Pulmonary Function Characteristics of Selected Individuals with Dysarthria: The Effects of a Palatal Lift Appliance

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Individuals with neurological deficits often manifest difficulties producing speech. Typically, several subsystems serving speech production, that is, respiratory, phonatory, resonatory, and articulatory, are affected (Netsell, 1984). Thus, it is not uncommon for individuals with neurological problems and concomitant dysarthria to present with a variety of speech difficulties. These deficits often include articulation errors, weak or breathy phonation, decreased speaking rate, poor expiration for speech, loudness variations, reduced prosodic variability, reduced oral air pressure/flow, hypernasality and nasal air emission, and in many cases, decreased speech intelligibility (Darley, Aronson, & Brown, 1975). While many of these features may be described in perceptual terms (e.g., hypernasality), other speech characteristics may be described as physical components (e.g., nasal airflow) of speech, and/or may be described using a dual method of coding (e.g., nasal air emission/nasal airflow rate).

One characteristic of individuals with dysarthria is alteration of resonance that results from a faulty velopharyngeal mechanism. The preferred method of management for individuals with velopharyngeal incompetence associated with neuromotor disorders affecting speech is the use of a dental speech aid (palatal lift appliance). First described by Gibbons and Bloomer (1958), the palatal appliance lifts the inactive soft palate and brings it close to the posterior pharyngeal wall to facilitate separation of the oral and nasal passages. A number of investigators (Aten, McDonald, Simpson, & Gutierrez, 1984; Hardy, Netsell, Schweiger & Morris, 1969; LaVelle & Hardy, 1979; Leeper & Sills, 1986) have documented positive changes in speech production characteristics of dysarthric individuals following placement of a palatal lift which include: decreased hypernasality, increased oral airflow and pressure, improved speaking rate, and increased intelligibility.

While several researchers have developed their research designs following Netsell and Daniel's (1979) model for evaluating aerodynamically the "functional components" (valves) of the vocal tract (Rosenbek, 1984; Hixon & Putnam, 1983), only a few investigators (Putnam & Hixon, 1984; Hixon, Putnam & Sharp, 1983) have reported physiologic data of the respiratory activities of dysarthric patients. It is understood that reduction in the ability to move air from the lungs through the larynx and the oral articulators will cause a loss in the energy necessary to produce the acoustic features of speech needed for intelligible communication. Further, problems with sequencing the neurophysiological movements underlying articulation may lead to the under emphasis of some components (e.g., voicing contrasts) and the over emphasis of others (e.g., nasal air emission) to the detriment of overall speech proficiency. Thus, procedures that act to normalize one of the basic components of speech production (respiration) should serve, in a global sense, to improve speech intelligibility by increasing the availability of a steady air stream upon which the articulators may act.

The present paper describes selected aspects of pulmonary function (flow/volume loops; inspiratory-expiratory pressures and flows) and their relationship to velopharyngeal competence in two dysarthric patients who have been fitted with palatal lift speech appliances.

Method

Subjects

Patient A was a 49 year old male with a medical diagnosis of muscular dystrophy. He was 12 years post-diagnosis. Ambulation was via motorized wheelchair, and he had received

Table 1. Descriptors of the functional components of the speech producing system pre- and post-palatal lift placement (after Leeper & Sills, 1986).

Context	Patient A Pre	Patient A Post	Patient B Pre	Patient B Post
CAIDS* (words)	73%	78%	62%	70%
(sentences)	79%	83%	69%	72%
Articulation skill (whole word precision)	78%	84%	56%	67%
Resonance	(5)/7	(3)/7	(5.5)/7	(2)/7
Nasal air emission	(4.5)/7	(2)/7	(4.5)/7	(2)/7
Estimated V.P. Orifice Area	16mm^2	7mm^2	14mm^2	4mm^2
Laryngeal Quality	(2.5)/7	(2)/7	(5)/7	(3)/7
MPT /a/ (seconds)	8	10	9	12
Respiration	(5.5)/7	(3)/7	(5)/7	(2)/7

* CAIDS, Yorkston, D., Beukelman, D., & Traynor, C. (1984). Computerized Assessment of Intelligibility of Dysarthric Speech. Tegard, Oregon: CC Publications, Inc.)

speech, occupational, and physical therapy for the past 7 years. Hearing and vision were within normal limits for his age. He was described in the diagnostic summary received within his medical record as having flaccid dysarthria (characterized by hypotonicity and muscle weakness). The results of pre- and post-palatal lift fitting may be seen in summary form in Table 1. The time between the two fittings was approximately 6 weeks. The perceptual judgments of the patient's speech reported in Table 1 were made by five experienced speech-language pathologists as part of a larger study of dysarthric speech. Perceptual judgments of respiration, laryngeal (voice) quality, resonance, and nasal air emission were made employing separate 7 point equal-appearing interval scales. Each judge rated each feature separately during repeated listening to recorded samples of a test sentence. Articulation skills were assessed by having the examiners transcribe the words spoken by the patient. The number of errors recorded by the judges served as a measure of whole word precision. Whole word and sentence intelligibility was obtained using the Computerized Assessment of Intelligibility of Dysarthric Speech (CAIDS) (Yorkston, Beukelman, & Traynor 1984) following standard instructions found in the manual. Measures of estimated velopharyngeal orifice area were obtained using flow-pressure measures (see Warren & DuBois, 1964) during syllable (VCV) production using voiceless plosives and fricatives as consonant elements (e.g., [ipi], [isi]). Phonation times were calculated by one of the authors using a commercial stop watch.

Patient B was a 51 year old male who had suffered a cerebral trauma 8 years ago. He was also ambulatory via wheelchair, and he had undergone speech, physical, and occupational therapy for the past 7.5 years. Hearing was within normal limits for his age. He was described in his medical records as having a mixed dysarthria, with primary spasticity in the limbs (characterized by hypertonicity and increased muscle resistance to stretch) and more flaccid (hypotonicity) dysarthria in the oral-motor system. He wore corrective lenses for reading tasks. The patient was given the same battery of tests (see above) as Patient A during visits to the Orofacial Rehabilitation Unit. Results of the speech assessment pre- and post-fitting of the palatal lift may be seen in Table 1. The time between the two testing sessions was 7 weeks.

Procedures

Each subject was a patient in an Orofacial Rehabilitation Unit (OFRU) in a university affiliated teaching hospital (University Hospital, London, Ontario). Dental, speech, and pulmonary function assessments were undertaken following initial medical and behavioral (physical therapy, occupational therapy, speech-language therapy) management. Each person was medically stable, cognitively aware, and compliant for dental management. Each individual underwent subsequent speech and respiratory testing according to a specific protocol for prosthetic management (Leeper & Sills, 1986).

The assessment within the OFRU included: (1) examination of oral and dental health records; (2) full mouth X-rays and panorex films to document oral health, structure, and dental relationships; and (3) prophylaxis and necessary dental restorations.

The initial speech assessment (pre-lift) was performed by two certified speech-language pathologists with extensive experience in perceptual and physical measures of speech performance of individuals with oral-facial defects. The examination included perceptual evaluations (judgments) of the respiratory, phonatory, resonatory, and articulatory capabilities of each patient employing separate 7 point equal-appearing interval scales (described in more detail under "subjects"). In addition, aerodynamic and acoustical measures, nasendoscopic views, and lateral cephalometric X-rays were used to document velopharyngeal competency during speech production. The reader is referred to an earlier article by Leeper and Sills (1986) concerning the specific procedures used to determine eligibility for placement of a palatal lift appliance.

Following the initial dental and speech evaluations, a determination of the patient's candidacy for the palatal lift

Figure 1. Schematic of flow-volume loop for measures of forced inspiratory and forced expiratory activity during single respiratory cycle.

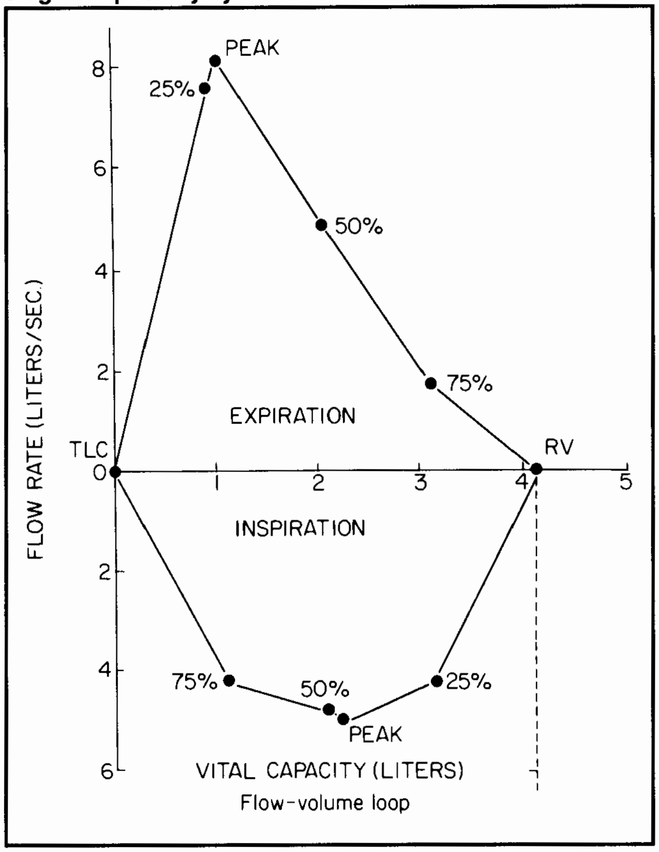
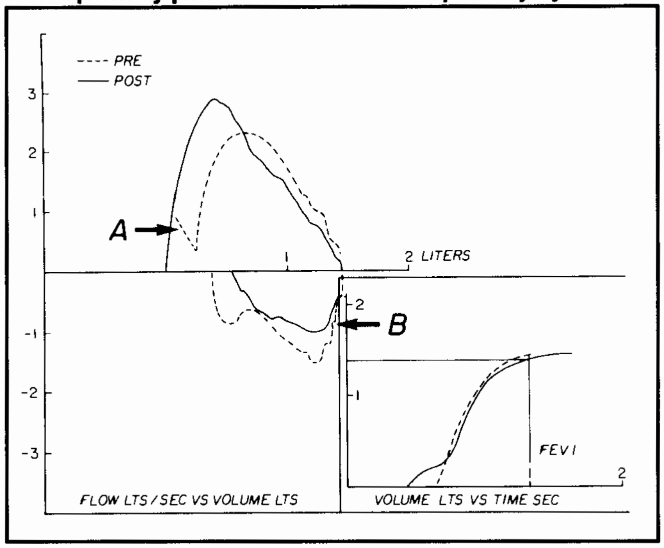


Figure 2. Flow-volume loop for Patient A showing "jogs" in the expiratory side (point A) and "chatter" (point B) in the inspiratory portion of the forced respiratory cycle.



appliance was made. With a positive candidacy, dental impressions were taken, a master cast was made of the oral and oral-pharyngeal cavities, and a framework of chromium-cobalt fabricated in the dental laboratory. A clear acrylic posterior (tail) section of the appliance was fitted to the framework following specifications of the patient's oral-pharyngeal structures. The appliance was placed in the patient's mouth, modified, and refitted following estimates of speech proficiency from perceptual, aerodynamic, nasendoscopic, and lateral X-ray assessments (the post-lift placement speech assessment; see Leeper & Sills, 1986). The refitting occurred approximately two weeks after the initial placement. Following the final fitting of the appliance and the speech assessment, each patient was referred to the Pulmonary Function Laboratory (University Hospital) for a series of standard tests to assess inspiratory and expiratory volumes and flows with and without the palatal lift in place.

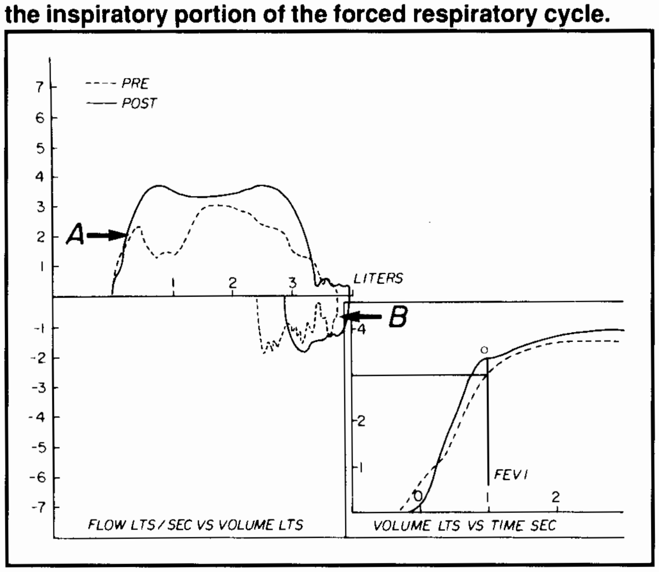
Instrumentation and Measures of Pulmonary Function

A standard pulmonary function analysis was performed using a waterless spirometer (Rolling Seals, Ohio Medical, model 100). Each patient performed three trials each with the lift in place and with the lift removed to determine forced vital capacity (FVC), forced expiratory volume during the first second (FEV_1), a ratio of the two (FEV_1/FVC) (a measure of airway resistance), peak expiratory flow (PEF), forced expiratory flow at 50% VC (FEF50), forced expiratory flow at the mid-ranges of flow (FEF25-75), and mid-inspiratory flow at 50% VC (MIF50). The above measures, as well as the flow-volume loop characteristics with and without the palatal lift in place, were collected, analyzed, and displayed via a custom software package and a Zenith XT computer and associated printer (Okidata). These data served as the basis for a description of respiratory function (see Figure 1). For a more detailed description of the ventilatory and flow-volume measurement techniques, the reader is referred to Darby (1981) concerning the interaction between speech, breathing, and disease processes.

Results

Data for the pre- and post-palatal lift placement pulmonary function analyses for patient A may be seen in Figure 2. In this figure, the solid line represents the *lift-in* condition and the dotted line the *lift-out* condition. For this patient, FVC did not change with or without the lift in place. FEV_1 decreased slightly (4%) with the lift in place. Airway resistance (as noted from the FEV_1/FVC measure) decreased by 4%. PEF values changed by 20% from the lift out to the lift in condition. FEF50 and FEF25-75 showed 10% and 13% changes, respectively, with the palatal lift in place. MIF50 (inspiratory) values were slightly reduced. In addition, descriptive information from the flow/volume loops for palatal lift-out versus lift-in conditions demonstrated that an acceleration, deceleration, acceleration "jog" (decrease or increase in slope) in the loops (Vincken, Elleker & Cosio, 1986) occurred without the lift in place (see point A of the solid line). This characteristic was greatly reduced with the palatal appliance in position. In addition, the step-like increases in "chatter" (small rapid alterations in slope) (Vincken, et al., 1986) that were apparent on the inspiratory trace (point B) with the lift removed were reduced when the lift was in place. Further, this patient estimated that his self

Figure 3. Flow-volume loop for Patient B showing "jogs" in the expiratory side (point A) and "chatter" (point B) in the inspiratory portion of the forced respiratory cycle.



perceived "effort of breathing," as measured using the Borg Scale (Borg, 1982), had decreased from a rating of 6 to a rating of 3 with the palatal lift in place.

Pulmonary function data for patient B may be seen in Figure 3. In this graph, the solid line represents the lift-in condition, and the dotted line represents the lift-out condition. For this individual, the FVC is slightly greater (5%) with the lift in place. FEV_1 increased by 11% with the lift in, and overall airway resistance (FEV_1/FVC) was increased by about 5% with the lift in place. PEF values increased by 20% with the lift in position. The forced expiratory flow (FEF50 and FEF25-75) values also showed changes of 15% and 41%, respectively, with the aid of the palatal lift. MIF50 values showed a moderate decrease (35%) with lift placement. As with patient A, this patient showed the acceleration, deceleration, acceleration jog (point A in Figure 3) within the flow/volume loop for the lift-out condition. Again, the inspiratory chatter (point B in Figure 3) during inspiration was greatly reduced with the palatal lift in position. With the lift in place, the jogs in the loops are reduced greatly or eliminated from the inspiratory (lower) and expiratory (upper) portions of the graph. As with patient A, this individual reported a decrease in the exertion for breathing from a rating of 7 to one of 2 on the Borg Scale.

Discussion

The present paper describes the pulmonary function of two dysarthric patients with accompanying nasalization who were tested with and without a palatal lift speech appliance. While this study focused on the non-speech aspects of breathing with a palatal lift in position, it seems important to note that the appliances were primarily designed to improve oralization of speech and to reduce the negative effects of an incompetent velopharyngeal mechanism.

Generally, we have observed in the present patients (as noted in the pre- and post lift placement data in Table 1), as well as others we have treated (Leeper & Sills, 1985) that appropriate fitting of the palatal lift appliance results in improved speech production abilities. Employing perceptual, acoustic, and aerodynamic measures (see Leeper & Sills, 1986), the present patients data show (see Table 1), on average, a 5% improvement in intelligibility, an 8% improvement in whole word articulation precision, a positive improvement of 2 scale points (7 point scale) in judgments of hypernasality and nasal air emission, positive change in laryngeal quality (1 scale point), and a 9.5 mm^2 change (decrease) in estimated velopharyngeal orifice area. Support for the acoustical and aeromechanical usefulness of the palatal lift during speech has been reported previously (Hardy, Netsell, Schweiger, & Morris, 1969; LaVelle & Hardy, 1979; Leeper Sills, 1986; Yorkston, Beukelman, & Bell, 1988). In addition, there was a 2.5 scale point change (improvement) in subjective respiratory function noted by the patients as derived from the Borg Scale (Borg, 1987).

Improved physiological support for non-speech breathing indicated by our respiratory measures with the palatal lift appliance also may have an effect on breathing during speech activities. Physiological (respiratory) support for speech, which is a necessary precursor for the use of traditional methods of treatment directed towards improving articulation, may be seen in increased phonation times, increased oral air volume and pressure, and improved intelligibility (Yorkston, et al., 1988). Further investigations of direct measures of improved breath support for speech following palatal lift placement are necessary. While the improvement in the underlying physiological subsystems following palatal lift placement is not a new finding, the finding that respiratory function was improved with the lift in place has not been reported previously. Thus, it appears that in addition to improving oralization of speech, the palatal lift may aid in non-speech breathing.

From the present patient data, it appears that the "work of breathing," as measured both objectively and subjectively, is reduced when a palatal lift is used. It seems that the respiratory cycle is augmented to improve forced airflow volumes and airflow rate during expiration (FEV_1; FEF25-75), while reducing the amount of inspiratory oscillation or chatter and the amount of acceleration/deceleration jogs in the expiratory side of the breathing cycle. Our findings are consistent with recent reports by Vincken, Elleker, and Cosio (1986) who found that with patients with neuromuscular diseases, involvement of the upper-airway musculature is frequently associated with abnormal patterns described within the flow-volume loops. In particular, flow oscillations and plateaus on flow/volume may be potential markers for severe respiratory complications. From the present observations, we would argue that placement of a palatal lift appliance appears to decrease the abnormal flow oscillation patterns, particularly in these individuals with certain types of dysarthria (flaccid). We further suggest that the effect of the palatal lift is to hold the palatopharyngeal area in a more open posture, thus restricting collapse of the muscular walls of the pharynx during inspiratory and expiratory maneuvers. This augmentative procedure (lift placement) may allow for improved control of the upper portion of the neuromuscularly dysfunctional chest wall during respiration for speech. It is supported physiologically by data from peak inspiratory and expiratory flow maneuvers from the patients' data presented in this report.

Such a supposition is consistent with information reported by Rodenstein and Stanescu (1986) who noted the potential for such neuromuscular expansion and contraction control of the soft palate and surrounding tissues for breathing. Since the nostrils are closed during traditional spirometric testing, only the oropharyngeal area below the soft palate and/or the upper airway may be affected by the lift. It should be noted also, however, that both patients noted subjectively that they had to "work less" and felt "more comfortable" (both inspiratory and expiratory action) when breathing for speech with the palatal lift in place. Such subjective responses add to the credence of our hypotheses.

Additional studies involving real-time X-ray or magnetic resonance imaging of the upper airway during breathing may be used to confirm our hypotheses. We are currently examining measures of pulmonary function, nasal airway resistance, and aerodynamic measures of speech to determine changes in speech- related production activities as they relate to non-speech alterations in breathing, following placement of a palatal lift.

In summary, the present objective data show positive changes in pulmonary function for non-speech breathing. Additionally, subjective judgments by our patients indicate an improvement in the quality of life of these two individuals as it relates to the reduction in exertion for the work of breathing. If our findings are substantiated by additional research, we suggest that the palatal lift appliance may be a very useful augmentative device to provide physiological support for speech breathing. It may be particularly useful for individuals with dysarthria of speech and accompanying nasalization. Such a device would aid in the communication management of a variety of individuals with neurological disorders affecting the velopharyngeal mechanism.

Acknowledgments

The authors would like to thank Philip Doyle and several anonymous reviewers for their comments on an earlier version of this paper.

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References

Aten, J., A., Simpson, M., & Gutierrez, R. (1984). Efficacy of modified palatal lifts for improving resonance. In M.R. McNeil, J. Rosenbek, & A. Aronson (Eds.), *Dysarthrias: Physiology, Acoustics, Perception, Management*. San Diego: College-Hill Press, 331-342.

Borg, G.A.V. (1982). Psychophysical basis of perceived exertion. *Medical Psychology of Sports Exercise*. *14*, 377-381.

Darby, J.K. (1981). The interaction between speech and disease. In J.K. Darby (Ed.), *Speech Evaluation in Medicine*. New York: Grune and Stratton, Inc., 3-46.

Darley, F., Aronson, A., & Brown, J. (1975). *Motor Speech Disorders*, Phildelphia: WB Saunders.

Gibbons, P., & Bloomer, H.A. (1958). The palatal lift: A supportive type speech aid. *Journal of Prosthetic Dentistry*, *8*, 362-369.

Hardy, J., Netsell, R., Schweiger, J., & Morris, H. (1969). Management of velopharyngeal dysfunction of cerebral palsy. *Journal of Speech and Hearing Disorders*, *34*, 123-137.

Hixon, T., & Putnam, A.H.B. (1983). Voice disorders in relation to respiratory kinematics. In D. Boone (Ed.), *Voice Disorders in Children and Adults: Strategies of Management*. New York: Thieme-Stratton, Inc., 217-232.

Hixon, T., Putnam, A.H.B., & Sharp, J.T. (1983). Speech production with flaccid paralysis of the rib cage, diaphragm, and abdomen. *Journal of Speech and Hearing Research*, *48*, 315-327.

LaVelle, W.E., & Hardy, J.C. (1979). Palatal lift prosthesis for treatment of palatopharyngeal incompetence. *Journal of Prosthetic Dentistry*, *42*, 308-315.

Leeper, H.A., & Sills, P.S. (1986). Prosthetic and speech management of patients with velopharyngeal incompetence. *Human Communication Canada, 10*, 5-20.

Leeper, H.A., & Sills, P.S. (1985). The usefulness of a palatal lift appliance for altering speech behavior in dysarthric speakers with velolaryngeal incompetence. Paper presented at the Canadian Speech and Hearing Association conference, May.

Natsell, R. (1984). Physiological studies of dysarthria and their relevance to treatment. In J. Rosenbek (Ed.), *Current Views of Dysarthria. Seminars in Speech and Language*. New York: Thieme-Stratton, Inc., 293-314.

Netsell, R., Daniel, B. (1979). Dysarthria in adults: Physiologic approach to rehabilitation. *Archives of Physical Medicine and Rehabilitation, 60*, 502-508.

Putnam, A.H.B., & Hixon, T. (1984). Respiratory kinematics in speakers with motor disease. In M. McNeil, J. Rosenbek, & A. Aronson (Eds.), *The Dysarthrias: Psysiology, Acoustics, Perception, Management*. San Diego: College-Hill Press, 37-68.

Rodenstein, D.O., & Stanescu, D.C. (1986). The soft palate and breathing. *Review of Respiratory Disease, 134*, 311-325.

Rosenbek, J.C. (1984). Treating the dysarthrias. In J. Rosenbek, (Ed.), *Current Views of Dysarthria. Seminars in Speech and Language*. New York: Thieme-Stratton, Inc., 359-383.

Vincken, W., Elleker, M.D., & Cosio, M.D. (1986). Detection of upper airway involvement in neuromuscular disorders using the flow-volume loop. *Chest, 90*, 52-57.

Warren, D., & DuBois, A. (1964). A pressure-flow technique for measuring velopharyngeal orifice area during continuous speech. *Cleft Palate Journal, 1*, 52-71.

Yorkston, K.M., Beukelman, D.R., & Bell, K.R. (1988). *Clinical Management of Dysarthric Speakers*. Boston: College-Hill Press, 268-295.

Yorkston, K.M., Beukelman, D.R., & Traynor, C. (1984). *Computerized Assessment of Intelligibility of Dysarthric Speech*. Tigard, OR: C.C. Publications.