# Effect of Articulation Therapy on Palatopharyngeal Closure, Movement of the Pharyngeal Wall, and Tongue Posture

RALPH L. SHELTON, PH.D.
LINDA CHISUM, M.A.
KARL A. YOUNGSTROM, PH.D., M.D.
WILLIAM B. ARNDT, PH.D.
MARY ELBERT, M.A.
*Kansas City, Kansas*

Cinefluorographic data have been interpreted to indicate that speech therapy may improve palatopharyngeal closure (*7*). However, it is also possible that provision of therapy to persons with inadequate closure may result in undesirable compensatory elevation and retraction of the tongue, especially in contexts normally involving some degree of tongue retraction (*2*, *3*). This study is concerned with the effects of articulation therapy on a) patterns of palatopharyngeal closure, b) movement of the posterior wall of the pharynx near atlas, velum, or both, c) the relationship between the tongue and the anterior tubercle of the atlas, and d) the relationship between the tongue and the posterior wall of the pharynx.

Chisum and her associates (*5*) compared articulation changes in control and experimental subjects selected on the basis of speech observations as having mild deficiency of palatopharyngeal closure. In her study, articulation of the experimental subjects was tested before and after approximately six months of articulation therapy. Control subjects were tested at comparable time intervals with no intervening treatment. Individual therapy was provided for two thirty-minute periods per week for 30 to 48 lessons. A motor learning approach to therapy was used with emphasis on response-shaping procedures to improve articulation of specific phonemes and to reduce measurable nasal escape of air during articulation of nonnasal sounds (*4*). All experimental subjects worked on /s/, and most worked on additional fricatives. No attempt was made to strengthen any muscles in the speech mechanism or to develop reflex or voluntary movement of the posterior wall of the pharynx or of the velum. Experimental subjects

Dr. Shelton, Mrs. Chisum, and Mrs. Elbert are with the Hearing and Speech Department and Dr. Youngstrom with the Radiology Department of the University of Kansas Medical Center. Dr. Arndt is with the Psychology Department of the University of Missouri at Kansas City.

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made more articulation improvement than the control subjects. The conclusion was reached that the therapy was effective.

The current study involves analysis of cinefluorographic films of Chisum's subjects which were obtained on the same schedule as her articulation tests (before and after treatment). The films were obtained to determine whether the therapy provided influenced the pattern of palatopharyngeal closure, forward movement of the posterior wall of the pharynx, or tongue placement during the utterance of certain phonemes.

## Procedure

SUBJECTS. The subjects in this study were selected from the subject group described earlier by Chisum (*4*) and by Chisum and others (*5*). The subjects, who ranged in age from six to twelve years, made articulation errors on at least three phonemes and six items in a 223 item test. Persons with gross problems of intelligence, auditory perception, or hearing acuity were eliminated. The control group consisted of five persons with surgically repaired palate clefts and three persons with palatal insufficiency identified on the basis of speech observations. All were male. The experimental group consisted of six persons with surgically repaired clefts and three persons with palatal insufficiency. One group member was female. Two persons with palatal clefts and two persons with palatal insufficiency served in both groups.[1]

CINEFLUOROGRAPHIC FILMING. Cinefluorographic films were made at 24 frames per second and were later analyzed with stop frame projectors and tracing cabinets. The speech sample filmed by X ray included /ɑ/, /s/, /sɑs/, and two sentences "I see Lee sleeping by the seat" and "The cars are parked on the arcade".

PALATOPHARYNGEAL CLOSURE. The minimum distance between the soft palate and the posterior wall of the pharynx was measured in each frame from onset to termination of movement for the sentence "The cars . . .". These measures for each subject were averaged to give a mean palatopharyngeal gap, and the measures were plotted to give a closure pattern (*8*). All frames for all subjects were measured at life size on two occasions, usually by two different persons. Discrepancies of 3 mm or greater were resolved by remeasurement of the frame involved.

The plots of each subject's palatopharyngeal closure pattern were assigned by three independent judges to the closure pattern categories described by Shelton and associates (*8*). The six pattern categories were as

[1] Chisum also included in her control and experimental groups three persons who wore speech bulbs positioned behind surgically repaired palates and one person in her control group who had undergone a pharyngeal flap. These subjects were not included in the current groups because obturation or pharyngeal flap surgery might influence the oral movements that are made in response to articulation therapy. Chisum's conclusion regarding the effectiveness of her articulation therapy is not altered by the elimination of these subjects.

follows: *One.* Closure completed before first phonation and maintained until articulation was stopped except for breaks associated with nasal consonants and associated vowels. *Two.* Usually closed during the course of phonation but with more breaks from closure than in category one. *Three.* Sometimes closed during the course of phonation but with more breaks from closure than in category one (this category definition was extended to specify that closure was present in fewer than half of the frames associated with articulation of the test sentence). *Four.* Velar movement within three millimeters of closure. *Five.* Velar movement but no approximation to closure as close as three millimeters. *Six.* No velar movement reflected in the measure.

Agreement by at least two judges determined the category to which each plot was assigned. All three judges agreed on the categories to which they assigned 15 of the 30 plots. For the remaining plots, two of the three judges agreed, and the remaining judge disagreed by only one category. The disagreements were equally divided among the three judges.

Forward Movement of the Posterior Wall of the Pharynx. Each film was projected twice at 12 frames per second for study by three observers. Each observer was to indicate on a score sheet whether or not movement of the pharyngeal wall occurred for each of the five utterances described above and, if so, whether it was judged to be of sufficient magnitude that caliper measurement might be possible. The wall movement was to be independent of head or neck movement. Wall movement opposite the velum or the anterior tubercle of the atlas was to be counted, whereas movement below or above this area was not. Agreement between two judges determined how a response was scored. Eleven films showing a total of fifty-five utterances were selected by table of random numbers for repeated scoring by the three judges. Eighty per cent of the fifty-five classifications were unchanged. The three judges all agreed that only three subjects showed movement of the posterior pharyngeal wall of sufficient magnitude to measure.

The Tongue in Relation to the Anterior Tubercle of the Atlas and the Posterior Wall of the Pharynx. Tongue placement was examined by measuring the least distance between the tongue and the most anterior portion of the anterior tubercle of the atlas and the least distance between the tongue and the posterior wall of the pharynx. The first of these measures was made for the phonemes /ɑ/, /k/, /p/, and /b/. /ɑ/ was measured out of context, in /sɑs/, and as it occurred in the words *cars*, *parked*, and *arcade*. /k/ was measured as it occurred in *cars;* /p/ was measured in *parked* and *sleeping*. /b/ was measured as it occurred in *by*. These four sounds were chosen because their production was thought to invite tongue retraction in persons with inadequate palatopharyngeal closure. The plosives have relatively high intraoral air pressure requirements but do not require placement of the tongue tip in the front of the mouth; and tongue retraction associated with palate problems has previously been

reported for /ɑ/ (*3*). Frames associated with each of these phonemes were identified from repeated projection of the film with a stop-frame projector. Movements of the tongue, lips, and mandible were used as cues for identifying the phoneme of interest. Specifically, cues looked for in identifying /ɑ/ were depression of the mandible and tongue retraction, and the cue for the /k/ was contact between the tongue and the hard palate near the soft palate-hard palate junction. /p/ and /b/ were measured in the first frame in which lip closure occurred. Identification of phonemes adjacent to the phoneme of interest was helpful in frame selection. For example, lip closure for the /p/ in *parked* was easily identified and alerted the viewer to watch for the /ɑ/. Sometimes the sound track was monitored to find the approximate frame location of the phoneme of interest.

The minimum distance between the tongue and the posterior wall of the pharynx was measured in each of the following contexts: /k/ in *cars*, /ɑ/ in *cars*, /p/ and /ɑ/ in *parked*, and /ɑ/ in *arcade* as these words appeared in the sentence "The cars are parked on the arcade".

For both measures involving the tongue, each frame was identified and measured by two independent observers. Discrepancies of 3 mm or greater were resolved by remeasurement of the frame. Disagreements regarding selection of the frame associated with a given phoneme were resolved by reexamination of the film unless measures obtained from adjacent frames were in agreement.

Before analyzing the results in terms of the effect therapy may have had on the tongue-atlas measure, an analysis of variance was done to compare the distance between atlas and tongue in the various speech contexts studied. Measures from the first filming of experimental subjects and from the second filming of control subjects were used. Only one score was used for each of the four subjects who were included in both groups. The obtained $F$ of 24.01 was statistically significant at the .01 level. Use of the Newman-Keuls procedure (*11*, p. 80) indicated that the /ɑ/ measures did not differ from one another. /p/ in *sleeping* differed from /p/ in *parked*, from /k/ in *cars*, and from /b/ in *by*. The /b/ in *by* differed from the /k/ in *cars*. Other differences were not significant. Comparison of each of the /ɑ/ contexts, which did not differ from one another, with the other contexts showed orderly results except for the /k/. That is, all the /ɑ/s differed from /p/ in *sleeping* and /b/ in *by*, but none differed from /p/ in *parked*. Two of the /ɑ/s differed from /k/ and three did not. Thus, we note that tongue to atlas distance for /p/ was similar to that for /ɑ/ when the /p/ was next to an /ɑ/ but not when it was next to an /i/. The consistency of differences among contexts other than /k/ suggest that the cinefluorographic measures were accurate. Persons making the measures reported some difficulty identifying /k/ contexts. On the basis of these results, each subject's tongue-atlas measures for /ɑ/ were pooled for study of treatment effects. That is, an /ɑ/ score was obtained for each subject by averaging the measures obtained from his several /ɑ/ productions.

TABLE 1. Average mean gaps for control and experimental subjects on each filming occasion, plus the lowest and highest mean gaps (limits) for individuals.

| | *control* | | *experimental* | |
|---|---|---|---|---|
| | *1st* | *2nd* | *1st* | *2nd* |
| mean | 1.6 | 1.2 | 1.6 | 1.4 |
| N | 8 | 8 | 9 | 9 |
| limits | 0.6 to 4.2 | 0.9 to 2.1 | −0.9 to 2.9 | 0.4 to 3.1 |

## Results

PALATOPHARYNGEAL CLOSURE. Data regarding palatopharyngeal closure are reported in Table 1. That table includes the mean palatopharyngeal gap for each group on each filming occasion. The group means were obtained by averaging the means for individual subjects. The lowest and highest mean gaps obtained by individual subjects are also reported. Those extremes are termed limits in Table 1. Inspection of first and second mean gaps for each group indicates that the second means are slightly smaller for both groups but that the experimental and control groups are similar. The control group reduced its mean gap an average of .4 mm, compared with .2 mm for the experimental group. Thus, treatment did not result in reduction of palatopharyngeal gap.

Study of the palatopharyngeal closure patterns did not show any treatment effect. Five of the experimental subjects did not change their closure patterns. The remaining subjects changed only one category, and one of these changes was toward a less satisfactory pattern. One control subject improved by three categories, one by two categories, and two by one category. Two control subjects changed one category toward poorer closure. Thus, a greater number of pattern category changes was observed in control group subjects than in experimental group subjects. Application of categories like these would be enhanced by accumulation of information concerning their stability over time.

FORWARD MOVEMENT OF THE POSTERIOR WALL OF THE PHARYNX. The number of utterances in which a subject showed movement of the posterior wall was used as a score. Thus, if a subject showed movement during all five utterances, his score was five. The mean number of utterances showing movement by control and experimental subjects is shown in Table 2. The first and second scores for the two groups were submitted to a two factor-repeated measures analysis of variance (*11*, pp. 298–318). This analysis showed no difference between groups ($F = 2.70$, $p > .05$), no difference between first and second measures ($F = 2.52$, $p > .05$), and no interaction between group and measure ($F < 1$, $p > .05$). For each subject the difference between first and second measure was determined. The experimental group showed a mean reduction of 1.1 in number of utterences during which

TABLE 2. Mean number of utterances per subject showing movement of the posterior wall of the pharynx.

| | *control* | | *experimental* | |
|---|---|---|---|---|
| | *1st filming* | *2nd filming* | *1st filming* | *2nd filming* |
| mean | 3.9 | 2.7 | 2.3 | 1.7 |
| SD | 1.27 | 2.11 | 2.00 | 2.00 |
| N | 8 | 8 | 9 | 9 |

the posterior pharyngeal wall moved. The control group showed a mean reduction of 0.7. These difference figures for the two groups were compared by use of a $t$ test for independent means. The obtained $t$ was .49 ($p > .05$).

The results reported in the above paragraph indicate that the two groups did not differ on first or second measure and that treatment had no effect on movement of the posterior wall of the pharynx. Only three of the subjects were thought to have pharyngeal wall movement of sufficient magnitude to be measurable by stop-frame projection. Relatively great movement was evident in all three films of each of these subjects (they were in both the experimental and control groups). Two of these persons were among those identified as having palatal insufficiency. One produced a Passavant's ridge. The other two produced a less extensive movement, but the movement involved a greater region of the posterior wall than we associate with Passavant's ridge. The magnitude of pharyngeal wall movements observed in the other subjects supports the conclusion that the therapy provided did nothing to develop movement of the posterior pharyngeal wall sufficient to contribute to palatopharyngeal closure.

Distances between the Tongue and the Atlas and between the Tongue and the Posterior Wall of the Pharynx. The tongue to atlas and tongue to posterior pharyngeal wall measures were each submitted to a three-way analysis of variance (first and second filming X experimental and control groups X contexts) with repeated measures on two factors (*11*, p. 319). In each analysis, only the $F$ ratios for context were significant ($F$s = 42.46 and 31.65; $p < .01$). As discussed in the procedures section, differences among contexts were interpreted as evidence of measurement adequacy. No evidence was found for differences between first and second filming or between experimental and control groups. Thus the study procedure did not result in tongue elevation or retraction. Means and standard deviations for the cinefluorographic measures involving the tongue are reported in Tables 3 and 4. Figures are reported for each context studied in both the experimental and control groups.

## Discussion

Improvement of palatopharyngeal closure, whether by increase in movement of the velum or of the posterior pharyngeal wall or both, would be

TABLE 3. Means and standard deviations for cinefluorographic measures of the distance between the tongue and the atlas.

| *context* | *control* | | | | *experimental* | | | |
|---|---|---|---|---|---|---|---|---|
| | *1st test* | | *2nd Test* | | *1st Test* | | *2nd Test* | |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| x̄ /ɑ/ | 15.59 | 3.87 | 16.19 | 3.50 | 14.93 | 2.88 | 15.07 | 3.09 |
| sleeping | 23.54 | 6.21 | 23.30 | 3.22 | 21.81 | 2.11 | 23.37 | 3.18 |
| parked | 16.75 | 4.48 | 16.29 | 2.35 | 15.90 | 1.76 | 16.47 | 3.16 |
| by | 22.83 | 4.62 | 20.60 | 3.13 | 20.58 | 2.62 | 21.62 | 3.74 |
| cars | 16.88 | 5.18 | 17.70 | 3.70 | 17.43 | 3.59 | 17.02 | 3.72 |

TABLE 4. Means and standard deviations for cinefluorographic measures of the minimal distance between tongue and the posterior wall of the pharynx.

| *context* | *control* | | | | *experimental* | | | |
|---|---|---|---|---|---|---|---|---|
| | *1st test* | | *2nd Test* | | *1st Test* | | *2nd Test* | |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| x̄ /ɑ/ | 4.93 | 3.53 | 5.41 | 3.60 | 4.30 | 2.89 | 4.09 | 1.44 |
| parked | 6.73 | 2.59 | 6.80 | 3.55 | 5.01 | 1.49 | 5.09 | 2.00 |
| cars | 3.74 | 3.87 | 8.66 | 3.45 | 8.03 | 2.01 | 9.10 | 2.24 |

desirable results of treatment. However, no such effect was observed in this study. If closure is to be improved by therapeutic exercise or motor learning, procedures other than those used in this study will have to be used. Yules and Chase (*10*) were able to improve palatopharyngeal closure through a combination of voluntary nonspeech palatopharyngeal movements and provision during speech of visual feedback regarding relative intensity of sound recorded through microphones positioned at a naris and at the mouth. Investigation is needed to determine whether their training produces unwanted results such as laryngeal abuse and whether the positive results can be maintained in automatic speech.

Unwanted articulatory compensations for inadequate palatopharyngeal closure include tongue elevation and retraction as well as laryngeal abuse and nares constriction. Elevation and retraction of the tongue to contribute to reduction of the palatopharyngeal port may be established to the point of automatic performance even though they do not result in normal articulation. This hypothesis is not discredited by the finding that lingual compensations did not result from the treatments used in this study. These lin-

gual movements could be developed under other treatment or subject conditions. The speech clinician should watch for tongue elevation and retraction movements and direct the patient away from their use. Like nares constriction, they may indicate inadequate palatopharyngeal closure.

As reported by Chisum (*4*), the treatments provided the experimental subjects in this study did result in articulation improvement. Her data combined with the cinefluorographic results reported here indicate that articulatory improvement can be made in the presence of mild palatal closure deficits. Nevertheless, those deficits may have contributed to the articulation errors that remained at the termination of the study.

Measurement error and subject variability are sufficiently large that small changes in palatopharyngeal closure adequacy may not have been recognized. The measurement of distance between tongue and atlas may have been influenced by variability in posture. While a head-holder was used, the subjects were not placed in the Frankfort plane, and variability in the relationship between head position and long axis of the body was possible (*6*).

Finally, we note that precise identification of movement onset and termination is essential to determination of palatopharyngeal gap. Extra frames will show large gaps and will influence the result obtained. Subject rehearsal is also important if test utterances are to be produced correctly and in a uniform manner across subjects.

## Summary

This study pertains to the effect of articulation on oropharyngeal movements produced by persons with mild palatopharyngeal closure deficits. An experimental group that was given speech therapy was compared with a control group with reference to the effect of therapy on palatopharyngeal closure, forward movement of the posterior pharyngeal wall, and tongue retraction and elevation. These observations were made by cinefluorography. While the subjects did improve their articulation, no compensatory movements were identified.

reprints: *Dr. Ralph L. Shelton*
*Hearing and Speech Department*
*University of Kansas Medical Center*
*Kansas City, Kansas 66103*

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