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Exercise Prescription for Dysphagia: Intensity and Duration Manipulation

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Abstract

This paper briefly reviews information available on exercise stimulus intensity and its interaction with stimulus duration, as well as reviews the current information on different dysphagia treatment modalities as they relate to treatment intensity and duration. The available literature in this area suggests that exercise modalities are distinct and different with regard to the metabolic pathways accessed as a function of both stimulus intensity and duration. Defining treatment prescriptions for dysphagia is difficult at this time, however, because only limited data on stimulus duration or intensity is available for existing indirect and direct treatments. Acknowledgment of exercise physiology paradigms and mechanisms of muscle response to treatment is critical to design of rehabilitation protocols.

Introduction

Presently, there is a vast array of options available to clinicians for dysphagia rehabilitation. These options include direct treatments involving compensatory strategies and maneuvers that involve bolus manipulation and swallowing of a bolus, as well as indirect treatments such as stimulation and/or exercise used to stimulate swallowing function and to restore oropharyngeal activity without the swallowing of a bolus (Neumann, Bartolome, Buchholz, & Prosiegel, 1995). Depending on a clinician's availability and other treatment indicators, therapy may be prescribed 1 to 7 days per week, in clinical settings, in home-based settings, for a few minutes to several hours and/or across one or multiple sessions per day. The number of trials, or repetitions, within those sessions varies as well. All of these variables contribute to the *defined* exercise prescription of the treatment, and presently a gold standard does not exist for the most optimal prescription for the majority of treatment options. Typically, *exercise prescription* includes the *intensity, duration, mode* and *frequency* of the exercise. This paper focuses on a few aspects of an exercise prescription, that of treatment *intensity* and that of treatment *duration*. They are distinct and can be manipulated independently.

Generally, rehabilitative treatments for dysphagia, which are discussed below, target either muscle force production or coordination of swallow skeletal muscles to ensure a more efficient and safe swallow. Some treatments achieve these targets via direct exercise, some via indirect exercise, and some via sensory rather than motor stimulation.

With regard to an exercise's treatment intensity, we believe it should be defined in our literature solely as the intensity of a stimulus delivered during exercise and should only be used when referring to the *magnitude* of the intensity of the training stimulus. The magnitude of the intensity may be expressed in a number of different ways. For example, we may define it as the mechanical or resistive load provided during exercise, or we may establish a measure of the percentage of maximum performance that is targeted during a task (e.g., 50% of maximum effort). In these instances, the measure of mechanical or resistive load and the performance level of 50% of maximum effort constitute specifications of treatment intensity. While some of the exercise-based treatments used in the rehabilitation of dysphagia provide a calibrated method in which to manipulate the magnitude of stimulus intensity, most do not.

Treatment duration, on the other hand, is the *length of time* a given magnitude of stimulus intensity is applied within and/or across treatment sessions. Treatment duration can also be expressed in a number of different ways. For example, a stimulus of a magnitude of 50% of maximum effort may be required during 5 seconds of exercise. Alternatively, a given magnitude of resistive load may be applied to a muscle during training in two sessions per week. Five seconds of sustained effort and two sessions per week are examples of specifications of treatment duration. Some exercise-based treatments used in dysphagia rehabilitation (especially indirect treatments) do provide specific recommendations of treatment duration, but continued work in this area is needed.

Depending on the intensity and duration of the therapeutic stimulus, the metabolic pathways that will be accessed for chemical energy transport in the body are different (Brooks, Fahey & Baldwin, 2005; Powers & Howley, 2001). Basically, the body has three systems that produce the energy, or adenosine 5'- triphosphate (ATP), required for the occurrence of a muscular contraction. These three systems produce various amounts of ATP at different rates and consist of an aerobic system (oxidative system) and two anaerobic systems (alactic or creatine phosphate system and glycolytic system). While all three systems are activated simultaneously, the relative contribution of each system to the process of producing ATP depends on the intensity and duration of the exercise. Muscle contractions, or exercise, for only a few seconds are completely independent of oxygen drawn from the environment; therefore, the metabolic power required for these bursts is believed to be provided almost entirely by anaerobic sources of muscular energy. Appropriate for quick movements, the anaerobic, phosphocreatine (PCr) system provides energy four to five times faster than the aerobic system; however, there is only enough energy for about 4 to 10 seconds and it takes nearly 2 minutes for this system to replenish itself. The glycolytic system provides around four times more ATP than the PCr system and is about two to three times faster than the aerobic system; however, it is less efficient than the aerobic system whereby energy supply is limited and easily depleted. On the other hand, the aerobic system, which requires oxygen to produce ATP, takes about 2 minutes to reach full capacity, but can provide energy for hours. Both the aerobic system and glycolytic system work in conjunction with each other.

We believe that training of the anaerobic energy system that produces the ATP quickly (Powers & Howley, 2001) is necessary to improve the forceful muscular contractions that are warranted for swallowing, whereas training of the aerobic system is necessary to improve muscular endurance and maintain that forceful contraction over a period of time. Furthermore, based on the specificity of training principles and this paradigm, a balanced training of both systems must be considered for completion of the repetitive swallowing that is required over the course of a meal.

Hence, it is important to base the intensity and duration of the treatment on a target that can be met and sustained. It is also important to train a muscle's response for the type of task in which you are trying to improve function, either that of a brief forceful contraction or that of a sustained muscle contraction over a longer period of time. Proper rest intervals between each contraction must be implemented to continually produce the intended force, in order to get maximum benefit of the training and to prevent fatigue.

In reviewing the dysphagia literature, we have identified several interesting findings. First, the definition of training intensity is varied, with some authors including magnitude and duration within the definition. As stated above, we follow the exercise physiology literature which defines training intensity as stimulus magnitude *only,* while recognizing that an exercise prescription can manipulate intensity and duration independently (Baechle, Earle, & Wathen, 2000; Brooks et al., 2005). The next section reviews what we have covered about treatment prescription in terms of duration and intensity within the scope of existing dysphagia treatments.

Direct Treatments

Currently, there is no duration or intensity data available for individual direct dysphagia treatments, including the Mendelsohn maneuver, effortful swallow, supraglottic swallow, and super-supraglottic swallow. This is because they have been studied predominantly in combinations (either with each other or with other indirect treatments), making the definition of treatment prescription very difficult. One study suggests the implementation of the Mendelsohn maneuver and effortful swallow (in combination with other treatment modalities) act in a "preventative" manner to help improve swallowing outcome in head and neck cancer patients when delivered prior to chemo-radiation treatment (see Table 1; Carroll et al., 2008). In addition, studies of acute stroke patients (1-3 weeks post onset) indicate improvements in diet tolerance and oral and pharyngeal function and reduction of material penetrating the airway following implementation of combinations of direct therapies (see Table 1; Carnaby, Hankey, & Pizzi, 2006; Emstahl, Bulow, Okberg, Peterssen, & Tegner, 1999). Thus, it is possible that direct therapies can help to prevent the "lose it" portion of the "use it or lose it" principle defined in the field of neuroplasticity (for review, see Kleim and Jones, 2008) when applied in a prophylactic manner (as in head and neck cancer), or in the acute phase post neurologic injury, as in stroke.

View this table: Table 1. Summary of Treatment Studies

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Study	Subjects	Treatment	Time to Treatment Onset	Diagnoses
Carnaby et al., 2007	N = 306	Direct and indirect treatments (combinations)	0 to 7 days	Stroke
Crary et al., 2004	N = 45	Biofeedback with Mendelsohn maneuver	Average: 16.5 to 24.8 months	Stroke and head and neck cancer
El Sharkawi et al., 2002	N = 8	LSVT	Not Applicable	IPD (Hoehn & Yahr stage IV)
Robbins et al., 2007	N = 10	Lingual exercise	n = 4: more than 3 months n = 6: less than 3 months	Stroke
Shaker et al., 2002	N = 27	Sustained and repetitive head raise exercise	9 to 2880 days Post-hoc groupings: 1. 0-2 months 2. 2-4 months 3. 4-6 months 4. 6+ months	Abnormal upper esophageal sphincter opening; variety of causes (stroke, radiation, surgery)
Troche et al., 2008	N = 18	EMST	Not Applicable	IPD (Hoehn & Yahr rating of II-III)
Freed et al., 2001	N = 99	Electrical stimulation	Not stated	Multiple etiologies
Leelamanit et al., 2002	N = 23	Synchronized electrical stimulation	At least 2 months with dysphagia	Dysphagia with reduced laryngeal elevation (multiple etiologies)
Ludlow et al., 2007	N = 11	Electrical stimulation	At least 6 months with dysphagia	Stroke, traumatic brain injury, craniotomy, IPD
Rosenbek et al., 1998	N = 45	Thermal-tactile application	1 to 12 weeks	Stroke
Emstahl et al., 1999	N = 52	Direct and indirect swallow therapies (various combinations)	2 weeks	Ischemic or hemorrhagic stroke
Carroll et al., 2008	N = 18	Tongue hold (Masako), tongue resistance, Shaker head raise, effortful swallow, Mendelsohn maneuver	*Pre-treatment* = 2 weeks prior to radiation treatment *Treatment* = after completion of radiation treatment	Cancer (oropharynx, hypopharynx, larynx)
Neumann et al., 1995	N = 58	Direct and indirect treatments	Post-hoc assignment: Less than 25 weeks More than 25 weeks	Ischemic or hemorrhagic stroke, traumatic brain injury

Note: LSVT = Lee Silverman Voice Therapy. EMST = Expiratory muscle strength training. IPD = Idiopathic Parkinson Disease.

It is known that some of these swallow exercises (specifically, the Mendelsohn maneuver and effortful swallow) increase motor output (activation) of swallowing muscles, such as the submental muscle group (e.g., Wheeler, Rosenbek, & Sapienza, in press). Quantifying the magnitude of stimulus intensity as well as treatment duration would be a next logical step in prescribing these treatments. For example, using the magnitude of submental muscle contraction as measured by surface electromyography (sEMG) to set treatment targets (e.g., 75% of maximum muscle contraction) for the effortful swallow would define an intensity level for this treatment. Further, each direct treatment is delivered over short periods of time (one repetition of each task may take only 1-2 seconds), which indicates that ATP for these muscle contractions would be accessed primarily via anaerobic pathways, with possible contribution of the aerobic mechanism when multiple trials are performed over a long treatment session (Powers & Howley, 2001). This is similar to what would be expected during "normal" swallowing (i.e., during a meal). Therefore, direct treatment tasks may be more desirable because they guide the intervention effects towards the same mechanisms underlying muscle contractions, more closely representing realistic swallow conditions. For example, the duration of treatment may include a specific number of trials (e.g., 30) over a 30-minute session (approximating the length of a meal), 5 days per week. This type of treatment task would be doable for most patients since the duration of a swallow trial ranges from .50 second to 2 seconds, depending on the severity of the dysphagia. It is ultimately important to initiate research protocols that explicitly examine both the intensity and duration of direct treatments in order for clinicians to clearly prescribe them for patients.

Indirect Treatments

There are several indirect treatments for dysphagia, including motor exercise protocols, sensory stimulation, and neuromuscular stimulation. Four motor exercises protocols, including Lee Silverman Voice Therapy (LSVT), lingual exercise, the Shaker head-raise exercise, and expiratory muscle strength training (EMST) include intensity and/or duration regimens and have been studied in different populations of dysphagic patients (see Table 1). The prescribed duration for each of these treatments is based on knowledge adapted from exercise physiology literature, indicating the importance of the amount of exercise performed over time as it relates to both muscular, or myogenic, changes, and changes occurring within the nervous system. Thus, these four treatments are delivered over a time period ranging from 4 to 8 weeks, between 3 and 5 days per week, and in one to three sessions per day. Within a daily session, 25 to 30 repetitions are completed for lingual exercise and EMST; the Shaker head-raise consists of 3 sustained and 30 repetitive exercises; and LSVT daily sessions are 1 hour in length.

Of these indirect treatments, lingual exercise, LVST, and EMST incorporate intensity levels targeting muscle strength within their paradigms, and, thus, targeted muscle groups may benefit from improved force-generating capability. In fact, quantitative, objective measures of strength for the tongue and respiratory muscles are noted to increase significantly with both lingual exercise and EMST (Baker, Davenport, & Sapienza, 2005; Robbins et al., 2005). As a specific example, the Iowa Oral Performance Instrument (IOPI) is used to quantify lingual motor output during lingual exercise; a patient's targeted intensity level for lingual exercise is then based on a percentage (e.g., 60%) of his/her maximum tongue pressure output. Hence, lingual exercise consists of specific intensity level targets (in this case, 60% of maximum lingual pressure) and specific treatment duration (see Table 2). Following this lingual exercise prescription, changes in swallow outcome measures include reduced oral transit time (OTT) and residue, and improved Penetration-Aspiration score (P-A score; Rosenbek, Robbins, Roecker, Coyle, & Wood, 1996; Robbins, Kays, Gangnon, Hind, Hewitt, Gentry, et al. 2007). Both LSVT and EMST include similarly prescribed intensity and duration parameters and each also result in physiologic changes to the swallowing mechanism (El Sharkawi et al., 2002; Troche, Wheeler-Hegland, Musson, Rosenbek, & Sapienza, 2008). Clearly, strength gains achieved with concisely prescribed exercises impact physiologic and functional measures of swallowing. Further, based on known mechanisms of myogenic and neurologic adaptations to exercise, it would seem that many sub-populations (e.g., stroke, certain neurodegenerative diseases, some head and neck cancer) with acute or chronic dysphagia may benefit from strength-training.

View this Table 2. Summary of Treatment Duration for Various Modalities

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Treatment	Total treatment duration	Days per week	Sessions per day	Length/repetitions per session	Total amount of treatment
Biofeedback and Mendelsohn maneuver	Variable (1 to 6 weeks)	3 to 6	1	50 minutes	Variable
LSVT	4 weeks	4	1	1 hour	16 hours
Lingual exercise	8 weeks	3	3	30 repetitions	2160 repetitions
EMST	4 weeks	5	1	5 sets of 5 repetitions	500 repetitions
Shaker head raise	6 weeks	7	3	3 sustained and 30 repetitive head raises	378 sustained and 30 repetitive
TTA	2 weeks	3 to 5	Variable	Variable: 150, 300, 450, or 600 per week	Variable: 300, 600, 900, or 1200
ES (Oh et al., 2007)	2 weeks	5	1	1 hour	10 hours
ES (Freed et al., 2001)	Variable (more than 2 days)	3 to 7	1	1 hour	Variable
SES	Variable (2 to 30 days)	7	1	4 hours	Variable

Note: LSVT = Lee Silverman Voice Therapy. EMST = Expiratory muscle strength training. TTA = thermal-tactile application. ES = electrical stimulation. SES = synchronized electrical stimulation.

Focusing on sensory rather than motor aspects of swallowing is the basis of sensory stimulation treatments. Swallowing is an inherently sensorimotor act whereby the motor output is dependent upon sensory input; hence, focusing on enhanced sensation may lead to motoric changes impacting the physiology and functional aspects of swallowing. Temperature, touch, and taste are features of stimulus manipulation which may be targeted during sensory stimulation in isolation, or in combination. Currently, there is a paucity of data pointing towards anything more than short-term transient effects of these sensory treatments and very few studies have systematically investigated the treatments over time (i.e., beyond one treatment session).

Thermal-tactile application (TTA), which includes temperature manipulation via application of a cold stimulus to the anterior faucial pillars, is a sensory modality that has been studied with regard to the duration of treatment over several weeks. Following 2 weeks of TTA delivered at rates of 150, 300, 450, or 600 trials per week, there was no amount of treatment that emerged as superior to others in a cohort of stroke patients randomly assigned to one of the treatment duration groups (Rosenbek, 1998). Sample size and the dysphagia severity levels of participants may have limited the ability of this study to identify real treatment effects. Because at least 4 weeks of treatment are typically necessary with motor-focused exercises/treatments in order to induce neurogenic changes (Powers & Howley, 2001), it may be that lengthening sensory protocols to span 4 or more weeks of treatment would yield more promising results.

A third indirect type of treatment involves delivery of electric current to a muscle or group of muscles. Various types of electrical stimulation (ES) have been utilized therapeutically for dysphagia from multiple etiologies. ES has been applied to oral and pharyngeal regions, using surface and subcutaneous electrodes, and has been used with and without concurrent swallows. In addition, synchronized ES (SES), whereby delivery of the electrical stimulus is synchronized with volitional muscle contraction, has also been examined (e.g., Freed, Freed, Chatburn, & Christian, 2001; Leelamanit, Limsakul, & Geater, 2001). With regard to treatment duration, in both acute and chronic stroke patients, one-session application of surface ES to the oral or pharyngeal regions does not appear to have an effect on swallowing function in stroke patients (Power et al., 2006; Ludlow et al., 2007).

The use of ES at lower sensory thresholds during swallowing may be more immediately beneficial in chronic stroke patients, because improvements to a functional swallowing measure have been noted (Ludlow et al., 2007). More notable changes to swallow function occur when ES is applied in multiple treatment sessions over time. Swallowing improvements have been noted following 2 to 30 days of SES (4 hours per day; Leelamanit et al., 2002), as well as following ES applied to the neck for variable lengths of treatment (more than 2 days, 1 hour per day; Freed et al., 2001). A recently published study, including a cohort of stroke patients with dysphagia, examined controlled treatment duration and found improvement in swallow function and cortical reorganization following 2 weeks of surface ES to the neck (Oh, Kim, & Paik, 2007). Based on studies currently available, ES appears to be a viable treatment for acute or chronic dysphagia resulting from stroke and possibly other etiologies. More than one treatment session is needed; however, the necessary duration of treatment beyond that is unclear. At least 2 weeks with 1-hour treatment sessions each day for 5 days per week seems a reasonable starting point in light of functional swallow improvement and changes in the motor cortex demonstrated by Oh and colleagues.

One potential important difference with ES versus other motor-focused treatments has to do with the duration of muscle contractions that may result from electrical stimulation. The motor output (muscle contraction) resulting from direct or indirect exercises is brief (1-2 seconds in length) and, therefore, presumably accesses ATP via anaerobic pathways. Alternatively, the application of ES over the course of an hour, for example, should theoretically be accessing ATP via aerobic pathways. Hence, carryover method(s) of ES treatment effects to typical swallowing might be questioned because of the different mechanisms by which muscles are deriving energy for contraction between the two tasks.

It is important to note that the term "intensity" is applied differently in sensory treatments than it is during motor-focused treatments. Intensity as we have defined it refers to the strength of a stimulus delivered during exercise, where "exercise" implies muscle contraction resulting directly from the stimulus. While the magnitude of sensory stimulus intensity *can* be defined (e.g., quantifying the exact temperature of a TTA stimulus, or setting specific electrical stimulation levels) the motor output, and resulting magnitude of muscle contraction, is not. Therefore, it is difficult to speculate on what changes to the muscles may occur with different sensory levels of stimulation.

In summary, duration and intensity data are not currently available for direct dysphagia treatments. Indirect motor treatments, such as lingual exercise, LSVT, EMST, and Shaker head raise, use well-defined treatment durations. In addition, three of the four (lingual exercise, LSVT, and EMST) incorporate well-defined treatment intensities. There is great variability, however, in the duration data available for indirect sensory treatments, and the term stimulus "intensity" focuses solely on sensory input with these treatments, which is very different from the stimulus intensity as applied when motor-output is involved. Common to all potential treatments is the fact that treatment must be sustained over time in order to result in physiologic or functional gains with regard to swallowing. Both acute and chronic sufferers of dysphagia stand to benefit from treatment; these benefits may occur peripherally and may also correlate with cortical modulation or adaptation. Based on this review of study findings, it can be hypothesized that no less than 2 weeks of treatment delivered three to five times per week can be recommended with reasonable expectation for improvements. For motor-focused treatments (e.g., EMST, Shaker head-raise), a minimum of 4 weeks of treatment should be targeted before function can be expected to improve significantly. Finally, treatment prescriptions including both duration and intensity parameters make the process of rehabilitating swallowing function more clear for the clinician and for the patient.

Footnotes

Disclosure: *Dr. Christine Sapienza is a co-founder of and has financial interest in Aspire, the company that makes the EMST device mentioned in this manuscript. Dr. Sapienza is also a member of the Scientific Advisory Board of the company. She could benefit financially if the device is sold commercially. The University of Florida will own stock in Aspire, and could benefit financially if the device is sold commercially. No other conflict of interest has been declared.*

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