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ORIGINAL ARTICLE

A randomized controlled trial of scapular exercises with electromyography biofeedback in oral cancer patients with accessory nerve dysfunction

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Abstract
Purpose This study aims to investigate the effects of electromyography (EMG) biofeedback on scapular positions and muscle activities during scapular-focused exercises in oral cancer patients with accessory nerve dysfunction.
Methods Twenty-four participants were randomly allocated to the motor-control with biofeedback group ($N = 12$) or the motor-control group ($N = 12$) immediately after neck dissection. Each group performed scapular-focused exercises with conscious control of scapular orientation for 3 months. EMG biofeedback of upper trapezius (UT), middle trapezius (MT), and lower trapezius (LT) was provided in the motor-control with biofeedback group. Scapular symmetry measured by modified lateral scapular slide test; shoulder pain; active range of motion (AROM) of shoulder abduction; upper extremity function; maximal isometric muscle strength of UT, MT, and LT; and muscle activities during arm elevation/lowering in the scapular plane were evaluated at baseline and the end of the intervention.
Results After the 3-month intervention, only the motor-control with biofeedback group showed improving scapular symmetry. Although both groups did not show significant improvement in shoulder pain, increased AROM of shoulder abduction and muscle strength of the UT and MT were observed in both groups. In addition, only the motor-control with biofeedback group had improved LT muscle strength, upper extremity function, and reduced UT and MT muscle activations during arm elevation/lowering.
Conclusions Early interventions for scapular control training significantly improved shoulder mobility and trapezius muscle strength. Furthermore, by adding EMG biofeedback to motor-control training, oral cancer patients demonstrated greater effectiveness in stabilizing scapular position, muscle efficiency, and upper extremity function than motor-control training alone.
Trial registration Institutional Review Board: This study was approved by the Chang Gung Medical Foundation Institutional Review Board (Approval No: 201901788A3. Approval Date: 2 January, 2020).
Clinical trial Registration: This trial was registered at ClinicalTrials.gov (ClinicalTrials.gov ID: NCT04476004. Initial released Date: 16 July, 2020).

Keywords Accessory nerve · Scapula · Trapezius muscle · Electromyography

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Introduction

The accessory nerve superficially crosses the posterior triangle of the neck, which makes it susceptible to injury during surgery [1]. The accessory nerve innervates sternocleidomastoid and trapezius muscles. Among these, the trapezius is the dominant muscle for scapular movement and stabilization. The upper trapezius (UT) is responsible for scapular anterior tilt and external rotation [2]. The middle trapezius (MT) and lower trapezius (LT) also contribute to scapular external rotation. In addition, the LT couples with the serratus anterior to generate scapular posterior tilt and upward rotation [2]. It has been shown that complete or incomplete denervation of the UT by 4 months after nerve-sparing neck dissection [3] and the decreased amplitudes of trapezius muscle might persist at least 9 months after neck dissection [4]. In case of accessory nerve dysfunction, trapezius paralysis may lead to scapular dyskinesis [1, 5]. Early physiotherapy intervention could prevent secondary glenohumeral stiffness in patients with head and neck cancer after neck dissection [6].

It has been proposed that early interventions of scapular-focused exercises benefit shoulder pain, active range of motion (AROM) of the shoulder joint, scapular muscle strength, and quality of life in oral cancer patients with scapular dyskinesis [7, 8]. In addition to selective muscle strengthening, coordinated neuromuscular activations are essential for three-dimensional scapular kinematics. In particular, the sensorimotor system (e.g., proprioception) is affected in patients with shoulder problems [9], and altered cerebral sensorimotor representations would lead to poor motor function after peripheral nerve disorder (e.g., neuralgic amyotrophy) [10]. Evidence shows that integrating motor-control training into scapular-focused exercises could improve scapular position and kinematics by altering muscle recruitment patterns in patients with shoulder impingement syndrome [11, 12]. However, altered scapular position (e.g., lateral scapular winging), limited AROM of shoulder abduction, and shoulder pain are often observed in patients with accessory nerve dysfunction [1, 5]. To our knowledge, there is no study focusing on restoring scapular symmetry in oral cancer patients with accessory nerve dysfunction.

Patients with accessory nerve dysfunction may have difficulty learning optimal scapular orientation due to impaired proprioceptive sensation [13]. Electromyography (EMG) biofeedback has been used as visual feedback during scapular-focused exercises to improve scapular kinematics in healthy individuals [14] and muscle balance ratio in subjects with subacromial impingement syndrome [15]. It has been shown that EMG biofeedback effectively inhibited synkinesis in patients with facial palsy [16]. In addition, EMG biofeedback was used to facilitate and control muscle contraction during the phase of reinnervation after peripheral nerve transfer [17]. Therefore, the purpose of this study is to investigate whether motor-control training with EMG biofeedback during scapular-focused exercises specifically assists in scapular orientation in oral cancer patients with accessory nerve dysfunction. We hypothesized that adding EMG biofeedback during scapular-focused exercises would lead to a more symmetric scapular position, greater shoulder AROM, muscle strength, muscle activity during arm movement, and upper extremity function, and less shoulder pain than the motor-control training without EMG biofeedback.

Methods

Participants

This study is a single-blinded randomized controlled trial. The participants were enrolled from the rehabilitation center of a hospital. The inclusion criteria were (1) newly diagnosed oral cancer subjects with clinical signs of spinal accessory nerve dysfunction (e.g., shoulder droop, limited AROM of shoulder abduction, and insufficient muscle strength of the shoulder abductor against gravity) after neck dissection, (2) the presence of scapular dyskinesis (e.g., asymmetric scapular motion in multiple planes by observation) [18], (3) had prominent scapular asymmetry i.e., more than 1.5 cm side-to-side difference of the distance between the inferior angle of the scapula and the spinous process of the seventh thoracic vertebra when performing shoulder abduction to 90° with a 1 kg load in the scapular plane [19, 20], and (4) age between 20 and 65 years. Participants were excluded if they (1) had bilateral neck dissection, (2) had distant metastasis or recurrence, (3) were unable to communicate or comprehend the questionnaires, (4) had a history of shoulder pain in 1 year prior to neck dissection, (5) had any disorder that could influence movement performance, or (6) were pregnant or breastfeeding. This study was approved by the Chang Gung Medical Foundation Institutional Review Board (Approval No: 201901788A3) and Clinical Trials (Approval No: NCT04476004). Informed consent was obtained from each participant. This report was in accordance with the Consolidated Standards of Reporting Trials (CONSORT) Statement for randomized trials (Online Resource 1).

The sample size was analyzed priorly using G*Power 3.1.9 based on AROM of the shoulder joint from a previous study [8], and at least eight participants in each group were required (power = 80%, $\alpha = 0.05$). However, previous studies demonstrated that at least ten participants in each group need to be included to explore EMG activity involving the scapular muscles [14, 21]. Twelve participants in each group were recruited, considering the 10% dropout rate. A researcher who was not involved in the intervention and evaluation sessions used computer-generated random numbers to allocate four participants in one block. All participants were randomly assigned to the motor-control with biofeedback group or the motor-control group.

Interventions

Before the intervention, all participants acquired anatomical and functional education about the trapezius muscle.

Both groups received conventional physical therapy (e.g., scar massage, stretching, active and passive ROM exercise of the shoulder joint) and motor-control training integrated into scapular-focused exercises. The scapular-focused exercises were based on the previous studies (Online Resource 2) [7, 21, 22]. For both groups, a physical therapist provided kinesthetic and verbal cues during the exercises to enhance conscious control of scapular position and movement during exercises [22, 23]. For example, the therapist tapped the top of the acromion to instruct clavicle elevation or contacted the posterior acromion to instruct verbally to draw shoulder blades toward the spine for emphasizing scapular posterior tilt, external rotation, and upward rotation. In the motor-control with biofeedback group, additional online EMG biofeedback of the UT, MT, and LT was implemented during scapular-focused exercises (Fig. 1), and participants were instructed to increase muscle activities during exercises. The physical therapist instructed the participants to focus on the specific parts of the trapezius muscle shown in Online Resource 2 during each scapular-focused exercise. There were 12 intervention sessions in 3 months for each participant, and there were 60 min of each session.

Primary outcomes

The scapular position was assessed by the modified lateral scapular slide test (MLSST), which has been proposed as a reliable method for evaluating scapular symmetry [20]. The distance between the inferior angle of the scapula and the spinous process of the seventh thoracic vertebra was measured in centimeter three times for each side using a vernier caliper, and the difference between bilateral sides was averaged. MLSST was measured in three positions: bilateral arms placed by the side (position 1), hands placed on the hips (position 2), and holding a 1 kg dumbbell and arms elevated to 90° of shoulder abduction with maximal internal rotation in the scapular plane (position 3). Intraclass correlations (ICCs) for intra- and inter-rater reliability of MLSST is 0.81–0.96 in subjects with shoulder pain, and 95% confidence interval (CI) of minimal detectable change (MDC) for MLSST is 0.67–1.40 cm on the symptomatic side [20]. For more information on MLSST, please refer to Online Resource 3.

The AROM of shoulder abduction was measured in degrees three times using a universal goniometer, and shoulder pain was measured during exercises by a 10 cm visual analog scale (VAS). The internal reliability of the two-arm goniometer is 0.58–0.99 [24], and the MDC of the AROM of shoulder abduction is 11–16° with good intra-rater reliability (0.91) [25]. The test–retest reliability of the VAS is 0.94 [26], and the minimal clinically important difference (MCID) is 1.4–1.6 in the shoulder pain [27].

Secondary outcomes

The Disabilities of the Arm, Shoulder, and Hand (DASH) is a 30-item, reliable and valid assessment of upper extremity function and symptoms [28] and has been used for patients undergoing neck dissection [29]. The scores range from 1 to 100, with a higher score indicating greater disability. The ICC for test–retest reliability is 0.91 in patients with head and neck cancer after neck dissection [29]. A change in the DASH score exceeding 10.83 points is meaningful in discriminating between improved and unimproved states [30].

The strength of the maximum voluntary isometric contraction (MVIC) of the UT, MT, and LT was measured in newtons (N) by a hand-held dynamometer (MicroFET®3, Hoggan Scientific, LLC, USA), and the testing position was based on previous studies [7, 31]. The ICC for test–retest reliability of

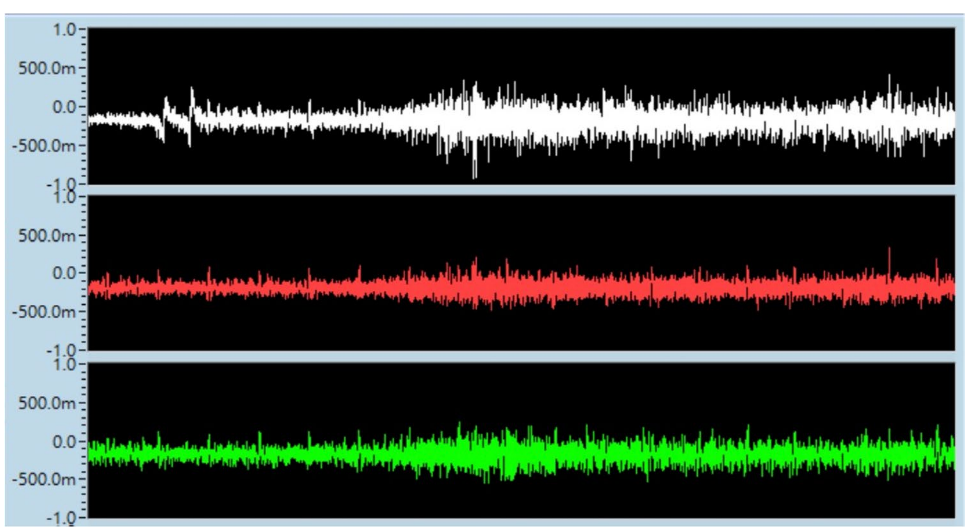

Fig. 1 An example of EMG biofeedback of the upper trapezius, middle trapezius, and lower trapezius. The participant was asked to increase muscle activation of upper trapezius during performing the movement of 90° shoulder abduction with neck side-bending to the ipsilateral side. (White line: upper trapezius, red line: middle trapezius, green line: lower trapezius)

the hand-held dynamometer is 0.85–0.96 [32], and for MVIC measurement is 0.84–0.98 [31]. The participants were asked to resist a manual force provided by the physical therapist for 5 s in each testing position. Each MVIC task was repeated three times with a 30 s rest between each repetition. There was a 60 s rest between different muscles.

The muscle activities of the UT, MT, and LT were recorded by surface EMG. The muscle activities of the UT, MT, and LT were recorded by surface EMG electrodes (Ambu® BlueSensor NF-50-K, Malaysia) with an AC amplifier (cut-off frequency: 10–450 Hz; sampling rate: 1000 Hz; sampling rate: 1000 Hz; Model: QP511, GRASS, USA) when conducting the tasks of MVIC and arm movement, including elevating and lowering arm with a 1 kg weight in the scapular plane for three times at a speed of 3 s per movement according to a metronome. The placement of the EMG electrodes (Online Resource 4) was based on previous studies [22]. The root mean square (RMS) values of the EMG data were calculated between 2 and 5 s for each MVIC task. The EMG RMS values of arm elevation and lowering were normalized by the RMS values of MVIC and were represented as %MVIC. The test–retest reliability of the EMG under MVIC is good for the scapular exercises (0.89–0.96) [33].

All assessments were employed at baseline (Pre-test) and the end of the intervention (Post-test) by a trained physical therapist who was blinded to the subject allocation.

Statistical analyses

The generalized estimating equation (GEE) procedure was conducted to analyze repeated-measures outcome variables over time, which has the benefit of providing higher power with a small sample size for repeated measurements with complete or missing data [34, 35]. Although the sample size of the presented study ($N = 24$) was estimated by previous studies with sufficient statistical power, 24 participants might be a relatively small sample size. Therefore, we chose the GEE for its robust analysis in the present study. We used a model-based estimator and an exchangeable working correlation matrix. Separate models were run for all outcome measures with post-test as the reference, and each muscle was analyzed separately for each task. Bonferroni adjustment was conducted for multiple analyses. The level of significance was set at $p < 0.05$. Statistical analyses were completed using SPSS version 21.

Results

A total of 24 participants were included in the present study. The CONSORT flow diagram is shown in Fig. 2. There was no significant difference between the two groups in terms of demographic data and clinical characteristics (Table 1).

Primary outcomes

For MLSST, there were significant group-by-time interaction effects in each testing position (position 1: $p = 0.001$; position 2: $p = 0.040$; position 3: $p = 0.004$). Post hoc analysis showed that after a 3-month intervention, the two groups had the difference of 1.0 cm (95% CI: − 1.6 to − 0.4 cm, $p = 0.001$; effect size = 1.53), 0.5 cm (95% CI: − 0.9 to 0 cm, $p = 0.040$; effect size = 0.88), 1.1 cm (95% CI: − 1.8 to − 0.3 cm, $p = 0.004$; effect size = 1.19) in positions 1, 2, and 3, respectively (Fig. 3), with less asymmetry of scapular position in the motor-control with biofeedback group, indicating more remarkable effects on scapular position over time in this group than in the motor-control group.

There was a significant time effect (95% CI: 0.2 to 2.0 cm, $p = 0.019$) on the VAS pain score without group (95% CI: − 0.3 to 0.9 cm, $p = 0.292$) and interaction effects (Table 2). However, post hoc analysis did not show significant change in either group (motor-control with biofeedback group: 95% CI: − 2.3 to 0.1 cm, $p = 0.116$; motor-control group: 95% CI: − 2.6 to 0.4 cm, $p = 0.307$). Although there was no interaction effect on the AROM of shoulder abduction (Table 2), a significant group effect was found after the intervention with 14° greater AROM in the motor-control with biofeedback group (95% CI: − 22 to − 7°, $p < 0.001$). Additionally, there was a significant time effect (95% CI: − 29 to − 16°, $p < 0.001$), and the AROM increased by 23° (95% CI: 14 to 31°, $p < 0.001$) in motor-control with biofeedback group and by 15° (95% CI: 6 to 24°, $p < 0.001$) in the motor-control group.

Secondary outcomes

There was a significant time effect (95% CI: 4 to 24, $p = 0.005$) on the DASH score without group (95% CI: − 4 to 14, $p = 0.264$) or interaction effect. However, post hoc analysis showed that the improved DASH score was only observed in the motor-control with biofeedback group (95% CI: 1 to 27, $p = 0.032$). Although there were no group or interaction effects on the strength of the MVIC (Table 2), significant time effects were observed in the UT (95% CI: -31 to − 14 N, $p < 0.001$), MT (95% CI: − 23 to -8 N, $p < 0.001$), and LT (95% CI: − 17 to − 11 N, $p < 0.001$). Post hoc analysis showed that the muscle strength of UT and MT increased after the intervention in both motor-control with biofeedback group (UT: 23 N, 95% CI: 11 to 34 N, $p < 0.001$; MT: 16 N, 95% CI: 6 to 25 N, $p < 0.001$) and motor-control group (UT: 20 N, 95% CI: 8 to 33 N, $p < 0.001$; MT: 19 N, 95% CI: 9 to 30 N, $p < 0.001$). However, the LT strength only increased in the motor-control with biofeedback group (15 N, 95% CI: 11 to 18 N, $p < 0.001$).

During arm elevation with a 1 kg weight in the scapular plane, both UT and LT showed significant group effect

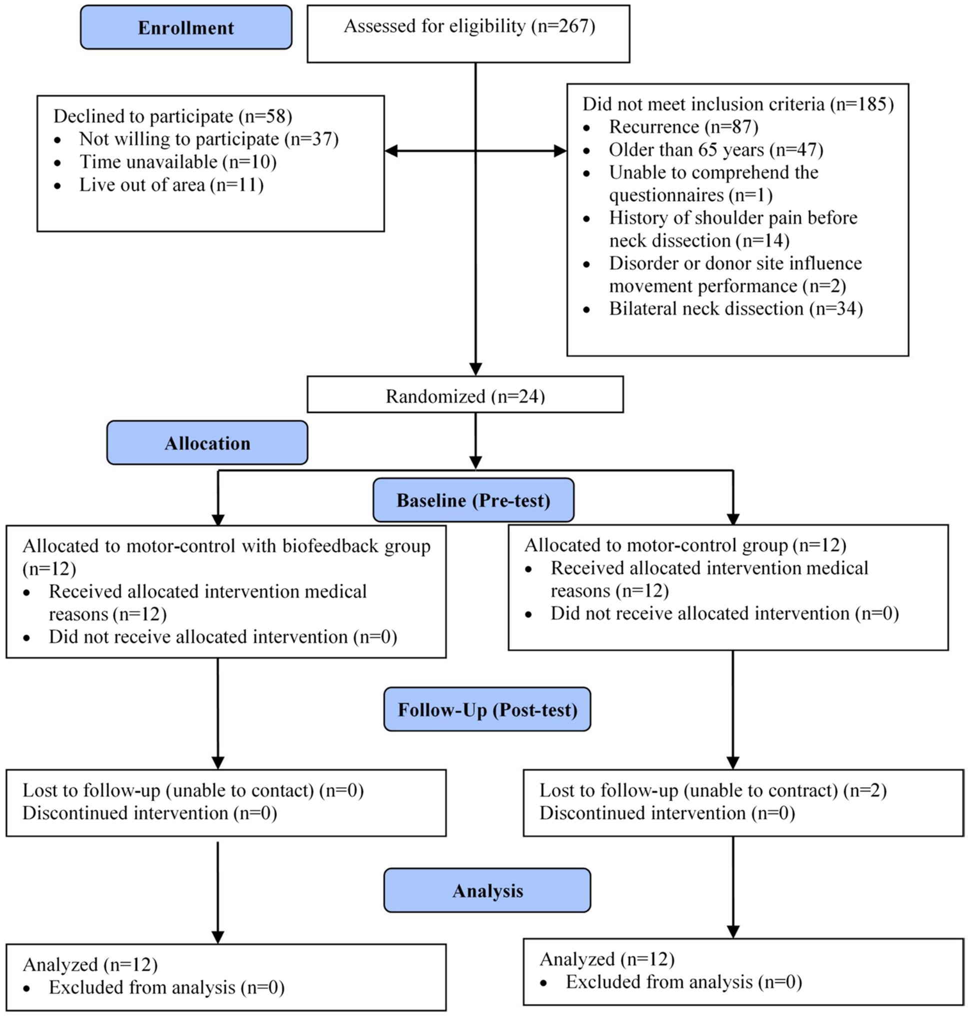

Fig. 2 CONSORT flow diagram

(UT: 95% CI: 4 to 131%, $p=0.037$; LT: 95% CI: 4 to 43%, $p=0.017$) and time effect (UT: 95% CI: 37 to 125%, $p<0.001$; LT: 95% CI: 0 to 31%, $p=0.046$) without interaction effect (Table 2). For the MT, there was a time effect (95% CI: 9 to 71%, $p=0.012$) without a group (95% CI: –44 to 22%, $p=0.507$) or interaction effect after the intervention. The post hoc analysis showed significantly decreased UT and MT muscle activities in the motor-control with biofeedback group, without significant change in the motor-control group. In addition, the LT in both groups did not show any significant change after the intervention.

For the EMG activities during arm lowering, both UT and MT showed significant time effect (UT: 95% CI: 22 to 73%, $p<0.001$; MT: 95% CI: 13 to 37%, $p<0.001$) without group (UT: 95% CI: –5 to 47%, $p=0.117$; MT: 95% CI: –20 to 18%, $p=0.900$) or interaction effect. Post hoc analysis showed decreased UT (95% CI: –82 to –14%, $p=0.001$) and MT (95% CI: –41 to –9%, $p<0.001$) muscle activities in the motor-control with biofeedback group without significant changes in the motor-control group. On the other hand, muscle activity of LT showed a group effect (95% CI: 4 to 18%, $p=0.003$) and time effect (95% CI: 1 to 15%, $p=0.016$) without interaction effect (Table 2). Post hoc analysis showed that the LT activity was smaller in the motor-control with biofeedback than the motor-control group (95% CI: –21 to -1%, $p=0.016$).

Discussion

The present study aimed to investigate whether adding EMG biofeedback during scapular-focused exercises could benefit scapular control in oral cancer patients with accessory nerve dysfunction. One key finding was that EMG biofeedback reduced scapular asymmetry and increased muscle efficacy during arm movements, as evidenced by the reductions in different distances of bilateral scapular positions and muscle activities of UT and MT.

The deficits of scapular stabilizers might impact the sensorimotor system (e.g., proprioception) [9], which impairs joint position sense and sensation of muscle force, particularly the possibility of proprioceptive neuron

Table 1 Demographic and clinical characteristics of the study participants

	Motor-control with biofeedback group ($n = 12$)	Motor-control group ($n = 12$)	*p*-value
Age (years), mean (SD)	49.9(8.1)	47.8(9.1)	0.543
Sex, n males (%)	12(100)	11(92)	0.307
Days after surgery (day), mean (SD)	17.1(9.9)	14.7(5.3)	0.462
Area of cancer, *n* (%)			0.571
Buccal	4(33)	4(33)	
Upper gum	1(8)	0(0)	
Lower gum	2(17)	4(33)	
Palate	1(8)	0(0)	
Retromolar	0(0)	1(8)	
Tongue	4(33)	3(25)	
Disease stage, *n* (%)			0.139
I	1(8)	3(25)	
II	4(33)	1(8)	
III	2(17)	0(0)	
IV	5(42)	8(67)	
Neck dissection, *n* (%)			0.615
Selective neck dissection	10(83)	9(75)	
Modified neck dissection	2(17)	3(25)	
Radiotherapy, *n* (%)	6(50)	9(75)	0.206

Abbreviation: *n*, number of participants

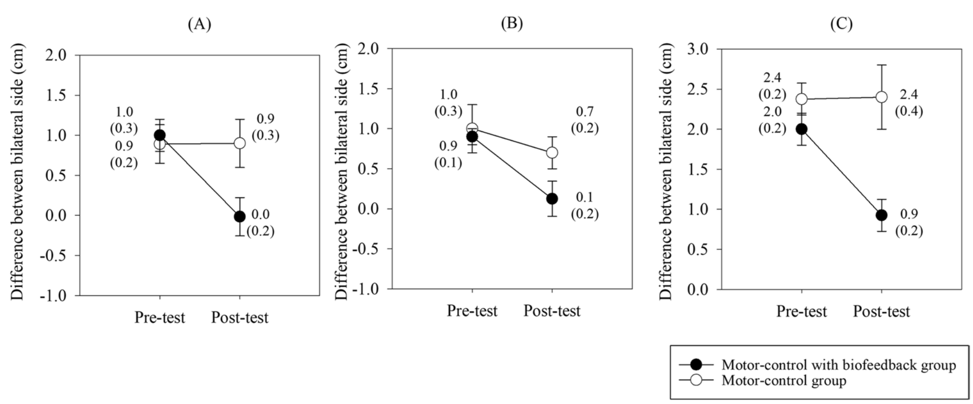

Fig. 3 Modified lateral scapular slide test comparison between the motor-control with biofeedback group and the motor-control group. (**A**) Arms by the side (position 1); (**B**) Hands on hips (position 2); (**C**) 90° of shoulder abduction with maximal internal rotation in the scapular plane with a 1 kg load (position 3)

impairment in accessory nerve dysfunction [13]. Concurrent visual feedback is suggested to be more beneficial for spatial and complex tasks, whereas multimodal feedback could predominantly reduce cognitive or memory workload during complex motor learning [36]. Although the effects of EMG biofeedback on motor function recovery after peripheral nerve injury were inconclusive [37], the present study confirms that visual biofeedback combined with haptic feedback during scapular-focused exercises could benefit oral cancer patients with accessory nerve dysfunction to observe the performance of the scapula and denervated muscles in the spatial orientation of the scapula.

The trapezius muscle produces external rotation of the scapulothoracic joint to project the glenoid fossa toward the frontal plane during shoulder abduction [2]. A significant improvement in AROM of shoulder abduction was found after scapular stabilization training in patients with shoulder impingement syndrome [38] or accessory nerve dysfunction [7, 8]. Although the scapular position did not significantly change in patients with shoulder impingement syndrome after the short-term intervention [38], more remarkable improvement in AROM of shoulder abduction was observed when integrating motor-control training during scapular-focused exercises after short-term [7] and long-term interventions [8]. The present study identified increased

Table 2 Comparison of shoulder pain, AROM of shoulder abduction, DASH score, strength of the MVIC, EMG activity of arm elevation/lowering with a 1-kg weight (%MVIC) measured in the motor-control with feedback group and motor-control group after 12-week intervention

Outcome	Group	Pre-test mean ± SE	Post-test mean ± SE	Estimate (95%CI)	Interaction *p*-value	Reach MDC/MCID	Effect size d
Shoulder pain (VAS, cm)	Motor-control	1.4 ± 0.8	0.3 ± 0.3	0 (− 1.4, 1.5)	0.964	No	0.65
	Motor-control with biofeedback	1.1 ± 0.5	0 ± 0	ref		No	0.92
AROM of shoulder abduction (degrees)	Motor-control	130 ± 3	144 ± 2†	8 (− 1, 17)	0.097	Yes	1.81
	Motor-control with biofeedback	136 ± 1	159 ± 3†*	ref		Yes	2.27
DASH Score	Motor-control	22 ± 4	14 ± 4	− 6 (− 19, 7)	0.383	No	0.75
	Motor-control with biofeedback	23 ± 5	9 ± 2	ref		Yes	0.95
Strength of the MVIC (N)							
Upper trapezius	Motor-control	50 ± 3	71 ± 4†	2 (− 11, 15)	0.745	-	
	Motor-control with biofeedback	48 ± 3	71 ± 3†	ref		-	
Middle trapezius	Motor-control	44 ± 2	63 ± 3†	− 4 (− 15, 7)	0.497	-	
	Motor-control with biofeedback	49 ± 4	64 ± 3†	ref		-	
Lower trapezius	Motor-control	31 ± 2	41 ± 3	4 (− 5, 13)	0.354	-	
	Motor-control with biofeedback	33 ± 2	47 ± 3†	ref		-	
EMG activity of arm elevation with a 1 kg weight (%MVIC)							
Upper trapezius	Motor-control	248 ± 34	199 ± 32	− 33 (− 115, 49)	0.435	-	
	Motor-control with biofeedback	213 ± 26	131 ± 6†	ref		-	
Middle trapezius	Motor-control	143 ± 15	97 ± 11	6 (− 37, 50)	0.772	-	
	Motor-control with biofeedback	147 ± 19	108 ± 12†	ref		-	
Lower trapezius	Motor-control	142 ± 11	129 ± 6	− 3 (− 27, 22)	0.837	-	
	Motor-control with biofeedback	121 ± 6	105 ± 8	ref		-	
EMG activity of arm lowering with a 1 kg weight (%MVIC)							
Upper trapezius	Motor-control	112 ± 16	81 ± 12	− 16 (-52, 19)	0.367	-	
	Motor-control with biofeedback	107 ± 13	60 ± 5†	ref		-	
Middle trapezius	Motor-control	77 ± 7	55 ± 8	− 3 (− 26, 20)	0.784	-	
	Motor-control with biofeedback	81 ± 11	56 ± 6†	ref		-	
Lower trapezius	Motor-control	71 ± 6	62 ± 3	− 4 (− 12, 13)	0.951	-	
	Motor-control with biofeedback	59 ± 4	51 ± 2*	ref		-	

Abbreviations: *VAS*, visual analog scale; *AROM*, active range of motion; *DASH*, Disability of the Arm, Shoulder, and Hand; *MVIC*, maximum, voluntary isometric contraction; *EMG*, electromyography; *MDC*, minimal detectable change; *MCID*, minimal clinically important difference

* Significant difference between groups ($p < 0.05$)

† Significant difference between pre-test and post-test ($p < 0.05$)

AROM of shoulder abduction in both groups; however, the group with biofeedback had greater improvement. The results of the scapular position imply that multimodal feedback leads to coordinated scapular motion that increases AROM of shoulder abduction. Additionally, upper limb function is associated with shoulder flexibility in patients with accessory nerve dysfunction after neck dissection [39], as evidenced by the reduction in DASH score in the group with biofeedback.

It has been reported that kinematic performance could be benefitted from visual feedback about knowledge of performance, particularly after muscle strength increases [40]. In addition, the individuals could selectively activate subdivisions of the trapezius muscle with online EMG biofeedback training [41], which assists motor control of independent activation of a specific muscle. The present study found increased UT and MT muscle strength under MVIC after scapular-focused exercises in both groups. However, the increased MVIC strength of LT was only observed in the motor-control with biofeedback group. It is supposed that conscious control of scapular orientation during scapular-focused exercises is difficult during accessory nerve regeneration, and concurrent visual feedback provides knowledge of performance to activate the LT, which is responsible for scapular upward rotation during shoulder abduction [2]. The increased muscle strength to stabilize the scapula during shoulder abduction corresponds to the finding of remarkable scapular position and increased AROM of shoulder abduction in the motor-control with biofeedback group.

Another interesting finding of the present study was that the decreased UT and MT activities (e.g., lower MVIC%) during arm elevation and lowering was only seen in the motor-control with biofeedback group. UT and MT are primarily responsible for scapular external rotation to stabilize the scapula during arm movement. With less asymmetrical scapular orientation in the motor-control with biofeedback group, the decreased muscle activation could be a phenomenon of neural adaptation or muscle economy after resistance training, leading to fewer motor units producing a given force [42]. The results provide evidence that augmented EMG biofeedback in motor-control training enhances the trapezius muscle to stabilize the scapula in an optimized position during arm elevation and lowering.

Scapular dyskinesis is a risk factor in developing shoulder pain [43], a complication after neck dissection [44]. In addition, neck dissection was a risk factor in developing myofascial pain syndrome after head and neck cancer treatment [45]. Previous studies showed that early intervention significantly improved shoulder mobility and reduced pain and secondary glenohumeral stiffness in patients after neck dissection [6]. However, the present study did not show the improvement in shoulder pain. It might be related to low shoulder pain intensity at baseline and early neuromuscular control of the scapula to restore scapular kinematics.

Shoulder function (e.g., DASH score) is associated with the AROM of shoulder abduction and quality of life [39]. The present study found a reduction in DASH score in the group with biofeedback and identified increased AROM of shoulder abduction in both groups. Therefore, a beneficial effect of this trial is to recover the function of the trapezius muscle to effectively stabilize the scapula during arm movement and enhance upper limb function which inhibits shoulder dysfunction and improves the quality of life in oral cancer patients with spinal accessory nerve dysfunction after neck dissection. In particular, this trial provides evidence that a three-month intervention of motor-control with EMG biofeedback remarkably improved scapular symmetry, upper limb function, lower trapezius muscle strength, and muscle efficiency of the upper and middle trapezius.

This study has some limitations. First, three-dimensional scapular kinematics were not measured. These can provide information about the biomechanical effects of the motor-control intervention on dynamic scapular movement. Second, a nerve study was not conducted to confirm accessory nerve dysfunction before enrollment. However, the present study used multiple criteria to represent accessory nerve dysfunction, which combined observational scapular dyskinesis and 1.5 cm side-to-side difference in the MLSST as a cut-point for scapular asymmetry with the clinical signs for verification [19, 20]. In addition, EMG activities revealed a significant difference under the 3 MVIC conditions between the neck dissection side and the non-operated side at baseline (Online Resource 5). The significantly smaller trapezius muscle activities of neck dissection side might provide neuromuscular evidence for accessory nerve impairment at baseline.

Conclusions

During scapular-focused training exercises, motor-control training with EMG biofeedback has superior effects on scapular orientation and increases muscle strength and efficiency when performing arm elevation/lowering than motor-control training alone. However, with or without biofeedback in motor-control training, scapular-focused exercises effectively increase the AROM of shoulder abduction. Further studies are required to evaluate the effects of the intervention in the chronic stage to identify the appropriate timing of the intervention for oral cancer patients with accessory nerve dysfunction.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00520-022-07263-4.

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Author contribution Yueh-Hsia Chen and Cheng-Ya Huang contributed to the study conception and design. Data collection and analysis were performed by Yueh-Hsia Chen. Wei-An Liang and Chi-Rung Lin assisted in intervention protocols. The first draft of the manuscript was written by Yueh-Hsia Chen, and Cheng-Ya Huang commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Chang Gung Medical Foundation Institutional Review Board (Date: 2 January, 2020/No: 201901788A3) and Clinical Trials (Date: 16 July, 2020/No: NCT04476004). Informed consent was obtained from all individual participants included in the study.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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