

Motor Imagery and Swallowing: Introduction to Literature and Discussion of Research needs in Dysphagia

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Abstract

Background: A large base of neurophysiological and neurobehavioral research supports motor imagery as an effective high-level, cognitive therapeutic strategy to enhance physical rehabilitation. One creates an imagined mental representation of a motor task without physical execution of the task. Mental practice, the repetitive rehearsal of a motor imagery task, complements physiotherapy treatment (active exercise) and has been shown to lead to increased motor learning and motor performance outcomes.

Aim and main contribution: The current paper provides a review of dysphagia and exercise rehabilitation, an introduction to motor imagery and mental practice in clinical rehabilitation, a discussion of emerging research of motor imagery of swallowing and swallowing-related movements, and potential novel and exciting applications of motor imagery to dysphagia rehabilitation that warrant investigation.

Conclusion: Despite an extensive research base supporting the benefit of using mental practice in addition to active exercise following neurological injury, the potential applications for dysphagia remain largely under-investigated. Given the need for evidence-based, cost-effective, and accessible clinical management, this paper discusses therapeutic applications important for preventative and rehabilitative considerations for motor imagery and encourages expanded research in the area of motor imagery and dysphagia.

Keywords: Deglutition disorders; Dysphagia; Speech-language pathology; Exercise; Mental processes; Rehabilitation; Motor imagery; Mental practice

Introduction

Dysphagia, difficulty swallowing, refers to atypical swallowing physiology and/or anatomy resulting in reduced safety and/or efficiency of functional swallowing ability [1]. In such cases, the normal transport of food, liquid or saliva through the upper aerodigestive tract to the cervical esophagus is disrupted. In adults, dysphagia generally results from a primary neurological injury or progressive disease, neuromuscular disease, head and neck cancer anatomical anomaly or treatment, or pulmonary disease [1]. However, it may also result from sarcopenia (as a result of the normal aging process or secondary to sequelae resulting from disease) of swallowing musculature [2,3]. The prevalence of dysphagia increases when considering the sarcopenic population of older adults. Up to 40% of adults over the age of 60 experience dysphagia [4-6]. With the projected growth in number of aging adults, the incidence of dysphagia in the geriatric population is likely to increase [7]. Health-related consequences of dysphagia include pneumonia, malnutrition/dehydration, and increased mortality [1]. Significant costs each year are associated with hospitalizations involving patients with dysphagia [8].

Dysphagia and the Aging Process

A syndrome associated with the typical aging process, sarcopenia, produces a reduction in the mass and strength of skeletal muscles affecting musculature important to swallowing [2]. In primary form, sarcopenia is related to the typical aging process [9]. Sarcopenia is considered secondary when related to activity, disease, or nutritional changes [9]. The etiology of sarcopenic dysphagia can be multifactorial and either form of sarcopenia can lead to a decline in swallowing function, nutritional status, and activities of daily and independent living abilities [2]. Sarcopenic dysphagia is not to be confused with presbyphagia,

which is associated with changes in the swallowing mechanism related to typical aging but do not lead to disordered functional swallowing [3]. However, even presbyphagia places older adults at a higher risk for dysphagia, perhaps representing a pre-dysphagic state, as these typical changes in the swallowing mechanism with aging include changes in swallowing anatomy, oropharyngeal timing during swallowing [1,10], reductions in head and neck structural movement [11,12], decreased lingual strength and functional reserve [13] and cortical activation for swallowing [14]. While rehabilitative measures have traditionally been the focus, preventative strategies are also being recognized as critical in research, especially with the aging population given its susceptibility to developing difficulty swallowing [15].

Managing Dysphagia in the Aging Population

Speech-language pathologists (SLPs) evaluate, diagnose, and treat patients with dysphagia, with three primary goals: safety, efficiency, and quality of life [1]. Keeping a patient as safe as possible when oral intake is indicated and preventing aspiration (i.e., ingested material or saliva aberrantly traveling below the level of the true vocal folds) is a primary focus. In addition, SLPs ensure the patient is able to intake their meals efficiently to support hydration and nutrition. As eating is a significant

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part of one's quality of life, this should always be incorporated during evaluation and treatment. Rehabilitative therapeutic interventions in dysphagia target direct changes to muscles and neural activation for swallowing in order to improve functional swallowing performance [1,16-18]. Active exercise, including swallowing and non-swallowing exercises have been included in rehabilitative dysphagia intervention for decades [17]. Active exercise of muscles important to swallowing in dysphagia treatment is believed to improve biomechanics of swallowing function [18]. Active exercise also fosters neuroplasticity and retrains neuromuscular systems involved in swallowing [16,17,19-22]. The field of speech-language pathology is still investigating the application of the principles of motor learning and training to bulbar musculature and functional swallowing improvement; however, a solid base of research points to the reversal of muscle strength loss with active exercise, even in older adults [18]. Promising outcomes include enhanced functional swallowing with improved protection of the airway, safer and more efficient bolus transport through the upper aerodigestive tract, nutritional improvements and higher ratings with quality of life measurement tools [18,23].

Motor Imagery and Clinical Rehabilitation

Motor imagery (MI) is a mind-body, cognitive, rehabilitation tool that refers to the creation of an imagined motor task without overt motor movement as the motor task is completed in working memory [24,25]. More simply stated, it is thinking about completing an action. Neural circuitry and cortical representations are receptive to modification and reorganization through experience (disuse or retraining) [26-29]. As with physiotherapy treatment, mental practice via MI contributes to activity-dependent experience required to drive neuroplasticity in neuromuscular systems to influence patterns of movement in both healthy populations and during motor rehabilitation [28]. Research indicates that MI activates similar neural substrates as active execution, even following a neurological insult [28]. A large body of literature indicates the promise of using MI in physical and occupational rehabilitation to enhance active exercise in motor learning and motor performance post-neurologic injury [30,31]. MI exercise, or mental practice, is not generally considered as a replacement for active exercise, rather to supplement active exercise [32-35]. In fact, the most effective approach appears to be when physiotherapy treatment is combined with mental practice, with motor performance outcomes increased when motor MI is included [30,32-35]. An extensive and growing body of literature supports MI as an effective cognitive tool for physical rehabilitation [36]. Despite the promising evidence, potential applications of MI and swallowing have only begun to receive attention in the area of dysphagia rehabilitation.

Motor Imagery and Swallowing

Just as corticospinal reorganization has been demonstrated, empirical evidence supports swallowing neuroplasticity [22,37,38]. Physiotherapy treatment during dysphagia rehabilitation is used to retrain neuromuscular systems important to swallowing and drive neuroplasticity to influence behavioral, functional swallowing improvement [16,17,19-22]. However, only a small number of research papers explore the potential for motor imagery (MI) of swallowing to enhance dysphagia rehabilitation. Research targeting neural correlates of head and neck movements related to swallowing during MI and detection of MI of swallowing is emerging [39-44]. Innovative approaches to improving detection of MI of swallowing using electroencephalogram continue [45]. A research team has also investigated the neural correlates of MI during swallowing in healthy

adults and adults with dysphagia using near-infrared spectroscopy (NIRS) [46,47]. The hemodynamic response during cortical activation shows a comparable pattern and topographical distribution when MI of swallowing is compared to motor execution of swallowing in both healthy adults and adults with dysphagia [46,47]. Further, the same research team has demonstrated cortical reorganization in motor areas of the cortex important to swallowing following neurofeedback training with NIRS using MI of swallowing in young adults [48]. The promise of using MI during dysphagia rehabilitation following neurological insult is recognized and is growing in focus and potential application [41,49]. The possible ability to harness comparable cortical activation systems for swallowing using motor MI is leading to the development of innovative therapeutic tools and techniques in dysphagia rehabilitation [49].

Exercise Principles and MI for Swallowing

Interestingly, a critique of current literature reviewing the efficacy of rehabilitative swallowing exercises in patients with dysphagia noted that primarily non-swallowing exercises such as Shaker Head Lift and Expiratory Muscle Strength Training were determined to have enough evidence for use with certain patient populations [17]. Tongue strengthening exercises are also a form of non-swallowing exercise that have "great potential" and warrant investigation using larger sample sizes and improved methodological study design, including samples with increased uniformity of subjects [17,23]. Non-swallowing exercises target important parts of swallowing but do not involve task-specific swallowing activity as part of the exercise [17]. Further, non-swallowing exercises do not meet the "use it or lose it," "use it and improve it" or "specificity" principles of motor learning for neuroplasticity [17,22]. Non-swallowing exercises target and capitalize on the motor principle of transference, just as strength training for an athlete contributes to increased motor performance of a sports skill [16,17,22]. The finding that non-swallowing exercise carries evidence for use in disordered populations may stem from the need for improved study design and larger sample sizes [17].

Principles of motor learning and neural plasticity that appear not to have received as much attention in the area of dysphagia exercise are the individual's interest in practice and practicing the correct form of a motor skill. Both are principles that may be supported by mental practice. Application of principles of motor learning and neural plasticity for smaller, bulbar musculature warrants attention. Muscles critical to deglutition, particularly the tongue muscles, are unique in muscle composition and their hybrid fiber types are different from other skeletal muscle in humans [16,50]. The bulbar musculature may demonstrate unique needs and responses in relation to the principles of neuromuscular training. The rules and principles of strength training would likely benefit from further exploration for oropharyngeal muscles. The challenge and the need to investigate "therapies that apply and/or manipulate different aspects of strength-training principles to optimize outcomes through the most efficacious, efficient, effective approaches possible" are recognized in dysphagia rehabilitation [16].

Furthermore, for decades, dysphagia rehabilitation has focused on the physiotherapy aspects of swallowing in rehabilitation. Growing evidence supports that central-level factors significantly contribute to motor outcomes like strength gain [51]. The cognitive and perceptual processes that continuously interact with the motor system both need to be considered in clinical rehabilitation [25]. Mental practice using motor imagery may serve as an innovative therapeutic tool for enhancing dysphagia exercise rehabilitation without inducing pain or

fatigue. The mental practice may prime subsequent swallowing tasks for improved performance through similar neural activation patterns as the actual motor task. The addition of mental practice to complement active swallowing exercise may lead to the greatest increase in motor performance, as it has been shown in research in the limbs musculature. Further, the contribution of neural adaptations in strength gain may be greater in the older population than morphological adaptation [16,52]. The combination of mental and physical exercise may maximize adaptation at both the central and peripheral levels.

Discussion and Future Directions

Thus far, the focus in growing attention to motor imagery (MI) of swallowing and dysphagia rehabilitation has used sophisticated neurofeedback during MI training and cortical reorganization for swallowing [41,45-49]. The contribution of using MI of swallowing and swallowing-related movements to enhance motor learning and motor performance has potential application in both preventative and rehabilitative arenas. Practical, cost-effective and accessible applications are needed, as most patients and speech-language therapists do not have access to sophisticated equipment for neurofeedback and detection of MI of swallowing. Mental practice via MI is voluntarily driven and accessible beyond the traditional therapeutic setting once trained [25,53]. Mental practice can be imagined in varied environmental contexts, meaning the correct motoric form of swallowing or swallowing-related movement can be practiced in working memory under different simulated feeding and exercise conditions. Further, MI is safe and thus, may present as an attractive therapeutic tool for patients with severe dysphagia, who are often apprehensive to practice even using only their saliva [36]. Mental practice may provide an option for early dysphagia rehabilitation in the acute stage of neurological injury that is safe to rehearse as a cognitive tool to prime the neuromuscular system for later active exercise. Additionally, even though MI practice is not considered a replacement for active exercise, it may prove a useful therapeutic strategy when active exercise is not possible for a period of time, such as when active practice is too painful or fatiguing (e.g. during head and neck cancer treatment). Lastly, the potential for using MI strategies with active exercise warrants investigation for preventative means in the typically aging population at risk for dysphagia secondary to changes in swallowing musculature. The authors of this paper are exploring practical, cost-effective, and accessible applications of using MI for swallowing and swallowing-related movements to enhance the efficacy (e.g. strength, endurance) of active exercise during dysphagia rehabilitation. Mental practice using MI of swallowing and swallowing-related movements represents an innovative and exciting therapeutic direction. Research exploring potential applications for preventative and rehabilitative measures focused on the function of oropharyngeal musculature for swallowing is promising and encouraged.

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