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*Information for Health Professionals*

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## Dysarthria in Multiple Sclerosis

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Studies of dysarthria in MS indicate a prevalence ranging from 41% to 51%.<sup>1-3</sup> Self-reporting of speech and other communication disorders has varied widely: 23% in a study in the United States (N=656);<sup>4</sup> 44% in a Swedish study (N=200);<sup>5</sup> and 57% in a preliminary South African study (N=30).<sup>6</sup> The range in prevalence figures reflects inconsistencies in study design, including the size and characteristics of the study samples, and the terminology and assessment tools used. In addition, a lack of congruence between evaluation results by a speech/language pathologist and self-report by individuals with MS has been proposed, and needs further study.

Speech and voice problems may be identified by the person with MS, a family member, or a healthcare professional. Common complaints include difficulty with precision of articulation, speech intelligibility, ease of conversational flow, speaking rate, loudness, and voice quality. When these problems interfere with a person's quality of life—particularly the ability to communicate daily needs—a referral for evaluation and treatment by a speech/language pathologist is recommended.

### NORMAL SPEECH PRODUCTION

The normal processes of speech and voice production are overlapping and require the following five processes to work together smoothly and rapidly:<sup>7-8</sup>

- 1. Respiration:** Using the diaphragm to quickly fill the lungs fully, followed by slow, controlled exhalation for speech.
- 2. Phonation:** Using the vocal cords and air flow to produce voice of varying pitch, loudness, and quality.
- 3. Resonance:** Raising and lowering the soft palate to direct the voice to resonate in the oral and/or nasal cavities to further affect voice quality.
- 4. Articulation:** Coordinating quick, precise movements of the lips, tongue, mandible, and soft palate for clarity of speech.

5. **Prosody:** Combining all elements for a natural flow of conversational speech, with adequate loudness, emphasis, and melodic line to enhance meaning.

## DEFINITION OF DYSARTHRIA AND DYSPHONIA

**Dysarthria** refers to a *speech disorder*, caused by neuromuscular impairment, which results in disturbances in motor control of the speech mechanism.<sup>9</sup> The demyelinating lesions caused by multiple sclerosis may result in spasticity, weakness, slowness, and/or ataxic incoordination of the lips, tongue, mandible, soft palate, vocal cords, and diaphragm. Therefore, articulation, speaking rate, intelligibility, and natural flow of speech in conversation are the areas most likely to be affected in those with multiple sclerosis.

**Dysphonia**, which refers to a *voice disorder*, often accompanies dysarthria because the same muscles, structures, and neural pathways are used for both speech and voice production. Therefore, voice quality, nasal resonance, pitch control, loudness, and emphasis may also be affected in those with MS.<sup>1</sup>

## COMMON FEATURES OF DYSARTHRIA IN MS

Dysarthria is considered the most common communication disorder in those with MS.<sup>10</sup> It is typically mild, with severity of dysarthria symptoms related to neurological involvement.

Darley and colleagues published the first comprehensive, scientific study identifying common features of dysarthria in 168 people with MS.<sup>11</sup> Analyses of speech characteristics and description of deviations in the five processes of respiration, phonation, resonance, articulation and prosody were rank ordered (see Table 1).

Since then, three replication studies have reported insufficient reliability of clinicians' judgments in the more specific areas, yet high agreement in such overall speech dimensions as intelligibility and naturalness.<sup>12</sup>

Percent (N = 168)	Deviation	Description
77%	Loudness control	Reduced, mono, excess, or variable
72%	Harsh voice quality	Strained, excess tone in vocal cords
46%	Imprecise articulation	Distorted, prolonged, irregular
39%	Impaired emphasis	Phrasing, rate, stress, intonation
37%	Impaired pitch control	Monopitch, pitch breaks, high, low
35%	Decreased vital capacity	Reduced breath support and control
24%	Hypernasality	Excessive nasal resonance

A cross-linguistic analysis of dysarthria in Australian (N=56) and Swedish (N=77) speakers with MS, using a 33-point protocol, identified six deviant features: harsh voice, imprecise articulation, impaired stress patterns, rate, breath support, and pitch variations.<sup>12</sup> Even though different rank orders and problem frequencies were seen, agreement with Darley's list of seven most common features was noted, with the exception of loudness and hypernasality.

## **DIFFERENTIAL DIAGNOSIS**

There are three types of dysarthria associated with MS (see Table 2): spastic, ataxic or mixed. Differential diagnosis depends on the extent and location of MS lesions, and the specific speech, voice, and accompanying physical signs that result. Mixed dysarthria is most common in MS, because multiple neurological systems are typically involved.<sup>13</sup>

## **SYMPTOM MANAGEMENT OF CONTRIBUTING FACTORS**

Differential diagnosis of the type of dysarthria has important implications for treatment planning by the speech/language pathologist, as well as decision-making by the physician regarding pharmacologic management. Dysarthria and dysphonia in MS may be accompanied by the underlying symptoms of spasticity, weakness, tremor and ataxia; and complicated by fatigue. Therefore, evaluation of medication trials to treat these symptoms, and ongoing communication with the patient and physician about the impact on speech and voice, is recommended during therapy.<sup>1</sup>

## **ASSESSMENT OF DYSARTHRIA**

Evaluation of dysarthria and dysphonia in MS typically involves three main aspects:

- 1.** Assessment of oral-motor function of the peripheral speech mechanism by:
  - ◆ Examining the structure and function of the articulators (lips, teeth, tongue, mandible, hard and soft palates) for symmetry, strength, speed, and coordination.
  - ◆ Evaluating respiratory support and control for speech.
  - ◆ Analyzing laryngeal control of loudness, pitch and voice quality during phonation.
- 2.** Perceptual analysis to describe the various dimensions of respiration, phonation, articulation, resonance, and prosody. To classify type and severity of dysarthria.
- 3.** Rating of speech intelligibility and naturalness in conversation.

Dysarthria evaluation in MS has traditionally included both informal and formal measures of a variety of oral-motor, speech, and voice functions, with comparison to referenced norms. Formal articulation tests are not commonly used because MS-related dysarthria tends to have an irregular pattern of breakdown that is not necessarily based on misarticulation of specific speech sounds. Rather, measures of oral reading rate in phonetically balanced passages (e.g., *My Grandfather*—one of many standardized, phonetically-balanced oral reading passages) and analysis of a brief, recorded spontaneous speech sample (e.g., describe job, family, interests, etc.) are standard

<b>TABLE 2 Comparing the Three Types of Dysarthria</b>	
<b>Speech and Voice Signs</b>	<b>Related Neuromuscular/Physical Signs</b>
<b>SPASTIC DYSARTHRIA: Due to bilateral lesions of corticobulbar tracts</b>	
<p>Harsh, strained voice quality</p> <p>Pitch breaks</p> <p>Imprecise articulation</p> <p>Slow rate of speech</p> <p>Reduced breath support and/or control</p> <p>Reduced or mono-loudness</p> <p>Short phrases, reduced stress</p> <p>Hypernasality</p>	<p>Hypertonicity (excess muscle tone)</p> <p>Bilateral spasticity</p> <p>Restricted range of motion (jaw)</p> <p>Reduced speed of movement</p> <p>Bilateral hyperreflexia</p> <p>Sucking and jaw jerk reflexes</p> <p>Cortical disinhibition</p>
<b>ATAXIC DYSARTHRIA: Due to bilateral or generalized lesions of the cerebellum</b>	
<p>Vocal tremor</p> <p>Irregular articulation breakdown</p> <p>Dysrhythmic rapid alternating movements of the tongue, lips, and mandible</p> <p>Excess and equal stress (scanning speech)</p> <p>Excess and variable loudness</p> <p>Prolonged phonemes and intervals</p>	<p>Intention tremor: head, trunk, arms, hands</p> <p>Broad-based, ataxic gait</p> <p>Nystagmus and irregular eye movements</p> <p>Balance or equilibrium problems</p> <p>Hypertonicity</p> <p>Overshooting; slow, voluntary movements</p>
<b>MIXED DYSARTHRIA: Due to bilateral, generalized lesions of multiple areas in the cerebral white matter, brainstem, cerebellum, and/or spinal cord</b>	
<p>Impaired loudness control (reduced, mono-loudness, or excess and variable)</p> <p>Harsh or hypernasal voice quality</p> <p>Impaired articulation (imprecise, distorted, prolonged, or irregular breakdowns)</p> <p>Impaired emphasis (slow, prolonged intervals or sounds, reduced, or excess and equal stress)</p> <p>Impaired pitch control (monopitch or pitch breaks, too low or too high)</p>	<p>Any combination of spastic and ataxic features as mentioned above</p>

procedures. Speaking rate, articulation precision, number of words/breath unit, pauses within and between words, intelligibility, and naturalness of conversational flow are then measured and described. Speaking rate varies according to the task: oral reading of sentences—190 words per minute; oral reading of paragraphs—160–170 words per minute; speaking rate in conversation—150–250 words per minute. The wide range in conversation is due to a variety of cognitive-language factors, including the complex verbal formulations that are used, word retrieval/fluency abilities, turn-taking, and lack of concrete cues for pauses (such as the commas and periods in reading materials).

Some formal, published measures used in dysarthria evaluation in MS include:

- ◆ **Assessment of Intelligibility in Dysarthric Speech** (word and sentence levels), in which a judge, unfamiliar with the material, transcribes the recorded responses.<sup>14</sup>
- ◆ **Dysarthri-test**, which includes 54 test items, scored on a five point interval scale. Items measured in each speech parameter include: respiration, phonation, oral-motor performance (divided into lips, jaw, tongue, and soft palate, plus a diadochokinesis rating), articulation, prosody and intelligibility.<sup>15</sup>
- ◆ **Queensland Protocol**, an adapted version of the perceptual analysis/dysarthria classification procedure introduced by Darley and colleagues. This protocol includes 33 items relating to the five speech dimensions of respiration, phonation, resonance, articulation and prosody, and uses a 4-point descriptive equal-interval scale to measure rate, intelligibility, articulation precision of consonants and vowels, and phoneme length.<sup>16</sup>

## NEW DIRECTIONS IN ASSESSMENT

There has been a trend in recent years, to supplement perceptual analyses of dysarthria with acoustic analyses of speech parameters. Advancement in physiological instrumentation for assessment is aimed at improving objectivity in measurement, refining our understanding of dysarthria features specific to MS, and ultimately aiding clinical decision-making and treatment planning.

- ◆ Spectrographic displays have been used to obtain specific measures of acoustic distinctiveness during speech samples. For example, Tjaden and Wilding used a sound-treated booth, head-mounted microphone, and recording software (such as the CSpeechSP 4.0 or windows-based version TF32, Turbo Pascal 5.5) to objectively measure variations in sound/syllable duration, rate of articulation, vocal intensity, and size of working space for vowel and consonant production.<sup>17-18</sup>
- ◆ Lip and tongue transducers have been used to objectively measure range, force, and diadochokinesis (or rapid alternating movements) of their function. Results of a recent study by Hartelius and Lillvik using this technique found that tongue function is more severely affected than lip function in MS, that tongue dysfunction can be detected subclinically (in non-dysarthric subjects), and that there was a moderate correlation to severity of neurological deficit and years in disease progression. Based on their findings,

the importance of targeting improvement in tongue functioning early in articulation therapy was suggested.<sup>19</sup>

Despite advances in the development of instrumental assessment techniques in recent years, perceptual analysis of recorded speech remains a primary tool for differential diagnosis and treatment planning.

## TREATMENT

Evaluation of evidence-based research and expert opinion to support the treatment of dysarthria and to develop practice guidelines has been a project of the American Speech/Language Hearing Association (ASHA) and Academy of Neurologic Communication Disorders and Sciences (ANCDs) since 1997.<sup>20</sup> A series of four practice guideline reports were published in the *Journal of Medical Speech/Language Pathology* (2001–2004) and are available at [www.ncds.org](http://www.ncds.org).<sup>21</sup> Guidelines for improving speech intelligibility and naturalness are forthcoming.

The World Health Organization's 2002 international classification of function, disability and health has had a significant impact in the field of rehabilitation. The goal of addressing physical function and structure within the broader context of a person's ability to participate actively in his or her world, has influenced both assessment protocols and treatment planning.<sup>22</sup> In dysarthria therapy, the trend has been away from a focus on specific impairments (e.g., oral exercises to normalize movement patterns), toward the acquisition of specific skills to facilitate participation in functional real-world activities (e.g., speaking with adequate loudness and intelligibility for telephone activities at work or home).<sup>23</sup>

Clinical decision-making in treatment planning is individualized according to the person's specific problems and communication needs. Improving speech intelligibility and naturalness should be the ultimate goal of therapy. Selection of appropriate treatment approaches, and where to begin therapy, depend on which deviant speech dimension(s) are most disabling in these two areas. Work on one target behavior can have overlapping, indirect effects on other physiological and acoustic variables. For example, improving breath support/control can increase loudness and indirectly reduce rate, thus allowing more precise articulation and improving overall speech intelligibility. Measuring impact on participation and quality of life are recommended, to assess functional outcomes of dysarthria therapy.

Traditional dysarthric compensations taught to MS speakers include: improving breath support and control; reducing the rate of speech; using strategic pauses within and between words; exaggerating articulation; and actively self-monitoring/self-correcting speech.

In a recent review of the intervention literature on respiratory/phonatory dysfunction in dysarthria,<sup>24</sup> evidence was found to support the following:

- 1. Improving breath support** by using biofeedback to gauge respiration (and loudness or phrase length) during speech tasks, and when learning a new breath pattern with deeper inhalation, increased force at exhalation, and use of abdomen. Physiological and acoustic

biofeedback methods, such as a Visi-pitch, Computer software, VU meter, recorder, RespiTrace, water manometer, velocity/air pressure transducer, oscilloscope, and EMG were mentioned.

2. **Improving respiratory/phonatory coordination** by increasing awareness of the irregular speech-respiratory pattern, determining optimal words/breath groups, gradually increasing them, and practicing flexibility in cued and non-cued conversational scripts.
3. **Improving phonatory functioning**
  - a. **Hyperadduction** (harsh voice quality, typical of MS): Often not directly treated because it is difficult to modify, with negligible impact on intelligibility.
  - b. **Hypoadduction** (soft, breathy, whispered voice quality): Significant improvement has been demonstrated using the *Lee Silverman Voice Treatment (LSVT)* in those with Parkinson's disease and hypokinetic dysarthria.<sup>25</sup> The LSVT seeks to increase vocal loudness, by increasing phonatory effort, which has been shown to improve speech intelligibility. Variable results with the LSVT technique have been noted in MS speakers and their spastic, ataxic, and mixed types of dysarthria.<sup>26</sup>

A review of the literature on evidence-based practices in dysarthria therapy also found the technique of **managing speaking rate** to be effective in improving speech intelligibility. However, with rate control techniques there can be a negative impact on naturalness of conversational flow, which must be considered in treatment. Slowing rate can be accomplished by changing either the speech time ("stretching out the word"), or the increasing the pause time (within or between words). The two types of rate control include:<sup>27</sup>

1. **Rigid:** Use of external aids—such as finger tapping, a pacing board, or a metronome—to slow speaking rate and allow more precise articulation of each word or syllable. Although this technique provides the fastest and greatest improvement in intelligibility, naturalness in flow of speech can suffer. It can be a motivating starting point, when combined with rhythmic rate control.
2. **Rhythmic:** Rate control techniques that also attempt to preserve naturalness by using biofeedback systems—including the Pacer/Tally software,<sup>28</sup> Visi-pitch, and delayed auditory feedback (DAF)—during speech tasks.<sup>29</sup> The direct magnitude production technique (DMP), which uses no external device, can also be effective. The DMP is self-devised, and asks the individual to speak at half his habitual rate. Whereas the rhythmic techniques take more time to learn, both speech intelligibility and naturalness may be improved.

Imprecise articulation of consonants has been noted as the greatest contributor to reduced overall speech intelligibility. In two studies specific to dysarthria treatment in MS speakers, the combined/overlapping effects of multiple techniques (**increasing loudness, reducing rate, and exaggerating articulation**) showed a positive impact on preciseness and speech intelligibility. Hartelius found tongue function to be more severely affected than lip function in dysarthric and non-dysarthric speakers with MS (N=77).<sup>19</sup> Therefore, increasing articulatory excursions while reducing rate is recommended.

Increasing loudness and reducing rate have also been associated with increasing the size of the articulatory-acoustic working space, and thus improving articulation precision and acoustic distinctiveness. Tjaden and Wilding performed acoustic and perceptual analyses of 15 mild to moderate spastic, ataxic, and mixed dysarthric speakers with MS and found that acoustic distinctiveness of vowels, as indexed by vowel space, was maximized in the slow condition, whereas distinctiveness of stop consonants was maximized in the loud condition.<sup>17</sup> These findings are important for treatment planning.

## **AUGMENTATIVE AND ALTERNATIVE COMMUNICATION**

The need for augmentative and alternative communication (AAC) devices in individuals with MS is relatively uncommon. However, when severe dysarthria interferes with the individual's well-being, safety, and functional communication of daily needs, evaluation for an appropriate speech generating device (SGD) is indicated.<sup>30</sup> Speech supplementation devices (such as voice amplifiers) and non-speech alternatives are also available. There are low-tech alternatives, such as: alphabet, picture, or eye gaze boards, as well as bells, buzzers, and yes–no systems—any of which offer manual, optical, or partner-assisted selection. And there are high-tech alternatives with such dedicated text-to-speech or “type and talk” devices as the Lightwriter, Dynawrite and Speakout. Applications (apps) may also be downloaded for the iPhone or iPad that do text-to-speech or visual scenes. If recommended, a wide variety of more complex, multipurpose/integrated computer-based devices, with word prediction software, are available through Tobii, Dynavox, FRS, and Prentke Romich to name a few. Modes of access depend on physical status, joystick, or mouse. Information about AAC devices, vendors, materials and tutorials can be found at [www.asha.org/public/speech/disorders/AAC](http://www.asha.org/public/speech/disorders/AAC) and <http://aac.unl.edu>.

Yorkston and Beukelman (2000) developed a functional staging system for AAC intervention to aid in clinical decision-making.<sup>32</sup> It rates five areas—speech, cognition, literacy, vision, and upper and lower extremity functioning—on a 5-point scale. A team approach to AAC evaluation (including a physical therapist, occupational therapist, and speech/language pathologist) that takes into account the full range of a person's symptoms, is recommended. Once assessment and training on the appropriate device has been completed, routine re-evaluation and update is essential.

In 2001, Medicare began providing reimbursement for evaluation, treatment, and appropriately-prescribed SGD devices. Medicare's assessment protocol and guidelines set the standard for state, federal, and private health plans. For example, prior to SLP recommendation and physician prescription, an assessment trial of at least three systems that incorporate the necessary features is required before Medicare will provide authorization. Information about Medicare funding is available at [www.aac-rerc.com](http://www.aac-rerc.com).

## **CONCLUSION**

In a preliminary MS study in South Africa, 62% of the respondents experiencing speech and language problems reported that these difficulties had a negative impact on their quality of life (QOL). Although the prevalence of dysarthria in MS has been reported to be at least 41%, referral rate is low—a significant gap that needs to be addressed. Assessment protocols and treatment



procedures for dysarthria in MS have shown recent advances. Trends have included the refinement of perceptual and acoustic analyses, and incorporation of the World Health Organization's international classification of function, disability and health, which aids functional goal-setting. Specific treatments are being studied with the MS population and controls, to add evidence-based research to the expert opinion of clinicians.

More MS research is needed in the international community in the areas of prevalence, acoustic and physiological dimensions as they relate to perceptual analysis, treatment outcomes as they relate to quality of life, and cross-linguistic perceptual ratings.

## **LITERATURE REVIEW UPDATE**

Since the initial writing of this Clinical Bulletin in 2007, there have been a number of relevant studies published specific to the clinical care of dysarthria in MS, three of which are summarized below. The trend has been to look at motor speech disorders in MS within the larger context of other clinical findings, such as cognitive-linguistic deficits, voice disorders, MRI features, and overall prosodic profile.

Mackenzie and Green<sup>33</sup> compared a group of those with dysarthria and chronic progressive MS (N=24) to a matched control group. Analysis of evaluation results using the Arizona Battery of Communication Disorders of Dementia (ABCD) and Assessment of Intelligibility in Dysarthric Speech (AIDS) showed a strong association between levels of speech intelligibility and cognitive-linguistic deficit in the MS group. Significant differences on the ABCD were identified, especially in the areas of story retelling delayed (SRD), word learning free recall (WLFR), Generative naming (GN), and object description (OD). Clinical application of the problems with language expression, comprehension and memory in this group was discussed. The importance of being alert to the presence of cognitive-linguistic deficits in this population was recommended, as it may affect the capacity to benefit from dysarthria therapy; and require modification of treatment approaches and goals.

Konstantopoulos and Misikostas<sup>34</sup> aimed to identify quantifiable differences in voice when comparing a group of 64 MS patients and their pair-matched healthy controls through objective voice analysis using electroglottography (EEG). They also correlated findings with other clinical and MRI features. Methods included a neurological exam with type of MS, EDSS rating, and brain MRI with number of T1 and T2 lesions recorded. Global measures of cognition using the Mini-Mental Status Exam (MMSE), depression using the Hamilton Depression Scale (HAMD) and speech were administered. Report of voice and/or articulation difficulties was 45.3% in the MS group. EGG assessment of voice parameters included recorded analysis of sustained phonation, oral reading of a standard passage and 3 minute monologue. Findings indicated more phonatory instability in the MS group during sustained phonation and less variation [fundamental frequency (Fo) range] in reading and monologue. Additionally the MS group exhibited lower scores in cognition and higher scores in depression, while voice variables in the subgroup of males with MS were associated with number of T1 lesions on MRI. The authors emphasized the use of objective instrumental techniques for the measurement of voice in MS and as a biofeedback tool in therapy.

Tjaden and Wilding<sup>35</sup> extended their 2004 study re: the effect of manipulating speaking rate and loudness in dysarthria (see page 8) by examining the impact on fundamental frequency (Fo) and

overall prosodic profile. Greater variation in pitch/intonation (fundamental frequency) has been associated with better speech intelligibility and naturalness. They analyzed the recorded speech of 3 groups: those with Parkinson's Disease (11), Multiple Sclerosis (15), and Healthy controls (14). Acoustic measurements were taken during oral reading of habitual, slow and loud conditions. For all speaker groups, slower than normal rate and increased loudness were found to have opposite effects. Whereas reduced rate showed less variation in fundamental frequency (possibly detrimental), increased loudness showed more variation (potentially beneficial). They discussed implications for treatment of dysarthria and the complex influences on speech intelligibility, which are only beginning to be understood.

## REFERENCES

1. Sorensen PM. Dysarthria. In Burks JB, Johnson KP (eds): *Multiple Sclerosis: Diagnosis, Medical Management, and Rehabilitation*. New York: Demos Medical Publishing, 2000; 21:385–405.
2. Darley F, Brown J, Goldstein N. Dysarthria in multiple sclerosis. *J Speech Hear Res* 1972; 15:229–245.
3. Hartelius L, Runmarker B, Anderson O. Prevalence and characteristics of dysarthria in a multiple sclerosis incidence cohort: In relation to neurological data. *Folia Phoniatr Logop* 2000; 52:160–177.
4. Beukelman D, Kraft G, Freal J. Expressive communication disorders in multiple sclerosis: A survey. *Arch Phys Med Rehabil* 1985; 10:675–677.
5. Hartelius L, Svensson P. Speech and swallowing disorders associated with Parkinson's disease and multiple sclerosis: A survey. *Folia Phoniatr Logop* 1994; 46:9–17.
6. Klugman TM, Ross E. Perceptions of the impact of speech, language, swallowing, and hearing difficulties on quality of life of a group of South African persons with multiple sclerosis. *Folia Phoniatr Logop* 2002; 54:201–221.
7. Netsell R. Physiological studies of dysarthria and their relevance to treatment. In *Normal Aspects of Speech, Language, and Hearing*. Englewood Cliffs, NJ: Prentice-Hall, 1973.
8. Sorensen PM. Speech and voice disorders. In Kalb RC (ed): *Multiple Sclerosis: The Questions You Have, The Answers You Need*. New York: Demos Medical Publishing, 2004; 7:171–186.
9. Duffy JR. *Motor Speech Disorders: Substrates, Differential Diagnosis, and Management*. St. Louis: Mosby Year Book, 1995.
10. Murdoch BE, Theodoros DG (eds). *Speech and Language Disorders in Multiple Sclerosis*. London: Whurr, 2000.
11. Darley FL, Aronson AE, Brown JR. Differential diagnostic patterns of dysarthria. *J Speech Hear Res* 1969; 2:246–269.
12. Hartelius L, Theodoros D, Cahill L, Lillvik M. Comparability of perceptual analysis of speech characteristics in Australian and Swedish speakers with multiple sclerosis. *Folia Phoniatr Logop* 2003; 55:177–188.
13. Darley FL, Aronson AE, Brown JR. Clusters of deviant speech dimensions in dysarthria. *J Speech Hear Res* 1969; 12:462–496.

14. Yorkston KM, Beukelman DR. *Assessment of Intelligibility in Dysarthric Speech*. Austin: Pro-ed, 1984.
15. Hartelius L, Svensson P. *Dysarthri-test*. Stockholm: Psykologiforlaget, 1990.
16. Fitzgerald FJ, Murdoch BE, Chenary HJ. Multiple sclerosis: Associated speech and language disorders. *Aust J Hum Commun Disord* 1987; 15:15–33.
17. Tjaden K, Wilding GE. Rate and loudness manipulations in dysarthria: Acoustic and perceptual findings. *J Speech Lang Hear Research* 2004; 47:766–783.
18. Tjaden K, Watling E. Characteristics of diadochokinesis in multiple sclerosis and Parkinson's disease. *Folia Phoniater Logop* 2003; 55:241–259.
19. Hartelius L, Lillvik M. Lip and tongue function differently affected in individuals with multiple sclerosis. *Folia Phoniater Logop* 2003; 55:1–9.
20. Strand EA. Treatment of dysarthria: Support by evidence-based research and expert opinion. *ASHA Perspectives (Division 2)* 2002; 12(4):3–4.
21. Spencer KA, Yorkston KM. Evidence for the treatment of respiratory/phonatory dysfunction from dysarthria. In Strand EA (ed): *Treatment of dysarthria: Support by evidence-based research and expert opinion*. *ASHA Perspectives (Division 2)* 2002; 12(4):4–16.
22. World Health Organization. *International Classification of Function, Disability, and Health*. 2001. <http://www3.who.int/icf>.
23. Hodge MM. Nonspeech oral motor treatment for dysarthria: Perspectives on a controversial clinical practice. In Strand EA (ed): *Treatment of dysarthria: Support by evidence-based research and expert opinion*. *ASHA Perspectives (Division 2)* 2002; 12(4):22–27.
24. Spencer KA, Yorkston KM. Evidence for the treatment of respiratory/phonatory dysfunction from dysarthria. In Strand EA (ed): *Treatment of dysarthria: Support by evidence-based research and expert opinion*. *ASHA Perspectives (Division 2)* 2002; 12(4):4–16.
25. Ramig LO, Pawlas A, Countryman S. *The Lee Silverman Voice Treatment (LSVT): A Practical Guide to Treating the Voice and Speech Disorders in Parkinson Disease*. Iowa City: University of Iowa, National Center for Voice and Speech, 1995.
26. Sapir S, Pawlas A, Ramig LO, Seeley E, Fox C, Corboy J. Effects of intensive phonatory-respiratory treatment (LSVT) on voice in two individuals with multiple sclerosis. *J Med Speech Lang Path* 2001; 9:141–151.
27. Hammen VL. Managing speaking rate in dysarthria. In Strand EA (ed): *Treatment of dysarthria: Support by evidence-based research and expert opinion*. *ASHA Perspectives (Division 2)* 2002; 12(4):17–21.
28. Beukelman DR, Yorkston KM, Tice R. *Pacer/Tally Rate Measurement Software*. Lincoln, NE: Tice Technology Services, 1997.
29. Berry W, Goshorn E. Immediate visual feedback in the treatment of ataxic dysarthria: A case study. In Berry W (ed): *Clinical Dysarthria*. Austin, TX: Pro-Ed, 1983:253–266.

30. Buzolich MJ. Augmentative and alternative communication (AAC) assessment: Adult aphasia. *ASHA Perspectives (Division 2)* 2006; 16(4):6–12.
31. Mathy P. Augmentative and alternative communication intervention in neurogenic disorders with acquired dysarthria. In Strand EA (ed): *Treatment of dysarthria: Support by evidence-based research and expert opinion*. *ASHA Perspectives (Division 2)* 2002; 12(4):22–27.
32. Yorkston KM, Beukelman DR. Decision-making in AAC intervention. In Beukelman DR, Yorkston KM, Reichle J (eds): *Augmentative and Alternative Communication for Adults with Acquired Neurologic Disorders*. Baltimore: Paul H. Brookes, 2000.
33. Mackenzie C, Green J. Cognitive-linguistic deficit and speech intelligibility in chronic progressive MS. *International Journal of Language and Communication Disorders* 2009; 44(4):401–420
34. Konstantopoulos K, Vikelis M, Misikostas D. The existence of phonatory instability in MS: an acoustic and electroglottographic study. *Neurol Sci* 2010; 31:259–268.
35. Tjaden K, Wilding G. The impact of rate reduction and increased loudness on fundamental frequency characteristics in dysarthria. *Folia Phoniatr Logop* 2010; 63(4):174–186.