AJSLP

Research Note

Effect of Training Frequency on Maximum Expiratory Pressure

Supraja Anand,[a] Nour El-Bashiti,[a] and Christine Sapienza[a,b]

Purpose: To determine the effects of expiratory muscle strength training (EMST) frequency on maximum expiratory pressure (MEP).
Method: We assigned 12 healthy participants to 2 groups of training frequency (3 days per week and 5 days per week). They completed a 4-week training program on an EMST trainer (Aspire Products, LLC). MEP was the primary outcome measure used to determine the effect of training frequency.
Results: Participants who trained 3 days per week produced equivalent amounts of improvement in MEP compared with participants who trained 5 days per week. An overall improvement in MEP over the 4-week training period indicated a 33% increase when the data was collapsed across the 2 training groups.
Conclusion: The effects occurring with respiratory muscle strength training in healthy young adults are likely to be different from those occurring in patient populations. Therefore, the results of the present study suggest exploring the variable of training frequency in patient populations. Such knowledge will be informative for designing clinical protocols that are effective and may result in improved treatment compliance for those suffering from expiratory muscle weakness.

Key Words: expiratory muscle strength training, training frequency, maximum expiratory pressure

For general fitness purposes, the American College of Sports Medicine (ACSM) recommends a program of eight to 10 exercises, performed 2 to 3 days per week, covering all major muscle groups. Each exercise should be completed using a set number of repetitions (ACSM, 1998). Serving as an important subcomponent of general exercise and rehabilitation, strength training is a valuable method for improving musculoskeletal force production, muscle and bone mass, and connective tissue thickness (ACSM, 1998; Carpinelli & Otto, 1998). Overall, strength training can produce significant health benefits, including reduction in risk of coronary artery disease, improvement of blood glucose regulation, and reduction in risk of type 2 diabetes (ACSM, 2010; Powers & Howley, 2001).

Respiratory muscle strength training (RMST) programs produce effects similar to limb muscle strength training (Kim & Sapienza, 2005; Sapienza & Wheeler, 2006). Through its effects on respiratory muscle strength, RMST has the potential to improve functions of breathing as well as cough, swallow, and speech (Baker, Davenport, & Sapienza, 2005; Kim, Davenport, & Sapienza, 2009; Sapienza, Davenport, & Martin, 2002). Moreover, RMST has been used with a variety of populations including, but not limited to, those with spinal cord injury (Fitsimones, Davenport, & Sapienza, 2004; Sapienza & Wheeler, 2006; Sheel et al., 2008), chronic obstructive pulmonary disease (COPD; Battaglia, Fulgenzi, & Ferrero, 2009; Crisafulli, Costi, Fabbri, & Clini, 2007; Geddes, O'Brien, Reid, Brooks, & Crowe, 2008; Magadle, McConnell, Beckerman, & Weiner, 2007; O'Brien, Geddes, Reid, Brooks, & Crowe, 2008), multiple sclerosis (MS; Chiara, Martin, Davenport, & Bolser, 2006; Chiara, Martin, & Sapienza, 2007; Gosselink, Kovacs, Ketelaer, Carton, & Decramer, 2000; Sapienza & Wheeler, 2006), amyotrophic lateral sclerosis (ALS; Cheah et al., 2009), and Parkinson's disease (PD; Pitts et al., 2009; Saleem, Sapienza, & Okun, 2005; Silverman et al., 2006; Troche, Okun, & Rosenbek, 2010); as well as individuals with voice disorders (Baker, Sapienza, & Collins, 2003; Ruddy et al., 2004).

The two main subtypes of RMST programs include inspiratory and expiratory muscle strength training (IMST and EMST, respectively). The choice of the training depends on desired functional outcomes as well as the muscles involved in achieving these outcomes (Sapienza, 2008; Sapienza & Wheeler, 2006). For example, patients with spinal cord injury at a higher (such as cervical) level may likely have difficulty with both inspiratory and expiratory muscle strength and could be candidates for both types of training, whereas individuals with spinal cord injury at a

[a]University of Florida, Gainesville, FL
[b]Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL
Correspondence to Supraja Anand: supraja.anand@ufl.edu

Editor: Carol Scheffner Hammer
Associate Editor: Kate Bunton
Received May 6, 2011
Revision received October 26, 2011
Accepted April 25, 2012
DOI: 10.1044/1058-0360(2012/11-0048)

Disclosure Statement
Dr. Christine Sapienza has a financial interest as a scientific advisory board member of Aspire Products, LLC.

lower, perhaps thoracic, level may exhibit relatively more difficulty with expiratory muscle weakness and, therefore, be candidates for EMST.

Two main physiologic principles underlie the concept of strength training. First, the exercise stimulus must be sufficient to elicit a change in muscle function. This is referred to as *stimulus intensity* and is usually defined in terms of the amount (or weight) of load and the duration of the exercise task. The second principle concerns the *frequency* of the exercise stimulus, which is usually defined in terms of how many times the exercise is performed (minutes per day/days per week/total weeks).

Previous studies have focused on varying stimulus intensity and frequency levels of EMST (see Table 1). Review of these outcomes suggests that there is no consensus on either the intensity or frequency of training. Therefore, the minimum amount of training required to produce optimum training effects warrants continued investigation. One of the primary outcome measures for defining training with EMST is maximum expiratory pressure (MEP). Directly measuring the number and size of muscle fibers would require invasive procedures; direct measurement of the force output of the human respiratory muscles is also impractical (Tolep & Kelsen, 1993). A less invasive way to measure the overall respiratory muscle strength is by using indices such as maximum inspiratory pressure (MIP) and MEP (Epstein, 1994). MEP is the highest pressure developed during a forceful expiratory effort against an occluded airway (Caskey, Zerhouni, Fishman, & Rahmouni, 1989). The present study was a preliminary evaluation of the effect of EMST frequency on MEP.

Method

Participants. A total of 12 participants (eight women and four men) were included in this study. The average age for the male and female participants was 24.75 years and 23.75 years, respectively. None of the participants had a significant history of upper respiratory infection, chronic or acute cardiac/pulmonary disease, or neuromuscular or immune system disease. Obese participants (based on body mass index [BMI] > 30 kg/m^2) and those with a history of smoking within the preceding 5 years were excluded. Participants were asked to verbally self-report any major changes in their level of physical activity at each visit during their participation in the study, such as enrollment in a new fitness program or restriction of physical activity as a result of injury. None of the participants were discontinued during the study because of a change in activity level. The 12 participants were randomly assigned to the two training frequency groups. Each group consisted of four female and two male participants. A control group was not included because of evidence from prior studies that show a single baseline reliably predicts stability of multiple baseline measures (Baker et al., 2005; Sapienza et al., 2002). Use of single baseline procedures is not atypical in treatment studies to determine outcomes (Herman, Giladi, Gruendlinger, & Hausdorff, 2007; Robbins et al., 2007; Tripoliti et al., 2011).

EMST. An EMST device (Aspire Products, LLC, Gainesville, FL), consisting of a mouthpiece and one-way, spring-loaded valve, was used in this study. This EMST device has been used successfully in previous studies to increase MEP and improve functions related to breathing, cough, and swallow functions (Baker et al., 2005; Chiara et al., 2006, 2007; Gosselink et al., 2000; Kim et al., 2009; Pitts et al., 2009; Saleem et al., 2005; Silverman et al., 2006; Wheeler, Chiara, & Sapienza, 2007; Wingate, Brown, Shrivastav, Davenport, & Sapienza, 2007). When an individual exhales into the device, the one-way valve blocks the airflow until a sufficient threshold pressure is achieved to overcome the spring force. The EMST device used in the present investigation can be calibrated up to a pressure range of 150 cm H_2O, allowing for the pressure load to be varied as the force-generating capacity of the muscles improves. The force-generating capacity of the expiratory muscles is determined by measuring MEP.

TABLE 1. Summary of studies on maximum expiratory pressure (MEP) among different participant groups.

Study	Population Studied	Training Duration	Training Frequency	Training Load (% of MEP)	Outcome
Baker et al., 2005	Healthy subjects	4 and 8 weeks	5 days a week. 5 sets of 5 breaths.	75%	Expiratory muscle strength gains following a 4- and 8-week EMST program do not differ significantly.
Chiara et al., 2006	Healthy subjects, multiple sclerosis	8 weeks	5 days a week. 4 sets of 6 breaths.	Increased by 40%, 60%, and 80%	Increased MEP and peak expiratory flow.
Gosselink et al., 2000	Multiple sclerosis	12 weeks	2 times a day.	60%	Improvement in cough function.
Pitts et al., 2009	Parkinson's disease	4 weeks	5 days per week. 5 sets of 5 breaths.	75%	EMST is a viable treatment modality for individuals with Parkinson's who are at risk of aspiration.
Saleem et al., 2005	Parkinson's disease	4 weeks	5 days per week. 5 sets of 5 breaths.	75%	24%–74% gain of MEP from baseline, Improvement in speech, cough, and swallow functions.
Sapienza et al., 2002	High school band students	2 weeks	5 days per week. 4 sets of 6 breaths.	75%	47% gain of baseline MEP.
Sapienza & Wheeler, 2006	Healthy subjects, multiple sclerosis, spinal cord injury	2 weeks	5 days a week. 5 sets.	75%	50% improvement for healthy subjects, those with multiple sclerosis, and those with spinal cord injury.

MEP measurement. A calibrated digital manometer (Micro RPM, Micro Medical Ltd., Chatham, Kent, United Kingdom) measured MEP. The participants were asked to take a deep breath and blow out as hard and as fast as possible into a mouthpiece connected to the manometer. Each maneuver was performed in a standing position with the participant's nose occluded by nose clips. MEP values were displayed digitally and were recorded by the investigator. Repeated measurements were taken until three MEP values were obtained within 5% of each other to reflect consistency, as in the case of most maximum performance tests. The average of these three values was calculated. For the purposes of training, at the end of every week, the EMST device was set at 75% of each participant's most recent average MEP.

Training protocol. Training with the EMST device for each participant took place over a period of 4 weeks. Each participant's MEP was measured at the initiation of the study, during each week of training (primarily for the purpose of resetting the trainer), and at post-training. Training frequency was determined by group assignment. Participants were randomly assigned to either a "3 days per week" or "5 days per week" training frequency group. Each training session consisted of five sets of five breaths with the EMST device set at 75% of each participant's average MEP. The participants completed the training sessions, at the specified frequency, independently throughout the week. Training log sheets (see Appendix) were issued to the participants every week after their MEP recording. These log sheets helped the participants to monitor their compliance with the study protocol at home. The participants recorded completion of training sets, which was checked when the EMST device was readjusted. Similar training log sheets have been used extensively in home training exercise paradigms to check for compliance (Baker et al., 2005; Cyarto, Brown, & Marshall, 2006; Kim et al., 2009; Liu-Ambrose, Taunton, MacIntyre, McConkey, & Khan, 2003; Risberg, Holm, Myklebust, & Engebretsen, 2007; Saleem et al., 2005; Schoo, Morris, & Bui, 2005). In fact, the Centers for Disease Control and Prevention (2012) recommends the use of such exercise log sheets to help participants monitor their progress in strength training.

Statistical analyses. All statistical procedures were done using SPSS software (Version 20). To examine the differences in MEP measurement pre- and post-training, one-sample *t* tests were done for each group. In addition, an independent-samples *t* test was conducted to examine significant differences between the two training frequency groups. A significance level of $p = .05$ was used for all statistical testing.

Results

Our outcome variable for all analyses (within-group and between-groups) was the pre- to post-training difference in MEP for each participant. The *M* and *SD* data for each of the study groups (3 days per week versus 5 days per week) are depicted in Table 2. To confirm if training had an effect, we conducted one-sample *t* tests on the mean difference in MEP for each of the groups. The mean pre- to post-training difference in MEP for the 5-day group was 27.5 ($SD = 12.1$), and the mean difference for the 3-day group was 36.3 ($SD = 30.8$). There was a significant improvement in MEP scores post-training for 3 days per week, $t(5) = 2.888$, $p = .034$. Similar results were observed for 5 days per week, $t(5) = 5.562$, $p = .003$. An independent-samples *t* test showed that the mean change in MEP between the groups was not significantly different, $t(10) = 0.654$, $p = .528$.

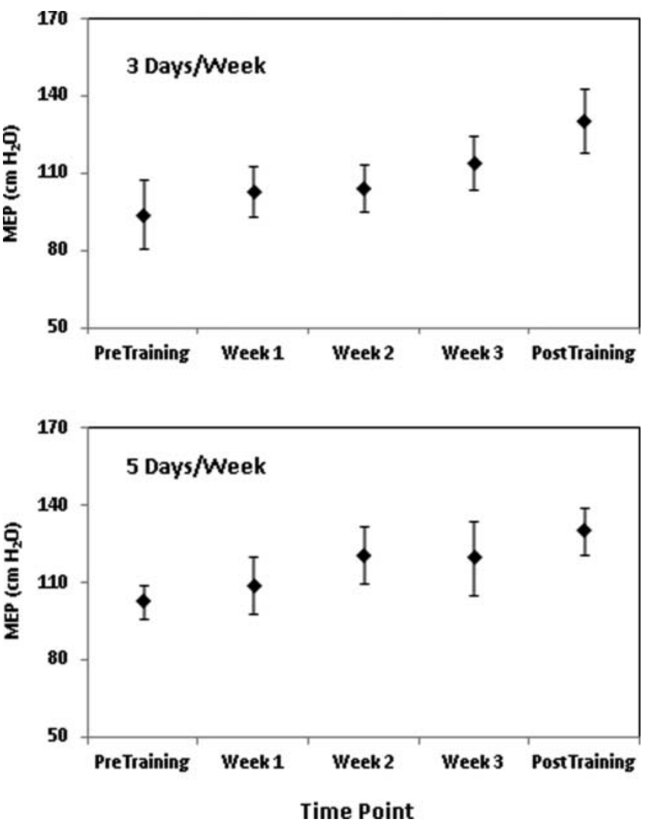
Figure 1 shows the pattern of improvement in MEP scores at the end of every week for each group. It is important to note that this week-to-week examination was not included in any of the main analyses and is reported here only for descriptive purposes. There was a continuous and gradual increase of MEP from the first to fourth week of training across participants in response to the EMST.

TABLE 2. Descriptive statistics for MEP as a function of training frequency.

Study Group	Pre-Training MEP (cm H_2O)	Post-Training MEP (cm H_2O)
3 days/week	94.00 ± 32.74	130.33 ± 30.68
5 days/week	102.67 ± 15.62	130.17 ± 22.43

Note. Plus-minus values represent *M* ± *SD*.

FIGURE 1. Maximum expiratory pressure (MEP) for different training frequencies.



Discussion

The current study examined the effects of training frequency on MEP. Participants were randomly assigned to one of the two training frequency groups (3 days per week or 5 days per week). Each participant completed a 4-week training program on an EMST device set at 75% of MEP level. The increase in MEP between baseline and post-training was 39% and 27% for the participants who trained 3 days per week and 5 days per week, respectively. Thus, the average increase in MEP collapsed across the groups was 33% following a 4-week training program. This reflects an increased expiratory force–generating capacity and is comparable to previously reported MEP increases of 25%–47% in healthy young adults participating in a similar 4-week EMST program (Baker et al., 2005; Sapienza et al., 2002).

The review of literature on strength training has demonstrated beneficial effects on functions of breathing, swallowing, and speech. The conclusions from this review also support the use of EMST as a treatment modality in different clinical populations, such as individuals with COPD, MS, and PD, among others. Strength training protocols commonly require participants to train 5 days per week. However, the literature suggests that reducing training frequency or prescription dosage improves patient compliance (Boulet, 2004; Claxton, Cramer, & Pierce, 2001; Haas et al., 2012; Paes, Bakker, & Soe-Agnie, 1997). With regard to EMST, anecdotal reports indicate that patients would appreciate fewer training days, as they are typically burdened with multiple medical appointments and rehabilitation schedules. This study lays the groundwork that reduction in training frequency to 3 days per week will result in a similar outcome in MEP. By reducing the training frequency from 5 days per week to 3 days per week, the amount of time spent in training is reduced. This step, in turn, should increase patient adherence to the RMST program by minimizing the degree of burden associated with the therapy regimen (Bjornshave & Korsgaard, 2005). While the current results are from healthy young adults and may be different for patient populations, this initial study shows potential in supporting a reduction in training time.

The observed mean difference in MEP change was only 8.83 cm H_2O; therefore, it is not unexpected that the groups did not reveal a significant difference ($p > .05$). To determine if the 3-days-per-week and 5-days-per-week programs are analogous, a future study on a larger sample of healthy individuals across a wide range of ages as well as different patient populations is needed.

Another related study would be to design an experiment in which the training frequency is constant but the intensity load is varied (i.e., 25%, 50%, and 75% of MEP). This would help in determining the optimum treatment intensity for strength training, in the same manner of determining the optimum training frequency. Considerable debate also has emerged over the optimal number of repetitions needed to improve musculoskeletal strength. Some researchers state that multiple sets are necessary to optimize strength gains (e.g., Kraemer, 1997; Rhea, Alvar, & Burkett, 2002; Schlumberger, Stec, & Schmidtbleicher, 2001), while others argue that a single set per exercise is all that is required, and further gains are not achieved by successive sets (Carpinelli, 2002; Carpinelli & Otto, 1998; Otto & Carpinelli, 2006). The above-mentioned studies have focused solely on limb muscle strength. Prospective studies could also investigate the influence of the number of sets of exercise on respiratory function measures. Thus, a combination of frequency, intensity, and number of sets of exercise could help in developing an optimally tailored exercise program to improve respiratory muscle strength in professional voice users and across clinical populations.

Acknowledgments

This work was supported by the Department of Speech, Language, and Hearing Sciences, University of Florida, Gainesville. Additional appreciation is given to Dan Neal, Department of Biostatistics, University of Florida, for his assistance with statistical analysis and interpretation. This study was approved by the institutional review board at the University of Florida (IRB No. 2009-U-1249).
Author Contributions: All authors have contributed to the paper's concept, methods, analysis and discussion. The first and second authors developed the protocol, collected and analyzed data (including statistical analysis), and wrote significant portions of the manuscript as a part of their doctoral requirements. The third author provided mentorship and technical assistance through every phase of the project, and edited significant portions of the manuscript.

References

American College of Sports Medicine. (1998). The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults [Position statement]. *Medicine & Science in Sports & Exercise, 30,* 975–991.

American College of Sports Medicine. (2010). Exercise and Type 2 Diabetes: American College of Sports Medicine and the American Diabetes Association [Joint position statement]. *Medicine & Science in Sports & Exercise, 42,* 2282–2303.

Baker, S., Davenport, P., & Sapienza, C. (2005). Examination of strength training and detraining effects in expiratory muscles. *Journal of Speech, Language, and Hearing Research, 48,* 1325–1333.

Baker, S. E., Sapienza, C. M., & Collins, S. (2003). Inspiratory pressure threshold training in a case of congenital bilateral abductor vocal fold paralysis. *International Journal of Pediatric Otorhinolaryngology, 67,* 413–416.

Battaglia, E., Fulgenzi, A., & Ferrero, M. E. (2009). Rationale of the combined use of inspiratory and expiratory devices in improving maximal inspiratory pressure and maximal expiratory pressure of patients with chronic obstructive pulmonary disease. *Archives of Physical Medicine and Rehabilitation, 90,* 913–918.

Bjornshave, B., & Korsgaard, J. (2005). Comparison of two different levels of physical training in patients with moderate to severe COPD. *Lung, 183,* 101–108.

Boulet, L. P. (2004). Once-daily inhaled corticosteroids for the treatment of asthma. *Current Opinions in Pulmonary Medicine, 10,* 15–21.

Carpinelli, R. N. (2002). Berger in retrospect: Effect of varied weight training programs on strength. *British Journal of Sports Medicine, 36,* 319–324.

Carpinelli, R. N., & Otto, R. M. (1998). Strength training: Single versus multiple sets. *Sports Medicine, 26,* 73–84.

Caskey, C. I., Zerhouni, E. A., Fishman, E. K., & Rahmouni, A. D. (1989). Aging of the diaphragm: A CT study. *Radiology, 171,* 385–389.

Centers for Disease Control and Prevention. (2012). *Physical activity, growing stronger-strength training for older adults, staying on track*. Retrieved from www.cdc.gov/physical activity/growingstronger/staying/index.html.

Cheah, B. C., Boland, R. A., Brodaty, N. E., Zoing, M. C., Jeffery, S. E., McKenzie, D. K., & Kierman, M. C. (2009). Inspirational-inspiratory muscle training in amyotrophic lateral sclerosis. *Amyotrophic Lateral Sclerosis, 10,* 384–392.

Chiara, T., Martin, A. D., Davenport, P. W., & Bolser, D. C. (2006). Expiratory muscle strength training in persons with multiple sclerosis having mild to moderate disability: Effect on maximal expiratory pressure, pulmonary function, and maximal voluntary cough. *Archives of Physical Medicine and Rehabilitation, 87,* 468–473.

Chiara, T., Martin, D., & Sapienza, C. (2007). Expiratory muscle strength training: Speech production outcomes in patients with multiple sclerosis. *Neurorehabilitation and Neural Repair, 21*(3), 239–249.

Claxton, A. J., Cramer, J., & Pierce, C. (2001). A systematic review of the associations between dose regimens and medication compliance. *Clinical Therapeutics, 23,* 1296–1310.

Crisafulli, E., Costi, S., Fabbri, L. M., & Clini, E. M. (2007). Respiratory muscles training in COPD patients. *International Journal of Chronic Obstructive Pulmonary Disease, 2,* 19–25.

Cyarto, E. V., Brown, W. J., & Marshall, A. L. (2006). Retention, adherence and compliance: Important considerations for home- and group-based resistance training programs for older adults. *Journal of Science and Medicine in Sport, 9,* 401–412.

Epstein, S. K. (1994). An overview of respiratory muscle function. *Clinics in Chest Medicine, 15,* 619–639.

Fitsimones, L. B., Davenport, P. W., & Sapienza, C. M. (2004). Expiratory muscle strength training in low cervical/high thoracic spinal cord injury. *American Journal of Respiratory and Critical Care Medicine, 167,* 167–174.

Geddes, E. L., O'Brien, K., Reid, W. D., Brooks, D., & Crowe, J. (2008). Inspiratory muscle training in adults with chronic obstructive pulmonary disease: An update of a systematic review. *Respiratory Medicine, 102,* 1715–1729.

Gosselink, R., Kovacs, L., Ketelaer, P., Carton, H., & Decramer, M. (2000). Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients. *Archives of Physical Medicine and Rehabilitation, 81,* 747–751.

Haas, R., Maloney, S., Pausenberger, E., Keating, J. L., Sims, J., Molloy, E., . . . Haines, T. (2012). Clinical decision making in exercise prescription for falls prevention. *Physical Therapy, 92,* 666–679.

Herman, T., Giladi, N., Gruendlinger, L., & Hausdorff, J. M. (2007). Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: A pilot study. *Archives of Physical Medicine and Rehabilitation, 88,* 1154–1158.

Kim, J., & Sapienza, C. M. (2005). Implications of expiratory muscle strength training for rehabilitation of the elderly: Tutorial. *Journal of Rehabilitation Research and Development, 42,* 183–195.

Kim, J., Davenport, P., & Sapienza, C. (2009). Effect of expiratory muscle strength training on elderly cough function. *Archives of Gerontology and Geriatrics, 48,* 361–366.

Kraemer, W. J. (1997). A series of studies—The physiological basis for strength training in American football: Fact over philosophy. *The Journal of Strength & Conditioning Research, 11,* 131–142.

Liu-Ambrose, T., Taunton, J. E., MacIntyre, D., McConkey, P., & Khan, K. M. (2003). The effects of proprioceptive or strength training on the neuromuscular function of the ACL reconstructed knee: A randomized clinical trial. *Scandinavian Journal of Medicine and Science in Sports, 13,* 115–123.

Magadle, R., McConnell, A. K., Beckerman, M., & Weiner, P. (2007). Inspiratory muscle training in pulmonary rehabilitation program in COPD patients. *Respiratory Medicine, 101,* 1500–1505.

O'Brien, K., Geddes, E. L., Reid, W. D., Brooks, D., & Crowe, J. (2008). Inspiratory muscle training compared with other rehabilitation interventions in chronic obstructive pulmonary disease: A systematic review update. *Journal of Cardiopulmonary Rehabilitation and Prevention, 28,* 128–141.

Otto, R. M., & Carpinelli, R. N. (2006). A critical analysis of the single versus multiple set debate. *Journal of Exercise Physiology Online, 9*(1), 32–57.

Paes, A. H., Bakker, A., & Soe-Agnie, C. J. (1997). Impact of dosage frequency on patient compliance. *Diabetes Care, 20*(10), 1512–1517.

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., Okun, M. S., & Sapienza, C. (2009). Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson disease. *Chest, 135,* 1301–1308.

Powers, S., & Howley, E. (2001). *Exercise physiology: Theory and application to fitness and performance* (4th ed.). New York, NY: McGraw-Hill.

Rhea, M. R., Alvar, B. A., & Burkett, L. N. (2002). Single versus multiple sets for strength: A meta-analysis to address the controversy. *Research Quarterly for Exercise and Sport, 73,* 485–488.

Risberg, M. A., Holm, I., Myklebust, G., & Engebretsen, L. (2007). Neuromuscluar training versus strength training during first 6 months after anterior cruciate ligament reconstruction: A randomized clinical trial. *Physical Therapy, 87,* 727–750.

Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., & Taylor, A. J. (2007). The effects of lingual exercise in stroke patients with dysphagia. *Archives of Physical Medicine and Rehabilitation, 88,* 150–158.

Ruddy, B. H., Davenport, P., Baylor, J., Lehman, J., Baker, S., & Sapienza, C. (2004). Inspiratory muscle strength training with behavioral therapy in a case of a rower with presumed exercise-induced paradoxical vocal-fold dysfunction. *International Journal of Pediatric Otorhinolaryngology, 68,* 1327–1332.

Saleem, A. F., Sapienza, C. M., & Okun, M. S. (2005). Respiratory muscle strength training: Treatment and response duration in a patient with early idiopathic Parkinson's disease. *NeuroRehabilitation, 20,* 323–333.

Sapienza, C. M. (2008). Respiratory muscle strength training applications. *Current Opinions in Otolaryngology and Head and Neck Surgery, 16,* 216–220.

Sapienza, C. M., Davenport, P. W., & Martin, A. D. (2002). Expiratory muscle training increases pressure support in high school band students. *Journal of Voice, 16,* 495–501.

Sapienza, C. M., & Wheeler, K. (2006). Respiratory muscle strength training: Functional outcomes versus plasticity. *Seminars in Speech and Language, 27,* 236–244.

Schlumberger, A., Stec, J., & Schmidtbleicher, D. (2001). Single vs. multiple-set strength training in women. *The Journal of Strength & Conditioning Research, 15,* 284–289.

Schoo, A. M. M., Morris, M. E., & Bui, Q. M. (2005). The effects of mode of exercise instruction on compliance with a home exercise program in older adults with osteoarthritis. *Physiotherapy, 91,* 79–86.

Sheel, A. W., Reid, W. D., Townson, A. F., Ayas, N. T., Konnyu, K. J., & the Spinal Cord Rehabilitation Evidence (SCIRE) Research Team. (2008). Effects of exercise training and inspiratory muscle training in spinal cord injury: A systematic review. *The Journal of Spinal Cord Medicine, 31,* 500–508.

Silverman, E. P., Sapienza, C. M., Saleem, A., Carmichael, C., Davenport, P. W., Hoffman-Ruddy, B., & Okun, M. S. (2006). Tutorial on maximum inspiratory and expiratory mouth pressures in individuals with idiopathic Parkinson disease (IPD) and the preliminary results of an expiratory muscle strength training program. *NeuroRehabilitation, 21,* 71–79.

Tolep, K., & Kelsen, S. G. (1993). Effect of aging on respiratory skeletal muscles. *Clinics in Chest Medicine, 14,* 363–378.

Tripoliti, E., Strong, L., Hickey, F., Foltynie, T., Zrinzo, L., Candelario, J., . . . Limousin, P. (2011). Treatment of dysarthria following subthalamic nucleus deep brain stimulation for Parkinson's disease. *Movement Disorders, 26,* 2434–2436.

Troche, M. S., Okun, M. S., & Rosenbek, J. (2010). Aspiration and swallowing in Parkinson disease and rehabilitation with EMST: A randomized trial. *Neurology, 75,* 1912–1919.

Wheeler, K., Chiara, T., & Sapienza, C. (2007). Surface electromyographic activity of the submental muscles during swallow and expiratory pressure threshold training tasks. *Dysphagia, 22,* 108–116.

Wingate, J. M., Brown, W. S., Shrivastav, R., Davenport, P., & Sapienza, C. M. (2007). Treatment outcomes for professional voice users. *Journal of Voice, 21,* 433–449.

Appendix

Sample Training Log

(sub 11)

Effect of Expiratory Muscle Strength Training (EMST) frequency on Maximum Expiratory Pressure

EMST Training Log

Start date 9/20/2010
Week No.: 2

75% : 80

MEP 1: 106	MEP 2: 101	MEP 3: 113	Avg. MEP: 106.6

Trainer setting 80 (If trainer moves off this mark, adjust back to this number)

Date	Time	SET 1 (5 breaths)	SET 2 (5 breaths)	SET 3 (5 breaths)	SET 4 (5 breaths)	SET 5 (5 breaths)
9/21/10	1:30	卌	卌	卌	卌	卌
9/23/10	1:00	卌	卌	卌	卌	卌
9/26/10	1:15	卌	卌	卌	卌	卌

Next appointment: Date 9/27/2010 Time 9:30 am

Questions or problems: Please contact

Supraja Anand

Nour El-Bashiti

Supervisor:
Christine Sapienza, Ph.D