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Reconsidering Rehabilitation for Neurogenic Dysphagia: Strengthening Skill in Swallowing

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Abstract

Purpose of Review Rehabilitation for oropharyngeal dysphagia aims to improve impaired swallowing biomechanics. However, adverse effects have been reported with strengthening exercises, such as effortful swallowing. Current research is highlighting improvements based on skill, rather than strength, training. Thus, the goal of this review is to determine what evidence exists for skill-based rehabilitation in dysphagia.

Recent Findings Skill training may be defined as functional repetition and refinement of movement patterns. Skill-based rehabilitation paradigms have been reported for rehabilitation interventions such as lingual accuracy tasks, respiratory-swallowing coordination, and using biofeedback to improve the efficiency of oropharyngeal swallowing. The ultimate goal is to acquire skill in execution of specific swallowing biomechanics at a central level.

Summary The studies reviewed provide favourable proof-of-concept and positive indicators that skill-based intervention may circumvent some limitations with existing strength-based intervention modalities. Skill-based training in dysphagia may be a promising area for future research.

Keywords Deglutition · Dysphagia · Rehabilitation · Strength · Skill training

Introduction

Dysphagia is a significant morbidity associated with ageing, neurologic impairment, congenital disorders and traumatic injury. Dysphagia increases the occurrence of a constellation of associated negative sequelae, including dehydration, malnutrition and pneumonia, which can greatly increase risk of mortality. Swallowing impairments can arise from central and peripheral nervous system damage, affecting any or all phases of swallowing. However, there are a limited number of rehabilitation options for patients, despite potential for widespread variation in the sensorimotor impairment exhibited by a patient. Therefore, the aim of this manuscript is to review existing publications that address the novel rehabilitation concept of skill-based training in dysphagia rehabilitation to circumvent current limitations with existing usual care in dysphagia rehabilitation, namely exercise and strength-based intervention modalities.

A Presumption of Weakness

Rehabilitation for oropharyngeal dysphagia aims to improve impaired swallowing biomechanics. For any given treatment, some patients with a swallowing impairment may not respond with improved function. There is often a presumption that the lack of progress is patient centred, e.g. the patient 'failed' to respond to treatment, by virtue of degree or nature of impairment, lack of capacity or lack of motivation. However, perhaps the error lies not in the patient but in the clinician and the clinical inaccuracy of diagnosis, leading to improper selection of rehabilitation approaches. Safe and efficient bolus transport through the pharynx minimally requires precise timing of biomechanical movements that produce a functional level of force acting on the bolus. However, our classification system

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of pathology in dysphagia diagnosis is rudimentary when compared to other areas of rehabilitation medicine, where pathology can be classified by the nature of underlying impairment, such as a spastic dysarthria or an ataxic gait.

The videofluoroscopic swallowing study (VFSS) is largely considered the gold standard in evaluation of deglutition as it can visualise all stages of swallowing as an integrated process [1] and has been utilised in research and clinical practice for over 30 years [2]. Although impaired biomechanics may be dynamically observed, this technique cannot provide information on the underlying nature of impairment, such as weakness, spasticity, apraxia or other neuromuscular change. Timing can be precisely measured, but we have no methods to delineate if errors in timing are centrally generated—a disorder of motor programming—or if timing errors reflect inadequacy in peripheral execution—the central command is executed without flaw but peripheral motor deficits restrict timely recruitment of muscle activation. This lack of specificity is also problematic in understanding mechanisms of peripheral force generated on the bolus. A failure to generate adequate force for bolus propulsion does not automatically equate to peripheral muscle weakness but may reflect central impairment in activating end-point muscle recruitment. Unfortunately, we have no clinically practical method of diagnosing peripheral muscle strength in the muscles involved in swallowing, and we rely solely on surrogate measures of strength, such as observation of bolus flow on VFSS or pressure measures from pharyngeal manometry, that do not measure contraction directly. The expansion of diagnostic modalities may provide some clarification, if not to rule out weakness as much as to rule in another underlying aetiology. Huckabee et al. (2014) reported on manometric investigation of 16 patients presenting with diffuse pharyngeal residue, routinely interpreted as a symptom of weakness when swallowing. Manometry identified mis-sequenced timing of pressure generation in the pharynx, despite relatively normal generation of force, as measured by amplitude of pressure generation [3]. This impaired sequencing of force generation occurs within 200 ms time frame and thus cannot be visualised on VFSS alone. Although undoubtedly a valuable tool, the widespread dependence on VFSS in isolation appears to impose a bias towards misinterpretation of pharyngeal bolus residual to be a consequence of 'weakness' and therefore development of a preponderance of strength-based rehabilitation options.

In a survey of dysphagia rehabilitation practices in the USA [4], responses from Speech Language Pathologists ($n = 254$) provided with clinical and instrumental data revealed five of the seven most recommended swallowing techniques could be classified as strengthening exercises. Importantly, only 3.9% of respondents reported deriving recommendations from a physiologic abnormality [4]. Strengthening exercises aim to increase muscle hypertrophy and therefore assumes weakness as a primary deficit. Such exercises include head lift exercises [5], expiratory muscle strength training [6] and Mendelsohn manoeuvre [7]; for a review of these techniques, the reader is directed to Burkhead et al. and Langmore and Pisegna [8, 9]. Strengthening may not be the best approach, given that swallowing does not require maximal muscle contraction [10] and that weakness may not underlie generation of adequate force. Additionally, there are suggestions in the literature of potential adverse effects of strength training, including development of fatigue [11], increased muscle tone [12], and detraining following treatment [13]. Additional concerns have been raised specific to the effect of effortful type swallowing [3, 14–16]. Muscle strengthening as a rehabilitation approach for dysphagia may in some cases be appropriate if weakness does, indeed, underlie impaired biomechanics; but in many, if not most cases, this approach may be ineffective, if not contraindicated.

From Peripheral to Central Rehabilitation Approaches

If we question the role of peripheral muscle weakness in producing swallowing impairment, we might alternately speculate that impaired biomechanics would be considered a deficit of swallowing motor control and generated from compromise in the central nervous system. Expansion of rehabilitation approaches beyond peripheral muscle change then requires consideration of the possibility of central change. A growing corpus of research is emerging regarding the use of techniques in swallowing rehabilitation that can be classified as neuro-modulatory. Non-invasive brain stimulation (NIBS) techniques may include repetitive transcranial magnetic stimulation or transcranial direct current stimulation. The key focus of NIBS is to alter the central neural substrates which drive swallowing behaviour. Well beyond the scope of this article, the curious reader is referred to an excellent analysis of this body of literature by Pisegna and colleagues (2016). The emergence of these techniques in swallowing rehabilitation has contributed substantially to shifting our thinking away from the muscle and into the brain and early research has documented an overall positive effect [17]. Despite this, these techniques also lack specificity in terms of directly targeting pathophysiologic features of swallowing. NIBS targets a change in brain in a very specific manner, but the consequent effect on swallowing is a non-specific by-product of altered neural function. There is no specific NIBS protocol or approach to specifically address delayed pharyngeal response that is different from an approach for reduced upper oesophageal sphincter opening, for example. Appreciating the complexity of the oropharyngeal swallowing response, this leads to a further question. Can we develop options that change swallowing behaviour first, in a physiologically specific manner, with a consequent effect on the brain, to ensure a neurophysiologic change which encodes and sustains improved function such that it is resistant to detraining?

Development of Skill-Based Training Paradigms for Swallowing

Skill-based training paradigms have been shown to induce cortical reorganisation of motor networks [18] and have received considerable attention in the physical therapy domain [19–21]. Skill training may be simply defined as the acquisition of skill through functional repetition and refinement of movement patterns [22, 23]. The ultimate goal in swallowing skill training is to acquire skill in execution of specific aspects of swallowing biomechanics at a central level. The process of consolidating skill acquisition at the neural level first requires refined and accurate task performance, followed by retention of motor behaviour patterns and finally task transfer [24]. To maximally foster skill acquisition, rehabilitation targets should have sufficient specificity of practice, wherein the target trained mirrors the functional task desired [25] and sufficient task challenge, as repetition of motor activity alone is not thought to result in functional recovery [20]. The use of some form of biofeedback may be a critical element to allow the participant to engage in on-line modification and enhancement of their performance of the desired task [26, 27]. This is particularly true in swallowing where accuracy of task performance cannot be easily observed by patients or clinicians.

Several approaches for translating the construct of skill training to the practice of dysphagia rehabilitation have emerged. The McNeill Dysphagia Therapy Program (MDTP) is a systematic exercise framework that is predicated on components of strength training [28]. An additional key component of this approach appears to be the systematic and hierarchical presentation of oral intake. This emphasises task specificity in that the treatment is focused on swallowing repetition; although, it is not specific to individual pathophysiologic features of swallowing. Task challenge is met through the hierarchical presentation of food with the purveyors of this approach advocating that assessment of task performance for advancement on the hierarchy is based on clinical presentation of bolus tolerance. The researchers have documented positive outcomes of the MDTP in subsequent studies [28–31]. However, as the approach fundamentally is focused on repetition of a type of effortful swallowing task, the active treatment is unclear.

Stepp et al. evaluated the feasibility of skill-based therapy for dysphagia rehabilitation by utilising sEMG biofeedback [32]. Electrodes were placed bilaterally on the anterior neck, overlying the thyrohyoid, sternohyoid and omohyoid muscles. Six healthy participants and one patient with severe oropharyngeal dysphagia following brainstem stroke received real-time visual feedback of muscle activity on a computer screen placed in front of them. sEMG data were presented in video-game format, with the leading edge of the waveform represented as a large fish that moves vertically on the screen based on the magnitude of sEMG output. The game involved using the muscles in an organised manner such that the larger fish 'caught' a smaller fish (target) that moved at a constant speed across the horizontal (time) axis but with a variable amplitude across the vertical axis. In the baseline session, healthy volunteers 'caught' significantly more fish than the single patient participant. Throughout five subsequent sessions, the patient significantly increased target accuracy and reported improved secretion management. As is evident, this study utilised biofeedback to increase task performance and provided significant challenge to facilitate motor learning. However, physiologic swallowing was not required to complete the task; thus, task specificity was not optimised.

Athukorala et al. addressed the limitation in task specificity in the above study with a similar approach [33]. Using submental electrode placement to detect timing and magnitude of anterior belly of digastric, mylohyoid and geniohyoid muscles, ten patients with dysphagia secondary to Parkinson's disease completed a 2-week, daily treatment protocol. The task, executed with specialised software, required the patient to control the timing and degree of muscle activation during swallowing such that the peak of the time-by-amplitude waveform 'hit' a target box that was placed randomly on the visualised computer screen. All targets were calibrated to fall within 2 and 25 s of a 30-s screen sweep and between 20 and 80% of maximal sEMG amplitude during five effortful swallows, thus avoiding the confound of effortful type swallowing. Task challenge was provided by a decrease in the size of the target by 10% following three successive 'hits' and, conversely, an increase of 10% in target size in the event of three successive misses. One hundred repetitions of the task were executed in blocks of ten, with 30 s between trials and 90 s between blocks. Outcomes were measured using the Timed Water Swallowing Test [34], the Test of Masticating and Swallowing Solids [33, 35] and sEMG timing measures of pre-motor, pre-swallow and total swallowing duration times. The Swallowing Quality of Life (SwalQOL) [36] measure was also derived. In this within-subject ABA design, patients demonstrated stable performance across a 2-week baseline period. They demonstrated significant improvement on all measures, with the exception of those from the TOMASS, following 2 weeks of treatment, with no decline in performance at 2 weeks following discontinuation of treatment. The absence of change on TOMASS measures likely reflected an absence of impairment in solid bolus swallowing, as described by participants and demonstrated through pre-treatment TOMASS scores. Although improvement was demonstrated and maintained in functional swallowing measures following this swallowing task-specific treatment, skill-based training in this context did not target a specific physiologic abnormality (e.g. reduced hyoid movement).

Steele et al. reported results from a tongue-pressure strength and accuracy training intervention in six individuals following acquired brain injury [37]. The aim of this study was to determine if a mixed strength and skill-based (e.g. accuracy) training would increase tongue strength for maximum isometric pressures, as well as improve swallowing safety and efficiency. Participants completed 24 twice weekly sessions in which the target was to complete a lingual strength and accuracy task using the Iowa Oral Performance Instrument (IOPI) [38]. While the strength task was to complete maximum isometric pressures with the anterior and posterior tongue, the skill-based task was accomplished only using 20–90% of maximum isometric pressure. Participants were asked to generate a randomly selected target pressure as accurately as possible within that submaximal pressure band. Feedback was provided through IOPI pressure amplitudes, and an equal number of trials between the strength and skill tasks were completed within a session. In addition to lingual pressure measures, pre- and post-treatment VFSS were undertaken to investigate differences in swallowing biomechanics. Results indicated increases in anterior and posterior tongue strength; however, VFSS data revealed no improvements in bolus clearance, with worsening pharyngeal residual in the majority of participants ($n = 5$) in the absence of any (unrelated) worsening in disease state or dysphagia severity. This result is consistent with findings from studies of other strength-based exercises, such as the effortful swallow [39], which have documented increased pharyngeal residual following the intervention. Further assessment of lingual accuracy tasks, trained independently from maximal isometric tasks, is indicated.

Huckabee et al. reported results from a group of patients ($n = 16$) with atypical pathophysiologic features of dysphagia [3]. On instrumental examination with VFSS, this patient cohort presented with decreased pharyngeal motility, diffuse pharyngeal residue and frequent nasal redirection. Subsequent assessment with pharyngeal manometry revealed a mis-sequenced pattern of pharyngeal pressure, with simultaneous pressure in the proximal and distal pharynx, respectively. All participants were seen for intensive, skill-based training 5 days per week for a period of 2 weeks (10 days), for a total of ten 1-h sessions. Previous research has documented that pressure and duration of brainstem-generated pharyngeal swallowing can be cortically modulated [7, 15, 40]; thus, participants were instructed to volitionally increase the temporal separation between the proximal and distal pharyngeal pressure waveforms when swallowing using pharyngeal manometry as a visual biofeedback modality. Following this intervention, the mean latency between peak pressures at the proximal and distal pharynx increased from a pre-treatment average of 15 ms (95% CI = −2 to 33 ms) to a post-treatment mean of 137 ms (95% CI = 86–187 ms). This correlated to subjective improvements in oral intake and led to a subsequent experiment evaluating manometric skill-based rehabilitation in healthy adults [41].

In a more recent publication, Martin-Harris et al. evaluated performance of a skill-based respiration-swallow training intervention in participants ($n = 30$) with head and neck cancer [42]. The aims of this study were to (i) determine whether the use a respiratory-related feedback protocol was effective in training desired respiratory-swallowing coordinative patterns, measured with respect to expiration preceding and following deglutitive apnoea, and (ii)) investigate the stability of the training 1 month post-treatment. Participants completed a 1-h session twice weekly for a duration of 4 weeks. During these sessions, respiratory-swallowing coordination was trained, with visual biofeedback from a KayPENTAX Digital Swallowing Workstation, on a motor skill acquisition hierarchy in which participants were first taught to identify the target, perform the desired response with a minimum of 80% accuracy and finally master the production in at least 90% of trials. Results indicated patients were able to learn and implement an optimal respiratory-swallowing pattern after treatment ($p < 0.001$); in fact, all study participants mastered the optimal pattern within eight sessions, with carry-over effects seen at 1-month follow-up. These gains in motor skill were associated with improvements in VFSS measures, including improved laryngeal vestibule closure ($p < 0.001$), improved tongue-base retraction ($p < 0.001$) and a reduction in pharyngeal residual ($p = 0.01$).

Discussion

Development of skill-based training paradigms may hold promise for rehabilitation above and beyond traditional strength-based methods. While the abovementioned studies provide favourable proof-of-concept and positive indicators that skill-based intervention may circumvent some limitations with existing strength-based intervention modalities, it is clear that further research is needed. These studies are limited by small sample sizes and heterogeneous aetiologies, including Parkinson's disease, acquired brain injury and head and neck cancer. It is simply too early to make wider inferences and generalisation without additional research.

Yet, there is a rapidly progressing field of research regarding skill training in the limb literature, with researchers documenting superior outcomes for task-oriented skill training over strength training programmes [25, 43–46]. Further, skill training in the limb literature has been linked with an increase in corticomotor excitability [47], increase in plasticity of the motor cortex [48] and greater functional movement improvements [42]. Translation to swallowing cannot be assured, however, due to the differences in muscle composition, sensorimotor complexity and neural processes [22, 49]. The critical component appears to be optimisation of motor learning, rather than motor repetition, to stimulate functional cortical reorganisation [23].

Our current diagnostic methods have a great impact on subsequent rehabilitation decisions. This begs the question—how does a clinician determine if residual on VFSS is secondary to a reduction of muscular strength or deficits in swallowing motor programming? Weakness can really only reliably and objectively be assessed through specific muscle function tests; current work is pursuing development of a clinical test of this differentiation. Evaluation of response to treatment in different aetiologies may also provide insights. Despite this, further research is also warranted directly comparing skill-based training to strength-based treatment. The studies evaluating only skill-based intervention documented favourable outcomes [3, 32, 33]. The two studies where skill training and strength training were combined produced dissimilar results [31, 37]. Steele et al. was the sole study to find a worsening of pharyngeal residual following their mixed strength- and skill-based rehabilitation paradigms [37]. This is fitting with emerging evidence regarding a similar strength-based exercise, namely effortful swallowing. Multiple studies have identified mixed outcomes regarding the effect of effortful swallowing on pharyngeal biomechanics. Bülow, Olsson, and Ekberg [15, 50] suggested that this technique may inhibit anterior hyoid movement [15, 47], while more recent evidence regarding effortful swallowing has demonstrated increased nasal redirection [14], increased pharyngeal mis-sequencing [3] and increased pharyngeal residual [35] as a result of this exercise. Considering this, it is critical to understand the impact that targeted rehabilitation has on the pharyngeal swallowing response overall. As the pharyngeal swallow is a highly orchestrated response, isolating targeted aspects can have unintended effects on the gestalt, which may support further research of skill-based training in dysphagia.

As discussed above, the process of consolidating skill acquisition at the neural level first requires sufficient specificity of practice [25], sufficient task challenge [20] as well as the use of some form of biofeedback [26, 27]. Biofeedback enables on-line modification of performance and may be particularly critical in deglution. Following this, it is notable that, in the studies reviewed, biofeedback was implemented to enhance skill training in all but a single study [28]. The studies utilised different modalities, including lingual pressure, nasal air flow and surface electromyography, to provide the participant on-line modification and enhancement of their performance of the desired task. Without inclusion of biofeedback, participants have limited reliable means to assess whether exercises are done correctly. Asking a patient to swallow with effort, or sustain hyolaryngeal excursion, may produce visible effort on the part of the patient, but it is unclear exactly where that effort lies. This may be even more challenging in skill-based tasks where patients are asked to finely modulate a select component of their swallowing at precise levels of timing or intensity.

Conclusions

The evolution of our clinical approaches to the management of dysphagia is bringing us to a point of exciting discoveries. This greater specificity will ultimately lead to improved patient outcomes as emerging research is making it clear that diagnostic precision is a mandate for rehabilitative effectiveness. Biofeedback supports this shift but is only as valuable as the method or manoeuvre it is used to visualise. Whether it be strength-based or skill-based rehabilitation approaches, it is wise to remember that if an intervention is powerful enough to effect a positive change and it is inherently powerful enough to effect a negative change. Until further data are accrued and the picture becomes clearer, practicing clinicians should always question their provision of services. Lack of favourable clinical outcomes may arise from multiple inter-related factors including treatment variables, patient factors and/or the way in which the treatment was provided.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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