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LARYNGOLOGY

Is the proprioceptive neuromuscular facilitation technique superior to Shaker exercises in swallowing rehabilitation?

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Abstract

Purpose This prospective study was planned to investigate whether the combined isotonic technique of proprioceptive neuromuscular facilitation (PNF) is superior to Shaker exercises in improving the function of swallowing muscles.

Methods Fifty individuals (30 females and 20 males; mean age 68 ± 3.89 years) with swallowing difficulties were separated into two groups randomly. The treatment groups were Shaker and PNF groups, which performed these exercises three times in a week for6 weeks. Swallowing difficulties were determined with the Turkish version of the eating assessment tool (T-EAT-10). The 100 ml-water swallow test was used to measure capacity, volume, and speed of swallowing. Contraction amplitude changes used as a universal measurement of motor unit activity during the muscle action were measured with superficial electromyography.

Result After 6 weeks of exercise training, T-EAT-10 scores decreased in both groups ($p < 0.001$). Water swallowing capacity and volume improved in both groups ($p < 0.001$). There was no change in swallowing speed in both groups ($p > 0.05$). Maximal voluntary contraction values of suprahyoid muscles were higher in PNF than the Shaker group ($p < 0.05$).

Conclusion Both the types of exercise can be used in the rehabilitation of swallowing difficulties. However, the PNF technique increased the contraction amplitude values that occur during maximum contraction more than the Shaker exercises. Different functional evaluations are needed to determine the effectiveness of PNF on swallowing difficulty.

Keywords Deglutition disorders · Shaker exercises · Proprioceptive neuromuscular facilitation · Electromyography

Introduction

Rehabilitative approaches for swallowing disorders include several techniques including neuromuscular electrical stimulation [1, 2], transcranial magnetic stimulation [3], thermal tactile stimulation [4], postural techniques [5], maneuvers [6], biofeedback [7], changing food consistency, texture and/or shape [8] and swallowing exercises [9]. In particular, strengthening exercises for suprahyoid muscles that initiate swallowing function by pulling the larynx to anterior and upward direction are used to prevent aspiration [10, 11].

Shaker exercises are frequently used in the rehabilitation of swallowing disorders. These exercises, which include isometric and isotonic exercises, are used to improve the anterior and upward movement of the larynx, increase the opening of the upper esophageal sphincter (UOS), decrease the amount of residue in the piriform sinus and prevent aspiration after swallowing by strengthening the suprahyoid muscular activity [6, 12].

Physiotherapists frequently use proprioceptive neuromuscular facilitation (PNF) technique to increase muscle intensities, proprioception, active range of motion, force, motor control, and learning. In this way, the function can be improved [13, 14]. If movement is performed against maximum resistance that is always used in PNF techniques,

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more motor neurons can be stimulated by the effect of force spread in other muscles and thus, the contraction force of the weak muscles can increase. Short neck flexion exercises are known to effectively strengthen suprahyoid and infrahyoid muscles [13], as a result, there can be decreased swallowing difficulty [6, 12]. Although there are studies investigating the effect of tongue, face, breathing exercises, and short neck flexion exercise performed with PNF technique on swallowing difficulty [15, 16], these studies did not report which PNF technique was used. To our knowledge, there is no study to show the effect of combined isotonic technique of PNF on swallowing difficulty. We hypothesized that combined isotonic technique of PNF improves suprahyoid muscle strength and swallowing function. The aim of this study was to compare the effects of Shaker exercises and combined isotonic technique of PNF on suprahyoid muscle strength and swallowing function.

Methods

The current study was designed as a randomized controlled trial (RCT). The Noninvasive Clinical Research Ethics Committee approved the study protocol (Decision No. 2017/22). The participants were informed about the scope and procedures of the study. All individuals provided written informed consent before participating in the study.

Patient selection

Elderly patients who applied to the physical therapy and rehabilitation research center, oral-motor rehabilitation clinic with the complaint of swallowing difficulty, but were not found to have neurological problems after neurologist's examination were included in the present study. Patients aged over 65 years , having an adequate cognitive status determined by the cognitive part of the Yale swallowing test [17], with two or more score from the eating assessment tool (EAT-10) [18] and having < 30 kg/m^2 of body mass index were included. The instrument includes ten questions. Each question is scored between '0' (no problem) to '4' (serious problem). The total score ranges between 0 and 40. If total score was 2 or more (≥ 2), it could predict swallowing dysfunction [18]. Turkish version of the eating assessment tool (T-EAT-10) was used in the present study [19].

The exclusion criteria of the study were, having inadequate cognitive status according to the cognitive part of the Yale swallowing test [17], pneumonia, continuous neck pain and/or radiculopathy, neurological disease (cerebrovascular disease, myasthenia gravis, Parkinson, etc.), inadequate head control, using antidopaminergic or antihistaminic drugs, doing regular sport (three times or above a week), having structural problems that may affect swallowing function, and having a history of neck surgery, head and neck cancer.

Randomization

Patients who participated in the study were divided into two treatment groups that were Shaker group and PNF group by simple randomization procedure, the lottery method. Since gender could directly affect the results of evaluations, the number of men and women was evenly distributed between the groups. Group names were written under the boxes. Then, the names of female patients were written on pink papers, and names of male patients on blue papers. Randomization was done by a person who did not know which box belonged to which group. She was asked to divide the same colored papers into two boxes in equal numbers.

Evaluation procedure

The demographic characteristics including age, gender, height, weight and health history were recorded. Patients completed the T-EAT-10 questionnaire. After the 100 ml-water swallowing test was performed, surface electromyography (sEMG) was assessed. The assessment was done by people who had no information about group distributions and the patients.

Swallowing performance was assessed with the 100 ml-water swallowing test which is cheap, easy to use [20], and with the highest reliability [21]. The water swallowing speed (ml/s) has been demonstrated to have high intra-/inter-rater and test–retest reliabilities [22]. A strong relationship between water swallowing speed and swallowing difficulty was known [22]. This test can be reliably carried out with minimal specific training [22] and it is an ideal assessment tool to compare pre-treatment measures with the post-treatment measures in swallowing difficulty [20]. Also, it allows regular and frequent monitoring for controlling patients in the time [20]. A total of 100 ml-water was put on a plastic cup. The patient was ordered to drink the water 'as quickly as comfortably possible' in an upright seated position. The time to drink and the amount of swallowed liquid were recorded. If the patient was unable to complete swallowing of water, the residual water was measured by syringe, using a minimum scale of 1 ml. The number of swallows was counted simultaneously by the researcher (by feeling the thyroid cartilage for laryngeal elevation during swallowing). The timing was started to record when the water first touched the bottom of lip after "start" command, and finished when the larynx came to rest after the last swallow (this was usually accompanied by other signals, e.g. exhalation, phonation or opening of the mouth). Three swallowing performance parameters were calculated including swallow volume (milliliters per swallow = ml swallowed divided by number of swallows taken), swallow capacity (milliliters per second = ml swallowed divided by time taken), and swallow speed (time per swallow = time taken divided by number of swallows) [21]. The test was not used if the patient reported coughing on liquids every time. If patients coughed during swallowing, the test was stopped immediately, regardless of whether they had finished drinking the water. No systematic effect is thought on the number of test repetitions, water taste, and temperature in elderly patients [22]. Although there was insufficient data, in our study, the evaluation was made using the same brand of water kept in the same room conditions to avoid any negative or positive effect.

sEMG activities of suprahyoid muscle were collected during maximum voluntary muscle contraction. All sEMG evaluations were performed by the same neurologist who was an expert in EMG. Given the recommended amplifier bandpass settings from 20 Hz high-pass up to at least 2 kHz low-pass and the signal picked up by the electrodes was amplified 2000 times [23]. The signal input range was set to 20 mV [24]. yEMG's values were recorded as microvolts. Before fixing the electrodes, the skin was cleaned with alcohol and waited 30 s for drying. Then, two superficial electrodes were placed on right and left geniohyoid muscles [25], and away from 1 cm of the midline in-between two geniohyoid muscles [23]. The surface areas of the electrodes were similar (1 × 2.5 cm) and it was preferred according to the length of the muscle. The distance between the centers of the electrodes was set to be less than 20 mm [25]. In addition, due to the sweat that might occur, attention had been paid to allow an air gap between the electrodes to prevent short-circuiting of the sEMG and resultant variation of the contraction amplitude value [26]. There might be a gain difference of up to 5% between the channels used. To Prevent this, the same channel was connected to the right and left sides of all the patients participating inthe study. The same channel was connected to same sides of all the patients participating in study for prevention of gain difference of up to 5% between the channels used [26]. The reference electrode was placed on the left ear lobe for preventing the record of another muscle activation [26]. The patient was sitting upright during the evaluation with the sEMG. Before recording, the cables and electrodes were fixed using tape to avoid pulling of the artifacts [25]. Before the recording, participants were taught a movement that they would do during the activity. After making sure that the patient did the correct move, the sEMG was started to record. If the MVC record time is longer or shorter than necessary, the margin of error increases [27]. For preventing the margin of error, the duration of the contraction and the record was set at 5 s. The maximum contraction was recorded when the patients were asked patients to open the jaw fastly and to keep their position and contraction against the semi-rigid cervical neck brace for 5 s [26] (Fig. 1). Record was started 1 s after contraction. All sEMG records were repeated 5 times and after each record, the patient was rested for 60 s [26, 28]. The maximum electrical muscle activity obtained during the measurements was recorded. Maximum values were accepted for statistical analysis.

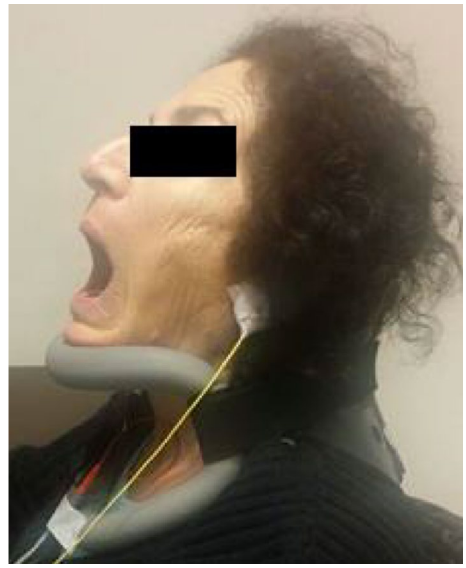

Fig. 1 Evaluation of MVC with sEMG

Exercise protocol

Patients were randomly allocated two exercise groups such as Shaker group and PNF group.

Shaker group

Patients were asked to perform Shaker exercises which consist of the isometric (3 repetitions) and the isotonic contractions (30 repetitions) for neck flexor muscles. Patients were instructed to raise their head high enough to be able to observe their toes without raising their shoulders when lying on their back. For isometric contractions, patients lifted their head and held on this position for 1-min three times with a 1-min rest between the lifts. For isotonic contractions, patients lifted their head by 30 consecutive repetitions without ''holding'' the head lift, as described in the isometric contractions [29]. Both isometric and isotonic contractions have to be finished at the same treatment session. Shaker exercises were taught by CS. The exercises were given as a home exercise and monitorization was done by the follow-up form. They were asked to perform each exercise at 1 set per day/3 days a week for 6 weeks.

PNF group

Combined isotonic technique which includes concentric contractions, stabilizing contractions, and eccentric contraction without relaxation was used in the present study. Stabilizing contractions were used to improve control, force, coordination, and eccentric contraction ability of muscles [13]. Patients were asked to move their head against resistance from end of the extension-left rotation to end of the flexion-right rotation with open mouth in a diagonal direction (concentric contraction), at the end of the movement they kept the position for 6 s against resistance (stabilizing contractions) at upright seated position (Fig. 2). Then, the patients tried to keep her/his head and mouth in position, the physiotherapist moved the patient's head and mouth to initial position (eccentric contraction). These movements were accepted as one repetition. These exercises were done as 30 repetitions per day consecutively considering fatigue and tolerance without relaxation. If the patient felt fatigue or did not tolerate, the exercise was finished. After 1 min rest, it was repeated from opposite diagonal position, that is from the end of the extension-right rotation to end of the flexion-left rotation with open mouth [13, 14]. They were asked to do 1 set per day/3 days a week for 6 weeks.

Statistical analysis

Statistical analyses were performed with the IBM-SPSS for Windows version 20 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were given as mean ± standard deviation for numerical data. The normal distribution of the obtained numerical variables were determined by visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk tests, variation coefficient analysis). Logarithmic transformation was used to normalize the data distribution for swallow volume, and capacity. Wilcoxon test was used to analyze T-EAT-10 score pre-/post-treatment in groups. Mann–Whitney *U* test was used to analyze T-EAT-10 score pre-/post-treatment between groups. Pre-/post-treatment, peak contraction amplitude, swallow speed/capacity/volume were analyzed with paired *t* test in groups, and independent sample *t* test between groups. Since PNF exercise was primarily used in this study, sample size was calculated to be 25 subjects with a 5% type 1 and 20% type 2 error limits before and after exercise to provide 80% working power, to gain 0.60 of effect size and a 95% confidence interval. The significance level was accepted $p < 0.05$.

Results

Fifty of the 58 patients completed the study. The Consolidated Standards of Reporting Trials (CONSORT) table depicts patient flow throughout the study (Fig. 3).

There were 15 females and 10 males in each group. The mean age, height, weight, and body mass index of Shaker group were 69 ± 4.93 years (range of 65–88 years), 163.16 ± 7.89 cm (range of 148–178 cm), 72.28 ± 8.22 kg (range of 52–87 kg), and 27.13 ± 2.21 kg/cm^2 (range of 20–29 kg/cm^2), respectively. The mean age, height, weight, and body mass index of PNF group were 67 ± 2.05 years (range of 65–75 years), 161.20 ± 6.95 cm (range of 140–171 cm), 71.48 ± 7.12 kg (range of 56–82 kg), and 27.47 ± 1.79 kg/cm^2 (range of 23–29 kg/cm^2), respectively. There were no statistically significant differences in age, height, body weight, and body mass index between the Shaker and PNF groups ($p > 0.05$).

There was significantly differences in T-EAT-10 scores between pre-/post-treatment at each group ($p < 0.01$). After treatment, T-EAT-10 scores decreased. There was no significant difference in T-EAT-10 scores both of the pre-/post-treatment between groups ($p > 0.05$) (Table 1).

There were significant difference in peak contraction amplitude ($p < 0.001$) during maximum voluntary contraction; swallow capacity ($p < 0.001$) and swallow volume ($p < 0.001$) at pre-/post-treatment in Shaker group. There was a significant difference in peak contraction amplitude

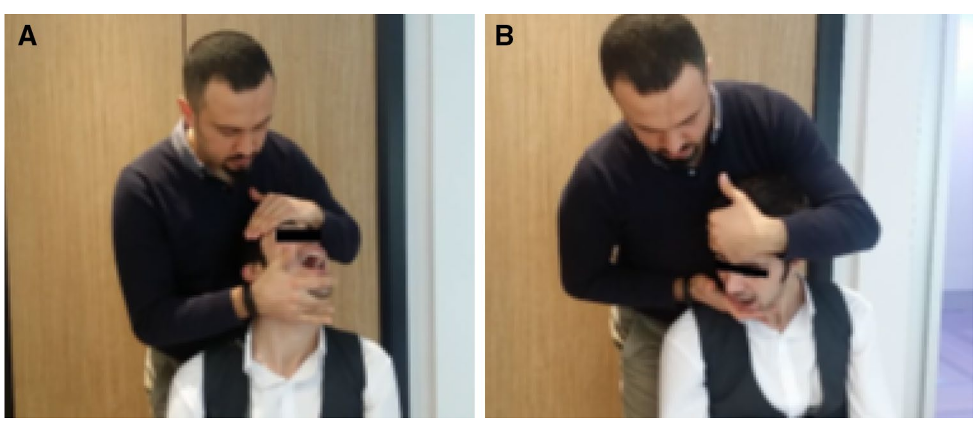

Fig. 2 Applying of PNF for right flexion and rotation. **a** start position, **b** finish position

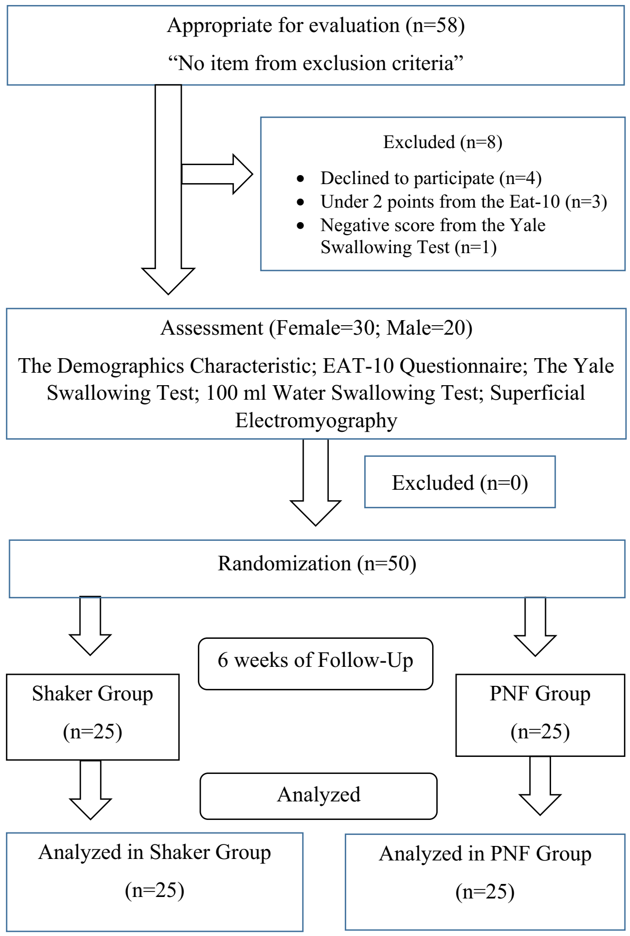

Fig. 3 Consolidated standards of reporting trials (CONSORT) table

($p<0.01$) during maximum voluntary contraction; swallow capacity ($p<0.001$) and swallow volume ($p<0.001$) at pre-/post-treatment in PNF group. There was no significant differences in swallow speed at pre-/post-treatment in each group ($p>0.05$) (Table 1). There were significant differences in peak contraction amplitude ($p<0.05$) during maximum voluntary contraction at post-treatment between groups. There was no significant difference at swallow speed/capacity/volume at pre-/post-treatment between groups ($p>0.05$) (Table 1).

Discussion

The primary finding of this study was that strengthening exercises with PNF techniques using combined isotonic contractions reduced dysphagia severity as much as the Shaker exercises. The secondary finding was that PNF technique increased the mean peak contraction amplitude obtained during maximum voluntary contraction of suprahyoid muscles more than Shaker exercises. The third finding was that both exercise methods increased the velocity, capacity, and quantity of water swallowing. Our hypotheses which were combined isotonic technique of PNF increases peak contraction amplitudes of suprahyoid muscles, and improves swallowing function were supported by findings of the present study.

Swallowing could be negatively affected by the weakness of suprahyoid muscles, and consequently, result in dysphagia and aspiration pneumonia [30]. The weakness of suprahyoid muscle associated with swallowing function can lead to decreased hyoid movement [31]. Shaker exercises are frequently used in the treatment of swallowing difficulty to strengthen suprahyoid muscles that provide the primary control of the hyoid movement [6, 12, 32, 33] while only two papers used PNF techniques for swallowing problems in the literature [15, 16]. In a study which compared PNF with the Shaker exercise [15], improvements in prematurity bolus, the amounts of residue in the vallecula–pyriform sinus, laryngeal elevation, epiglottic closure and pharynx transition time were observed in both groups, but no difference was determined between groups. In another study, the effect of facial, tongue and breathing exercises performed with PNF technique on swallowing function after stroke was investigated and it was emphasized that these exercises were effective [16]. Therefore, PNF is also considered as an effective exercise method for swallowing rehabilitation as Shaker exercises [15, 16]. This is the first study to use combined isotonic technique of PNF which comprised three contraction types as isometric, eccentric, and concentric.

In the PNF technique, the resistance of the clinician should be applied against the maximal voluntary contraction of the patient and should not prevent the smoothness of the movement. More motor neurons are stimulated with PNF, and thereby the muscular ability of the muscle, motor control, learning ability of movement, proprioception and active range of motion increase, and muscle strength increase with force transmission [13, 14]. The force transmission, individual loading, progress, specialization, and other force transmission parameters due to the nature of the PNF technique do not occur in Shaker exercises. Both peripheral [13, 14] and cortical effects [34, 35] of PNF technique to increase exercise efficiency have been demonstrated by studies, but there were no studies on the peripheral and cortical effects of Shaker exercise. Therefore, the PNF technique was selected to increase the effectiveness of exercise in this study, and as a result, although there is no significant difference between groups, improvement in swallowing performance was better in PNF group than Shaker group.

Studies evaluating the suprahyoid muscle activity of healthy individuals by sEMG compared Shaker exercises with different exercises and examined the effects of acute [28, 36] and 6-week treatment results [37]. Compared with Shaker exercises, the immediate effects of resistant jaw-body exercises

Table 1 The T-EAT-10 scores of patients, sEMG activities of suprahyoid muscle, and speed and capacity and volume of the swallow at pre-/post- treatment in groups, and between the groups

	Group	Pre-treatment X̄ ± SD	Post-treatment X̄ ± SD	*p*
T-EAT-10 scores	Shaker	3.48 ± 1.83 (Min: 2–Max: 7)	0.76 ± 0.78 (Min: 0–Max: 2)	**0.000**$^{\beta}$
	PNF	3.56 ± 1.29 (Min: 2–Max: 8)	0.64 ± 0.81 (Min: 0–Max:3)	**0.000**$^{\beta}$
	p	0.542[a]	0.505[a]	
Peak amplitude (µV)	Shaker	425.04 ± 170.73	614.80 ± 262.04	**0.000***
	PNF	417.96 ± 143.00	807.28 ± 300.00	**0.001***
	p	− 2.42[b]	**0.020**[b]	
Swallow speed (second per swallow)	Shaker	1.29 ± 0.25	1.27 ± 0.22	0.589*
	PNF	1.33 ± 0.28	1.25 ± 0.26	0.145*
	p	0.615[b]	0.746[b]	
Swallow capacity[c] (millilitres per second)	Shaker	1.19 ± 0.12	1.26 ± 0.09	**0.000***
	PNF	1.19 ± 0.12	1.30 ± 0.08	**0.000***
	p	0.804[b]	0.092[b]	
Swallow volume[c] (millilitres per swallow)	Shaker	1.30 ± 0.10	1.36 ± 0.09	**0.000***
	PNF	1.30 ± 0.12	1.39 ± 0.10	**0.000***
	p	0.948[b]	0.250[b]	

Bold values indicate $p < 0.05$

[a]Mann–Whitney *U* test

[b]Independent sample *t* test

[c]Logarithmic transformation was used

$^{\beta}$Wilcoxon test

*Paired *t* test; $p < 0.05$

[30] and Chin Tuck against resistance exercises [36] have been shown to increase suprahyoid muscle activation more than Shaker exercises [28, 36]. The recline exercise which is performed against gravity similar to Shaker exercises without resistance did not show a significant difference in peak contraction amplitude values at the end of six weeks compared to Shaker exercises [37]. In our study, contraction amplitude obtained after maximum contraction in individuals who suffered from swallowing difficulties was significantly higher in PNF group compared to Shaker group after 6 weeks of treatment. Findings from previous studies [28, 36, 37] suggest that resistance exercises are more effective in increasing muscular activation compared to movements against gravity. As known, loading in excess of 70% of one repetition maximum is needed to maximum adaptations in muscular strength and hypertrophy [38]. Although Shaker exercise is designed against gravity, it may be insufficient to increase muscular activation and loading due to a lack of resistance component. Therefore, we thought that more decrease in swallowing difficulty in PNF group may be related to the increase in the amplitude during contraction.

Reduction in water swallow performance may be a sign of neurogenic dysphagia or a potential respiratory complication [22]. Additionally, decreased water swallowing performance may be a compensatory behavior for dysphagic patients [20]. In this current study, both exercise groups improved water swallowing performance when related data (amount and capacity of water swallowing) was analyzed. The result of improving water swallowing performance showed that exercise programs could improve water swallowing performance, prevent pulmonary complications due to aspiration, and improve quality of life in elderly individuals without having any neurodegenerative problems but having a swallowing difficulty.

During water swallowing, despite no statistical differences, clinical results of the PNF group were found better than Shaker group. This positive result showed that exercise programs in elderly individuals without neurodegenerative problems who have swallowing difficulty could improve water swallowing performance, prevent pulmonary complications due to aspiration and improve quality of life.

It is known that Shaker exercises increase anterior and upward movement of the larynx and opening of UOS, decrease residue in piriform sinus and prevent aspiration by strengthening suprahyoid muscles [6, 12]. In the current study, since videofluoroscopic swallowing evaluation was not performed, the effects of PNF technique and differences with Shaker exercises could not be determined. However, we could suggest that the clinical improvements obtained from Shaker exercises can also be obtained using PNF techniques as a result of this study. There is a need for new studies to evaluate the effects of PNF techniques by videofluoroscopic swallowing evaluation.

The current study also has some limitations. The swallowing difficulty was determined by the T-EAT-10 which was commonly used clinical instrument, and videofluoroscopic swallowing evaluation as a gold standard was not performed. In addition, the effects of training programs on the quality of life of patients have not been investigated. Thus, there is a need for studies to evaluate the effects of improvement in suprahyoid muscle activation by videofluoroscopic swallowing evaluation which shows functional parameters, and also investigate the effects of improvement in suprahyoid muscle activation on quality of life of patients.

Conclusion

The present study was the first study to evaluate the effects of combined isotonic technique of PNF and Shaker exercises in the rehabilitation of swallowing difficulties seen in elderly individuals. Combined isotonic technique of PNF increased peak contraction amplitude's value of suprahyoid musles than Shaker exercise. Despite no statistical difference in T-EAT-10 scores and swallow speed–capacity–volume, they showed positive improvement in PNF group than Shaker group. It is an important clinical outcome of this currect study in which the PNF technique is an effective and improvable treatment option to increase muscular peak strength and improve swallowing function. There is a need for studies to investigate the effects of Shaker exercises and PNF techniques on muscular thickness, motor unit switching time, histological changes of suprahyoid muscles and cortical representation.

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Compliance with ethical standards

Conflict of interest All authors have no conflicts of interest with respect to the data collected and procedures used in this study. The authors declare that they have no sponsor for the study design, in the collection, analysis and interpretation of data, in writing of the manuscript, and in the decision to submit the manuscript for publication.

Ethical statement The authors confirm this study meets the guidelines of the Declaration of Helsinki and after local ethical approval all subjects provided written informed consent.

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