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ORIGINAL ARTICLE

Skill Training for Swallowing Rehabilitation in Patients With Parkinson's Disease

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Abstract

Objective: To examine the effects of skill training on swallowing in individuals with dysphagia secondary to Parkinson's disease (PD) and to explore skill retention after treatment termination.

Design: Within-subject pilot study with follow-up after 2 weeks of treatment and after a 2-week nontreatment period.

Setting: Clinic in a research institute.

Participants: Patients (N=10; mean age, 67.4y) included 3 women (mean Hoehn and Yahr score, 2.6) and 7 men (mean Hoehn and Yahr score, 2.4).

Intervention: Patients underwent 10 daily sessions of skill training therapy focused on increasing precision in muscle contraction during swallowing using visual feedback.

Main Outcome Measures: Data from the timed water swallow test, Test of Mastication and Swallowing Solids, surface electromyography (sEMG) of submental muscles, and swallowing-related quality of life questionnaire were collected at 2 baseline sessions (conducted 2wk apart) at the end of treatment and after 2 nontreatment weeks to assess skill retention.

Results: Immediately after posttreatment, the swallowing rate for liquids ($P=.034$), sEMG durational parameters of premotor time ($P=.003$), and preswallow time ($P<.001$) improved. A functional carryover effect was seen from dry to water swallows ($P=.009$). Additionally, swallowing-related quality of life improved ($P=.018$). Reassessment at 2 weeks after treatment termination revealed short-term retention of treatment effects.

Conclusions: A skill-based training approach produced functional, biomechanical, and swallowing-related quality of life improvements in this cohort indicating compelling evidence for the effectiveness of this novel approach for dysphagia rehabilitation in PD.

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Approximately 90% of patients with Parkinson's disease (PD) are reported to have dysphagia,[1] with all stages of swallowing being affected.[2] Dysphagia can result in malnutrition, dehydration, and aspiration pneumonia.[3] Additionally, negative impact on quality of life in PD[4] has been indicated with reduced subsection scores on the Swallowing Quality of Life (SWAL-QOL) questionnaire.[5]

Current rehabilitation practices focus primarily on increasing muscle strength to alter biomechanical features of swallowing pathophysiology.[6] Techniques performed within the functional context of swallowing include the effortful swallow, tongue-hold maneuver, and Mendelsohn maneuver, whereas techniques outside the context of swallowing include the head-lift exercise, expiratory muscle strength training,[6] and lingual exercises.[7,8] The effects of these exercises on swallowing biomechanics remain mixed, with both positive[9] and adverse effects[10] reported on swallowing biomechanics. In addition to strength, effective swallowing requires neuromuscular coordination, precision, timing, speed of reaction, and planning of motor movements.[11] In PD, swallowing deficits have been attributed to muscle rigidity, tremor, and bradykinesia.[2,12] Strength training may exacerbate deficits resulting from muscle rigidity[13] or could be ineffective for impairments as a result of imprecise timing. Hence, an alternative approach of skill training is proposed.

Skill training is the process of learning and fine-tuning new sequences of movements.[14] When an individual executes a novel

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task and/or challenging activity, skill learning occurs. A challenge component requires an individual to problem-solve the movement during practice rather than memorizing and replaying the sequences of muscle/joint contractions.[15] The literature in swallowing reports positive outcomes after the use of task-specific exercises in combination with surface electromyography (sEMG) biofeedback.[16,17] Using biofeedback modalities to master task-specific exercises enhances the skill component likely through recruitment of cognitive modulation of biomechanical performance. This type of task-specific treatment regimen, which challenges the functional system, may bring about optimal swallowing outcomes.[6] Current evidence of skill training comes from limb rehabilitation.[18] Furthermore, effects of oromotor training at the neural level have been documented,[19,20] suggesting the possibility of corticobulbar skill training.

The aims of this pilot study were to evaluate the effects of a newly designed skill training paradigm on swallowing function using multiple outcome measures (timed water swallow test,[21] Test of Mastication and Swallowing Solids, sEMG, SWAL-QOL) and to determine the retention of treatment effects after training in patients with dysphagia associated with PD.

Methods

Participants

Ten patients were recruited from 4 PD outpatient movement disorders clinics. Selection criteria included the following: diagnosis of PD by a neurologist, self-identified dysphagia of ≥3 months' duration using the Eating Assessment Tool,[22] and dysphagic presentation on clinical swallowing evaluation. The primary researcher conducted the clinical swallowing evaluation for all the patients. This consisted of a detailed case history, cranial nerve examination, inhalation cough challenge, oral intake trials, and the timed water swallow test.[21] Dysphagia presentation was defined as patients who showed deficits with structural symmetry, strength, range of movement, and laterality on the cranial nerve examination; exhibited consistent overt signs of coughing, altered voice, breathlessness, clearing throat, oral residue, and multiple swallows on ≥1 consistency; reduced scores on the timed water swallow test, as subsequently described, when compared with age- and sex-matched controls; and/or exhibited consistent overt signs (first 4 signs as described above) on the timed water swallow test, and/or failed the inhalation cough challenge.

Patients with dementia, stroke, head and/or neck injury/surgery, muscular disease, and Parkinsonism signs that were caused by multiple system atrophy, progressive supranuclear palsy, and side effects of medications were excluded. The study was approved by an appropriate regional health ethics committee, and patient consent was obtained. The mean age was 67.4±8.6 years with a mean disease duration of 6.6±4 years, mean dysphagia onset of 1.9±1 years, and mean Hoehn and Yahr score of 2.7±0.4.

Patient characteristics and demographics are summarized in table 1.

List of abbreviations:

BiSSkiT	**Biofeedback in Swallowing Skill Training**
PD	**Parkinson's disease**
PMT	**premotor time**
sEMG	**surface electromyography**
SWAL-QOL	**swallowing-related quality of life**

Outcome measures

Patients underwent 2 baseline and 2 posttreatment data collection sessions, all conducted 2 weeks apart. As this was a pilot study, a broad range of outcome measures (ie, timed water swallow test,[21] Test of Mastication and Swallowing Solids, sEMG, SWAL-QOL) were engaged to identify potential areas of change. All outcome measures were conducted at all evaluations points. The timed water swallow test was performed using the protocol proposed by Hughes and Wiles[21] in which patients were asked to swallow 150mL of water "as quickly as is comfortably possible." The number of swallows, time taken, and total volume swallowed were measured as per protocol, and the following were calculated: time per swallow, volume per swallow, and swallowing capacity.

A similar Test of Mastication and Swallowing Solids was developed to assess the swallowing rate of solids. Patients were given a quarter (1 portion) of an Arnotts Salada cracker[a] to ingest with the instruction, "Eat this biscuit as quickly and comfortably as possible." The number of swallows and time taken were measured as per the method in the timed water swallow test.[21] The number of bites was identified by discrete segments of cracker taken to eat the whole. The number of masticatory cycles was confirmed with sEMG measures recorded from the masseter muscles using the KayPentax Digital Swallowing Workstation.[b] Measures calculated were time per swallow, masticatory cycles per swallow, and swallows per bite. Both the timed water swallow tests and Test of Mastication and Swallowing Solids were video recorded[c] for all patients at each session to facilitate inter/intra-rater reliability assessment.

Submental sEMG duration during swallowing was also collected and analyzed using the KayPentax Digital Swallowing Workstation. The data were saved to a patient database on this workstation for offline analysis by the raters. After skin preparation underneath the chin, a triode patch electrode[d] was placed midline between the mental spine of the mandible and the superior palpable notch of the thyroid cartilage. Patients performed 5 saliva and 5 10-mL water swallows with task types randomized within and between participants. The instructions were, "Hold the water/saliva in your mouth and when you hear the go signal, swallow as quickly as possible." A digital tag was placed in the data acquisition file with time locked to the "go" command, which was presented at random intervals. Durational measurements extracted included premotor time (PMT), preswallow time, and duration of submental muscle contraction (fig 1). PMT was defined as the time duration between the presentation of the stimulus ("go" signal/digital tag) to the first change in the sEMG waveform. Preswallow time was defined as the time duration between the first change in the sEMG waveform to the base of the onset of swallowing, which was identified as the highest peak of the overall event. Duration of submental muscles contraction was defined as the duration between the onset and offset of the sEMG waveform. These extraction methods were conducted for all saliva and 10-mL water bolus swallows. The average PMT, preswallow time, duration of submental muscle contraction for saliva and 10-mL water bolus swallows were calculated separately across the 5 trials, at each session, per patient.

Finally, patients were evaluated for perceived changes in quality of life related to swallowing using the SWAL-QOL.

Table 1 Patient characteristics and demographics

Age/Sex	PD Onset (y)	H-Y Score	EAT-10 Scores	Dysphagia Onset (m)	Complaints	Medication On/Off Status
84/M	6	3	4	36	Coughs on food/liquid, takes longer time to chew, food sticking in throat and mouth, drooling	Carbidopa/levodopa
76/M	10	3	4	36	Loss of weight, difficulty swallowing pills, longer time to chew, food sticking on mouth/throat	Carbidopa/levodopa; changed to pramipexole during posttreatment period
71/F	16	3	4	10	Difficulty swallowing solids more than liquids, coughs on food/liquid daily, food sticking in mouth and throat, uses straw to drink liquid	Carbidopa/levodopa
69/M	7	3	4	36	Coughs on liquid/food, drooling, food sticking in mouth/throat	Carbidopa/levodopa
66/M	2	2	3	11	Coughs on food/liquid, food sticking in mouth/throat	Carbidopa/levodopa
66/F	6	3	3	12	Coughs on food/liquid, food sticking in mouth/throat, drinks a lot of thickened liquid, struggle to swallow, pain while swallowing	Carbidopa/levodopa; changed to rotigotine during treatment period
67/M	5	3	3	7	Difficulty swallowing pills, cough on liquid, solids more than liquid	Carbidopa/levodopa
64/M	4	3	3	24	Food sticking in mouth/throat, difficulty swallowing pills, coughs on liquid more than solids, drooling	Carbidopa/levodopa
57/F	3	2	3	36	Loss of weight, longer time to chew, eating unpleasurable, uses bottle/straw, swallowing solids more than liquid	Carbidopa/levodopa
54/M	7	2	3	24	Food sticking in mouth/throat, needs to swallow hard	Carbidopa/levodopa; changed to rotigotine during pretreatment period

Abbreviations: EAT-10, eating assessment tool-10 items; F, female; H-Y, Hoehn and Yahr; M, male.

Patients completed this questionnaire independently prior to evaluation sessions, and clarification, if requested, was provided on the day of the assessments. SWAL-QOL scores were calculated using the Likert method.[23] This allows each question to be linearly converted into a 0 (suggestive of greatest perceived difficulty) to 100 (suggestive of no perceived difficulty) metric, with in-between scores indicating the possible percentage score achieved.

Skill training exercise protocol

Skill training therapy commenced immediately after the second baseline session. Each patient underwent 10 skill training therapy sessions, which were conducted over a 2-week period using an sEMG biofeedback device.[e] This served as the hardware platform for the Biofeedback in Swallowing Skill Training (BiSSkiT) software.[e] The sEMG activity was measured from electrodes secured over the patient's submental muscles (collectively the mylohyoid, geniohyoid, anterior belly of digastric, and genioglossus). The sEMG data were rectified, low-pass filtered at 50Hz, sampled at 10Hz, digitized, and sent to the computer via a Universal Serial Bus port. The BiSSkiT software then processed the data from the sEMG device and plotted it in real time as time by amplitude waveforms that were then displayed on the computer monitor. At the start of each therapy session patients performed 5 hard/effortful swallows to calibrate targeted amplitude range during swallowing.

The goal of skill training was to improve the precision of swallowing muscle contraction by developing conscious control over timing and strength of swallowing. This intensive protocol involved increasing levels of difficulty and required proficiency at a particular level before moving to the next level. The practice targets were task-specific, and immediate feedback was provided. The swallowing target was a green square, which moved randomly within the amplitude and temporal range of the computer monitor. The initial size of the square was calculated by taking 50% of the average amplitude of 5 effortful swallows with its height to width ratio fixed at 1:1 (fig 2). Subsequent size varied according to a patient's performance. Instructions were to "swallow so that the peak of the waveform falls within the square" (also referred to as a hit). This task required precision of swallowing movements to meet the amplitude and temporal aspects of the target. After 3 consecutive successful hits, the size of the target/square reduced by 10%; thus requiring greater amplitude and temporal precision of swallowing. Conversely, after 3 consecutive misses, the square size increased by 10%. Each session lasted 1 hour and consisted of 100 swallowing trials partitioned into 5 blocks of 20 swallowing trials followed by a brief break before the next block commenced. All therapy sessions were conducted with saliva/dry swallows with water provided between treatment blocks to avoid drying of oral mucosa and to facilitate saliva production.

Statistical analysis

All data were captured, extracted, and analyzed by the primary researcher. Statistical analyses were performed using SPSS version 19.[f] Intra- and interrater reliability were generated by the primary researcher (R.P.A.) reanalyzing a random sample of 20% of the total data set for each type of measurement, and the same 20% of samples

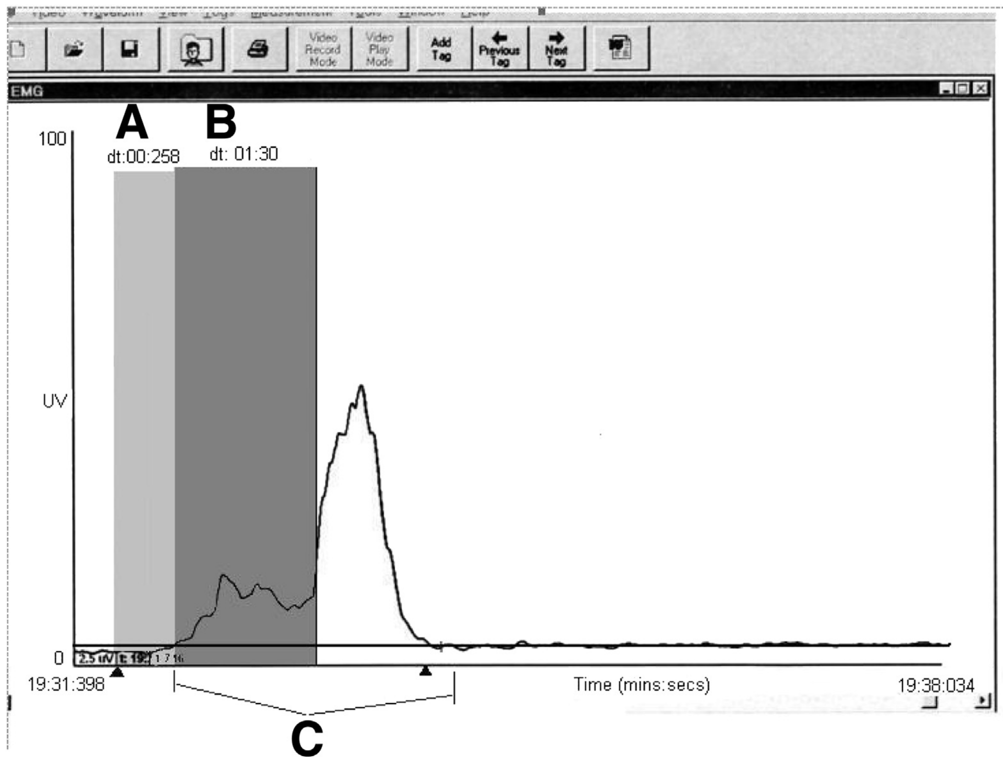

Fig 1 Durational parameters for 10-mL water bolus. First tag indicates the go stimulus, whereas the tag at the end depicts the type of swallow: (A) PMT; (B) preswallow time; and (C) duration of submental muscle contraction.

were analyzed by a second independent rater. Single-measure intraclass correlation coefficients were calculated for each measure of intra- and interrater reliability using SPSS. Both evaluators were blind to the treatment phase when analyzing the outcome measures, and analyses were performed only after all patients had completed the research protocol. General linear model repeated-measures analyses of variance (1 way) were performed; an a priori P value $<.05$ was taken as significant. Greenhouse-Geisser adjustment was applied if Mauchly test of sphericity was significant. Planned comparisons (all 2 tailed) were carried out between the 2 baseline sessions (B1 and B2) to evaluate the stability of measurement, the second baseline and the first outcome session (B2 and O1) to identify an immediate treatment effect, and the 2 outcome sessions (O1 and O2) to evaluate retention. Corrections for multiple comparisons were not conducted because they were considered too strictly conservative for exploratory studies.[24,25]

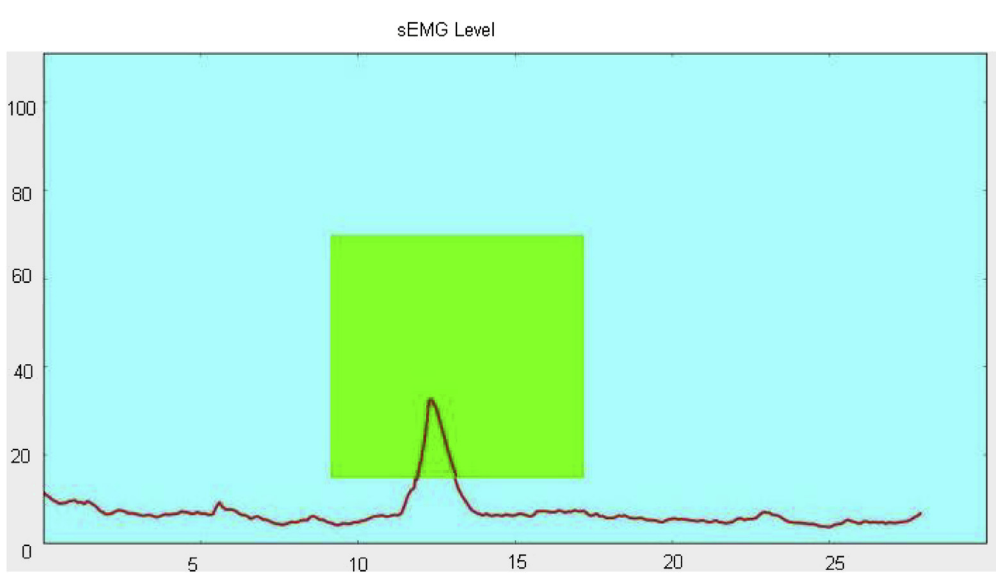

Fig 2 Skill training display (swallowing target) in the BiSSkiT software.

Hence, patterns of change, effect sizes, confidence intervals, and descriptive statistics were critically analyzed.

Results

Intrarater reliabilities across all outcome measurements were .94 to 1 (single-measure intraclass correlation coefficient), and interrater reliabilities for all parameters were .80 to .99; all were considered to indicate "almost" perfect agreement.[26,27]

Baseline measures

Baseline measures revealed no significant differences between the 2 baseline sessions (B1 and B2) for any of the parameters (P>.09) apart from SWAL-QOL, which approached significance (P=.052), indicating an improvement before treatment was initiated.

Treatment effect

Time per swallow in the timed water swallow test revealed a main effect of time ($F_{3,27}$=5.552, P=.02). Post hoc pairwise comparisons revealed an improvement between pretreatment and posttreatment, B2 and O1 (P=.034, d=.72, Δ=17%) (fig 3A). Similarly, a main effect of time ($F_{3,27}$=3, P=.048) was identified for volume per swallow. Post hoc pairwise comparisons revealed a difference between the outcome sessions, O1 and O2 (P=.032, d=.34, Δ=15%), indicating an improvement in the retention period for this parameter, despite a lack of significant change during the treatment phase (fig 3B). No significant main effect of time ($F_{3,27}$=3.69, P=.07) was identified for swallowing capacity.

No significant main effects of time on any of the parameters on the Test of Mastication and Swallowing Solids were detected: time per swallow ($F_{3,27}$=.398, P=.647), masticatory cycles per swallow ($F_{3,27}$=.111, P=.887), and swallows per bite ($F_{3,27}$=.189, P=.154).

Analyses of sEMG data revealed a significant main effect of time for PMT, preswallow time, and duration of submental muscle contraction ($F_{3,27}$=8.864, P=.00; $F_{3,27}$=14.432, P<.001; $F_{3,27}$=4.5, P=.011, respectively) for dry swallows. Post hoc pairwise comparisons were then conducted for these durational parameters, which revealed improvements from pretreatment to posttreatment (P=.003, d=1.14, Δ=44%; P<.001, d=1.62, Δ=43%; P=.012, d=1.27, Δ=26%, respectively) (figs 4A, B, C). Evaluation of translation to water swallows revealed a similar main effect of time for PMT ($F_{3,27}$=4.528, P=.044) and preswallow time ($F_{3,27}$=8.604, P=.007). Post hoc pairwise comparisons indicated improvements between pretreatment and posttreatment (P=.009, d=1.2, Δ=23%; P=.034, d=1.1, Δ=45%, respectively) (figs 4D, E). There was no significant main effect of time for duration of submental muscle contraction for water swallows ($F_{3,27}$=1.747, P=.181).

There was a significant main effect of time ($F_{3,27}$=8.163, P=.009) in swallowing quality of life. Post hoc pairwise comparisons revealed an improvement in swallowing quality of life between pretreatment and posttreatment, B2 and O1 (P=.018, d=.46, Δ=8%) (fig 5). Additionally, an improvement (approaching significance) during the nontreatment phase, B1 and B2 (P=.052, d=.27, Δ=6%), was seen.

Retention measures

Retention measures revealed no significant difference between the 2 outcome sessions (O1 and O2) for any parameter (P>.09), with the exception of volume per swallow in the timed water swallow test (P=.032) as previously mentioned.

Discussion

This study evaluated a uniquely designed skill training approach for dysphagia rehabilitation in patients with PD. Despite the small sample size, there were significant effects of treatment in many of the outcome measures providing compelling evidence for the efficacy of this novel treatment approach.

As expected, during the nontreatment baseline phase, all outcome measures remained unchanged, apart from the SWAL-QOL. This indicates that the group as a whole was physiologically stable, exhibiting consistent behavior before treatment with no order/practice effects confounding any effects of treatment. The SWAL-QOL revealed that patients perceived improvements in their swallowing even prior to treatment initiation, suggesting a possible placebo effect associated with clinician engagement. However, a comparison of the significance values between the nontreatment and treatment phases revealed a greater improvement during the treatment phase, suggesting a positive effect of treatment on patient quality of life.

Significant improvements in timing/durational parameters (eg, time per swallow in timed water swallow test, PMT, preswallow time) during the treatment phase are consistent with similar improvements seen in limb studies on gait rehabilitation in PD,[28-30] suggesting improved neuromuscular coordination, timing, speed of reaction, planning of movement, and range of movements after skill training. Biofeedback inhibits abnormal antagonistic muscle synergies resulting in an increased range of movement and efficient recruitment of muscle fibers.[31] Therefore, after skill training, the reduced coactivation of antagonistic muscles may have resulted in a better range of movement and better coordination of orolingual muscles, therefore facilitating pharyngeal swallowing. This is indicated by the significant reductions in preswallow time for both task conditions. Additionally, improved precision and motor control of swallowing resulted in the reduction of unwanted preswallow lingual movements as indicated by the reduction in preswallow time.

Increased cortical awareness may have contributed to improved timing/durational parameters of swallowing. Research on the role of attention in swallowing in PD has revealed increased reaction time for dual-task conditions during the anticipatory than the oropharyngeal phase of swallowing.[32] This suggests greater demand of attention for planning and organizing rather than executing oral movements.[32] Biofeedback facilitates active patient participation and helps the patient identify the correct movement patterns and modify them to meet the target.[31,33] Therefore, skill training increased the patient's awareness regarding movement sequences and facilitated conscious control over the timing and strength of their preswallowing behavior, resulting in more efficient initiation and execution of swallowing.

Finally, external feedback may have partially bypassed the defective basal ganglia and activated the cortical and parieto-premotor pathways, providing access to the cortical motor programs involved with swallowing and facilitating greater conscious control. Mechanisms involved in augmentation of motor learning/relearning with the use of biofeedback can be inferred[34] from neuroscience literature.[35] Of particular interest is the mechanism of bypassing[34] in which different neural pathways are activated in the presence and absence of biofeedback, specifically external visual feedback.[35] A bimanual hand movement coordination task using external visual feedback activated the premotor cortex, superior parietal, and thalamus.[36] Conversely, the basal ganglia, supplementary motor area, cingulate motor cortex, inferior parietal cortex,

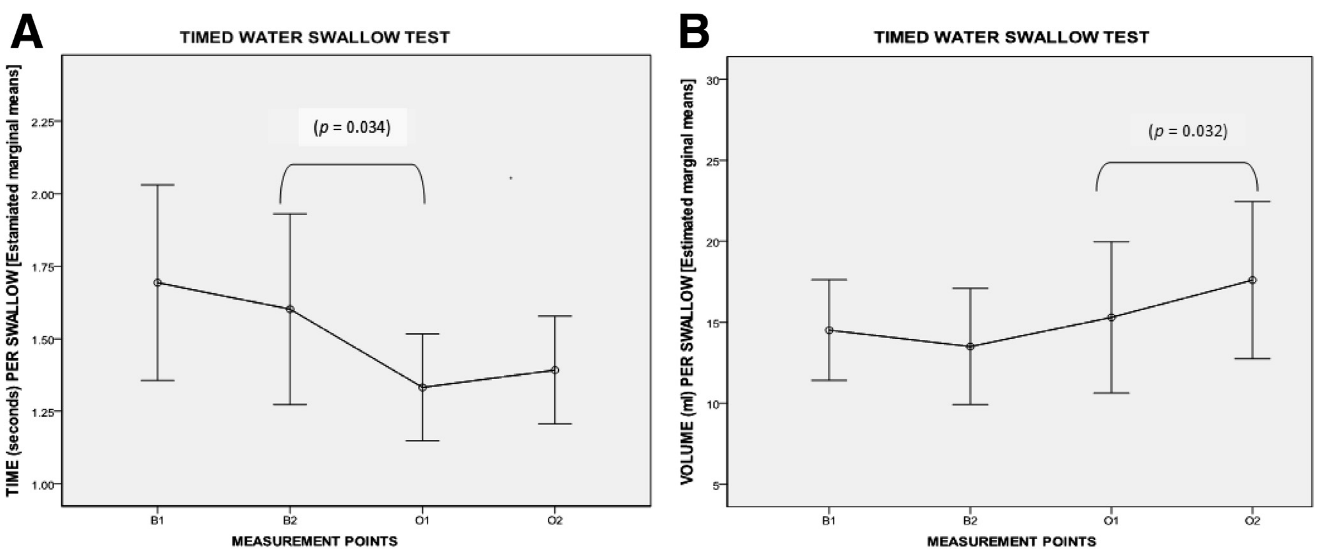

Fig 3 (A) Means and confidence intervals for time per swallow; and (B) means and confidence intervals for volume per swallow.

and frontal operculum were activated for internally generated movements. Hence, for motor disorders (eg, PD), providing external feedback may activate the parietal-premotor network by bypassing the basal ganglia and facilitating movement control.[35] Similar improvements have been reported in gait speed and step length in patients with PD when external visual and auditory cues were provided[36,37] as a result of bypassing the defective basal ganglia and using the frontal cortex to consciously control movement.[38] However, this speculation warrants investigation in the area of swallowing motor control. The extent to which bimanual motor activity can be compared with swallowing is unclear. Despite this, several studies have revealed corticomotor plasticity after novel tongue training tasks,[19,20] suggesting that corticobulbar skill training is possible and can result in changes at the neural level.

The skill training task involved swallowing saliva; therefore, the reduction in time taken to consume water (time per swallow) on the water swallow test suggests a carryover of improvements to functional swallowing. In other words, there was generalization of skills learned from the practiced task (saliva/dry swallows) to the nonpracticed but related task (water swallows) as indicated by the reduction in time taken to consume water (time per swallow) on the timed water swallow test. This suggests transference of skills to functional swallowing. In addition to transference of skills to functional swallowing, all patients demonstrated improved quality of life as measured on the SWAL-QOL. Despite this carryover effect seen for the time per swallow parameter, the duration of submental muscle contraction for water swallows did not reduce. Likewise, swallowing capacity on the timed water test did not change posttreatment. The prescribed dose of the treatment may have been insufficient to produce significant changes in these parameters. Until further research is conducted, it is difficult to distinguish whether these 2 parameters did not improve as a result of insufficient dose or ineffectiveness of the treatment.

No improvements were seen in the swallowing rate of ingesting solid textures as measured by the Test of Mastication and Swallowing Solids. The longest duration taken to consume the biscuit by a patient was approximately 2 minutes, only about 1 minute greater than age- and sex-matched controls (T. McIntosh, M.L. Huckabee, unpublished laboratory data, 2012). As swallowing rates for solids pretreatment were not severely affected, substantial improvements in the Test of Mastication and Swallowing Solids would be less likely. Also, PD patients exhibit greater difficulty with liquids than solids[39] and can manage solids using self-learned compensatory techniques (eg, taking smaller bites, chewing for longer, avoidance[40]). In our cohort, 7 patients complained of greater difficulty with liquids, whereas only 3 complained of difficulty with solids. Therefore, the use of self-learned compensatory behaviors may have lessened the symptoms for solids in this cohort. Hence, the Test of Mastication and Swallowing Solids may not have been sensitive for identifying the proportion of patients who actually exhibited problems with solid food. This limited sensitivity of the Test of Mastication and Swallowing Solids might have falsely diminished the overall magnitude of the intervention effect.

As hypothesized, no outcome measures deteriorated during the skill retention phase. This is consistent with findings that cortical reorganization after skill training effects remain in the absence of practice.[41,42] The limb literature indicates similar findings after the termination of treadmill training in PD.[29] Interestingly, volume per swallow on the timed water swallow test improved during the skill retention phase, despite no change during the treatment phase. This suggests that it may have taken longer than hypothesized for the treatment to transfer into functional swallowing. Immediate posttreatment improvements might have been insufficient to reach statistical significance. However, after skill training, the neuromuscular system may have been primed for functional change as detected during skill retention.

Study limitations

There are several limitations to this study. Importantly, no instrumental evaluations (eg, videofluoroscopy) were performed to clarify swallowing pathophysiology or aspiration/penetration, and patient selection was based only on the subjective clinical swallowing evaluation. Furthermore, inclusionary criteria were broad, sample size was small, and there was a lack of double-blinding.

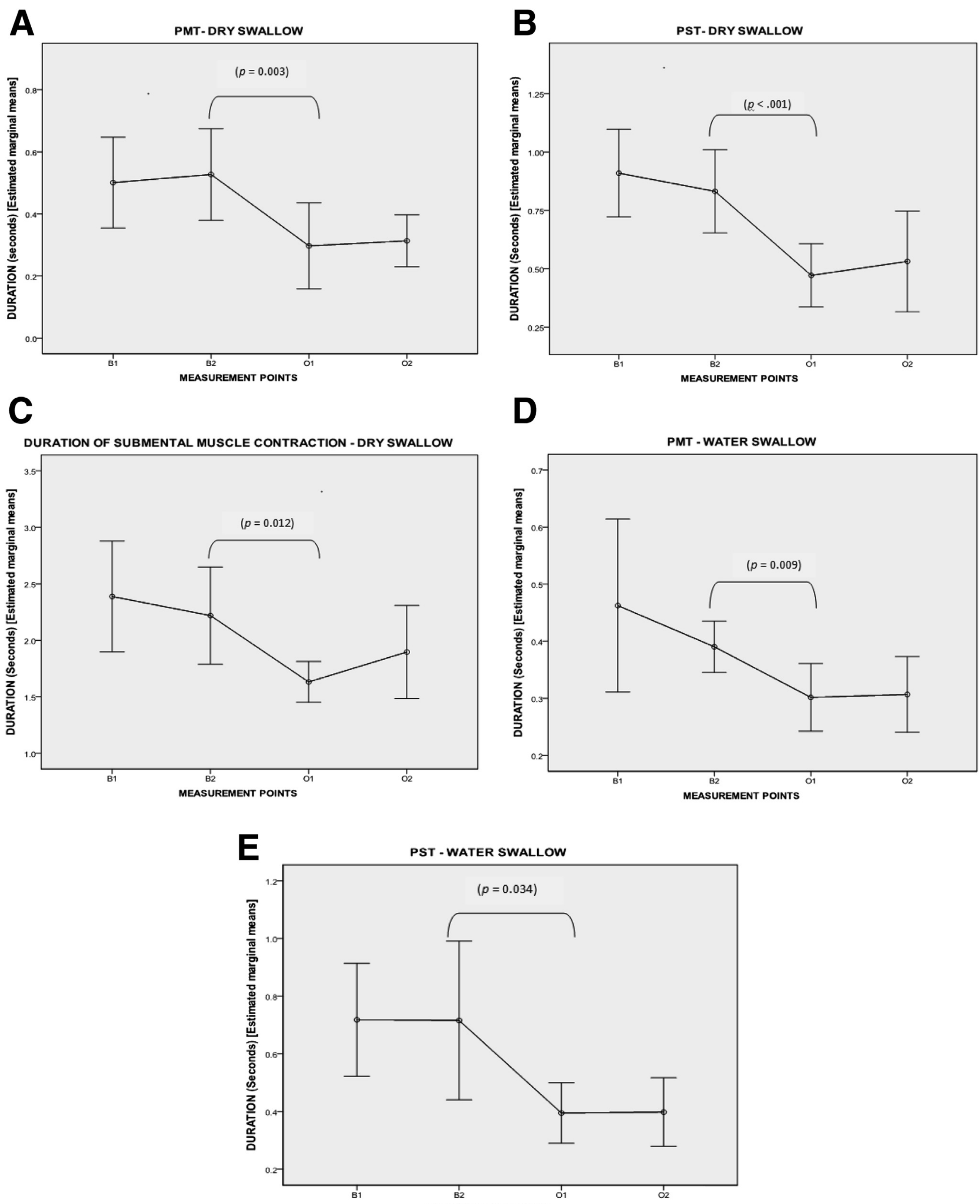

Fig 4 (A) Means and confidence intervals for dry swallow PMT; (B) means and confidence intervals for dry swallow preswallow time (PST); (C) means and confidence intervals for dry swallow duration of submental muscle contraction; (D) means and confidence intervals for water swallow PMT; and (E) means and confidence intervals for water swallow PST.

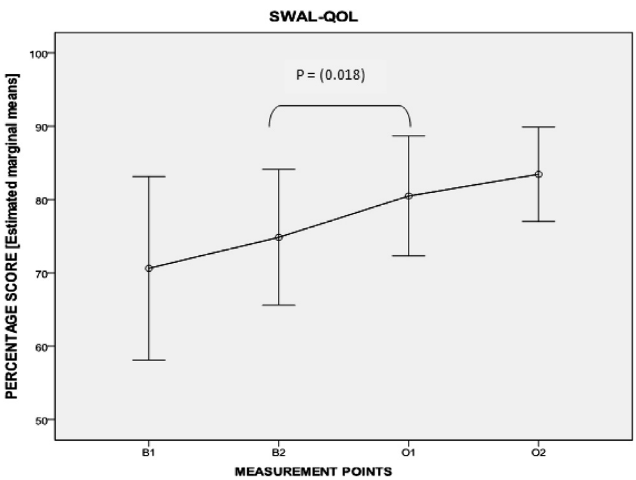

Fig 5 Means and confidence intervals for SWAL-QOL.

Also, within-patient changes during the 6-week period were not controlled. Three patients underwent a medication change; therefore, interaction between maturational factors might have an effect on the internal validity of the study. All testing, treatment, and analyses were done during the on phase of medication; therefore, results cannot be generalized to the off phase of medication. Although double-blinding was not performed, high inter- and intrarater reliability of physiological measurements suggests that bias was not a significant influence on data.

Conclusions

Skill training provided functional, biomechanical, and SWAL-QOL improvements in this cohort of dysphagic patients secondary to PD. Despite the small sample size, this study provides evidence for the viability and efficacy of this novel approach for dysphagia rehabilitation. Findings suggest that skill training may have increased the neuromuscular coordination, timing, speed of reaction, and planning of movement of orolingual structures in this sample. Additionally, heightened cortical awareness may have contributed to better movement planning and sequencing, resulting in an increased rate of swallowing. Replication of these findings in a larger study with expanded outcome measures is needed before findings can be generalized to the broader population.

Suppliers

a. Arnott's Biscuit Ltd, 24 George St, North Strathfield, NSW 2137 Australia.
b. Model 7120; KayPentax, 2 Bridgewater Ln, Lincoln Park, NJ 07035.
c. Model ES65; Samsung, Dongguan, China, 523000.
d. Thought Technology Ltd, 8205 Montreal/Toronto Blvd, Ste 223, Montreal West, QC, Canada, H4X1N1.
e. BiSSKiT; Niche Technology Ltd, 63 Northcote Rd, Christchurch, 8052, New Zealand.
f. Myopace, Model NE-1; Niche Technology Ltd, Christchurch, 8011, New Zealand.
g. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Keywords

Deglutition; Parkinson disease; Rehabilitation

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