# Applications of Exercise Science in Dysphagia Rehabilitation

*Lori M. Burkhead*

Department of Otolaryngology, Medical College of Georgia
Augusta, GA

## Abstract

*Dysphagia clinicians are charged with improving strength, skill, and endurance in order to rehabilitate oropharyngeal swallowing. The obvious method is exercise training. Dysphagia clinicians often use trial-and-error and experience to develop effective regimens. This article is intended to invoke broader and more accurate perspectives from our colleagues in exercise science.*

## Introduction

There is a charge in our field for more methodologically sound, exercise-based treatment regimens for dysphagia. Even with the strides made, the volume of evidence lags behind the need. As practitioners treating patients with swallowing disabilities today, we must incorporate existing evidence as best we can, even if we need to look beyond the confines of our own research literature to do so. There is much to be learned from the exercise science literature. Even though the skeletal muscles in our colleagues' literature differ in structure and function from oropharyngeal muscle, the basic principles apply. Despite these differences, we can scaffold our clinical practice and research endeavors onto these principles for effective exercise. As research unfolds in dysphagia rehabilitation, nuances may emerge on how to best structure exercise programs. Nonetheless, because we are armed with a working knowledge of the aerodigestive mechanism, these resources provide us with a foundation upon which to build treatment regimens. The intent of this article is to provide the reader with a basic understanding of neuromuscular function and exercise principles to assist the clinician with more effective treatment development. A more detailed review is provided by Burkhead, Sapienza, and Rosenbek (2007).

## Structure and Function

Fundamental knowledge of muscle composition and neuromuscular physiology is essential to understanding movement and exercise. Whole muscle is composed of hierarchically arranged fibers that can be broken down into functional units. The largest functional unit is the myofibril. Myofibrils are arranged in parallel, bundled together to form a muscle fiber. Myofibrils can be divided into sub-units known as sarcomeres, which are arranged end-to-end and are considered to be the "workhorse" of contraction. Sarcomeres contain myofilaments with two major types of contractile proteins: actin and myosin. When activated, actin and myosin interdigitate in a repetitive cycle causing the myofilaments to slide together and shorten. This shortening ultimately results in contraction (Figures 1 and 2). Contraction alone does not necessarily result in functional movement, which is what occurs when muscle contraction meets intent.

*Figure 1*

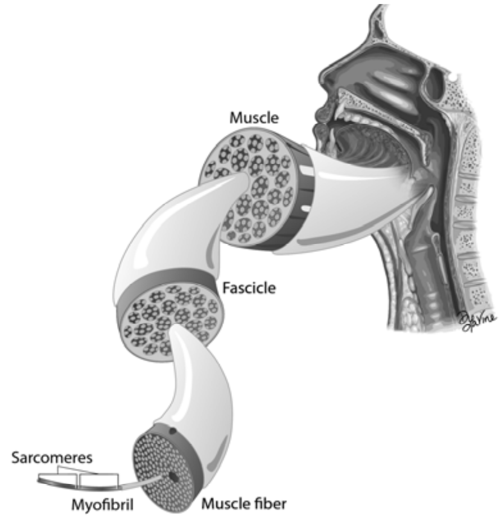
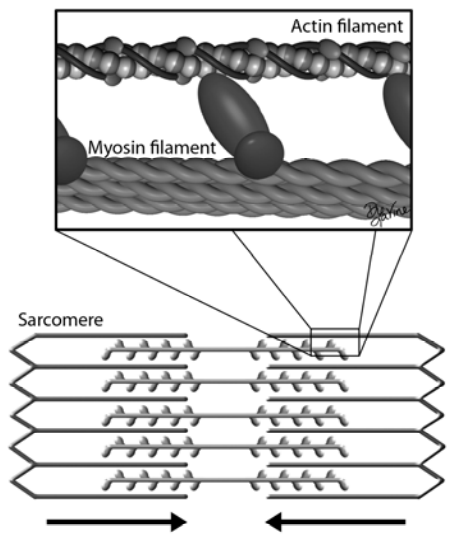



*Figure 2*




Movements are caused by a cascade of events, beginning within the central nervous system. The intent to move is communicated from the central nervous system to the periphery through electrochemical events known as an action potential. This impulse (or action potential) is transmitted across the neuromuscular junction through the release of the neurotransmitter acetylcholine (Ach) that binds to postsynaptic receptors on the muscle membrane. The action potential is then transmitted deep into the muscle by way of an intricate lattice-like network of structures known as the transverse tubule system. The action potential triggers a chemical reaction deep within the muscle fiber that ultimately results in actin and myosin cross bridge formation and resultant muscle contraction. A coordinated series of muscle contraction and relaxation in agonist and antagonist muscles produces purposeful movement.

The type of fibers that make up a muscle determines the force produced (strength). It also determines how well a muscle responds over time (endurance). Several types of fibers are present in muscle, but there is a predominance of one type or another. In general, skeletal muscle fibers can be categorized as Type I or Type II. Fiber type determines the bioenergetic properties of a muscle (i.e., the type of fuel it uses to work and it's "fuel efficiency") as well as its force-generating capacity. Comparatively speaking, Type I fibers are smaller in diameter and produce less force than Type II fibers. While Type II fibers are structurally superior for force generation, their bioenergetic characteristics predispose them to fatigue more quickly than Type I fibers. Therefore, muscles with mostly Type II fibers are better-suited for quick, forceful movements, and muscles with mostly Type I fibers are characteristically better for low-force, high-endurance activities.

Kent (2004) provides an enlightening review highlighting the uniqueness of the oropharyngeal musculature and how its structure and function differs vastly from any other muscle group in the human body. The same muscles that constrict the aerodigestive tract to create positive pressure to drive a bolus through the upper aerodigestive tract must also dilate the same chamber to decrease resistance during inhalation. Because form follows function, it is not surprising that the architecture and muscle fiber types in the aerodigestive tract are unlike any other in the human body. This phenomenon is best illustrated in the genioglossus muscle that makes up the tongue body. The anterior portion contains primarily Type I fibers, which are best suited for producing movements requiring low force but high endurance. This is conducive to repetitive, low-force movements necessary in manipulating food during mastication and to collect and form food particles into a cohesive bolus. Posteriorly, there is an accumulation of Type II fibers, which are best suited for quick, ballistic movements necessary to drive a bolus though the hypopharynx and toward the esophagus during swallowing. While a mixture of fibers exist, the majority of upper aerodigestive tract muscles are Type II.

## Deconditioning vs. Conditioning

Many individuals with dysphagia are deconditioned or have decreased physical fitness. Deconditioning may occur due to disease, injury, or disuse, and even occurs in normal aging (a phenomenon termed "sarcopenia"). When muscle is not utilized to its usual capacity, neuromuscular changes occur. No matter the cause, deconditioning occurs quickly and tends to preferentially affect Type II fibers, which would likely affect swallowing because the swallowing musculature is predominantly Type II.

Changes that occur in response to deconditioning include muscle atrophy (loss in cross sectional area) and a shift in the muscle fiber type, making it less efficient and more easily fatigable. With less size comes less force-generating capacity or strength. Structural adaptation not only occurs in the muscle, but also in the nervous system driving muscle activation. The number of motor units (the nerve plus all the muscle fibers it innervates) decreases. Not only are there less motor units available to drive movement, but synchronization is also altered. These alterations result in weaker, slower, and less efficient movement.

Deconditioning can occur quickly. Anyone who has taken a break from their favorite sport or working out at the gym has likely been surprised at how quickly strength, endurance, and performance diminish. Mujika and Padilla (1997) report significant decreases in strength gains as soon as 4 weeks after ceasing strength training. In a study investigating the effects of chronic bed rest in healthy individuals, Bloomfield (1997) reports that muscle mass decreases dramatically accompanied by as much as a 40% decrease in strength. Of note, these deleterious neuromuscular adaptations are even more pronounced in those with co-morbid disease and the aged (Urso, Clarkson, & Price, 2006).

While oropharyngeal deconditioning has not specifically been investigated, we know that swallowing frequency, at rest, differs when comparing hospitalized patients with to those without dysphagia. Murray, Langmore, Ginsberg, and Dotsie (1996) observed that individuals with dysphagia produce less spontaneous saliva swallows than other hospitalized but non-dysphagic individuals. This reduced activity may be the result of deconditioning as well as an underlying disease or disorder. In addition, those relying on non-oral feeding methods have less opportunity to swallow, which may only exacerbate the deconditioning process.

Adaptations in response to exercise training begin with nervous system changes followed by structural changes in muscle. The first changes are manifest as an increase in the number of motor units recruited or the speed and coordination of motor unit recruitment (Powers & Howley, 2001). These early modifications can improve force production, coordination, and skill. Over time, the relative contribution of neural adaptation decreases as the muscle fiber begins to hypertrophy (muscle fiber enlargement) and shift toward improved endurance (Powers & Howley, 2001).

## *Exercise vs. Activity*

There are criteria that distinguish mere activity from effective, goal-oriented exercise. There are numerous ways to approach exercise and specific methods that can be conducted; a discussion of all methods available is beyond the scope of this paper. This article will address the overriding principles for activity to qualify as exercise. However, interested readers can further explore how many of these concepts apply to speech-language pathologists in a tutorial by Clark (2003). Once underlying physiologic deficits are identified, the clinician should determine the treatment objective. Is it to improve strength, coordination, speed, or some combination thereof? With this in mind, the clinician should devise a targeted program, being mindful of the principles of intensity and specificity.

### Intensity

Activity that does not force the body beyond its usual level of activity will not result in neuromuscular adaptation (Pollock et al., 1998). The overload principle dictates that, when demand is consistently greater than one's capacity, adaptations are forced to occur in order to meet the heightened demand. The intensity of the activity must be elevated both within a session and over time in order to trigger the need for adaptation. There is no definitive agreement on exactly how many sets (the number of times an exercise activity is done) or repetitions (the number of times an exercise movement is repeated within a set) should be done to elicit the best outcomes. It likely varies greatly across age and fitness level. Rather, one should focus on working to the point of fatigue instead of simply performing a specific number of sets and repetitions. The American College of Sports Medicine offers some guidelines (Pollock et al., 1998) to help guide training efforts. To elicit strength gains, one should provide a load or resistance of 60% or more of maximum capacity. This can be expressed as a percentage of the load a person can bear with maximal effort on one repetition of an exercise. This is often referred to as the 1-repetition maximum (1RM). As strength increases and an individual's 1RM improves, the 60% value for training should be adjusted accordingly. The load must progressively increase throughout a training program in order to account for strength changes and to insure that the overload principle continues to be met. This practice is known as progressive resistance. Our literature contains excellent examples of exercises targeting dysphagia that adhere to the principles of overload and/or progressive resistance.

It is common for clinicians to utilize swallowing maneuvers repetitively in sets and repetitions as a form of swallowing exercise [e.g., Mendelsohn maneuver, tongue-holding maneuver (a.k.a., the Masako)]. While its use of these makes sense, there are no studies investigating the specific effect of the repetitive use of these for exercise, nor is there an agreed-upon method or regimen for doing so. While clinicians might use the concepts presented here in attempt to use these "traditional" approaches more effectively, there are some exercises regimens empirically studied and reported in our literature. Two studies incorporating high-intensity exercise and the overload principle are the Shaker Head Lift and Lee Silverman Voice Treatment (LSVT). The Shaker Head Lift exercise requires participants lie supine, lifting the head in an intense, structured protocol of varying repetitions and durations (Shaker et al., 2002). Following 6 weeks of this regimen, the authors report that individuals with dysphagia showed significant improvement in the following parameters:  upper esophageal sphincter opening in the anterior-posterior direction, anterior laryngeal excursion, improved bolus clearance, and safety and efficiency of oral intake. LSVT is a high-effort program targeting respiratory system and larynx that is intended for treating voice disorders in those with Parkinson's disease (PD). El Sharkawi, Ramig, Logemann, Pauloski, Rademaker, Smith, Pawlas, Baum, and Werner (2002) reported that following 4 weeks of LSVT, individuals with PD exhibited significant improvements in a number of oral, pharyngeal, and laryngeal swallowing measures.

There are two specific strength-training techniques that can improve swallowing function. Robbins, Gagnon, Theis, Kays, Hewitt, and Hind (2005) discovered that training healthy lingual muscle at or above 60% of 1RM could significantly increase force generating capacity of the tongue. Furthermore, following an 8-week progressive resistance lingual training program, individuals who had experienced stroke with dysphagia also improved oral pressure generation and airway protection during swallowing (Robbins, Kays, Gagnon, Hind, Hewitt, Gentry, & Taylor, 2007). Additionally, two participants exhibited increased lingual volume on magnetic resonance imaging (MRI), suggesting muscle hypertrophy in response to training. These findings suggest a training effect, not only in the tongue but also possible changes to structures involved in swallowing. Another strength training exercise affecting swallowing is expiratory muscle strength training (EMST). Pitt, Bolser, Rosenbek, Troche, Okun, and Sapienza (2008) reported that, following a 4-weeks of EMST, individuals with PD improved maximal expiratory pressure generation and airway protection during swallowing. During training, participants exhaled against a load of 75% of their maximal expiratory pressure. This activity has been shown to elicit high levels of neuromuscular activity in the suprahyoid muscle group, which is important for hyolaryngeal elevation and airway protection (Wheeler, Chiara, & Sapienza, 2007). Both resistive lingual exercise and EMST incorporated overload and progressive resistance thereby forcing adaptations in one or more of the subsystems involved in swallowing. These regimens involve specific muscle strengthening that resulted in carryover during swallowing. The exercise literature suggests that even greater outcomes may be elicited if paired with task-specific exercise.

### Specificity

Movement is synergistic. Several movements must occur together to result in an activity. An athlete might perform "drills" that break down their sport into smaller tasks. Athletes perform drills to build specific strength and skill, but this is always followed by performing the sport as a whole. Exercise science literature has shown, undoubtedly, that the greatest gains in performance occur when the training task resembles the target activity as much as possible. For example, a baseball player who forcefully swings a bat to hit a ball may not have his skill translate to golf wherein he still must swing an instrument to hit a ball, but in a very different way. Even though the tasks are quite similar and the same muscles are used, the ways in which they are recruited differ greatly. In addition, participating in general "endurance" or "strengthening" exercises may not necessarily be enough to force the neuromuscular adaptations needed to improve a particular activity. The principle of task specificity indicates that exercise that closely mimics the end-goal will result in the greatest improvements in performance. Hence, one must practice sprints to become a better sprinter or long-distance running to become a better marathon runner. Likewise, one might postulate that swallowing tasks need to be incorporated to achieve the optimum outcomes for improved swallowing. Clearly, swallowing can improve with non-swallowing exercises that target the involved structures and subsystems as noted previously. However, further research is warranted to investigate whether or not pairing these exercises with swallowing activities will maximize outcomes and speed results.

## Conclusion

In summary, our field has made strides toward developing evidence-based exercise regimens that integrate exercise science principles. Clinicians can utilize established treatments and other exercise tasks by adhering to the overlying principles from exercise science to develop more effective treatments.

## References


Bloomfield, S. (1997). Changes in musculoskeletal structure and function with prolonged bed rest. *Medicine and Science in Sports and Exercise, 20*, 197-206.

Burkhead, L. M., Sapienza, C. M., & Rosenbek, J. C. (2007). Strength-training exercise in dysphagia rehabilitation: Principles, procedures and directions for future research. *Dysphagia*, *22*, 251-265.

Clark, H. M. (2003). Neuromuscular treatments for speech and swallowing: A tutorial. *American Journal of Speech-Language Pathology, 12*, 400-415.

El Sharkawi, A., Ramig, L., Logemann, J., Pauloski, B., Rademaker, A., Smith, C., Pawlas, A., Baum, S., & Werner, C. (2002). Swallowing and voice effects of Lee Silverman Voice Treatment (LSVT): a pilot study. *Journal of Neurology, Neurosurgery, and Psychiatry, 72*, 31-36.

Mujika, I., & Padilla, S. (1997). Muscular characteristics of detraining in humans. *Medicine and Science in Sports and Exercise*, *33*, 1297-1303.

Murray, J., Langmore, S., Ginsberg, S., & Dotsie, A. The significance of accumulated oropharyngeal secretions and swallowing frequency in aspiration. *Dysphagia*, *11*, 99-103.

Pitt, T., Bolser, D., Rosenbek, J., Troche, M., Okun, M., & Sapienza, C. (2009). Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson disease. *Chest,* [ePub ahead of print, November 24, 2008].

Pollock, M. L., Gaeser, G. A., Butcher, J. D., Despres, J., Dishman, R. K., Franklin, B. A., & Garber, C. E. (1998). ACSM position stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Medicine and Science in Sports and Exercise 30*, 975-999.

Powers, S. K., & Howley, E. T. (2001). *Exercise physiology* (4th ed.). New York: McGraw-Hill.

Robbins, J., Kays, S. A., Gagnon, 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.

Shaker, R., Easterling, C., Kern, M., Nitschke, T., Massey, B., Daniels, S., Grande, B., Kazandjian, M., & Dikeman, K. (2002). Rehabilitation of swallowing by exercise in tube-fed patients with pharyngeal dysphagia secondary to abnormal UES opening. *Gastroenterology*, *12*, 1314-1321.

Urso, M., Clarkson, M., & Price, T. (2006). Immobilization effects in young and older adults. *European Journal of Applied Physiology*, *96*, 564-571.

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