The Link between Singing and Respiratory Health for People with Quadriplegia

Jeanette Tamplin, M.Mus, B.Mus(hons) RMT
Austin Health, Melbourne

Abstract
This article presents rationale and methodology for current music therapy research in spinal cord injury (SCI). Respiratory complications are the leading cause of illness and death following SCI and may cause long term hardship for those living with quadriplegia (DeVivo, Krause, & Lammertse, 1999). Music therapy intervention involving singing training may facilitate increased respiratory muscle strength and control for people with chronic C4-C5 quadriplegia. This, in turn, has implications for long-term respiratory health and voice quality. The effect of SCI on respiratory function and voice is discussed, as is the effect of vocal training on respiratory function. The music therapy literature on respiratory rehabilitation is reviewed and used to strengthen the case for investigation into the effect of singing training on respiratory and voice function in SCI. Finally, the methodology for a rigorous research study on this topic is presented.

Keywords: Spinal cord injury, quadriplegia, respiratory function, breathing, speech, singing, voice intensity

Background to the Research

The vulnerability of the voice to neurological damage and its responsiveness to music therapy treatment has continued to fascinate and intrigue me over my 10 years working as a music therapist in neurorehabilitation. The relationship between breath, voice, speech and singing is complex and even more so when affected by neurological damage. Music processing uses different pathways in the brain to verbal processing (Sergent, Zuck, Tenial, & MacDonald, 1992), thus providing a unique role for music therapy in assessment and treatment for speech and language disorders. I have witnessed the importance of effective communication (often in the face of severe physical disability) on the quality of life of my patients and regularly work alongside speech pathologists on communication goals. Effective communication involves not only articulated speech, but expressive qualities such as pitch and volume. My clinical work has often involved the design of music therapy programs to assist with phonation and control of breath, pitch and volume for speech. It was this work that lead to my research on the effects of singing on speech intelligibility for people with dysarthria

(Tamplin, 2008; Tamplin & Grocke, 2008). In addition to improvements in speech intelligibility, this research revealed unforeseen gains in speech naturalness following the singing intervention (probably due improved pitch variation and the effect of organizing the breath into lyrical phrase groups). The impetus for my current research evolved both from this dysarthria research and the commencement of my work in spinal cord injury rehabilitation several years ago. Some of the patients with quadriplegia that I worked with developed greater respiratory control and were able to sing in a way that did not seem feasible given their level of injury. In collaboration with A/Prof Doug Brown (Spinal Rehabilitation Consultant and Director of the Victorian Spinal Cord Service) I assembled a research team and submitted a funding proposal to the Victorian Neurotrauma Initiative to investigate this phenomenon further. We were granted $307,129 over 2 years to conduct two related studies investigating: 1) the physiological mechanisms people with quadriplegia use to sing, and 2) whether singing training can improve respiratory function or train unusual muscle recruitment for voice projection in people with a cervical spinal cord injury.

Spinal Cord Injury

Spinal cord injury (SCI) contributes significantly to worldwide rates of death and disability. In Australia, the annual incidence of SCI in 2006-07 was 14.9 cases per million (Cripps, 2009). Each year in Australia, 300-400 new cases of SCI are added to an estimated prevalent SCI population of about 9,000. Fifty percent of these injuries are at the cervical level (Cripps, 2009), resulting in reduction or loss of motor and/or sensory function in the arms, trunk, legs and pelvic organs. This type of impairment is referred to as quadriplegia or tetraplegia. Given the large percentage of young people with SCI and the increased life expectancy due to improvements in health care provision, any secondary disease or impairment resulting from SCI has a significant effect for many years (Berlowitz, Brown, Campbell, & Pierce, 2005).

Injury to the spinal cord is sudden and dramatically disabling because the spinal cord and nerve cells cannot regenerate. The spinal cord (a long rope-like piece of nervous tissue encased within the spine) is a continuation of the brain with nerves radiating out into the rest of the body, relaying signals up and down the spinal cord (Gray, 1985). When nerves in the spinal cord are damaged, messages cannot travel from the brain to the body's muscles or from the muscles to the brain. For example, a person may lose their sense of touch if nerve messages are not able to travel from the fingers to the brain. Or a person may lose the ability to walk if nerve messages cannot travel from the brain to leg and foot muscles. Transection of the spinal cord results in complete loss of feeling and muscle control in the parts of the body below the injury.

The Effect of SCI on Respiratory Function

Mortality rates are higher for people with SCI than for the able-bodied and the most common causes of death are related to respiratory dysfunction (DeVivo, et al., 1999). In quadriplegia, impairment of the respiratory system causes inefficient ventilation (i.e., energy cost that is high for the ventilation achieved). This respiratory dysfunction is characterised by reduced inspiratory capacity and vital capacity. Vital capacity is defined as the maximum amount of air that a person can exhale following a maximum inspiration and it is correlated with most of the other pulmonary function tests (Roth, et al., 1995). Therefore vital capacity is a useful indicator of overall respiratory function (i.e., ability to breathe deeply, cough effectively and clear secretions). Unlike other, more complicated testing methods, vital capacity can be measured using a convenient, easily transportable, hand-held device. For those with chronic cervical SCI, vital capacity is around 2 litres (i.e., 30-40% of predicted normal values). This may be adequate for a wheelchair-bound life, however does not provide ventilatory reserves necessary to deal with airway infections that can cause decreases of 1–1.5 litres in vital capacity (Fugl-Meyer & Grimby, 1984). Although diaphragm function (the most important muscle of respiration) is spared to varying degrees in SCI lesions below C3 (3rd cervical vertebra, located in the neck), its ability to work effectively is compromised by the paralysis of the abdominal and intercostal muscles.

Respiratory dysfunction following SCI is a major cause of morbidity, mortality and economic burden. Weak or paralysed respiratory muscles lead to reduced lung volume, ineffective cough, increased respiratory tract infections, reduced chest wall compliance, and an increased oxygen cost of breathing (Brown, DiMarco, Hoit, & Garshick, 2006; Chen, Lien, & Wu, 1990). Respiratory muscle atrophy and impaired pulmonary function result from both denervation of respiratory muscles and deconditioning due to lack of use. Therefore, respiratory muscle training may be a viable treatment option (Van Houtte, Vanlandewijck, Kiekens, Spengler, & Gosselink, 2008).

Respiratory Muscle Training in SCI

Like other muscles, the muscles of respiration can be trained for both strength and endurance (Leith & Bradley, 1976). Respiratory muscle weakness and inefficiency of breathing predispose people with quadriplegia to fatigue of the respiratory muscles, but several researchers have reported increased strength and endurance of respiratory muscles following respiratory muscle training (Brown, et al., 2006; Derrickson, Ciesla, Simpson, & Imle, 1992; Gross, Ladd, Riley, Mackelm, & Grassino, 1980; Rutchik, et al., 1998; Uijl, Houtman, Folgering, & Hopman, 1999). Respiratory muscle training typically involves inhaling (or exhaling) through a device against resistance at a target percentage of endurance or maximum pressure for a certain length of time in each training session. However, intensive training with vigorous and forceful effort is needed to produce a significant effect and when training ceases, respiratory function usually deteriorates again.

Singing may achieve comparable benefits to respiratory muscle training and is also likely to enhance breath control. It is sometimes necessary to sustain notes for a considerable length of time when singing and respiratory control is needed to supply the amount of air necessary to complete a line of lyrics. Singing can also provide personal satisfaction and emotional release. In addition, it is likely to facilitate greater compliance with therapy as the treatment (singing) is enjoyable to most people. Given the motivational qualities of music, and the ease and normality of incorporating singing into daily life, therapeutic singing instruction offers great potential for respiratory rehabilitation.

Breathing Patterns and Kinematics for Speech and Singing

During speech, breathing is usually an automatic process, one that requires little or no thought. However, when vocal demands are greater (as during singing), or when respiratory impairment is present, the need for adequate and efficient breath control becomes conscious. Bunch (1993) describes the reflex mechanism for resting breathing as follows: 1) a message from the brain causes the diaphragm to contract and expand the thoracic cavity; 2) this enlargement of the chest pulls on the lungs causing a big drop in pressure in the lungs relative to the pressure of the atmosphere outside which causes a vacuum and air is sucked in; 3) during expiration, the diaphragm relaxes and the lungs and chest wall recoil. This process is repeated about 17 times per minute in the healthy adult at rest (Bunch, 1993). During speech and singing more air passes through the nose than the mouth. Inspirations are quicker and shorter, expirations are longer and slower, and lung volume excursions are larger (Bailey & Hoit, 2002; Binazzi, et al., 2006; Hixon, Goldman, & Mead, 1973; Hoit & Lohmeier, 2000). Also, higher and more sustained expiratory pressures during both singing and speech help to maintain voice loudness at a relatively constant level (Binazzi, et al., 2006; Hoit & Lohmeier, 2000; Stathopoulos, Hoit, Hixon, Watson, & Solomon, 1991).

The Effect of Vocal Training on Respiratory Function

The respiratory system plays a major role in singing as it provides the driving air pressures required to initiate and maintain vocal fold function as well as control prosodic features of vocal intensity and stress. Together with the laryngeal system, it generates the subglottal pressure necessary for vocal fold vibration. The subglottal air pressure requirements are greater for singing tasks than for speaking tasks (Hixon, Mead, & Goldman, 1976; Leanderson & Sundberg, 1988; Leanderson, Sundberg, & Von Euler, 1987; Watson, Hoit, Lansing, & Hixon, 1989). In order to produce vocal sounds, the controlled act of respiration is of major importance. Using singing techniques for respiratory rehabilitation causes the brain to exert conscious control over the otherwise automatic, resting breath cycle. During controlled breathing (as when singing) the cortex takes over direct control of the respiratory muscles by imposing timing priorities on the pace and strength of contractions. The lungs must be able to be filled rapidly, and emptied at a steady controlled rate. Subglottal pressure must reach levels high enough to set the vocal cords in vibration. During singing, the subglottal pressure is approximately four times greater than that during normal conversation (Livingston, 1996). The lungs and muscles of expiration in the thorax and abdominal wall provide this pressure. A large portion (80%) of vital capacity is used, especially during loud singing (Haas, Pineda, & Axen, 1989). Singing exercises may therefore develop muscle control, expand lung capacity and increase vocal intensity.

Breath management can be considered as comprised of two components: breath control and breath support. Breath control is the ability to extend the expiratory phase and utilise the breath efficiently. Breath support is the power behind the voice and can be measured as intensity of speech (Engen, 2005). In the able-bodied, activation of the abdominal and oblique muscles during exhalation creates an internal pressure and energises the column of air. The purpose of breath control is to be able to maintain an energised air column while slowly releasing the air. Both support and control are necessary for a good singing tone, but more importantly, they provide skills for dealing with dyspnea and promoting a confident speaking voice.

The Effect of Quadriplegia on Speech and Voice Function

Common speech characteristics when diaphragm function is spared following SCI include reduced loudness, short phrases and longer inspiratory durations (Hixon & Putnam, 1983; Hoit, Banzett, Brown, & Loring, 1990; MacBean, et al., 2006), as well as deviations in prosody, articulatory precision, and voice quality (Watson & Hixon, 2001). Although most people with quadriplegia are able to maintain an adequate level of loudness during conversational speech in a quiet room, they are likely to encounter difficulties in increasing intensity to project over high levels of background noise (MacBean, et al., 2006; Watson, et al., 1989). Reduced loudness and decreased phonation length following SCI result directly from impaired respiratory function. Therefore, any method that could improve respiratory function for people with quadriplegia might also improve their speech as well.

Music Therapy and Respiratory Rehabilitation

A comprehensive search of the literature revealed three publications investigating the application of music therapy for respiratory function (Engen, 2005; Wade, 2002; Wiens, Reimer, & Guyn, 1999). Wade (2002) showed an increase or maintenance of lung functioning for children with asthma after singing. Wiens et al. (1999) showed an improvement in expiratory muscle strength following music therapy for people with advanced multiple sclerosis. Engen (2005) demonstrated a significant improvement in breath management (extent of counting) and breath support (intensity of speech) for people with emphysema following group vocal instruction, emphasizing breath management techniques.

Following SCI, the ability to produce sufficient subglottal pressure for audible, connected speech may be impaired and appropriate breathing techniques for speech need to be relearned. Acquisition of these skills is often difficult because improvement requires much repetition. When singing, patients are able to organize their breathing and phonation to the rhythmic structure of the music and thus potentially participate for longer periods before fatiguing. Learning how to distribute the breath to sing a musical phrase may help patients to increase both inspiratory capacity and expiratory control. Oral motor and respiratory exercises may be employed in addition to therapeutic singing exercises to enhance articulatory control, respiratory strength, and speech intensity. The rhythmic structure of lyrical phrases provides cues for where to pause and inhale and cues for how many syllables to sing between breaths. Additionally, as the words are propelled by the rhythm and tempo of the music, there is less time for hesitation.

Therapeutic singing exercises can assist patients to develop muscle control, expand lung capacity and increase vocal intensity as has been demonstrated with other clinical populations, such as stroke (Cohen, 1995), Parkinson's disease (Haneishi, 2001), traumatic brain injury (Livingston, 1996), and asthma (Wade, 2002). To date, no research has measured the effect of this type of intervention for patients with SCI.

A Research Study: Singing in SCI

A randomised controlled trial investigating the rehabilitative potential of singing training on respiratory and voice function for people with quadriplegia is currently underway.[1] To ensure specialist input into this research from a range of relevant fields of expertise, a comprehensive

[1] The Victorian Neurotrauma Initiative is gratefully acknowledged for their role in funding this research.

research team (including music therapy researchers, respiratory scientists and physiotherapists, a rehabilitation consultant and speech pathologist) was assembled.

Consenting participants with C4-C5 quadriplegia (at least one year post-injury) will be randomly assigned to experimental or control groups. Participants in the experimental group will undergo group singing training three times a week for 12 weeks. Participants in the control group will participate in group music appreciation and relaxation for 12 weeks. Results will be measured using standardised respiratory function tests, EMG analysis of muscle recruitment and respiratory-inductance plethysmography (RIP)[2] during vocal tasks, and acoustic voice analysis. These assessments will be conducted pre, mid, immediately post, and six months after the intervention. In addition, data will be collected from the following questionnaires: the Profile of Mood States (Lorr, McNair, Heuchert, & Droppleman, 2003), the Assessment of Quality of Life instrument (Hawthorne, Richardson, Osborne, & McNeil, 1997), the Voice Handicap Index (Jacobson, et al., 1997) and a Musical Background Questionnaire (Baker, 2004). Qualitative data will also be collected via focus groups after the invention.

Assessment Protocol

All assessors will be blinded to group allocation. A research assistant will attach EMG electrodes the sternocleidomastoid, trapezius, and diaphragm muscles for each participant and connect these electrodes to a data acquisition unit connected to a computer. The research assistant will also fasten RIP bands around the participant's chest and abdomen and connect these to the data acquisition unit. An acoustic engineer will calibrate a condenser microphone and position it at a distance of 30cm from the participant's mouth. The researcher will then take the participant through a voice assessment protocol. This protocol consists of vocal exercises, standardised reading passages and singing familiar songs. The EMG electrodes and RIP bands will to capture electrical signals from muscle movements during these vocal tasks.

Acoustic parameters of vocal data (pitch, amplitude, and spectral characteristics) will be gathered using the calibrated recording equipment during assessment sessions. This vocal data will be analysed by an acoustic engineer and a speech pathologist specializing in voice analysis will conduct perceptual voice assessments.

Respiratory function assessments will be conducted by respiratory scientists at the Austin Hospital. Ventilatory function and upper airway

---

[2] Respiratory-inductive plethysmography – two elastic bands containing coils are placed around the chest and abdomen to measure the relative contributions of the thoracic/chest and abdominal compartments to ventilation.

function will be assessed using maximal flow-volume loops to determine maximal inspiratory and expiratory flow rates, and timed lung volumes. Static lung volumes will be measured using inert-gas dilution. Respiratory muscle strength will be assessed by measuring maximal inspiratory pressure, maximal expiratory pressure and sniff nasal inspiratory pressures. Patterns of tidal respiration will be assessed using calibrated RIP to document relative contributions to ventilation of thoracic and abdominal compartments.

Music Therapy Singing Intervention

Each participant in the treatment group will participate in one hour of group singing training three times weekly for 12 weeks. This total of 36 training sessions will consist of 16 group-singing training sessions facilitated by a Registered Music Therapist and 20 home training sessions with practise CDs provided. Vocal exercises and song singing form the basis of the therapeutic singing intervention used in this study. The program aims to holistically address all aspects of respiration for singing and speech affected by SCI. The vocal exercises involve physical preparation, oral motor respiratory exercises and pitch and intensity exercises and take approximately 20 minutes to complete. These exercises were designed to develop control and strength in the muscles and mechanisms used for speech and were kept short to minimise fatigue and maximise participation. The song singing component of the intervention incorporates the techniques for improved breath support and control (practised in the vocal exercises) into familiar songs. It consists of group and solo singing of familiar songs with live accompaniment, playing Singstar™ Playstation karaoke games and other "guess the tune" games.

Conclusion

Respiratory function and voice are often comprised for people with quadriplegia due to muscle paralysis, inactivity and deconditioning. Singing training, with its requirements for breath support (inspiratory exercise) and breath control (expiratory exercise) may provide an alternate form of respiratory muscle training. If effective, this type of intervention will have far-reaching implications for respiratory health and voice-related quality of life for people with quadriplegia. No research currently exists in this area. The randomised controlled trial described in this paper is currently underway and results will soon be published. Such research will enhance knowledge of the effects of singing for respiratory and voice rehabilitation and will be of use to music therapists, speech pathologists, physiotherapists and respiratory therapists alike. It is hoped that this study will stimulate further rigorous research into the rehabilitative capacities of therapeutic singing in neurorehabilitation.

References

Bailey, E. F., & Hoit, J. D. (2002). Speaking and breathing in high respiratory drive. *Journal of Speech, Language and Hearing Research, 45*(1), 89–99.

Baker, F. (2004). *The effects of song singing on improvements in affective intonation of people with traumatic brain injury.* Unpublished PhD dissertation, Aalborg University, Denmark.

Berlowitz, D. J., Brown, D. J., Campbell, D. A., & Pierce, R. J. (2005). A longitudinal evaluation of sleep and breathing in the first year after cervical spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 86*, 1193–1199.

Binazzi, B., Lanini, B., Bianchi, R., Romagnoli, I., Nerini, M., Gigliotti, F., et al. (2006). Breathing pattern and kinematics in normal subjects during speech, singing and loud whispering. *Acta Physiologica, 186*(3), 233–246.

Brown, R., DiMarco, A. F., Hoit, J. D., & Garshick, E. (2006). Respiratory dysfunction and management in spinal cord injury. *Respiratory Care, 52*(8), 853–868.

Bunch, M. (1993). *Dynamics of the singing voice* (2nd ed.). New York: Springer-Verlag Wien.

Chen, C. F., Lien, I. N., & Wu, M. C. (1990). Respiratory function in patients with spinal cord injuries: effects of posture. *Paraplegia, 28*(2), 81–86.

Cohen, N. (1995). The effect of vocal instruction and Visi-pitch™ feedback on the speech of persons with neurogenic communication disorders: Two case studies. *Music Therapy Perspectives, 13*, 69–75.

Cripps, R. A. (2009). Spinal cord injury, Australia, 2006-07. *Injury research and statistics series number. 48.* Adelaide: Australian Institute of Health and Welfare.

Derrickson, J., Ciesla, N., Simpson, N., & Imle, P. C. (1992). A comparison of two breathing exercise programs for patients with quadriplegia. *Physical Therapy, 72*(11), 763–769.

DeVivo, M. J., Krause, S., & Lammertse, D. P. (1999). Recent trends in mortality and causes of death among persons with spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 80*, 1141–1419.

Engen, R. L. (2005). The singer's breath: implications for treatment of persons with emphysema. *Journal of Music Therapy, 42*(1).

Fugl-Meyer, A. R., & Grimby, G. (1984). Respiration in tetraplegia and in hemiplegia: a review. *International Rehabilitation Medicine, 6*(4), 186–190.

Gray, H. (1985). *Gray's anatomy: Descriptive and surgical* (15th ed.). London: Chancellor Press.

Gross, E. R., Ladd, H. W., Riley, E. J., Mackelm, P. T., & Grassino, A. (1980). The effect of training on strength and endurance of the diaphragm in quadriplegia. *American Journal of Medicine, 68*, 27–35.

Haas, F., Pineda, H., & Axen, K. (1989). Music and respiration. In H. M. Lee (Ed.), *Rehabilitation, music and human well-being* (pp. 188–205). St Louis, MO: MMB Music, Inc.

Haneishi, E. (2001). Effects of a music therapy voice protocol on speech intelligibility, vocal acoustic measures, and mood of individuals with parkinson's disease. *Journal of Music Therapy, 38*(4), 273–290.

Hawthorne, G., Richardson, J., Osborne, R., & McNeil, H. (1997). *The Australian quality of life (AQoL) instrument:, Initial validation.*Unpublished manuscript, Melbourne.

Hixon, T. J., Goldman, M. D., & Mead, J. (1973). Kinematics of the chest wall during speech production: volume displacements of the rib cage, abdomen, and lung. *Journal of Speech and Hearing Research, 16*, 78–115.

Hixon, T. J., Mead, J., & Goldman, M. D. (1976). Dynamics of the chest wall during speech production: Function of the thorax, rib cage, diaphragm, and abdomen. *Journal of Speech and Hearing Research, 19*, 297–356.

Hixon, T. J., & Putnam, A. H. B. (1983). Voice disorders in relation to respiratory kinematics. *Seminars in Speech and Language, 4*(3), 217–231.

Hoit, J. D., Banzett, R. B., Brown, R., & Loring, S. H. (1990). Speech breathing in individuals with cervical spinal cord injury. *Journal of Speech and Hearing Research, 33*(4), 798–807.

Hoit, J. D., & Lohmeier, H. L. (2000). Influence of continuous speaking on ventilation. *Journal of Speech, Language and Hearing Research, 43*(5), 1240–1251.

Jacobson, B. H., Johnson, A., Grywalski, C., Silbergleit, A., Jacobson, G., Benninger, M. S., et al. (1997). The Voice Handicap Index (VHI): development and validation. *American Journal of Speech-Language Pathology, 6*(3), 66–70.

Leanderson, R., & Sundberg, J. (1988). Breathing for singing. *Journal of Voice, 2*, 2-12.

Leanderson, R., Sundberg, J., & Von Euler, C. (1987). Breathing muscle activity and subglottal pressure dynamics in singing and speech. *Journal of Voice, 3*, 258–261.

Leith, D. E., & Bradley, M. (1976). Ventilatory muscle strength and endurance training. *Journal of Applied Physiology, 41*, 508-516.

Livingston, F. (1996). Can rock music really be therapy: Music therapy programs for the rehabilitation of clients with acquired brain injury. *Australasian Journal of Neuroscience, 9*(1), 12–14.

Lorr, M., McNair, D. M., Heuchert, J. W. P., & Droppleman, L. F. (2003). *Profile of Mood States*. Canada: Multi-Health Systems Inc.
MacBean, N., Ward, E., Murdoch, B. E., Cahill, L., Salley, M., & Geraghty, T. (2006). Characteristics of speech following cervical spinal cord injury. *Journal of Medical Speech-Language Pathology, 14*(3), 167–184.
Roth, E. J., Nussbaum, S. B., Berkowitz, M., Primack, S., Oken, J., Powley, S., et al. (1995). Pulmonary function testing spinal cord injury: correlation with vital capacity. *Paraplegia, 33*, 454–457.
Rutchik, A., Weissman, A. R., Almenoff, P. L., Spungen, A. M., Bauman, W. A., & Grimm, D. R. (1998). Resistive inspiratory muscle training in subjects with chronic cervical spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 79*(3), 283–297.
Sergent, J., Zuck, S., Tenial, S., & MacDonald, B. (1992). Distrbuted neural network underlying musical sightreading and keyboard performance. *Science, 257*, 106-109.
Stathopoulos, E. T., Hoit, J. D., Hixon, T. J., Watson, P. J., & Solomon, N. P. (1991). Respiratory and laryngeal function during whispering. *Journal of Speech and Hearing Research, 34*, 761–767.
Tamplin, J. (2008). A pilot study into the effect of vocal exercises and singing on dysarthric speech. *Neurorehabilitation, 23*(3), 207–216.
Tamplin, J., & Grocke, D. (2008). A music therapy treatment protocol for acquired dysarthria rehabilitation. *Music Therapy Perspectives, 26*, 23–30.
Uijl, S. G., Houtman, S., Folgering, H. T., & Hopman, M. T. (1999). Training of the respiratory muscles in individuals with tetraplegia. *Spinal Cord, 27*, 329–339.
Van Houtte, S., Vanlandewijck, Y., Kiekens, C., Spengler, C. M., & Gosselink, R. (2008). Patients with acute spinal cord injury benefit from normocapnic hyperpnoea training. *Journal of Rehabilitation Medicine, 40*(2), 119–125.
Wade, L. M. (2002). A comparison of the effects of vocal exercises/singing versus music-assisted relaxation on peak expiratory flow rates of children with asthma. *Music Therapy Perspectives, 20*(1), 31–37.
Watson, P. J., & Hixon, T. J. (2001). Effects of abdominal trussing on breathing and speech in men with cervical spinal cord injury. *Journal of Speech, Language and Hearing Research, 44*, 751–762.
Watson, P. J., Hoit, J. D., Lansing, R., & Hixon, T. J. (1989). Abdominal muscle activity during classical singing. *Journal of Voice, 3*, 24–31.
Wiens, M. E., Reimer, M. A., & Guyn, H. L. (1999). Music therapy as a treatment method for improving respiratory muscle strength in patients with advanced multiple sclerosis: a pilot study. *Rehabilitation Nursing, 24*(2), 74–80.