject's palatopharyngeal structure and function. The measures were taken from the first cinefluorographic films under the no appliance condition. Palatopharyngeal gap was the smallest observed in the utterance series described later. Other measures were made either in prephonation frames of during articulation of /s/ in /sɑs/. C157 was in moderate extension, and the subjects varied in the relationship between palatal plane and atlas. Each subject showed a velopharyngeal gap throughout the utterances filmed.

Each child's pharyngeal section was attached to the anterior portion of the appliance by means of a carrier wire that passed under the palate. When wearing well-fitted speech appliances, each of the subjects was free from articulation errors which involved nasal escape of air or substitution of nasal consonants. They also produced plosive and sibilant consonants with sufficient air pressure to be intelligible to judges. The articulation

TABLE 1. Cinefluorographic measures of velopharyngeal structure and function.

Measure	*Subject*		
	C158	*C156*	*C157*
palate length[1]	24.5 mm.	21.4 mm.	24.4 mm.
pharynx depth[2]	19.5 mm.	15.8 mm.	24.3 mm.
extent of mid-palate movement..........	3.3 mm.	4.5 mm.	5.7 mm.
velopharyngeal gap.....................	6.8 mm.	4.8 mm.	7.8 mm.
number of frames from onset of palate movement to maximum elevation......	6 frames	4 frames	5 frames

[1] Distance between post nasal spine and tip of soft palate

[2] Least distance between the post nasal spine and the atlas along the palatal plane.

errors they made while wearing well-fitted sections did not appear to be attributable to poor closure.

Section Fitting. Fitting of the optimal pharyngeal section, termed section A, was guided by measurement of nasal air pressure, articulation judgments, and still x-ray observations as in our previous study (*6*). A single difference was that the section incorporated an acrylic core[2] that attached to the carrier wire by means of a set screw. A hole was drilled into the side of the pharyngeal section so that the set screw could be loosened and sections exchanged (Figure 1).

Each subject was fitted with three or four sections. Sections B and D were so constructed that a gap existed between the section and the posterior pharyngeal wall when the subject was at rest. The gap was approximately 2 mm for B and 4 mm for D. The gap associated with B was confirmed by still x-ray. Sections C and E were constructed so that C was 2 mm narrower than A, and E was 4 mm narrower than A. These sections were expected to introduce a gap between the section and the lateral pharyngeal walls, but x-ray confirmation was not attempted. These sections were made from duplicates of A. For C and E, acrylic was removed from both sides in approximately equal amounts. A subject had only one section in his possession at any time.

Dependent Variables. The first three dependent variables, articulation, nasal SL, and nasal air pressure, were measured at intervals of approximately one month throughout the study. These measures were considered to be indices of palatopharyngeal closure and pharyngeal wall movements (*10*). Cinefluorographic films were made only before and after the treatment period.

The syllables, listed in Table 2, were tape recorded and then presented to the subjects through an Ampex 602 tape recorder and an AR 4 speaker. The syllables were ordered randomly for preparation of the stimulus tape,

[2] The core and carrier were manufactured by the Rocky Mountain Dental Supply Company.

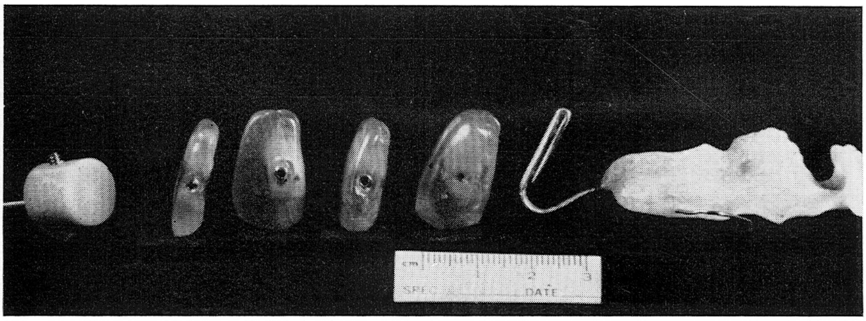


FIGURE 1. From right to left, the following objects are shown: an anterior appliance and carrier wire; a set of speech sections, and an acrylic core like those used in each section. From the right, the first section was optimally fitted. The second and fourth sections were reduced from front to back, and the third section was reduced from side to side.

and during preparation of the tape the final consonants were exploded or distinctly audible. The tape recorder was operated from a control room, and the subject imitating the syllables was located in an IAC 1200 room.

Subject responses to the articulation task were tape recorded by means of a B and K one inch condenser microphone with cathode follower, and B and K 2603 microphone amplifier, and an Ampex AG 350-2 tape recorder. The articulation tapes were scored by three or four persons who were instructed to classify a response as incorrect unless they were certain it was correct. Judges listened to each tape once to judge the pre-vowel consonant and a second time to score the post-vowel consonant. All consonants, except the nasals, were scored. Judges did not know the obturator condition associated with a given tape. Judging sessions did not exceed two hours and no more than two sessions were ever held in one day. The judges did not discuss their findings or observe other judges' responses. A response was considered to be correct if it was so scored by a majority of the judges. Scores obtained in this manner were termed consensus scores. Four judges served in the first part of the study, but one dropped out.

For each subject, articulation tasks involving several sections were rescored by the three judges after an interval of about a year. Percentages of item agreement were computed for each section-subject condition which had been scored twice. For the two sets of consensus scores, the percentages ranged from 74% to 100% with a mean of 84%. Chance level of agreement was determined to be 44 items with a standard deviation of 4.69. Thus, agreement on 57% of the items (50 items) or more would not occur by chance.

Oral SPL and nasal SL were measured in an IAC 1200 series room as described in our previous reports (*3, 5, 7*). A mouth to microphone distance of ten inches was used. One microphone amplifier functioning as a sound level meter, was positioned in front of the subject to permit him to monitor

TABLE 2. Articulation test syllables

	/p/	*/b/*	*/t/*	*/d/*	*/s/*	*/z/*	*/ʃ/*	*/f/*	*/v/*	*/k/*	*/g/*
/ɑ/	/pɑp/	/bɑb/	/tɑt/	/dɑd/	/sɑs/	/zɑz/	/ʃɑʃ/	/fɑf/	/vɑv/	/kɑk/	/gɑg/
/i/	/pip/	/bib/	/tit/	/did/	/sis/	/ziz	/ʃiʃ/	/fif/	/viv/	/kik/	/gig/
/u/	/pup/	/bub/	/tut/	/dud/	/sus/	/zuz/	/ʃuʃ/	/fuf/	/vuv/	/kuk/	/gug/
/m/ or /n/	/ɑmpip/	/ɑmbib/	/ɑntit/	/ɑndid/	/ɑnsis/	/ɑnziz/	/ɑnʃiʃ/	/ɑmfif/	/ɑnviv/	/ɑnkik/	/ɑngig/

his speech output. After comfort levels were determined for each utterance to be studied, the subject was shown where the indicator needle should peak for each production. Utterances included /sss/, /ʃʃʃ/, /ɝɝɝ/, and /so so so/, plus the sentence, *The cars are parked on the arcade,* and ten seconds of story telling.

Nasal air pressure was measured in one wing of a U-tube water manometer as described elsewhere (*4*). This variable was measured in the IAC chamber. A condenser microphone and microphone amplifier were used to help the subject to produce each test utterace at the oral SL initially established as comfortable for him.

The cinefluorographic films were made with a Phillips cinefluorographic unit that included a nine inch image intensifier. The Aurico Pro 600 special camera model CM 77 was operated at 24 frames per second, and x-ray pulses were synchronized with the frame exposures by means of a Siemens 3 phase x-ray generator. The utterances filmed included: /sɑs/, /sis/, /nɑnsɑs/, /nɑnsis/, /pɑp/, /kɑk/, /tɑt/, and the sentence, *The cars are parked on the arcade.* X-rays of pharyngeal wall movements were assessed by a scaling procedure. Four persons served as judges. They were shown films of two persons who produced approximately 4 mm of pharyngeal wall movement opposite to and synchronous with palate movement during each of several utterances. Each judge was to determine whether or not a pharyngeal wall movement similar in magnitude to those shown in the standard films was produced by the study subjects during each utterance filmed. The films were presented to the judges in a random order. A mean percentage of judge agreement of 94 was computed for all films judged.

Results

Figures 2 through 4 present measures of articulation, oral SPL, nasal SL, and manometry made within 24 hours of the time each subject first wore his A section. The ordinates of these figures present dependent variable measures, and the abscissas report pharyngeal sections. Figures 5 through 7 again report articulation, SL, and manometry results. This time, however, dates of recordings made throughout the study are presented on the abscissas. Table 3 reports which pharyngeal section was worn by a subject prior to each recording date. We did not expect a linear relationship between measures and sections because we could not anticipate how sections reduced in length would compare with those reduced in width in terms of their contribution to closure. Figure 8 reports cinefluorographic data.

Results from the First Recording Session. Figure 2 presents the number of correct articulations each subject achieved with each appliance condition. Generally, all subjects showed a trend toward lower articulation scores with adaptation sections and lowest scores under the no appliance condition. Subject C157 articulated less well than the other two subjects, and two subjects showed optimal performance with a section other than A.

Figure 3 reports oral SPL and nasal SL produced during the utterances

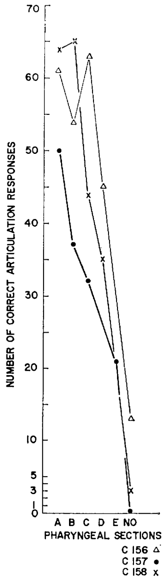
TABLE 3. Pharyngeal sections which were worn by a subject prior to the recording date designated

Subject C156		*Subject C157*		*Subject C158*	
Date	*Section*	*Date*	*Section*	*Date*	*Section*
1/18/68	Original	5/15/68	Original	5/22/68	Original
2/15/68	A	7/2/68	A	6/25/68	A
3/22/68	B	7/30/68	B	7/23/68	B
5/3/68	D	9/17/68	B	9/4/68	B
7/16/68	D	10/16/68	C	10/8/68	B
		12/4/68	C	11/27/68	B
		3/20/69	E	1/8/69	C
		7/17/69	C		

/ʃʃʃ, ʃʃʃ, ʃʃʃ/ and *The cars are parked on the arcade.* These utterances were selected for illustration because Craven's (*3*) correlation data indicated they are most representative of the total set of utterances studied. The general trend was for nasal SL to increase from section A through the no appliance condition. A notable exception was shown by subject C156 who was relatively stable in nasal SL across all section conditions while uttering the sentences. For all subjects, oral SPL was relatively constant across the appliance conditions.

Figure 4 reports water manometer readings for the three subjects. The entries are medians for repetitions of several different utterances. If one cm of water displacement, or less, is accepted as normal performance, subject C158 performed within normal limits under all except the no appliance condition. Subject C157 was within normal limits for the A section only; the remaining conditions showed increase in nasal escape with smaller sections. Subject C156 was within the normal range only for the A section. His performance across the other appliance conditions was relatively stable. On this measure, each subject showed an especially sharp increase in nasal air pressure with a specific section.

Results Obtained Across the Recording Dates. Figures 5A, B, and C report the total number of correct articulation responses made by each subject on each recording date for three section conditions. These conditions include the A section, no appliance, and an intermediate section possibly associated with articulation improvement indicative of pharyngeal adaptation. None of the subjects showed improvement in the no appliance condition, and performance during this condition was almost always poorer than that under other conditions, including those not shown. Subject C156 (Fig. 5A) articulated as well with section D as with section A at the end of the study. Similarly, C158 (Fig. 5B) improved her articulation performance with section C until it was on a level comparable to that obtained with section A. C157 (Fig. 5C) improved her articulation with both sections A and C, with C gaining on A. This subject was followed for a longer period



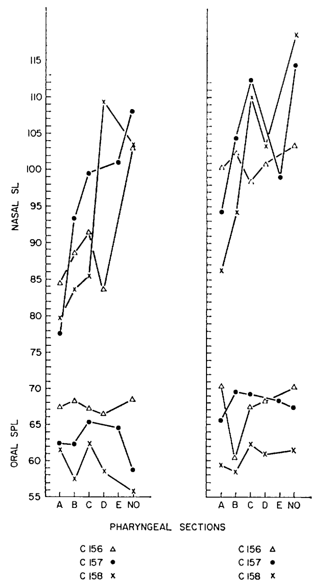


FIGURE 2. (Above left) Number of correct articulation responses made by each subject during each section condition on the first recording day.

FIGURE 3. (Above right) Oral SPL and nasal SL produced by each subject under each section condition while uttering /ʃʃʃ, ʃʃʃ, ʃʃʃ/ (left) and the sentence, *The cars are parked on the arcade* (right). These measures were made the first day each subject was tested.

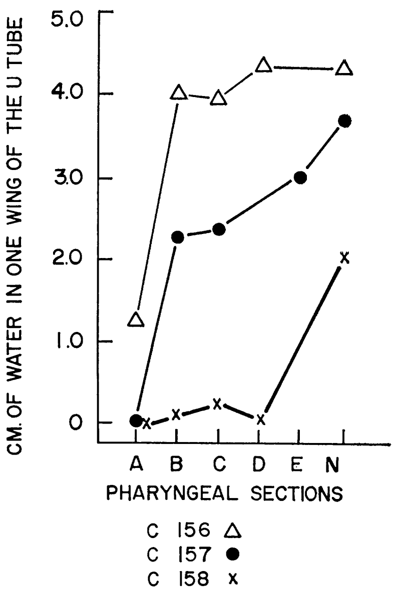


FIGURE 4. Water manometer median values produced by each subject under each section condition on the first day each subject was tested.

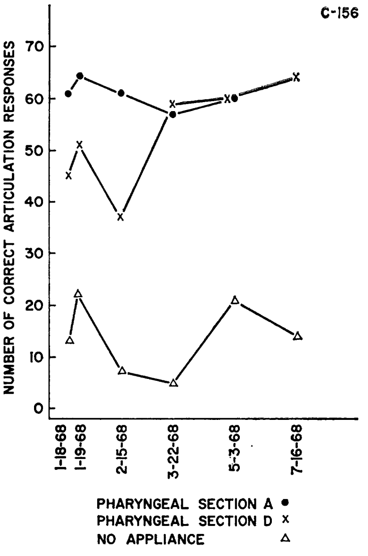


FIGURE 5A

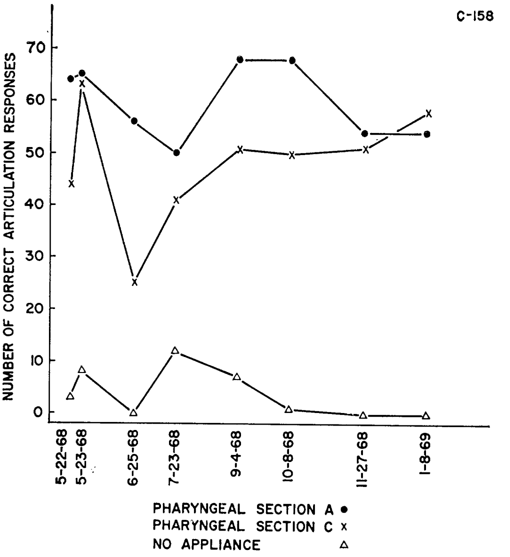


FIGURE 5B

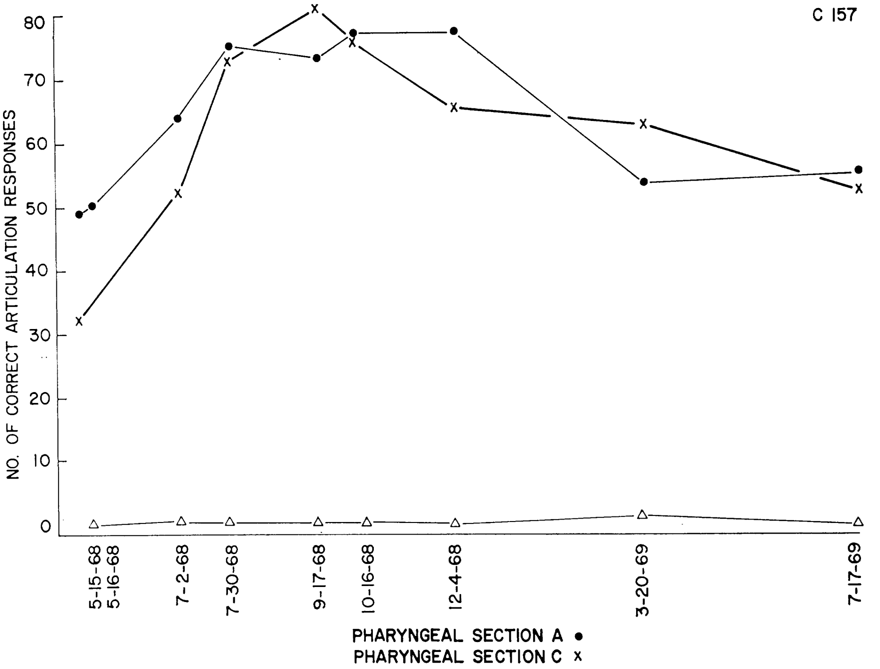


FIGURE 5C

FIGURE 5A. Number of correct articulation responses made by subject C156 under three section conditions on each recording date.

FIGURE 5B. Number of correct articulation responses made by subject C158 under three section conditions on each recording date.

FIGURE 5C. Number of correct articulation responses made by subject C157 under three section conditions on each recording date.

of time than either of the other subjects, and she showed some deterioration in performance later in the study.

Figures 6A and B report oral SPL and nasal SL data for the utterances /*ʃʃʃ*, *ʃʃʃ*, *ʃʃʃ*/ and *The cars are parked on the arcade*. Each of the four parts of Figure 6 reports data from a single subject. However, the data were selected as most representative of all three subjects. Figure 6A (left) shows data from subject C158 under the section A condition. Figure 6A (right) shows possible reduction by C156 in nasal SL over time with a B section. Figure 6B (left) shows no adaptation by C158 to a C section over time, and Figure 6B (right) shows subject C158's measures made with her appliance removed. The complete set of data showed no nasal SL reduction under the no appliance condition and little if any evidence of adaptation under the various section conditions.

Figure 7 shows each subject's nasal air pressure for the same sections used in Figure 5. In the no appliance condition, nasal pressure was relatively stable, and no adaptation was evident. With section A, C157 showed acceptable nasal pressure across the recording dates whereas the other two subjects, on occasion, produced pressure greater than the acceptable 1 cm. Subject C157 showed acceptable nasal pressure with her C section in the later sessions. The other subjects showed no evidence of adaptation.

Cinefluorographic data obtained before and after the treatment period are reported in Figure 8. Each entry is a sum of the number of utterances in which movement was observed by one or more of the four judges. If all four observers had reported movement during all nine utterances filmed with a given section, a score of 36 would have been obtained. The results indicated that C158 increased the number of movements produced with sections B and C. All four observers reported post treatment movements under the B condition for the utterances /sɑs/, /sis/, and /nɑnsɑs/. However, these movements were less extensive than those shown in the standard films. For this subject, the pre-treatment film was clearer than the post-treatment film. This could have been a confounding factor.

With reference to the four dependent variables, no subject showed improved performance across all measures for a single section condition.

Discussion

The results obtained in the first part of this study suggested that the measures used were sensitive to differences in pharyngeal sections. Because of this and other evidence regarding these measures, we thought they would be sensitive to small treatment effects concerning pharyngeal wall movement.

Throughout the study, all three subjects tended to show inferior performance on all dependent variable measures when speaking without any speech appliance. Closure in the absence of an appliance clearly was not established. The cinefluorographic films suggested that one subject developed pharyngeal wall movements under one or two section conditions.

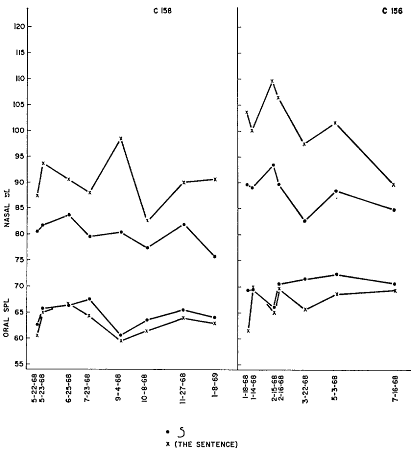


FIGURE 6A

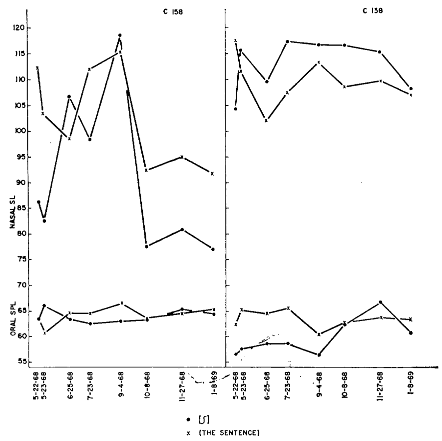


FIGURE 6B

FIGURE 6A. Oral SPL and nasal SL data for subject C158 (left) under the section A condition across all recording dates for two utterances: /ʃʃʃ, ʃʃʃ, ʃʃʃ/ and *The cars are parked on the arcade.* The right hand side of the figure shows the same measures for C156 wearing section B.

FIGURE 6B. Oral SPL and nasal SL data for subject C158 (left) under the section C condition across all recording dates for the repetitions of /ʃ/ and the sentence. The right hand side of the figure shows the same measures for the same subject with her appliance removed.

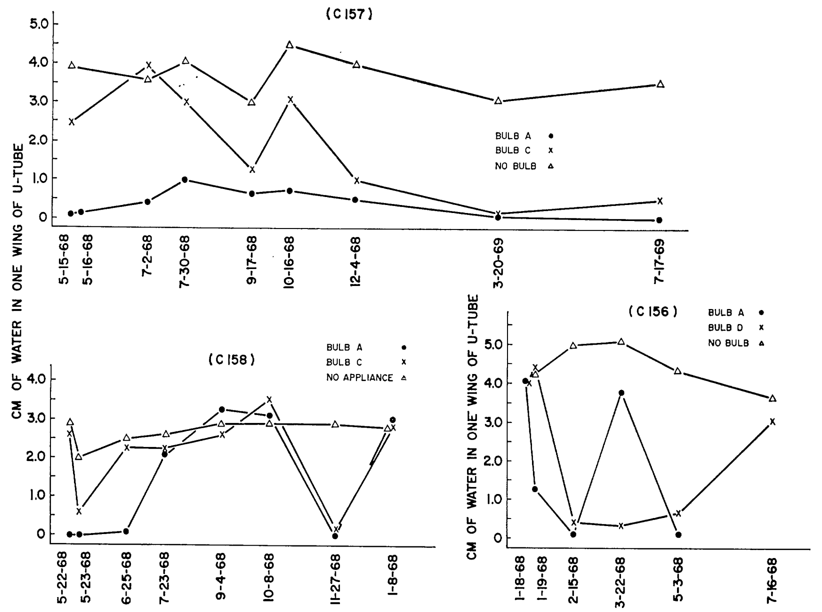


FIGURE 7. Nasal air pressure produced by the three subjects under three section conditions across all recording dates.

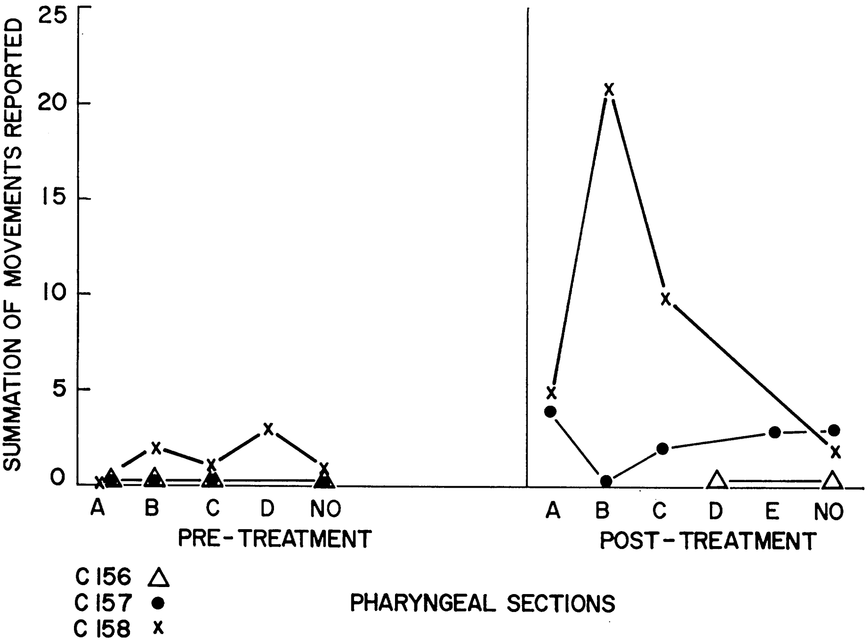


FIGURE 8. Index reflecting number of observations of posterior pharyngeal wall movement under each section condition before and after treatment. Data were taken from cinefluorographic films.

The question remains whether movements developed make a person a better candidate for pharyngeal flap surgery. Evidence to answer that question would be difficult to obtain.

The measures used here have differentiated between groups of persons differing in palatopharyngeal closure, and in the first part of this study they showed differences within individuals under different section conditions. However, across time the measures were sufficiently variable that it is improbable they would reflect small changes in pharyngeal wall movement. For a given subject, one or another of the measures used showed trends that could reflect adaptation to a specific section. However, variability within and between subjects was so great that claims of modest improvement in closure are not warranted. Enabling a subject to monitor his oral SPL output with a meter reduced oral SPL variability. If investigation of pharyngeal wall movement development is to continue, we need either a treatment that is sufficiently powerful that it will immediately show an effect through our indirect indices of closure, or we need a means of viewing the palatopharyngeal port directly without restraining articulatory movements. Perhaps a fiberoptic device passed through a naris would serve this purpose.

Cinefluorography provides direct inspection of the structures of interest during function. The base projection used by Skolnick (*9*) permits simultaneous observation of movement of the palate and the lateral and posterior pharyngeal walls. However, cinefluorography is difficult to use in study of behavioral changes. Radiation hazard and the time and facility required to obtain data impede such application.

This study utilized more quantitative description of dependent variables than did the older studies that fostered it. Investigation of techniques for development of pharyngeal wall movements, like clinical practice, requires repeated observation of the patient with the measures available to us. However, with the problem investigated here and with the measures used, it proved difficult to obtain unequivocal results. One subject's (C158) nasal patency was influenced by an allergy that was more active on some visits than others. Growth, fatigue, and change in hearing acuity may have each influenced results from session to session, and there may have been some variability in the performance of the measuring instruments. We formed the opinion that the subjects continued to adapt to the experimental situation beyond the observation periods that we used for baseline purposes. Indeed, subjects may continue to adapt to a long term study throughout its course. Age and prior subject experience with speech appliances may be important variables in this research. We worked to specify subject, treatment, and dependent variables precisely. Future studies must do better yet.

Summary

The subjects selected for study were three children who wore prosthetic speech appliances which supported good articulation. Each subject was provided with a new appliance which permitted the exchange of a series of pharyngeal sections. These sections differed from one another either in width or depth. The design of the study permitted examination of relationships between these appliance conditions and selected indices of palatopharyngeal closure.

Results of this study are presented in two parts. The first provides a description of subjects' performances on three variables measured during each subject's first test day. The data obtained for this part of the study suggested that the measures were sensitive to differences attributable to the sizes of the pharyngeal sections.

For the second part of the study, the same dependent variables, plus cinefluorography of the posterior pharyngeal wall, were used to determine whether a subject could maintain or reestablish closure of the palatopharyngeal port when wearing smaller speech appliance sections or no appliance. These results, which were generally negative, are discussed in terms of measurement and design problems involved in this applied research problem.

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reprints: *Ralph Shelton, Ph.D.*
College of Fine Arts
Department of Speech
The University of Arizona
Tucson, Arizona 85721

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