ORIGINAL PAPER

Physiotherapy Quarterly (ISSN 2544-4395)
2023, 31(3), 41–45

Does training to sustain the paretic upper limb on an unstable surface provoke contraction of muscles around the shoulder in patients with hemiplegia? A pilot randomized controlled trial

DOI: https://doi.org/10.5114/pq.2023.117444

Sivakumar Ramachandran[1], Monica Gopi[1], Steve Milanese[2]

[1] Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), Chennai, India

[2] International Centre for Allied Health Evidence, School of Health Science, University of South Australia, Adelaide, Australia

Abstract

Introduction. Activities with unstable supports provoke greater muscle contractions than those with stable surfaces. Using unstable surfaces to provoke upper limb muscle contraction after hemiplegia has not been explored. Hence, this study tested the effect of efforts to maintain the hemiparetic hand on an unstable surface on proximal muscle contractions of upper limb in patients with acute stroke.

Methods. First-time stroke patients in the acute phase were randomly allocated into 2 groups. The control group (n = 18) received conventional physiotherapy, whilst the experimental group (n = 19) was given activities to maintain their hemiparetic side hand on an unstable surface in 5 different positions, in addition to conventional physiotherapy. Surface electromyogram was recorded from deltoid and upper trapezius on the hemiparetic side before and after 10 sessions of training.

Results. Overall, 14 patients (aged 57.71 ± 10.70 years) in the control group and 14 (55.78 ± 7.52 years) in the experimental group completed the training. Non-parametric tests for between-group analysis showed that the average electromyography output in the deltoid and trapezius muscles was higher in the experimental group compared with the control group ($p < 0.05$).

Conclusions. Training involving efforts to maintain the hemiparetic side hand on an unstable surface can be used to provoke activity in upper limb proximal muscles. This could be a simple training with minimal equipment and minimal manual assistance required, added to routine physiotherapy to facilitate proximal muscle contraction in patients with stroke during the acute phase.

Key words: hemiplegia, stroke, rehabilitation, upper limb

Introduction

Motor impairments of the upper limb in hemiplegia due to stroke are often persistent and disabling. A multi-ethnic study on the acute stroke population reported that 77.4% of stroke survivors had motor impairments in the upper limb [1]. Only half of all stroke survivors with an initial hemiplegic upper limb regain some upper limb function after 6 months [2]. Restrictions in upper limb functions have been demonstrated even 4 years after stroke [3].

Strength training, task-specific training, and constraint-induced movement therapy are commonly used to improve motor control in the paretic upper limb [4–9]. All these methods focus on muscle contractions and movements in the paretic upper limb. These therapies generally require concentric contractions or eccentric contractions of the muscles. Activities which demand holding a position, requiring isometric contractions of the muscles, are less studied for their effect on improving motor control of the upper limb, specifically the proximal musculature of the upper extremity.

Exercises performed on unstable surface have been reported to provoke greater muscle work compared with those on stable surfaces in healthy adults [10–12]. Swiss ball has been used to induce better recruitment of trunk muscles after stroke [13]. We anticipate that efforts to place and maintain the hand on an unstable surface are likely to provoke muscle contraction around the shoulder girdle of the paretic upper limb. Generally, patients who have experienced a stroke will demonstrate difficulty in maintaining their paretic limb on a wheelchair arm rest or table. This difficulty may lead to the upper limb slipping from the support surface, resulting in soft tissue injuries around the hand and shoulder.

In this study, we aimed to test the effect of efforts to sustain the paretic upper limb on an unstable surface on proximal muscle contraction in patients with hemiplegia. Surface electromyography (SEMG) was used to assess the muscle activity. If the effort is successful in provoking activity in muscles around the shoulder, this could be an easy self-exercise for the patient, as well as a functional training activity to help maintain the hemiparetic upper limb on a support surface.

Subjects and methods

Patient recruitment and intervention

First-time stroke patients who were able to comprehend oral commands were screened for inclusion in the study. The inclusion criteria were: (1) diagnosed ischemic stroke within 5 days of stroke; (2) ability to understand commands to perform the activities for the study; (3) Chedoke-McMaster

Correspondence address: Sivakumar Ramachandran, Sri Ramachandra Faculty of Physiotherapy, Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), No 1, Sri Ramachandra Nagar, Porur, Chennai 600116, India, e-mail: rsivakumar.physiotherapy@sriramachandra.edu.in; https://orcid.org/0000-0002-7456-2861

Received: 11.06.2021
Accepted: 07.10.2021

Citation: Ramachandran S, Gopi M, Milanese S. Does training to sustain the paretic upper limb on an unstable surface provoke contraction of muscles around the shoulder in patients with hemiplegia? A pilot randomized controlled trial. Physiother Quart. 2023;31(3):41–45; https://doi.org/10.5114/pq.2023.117444.

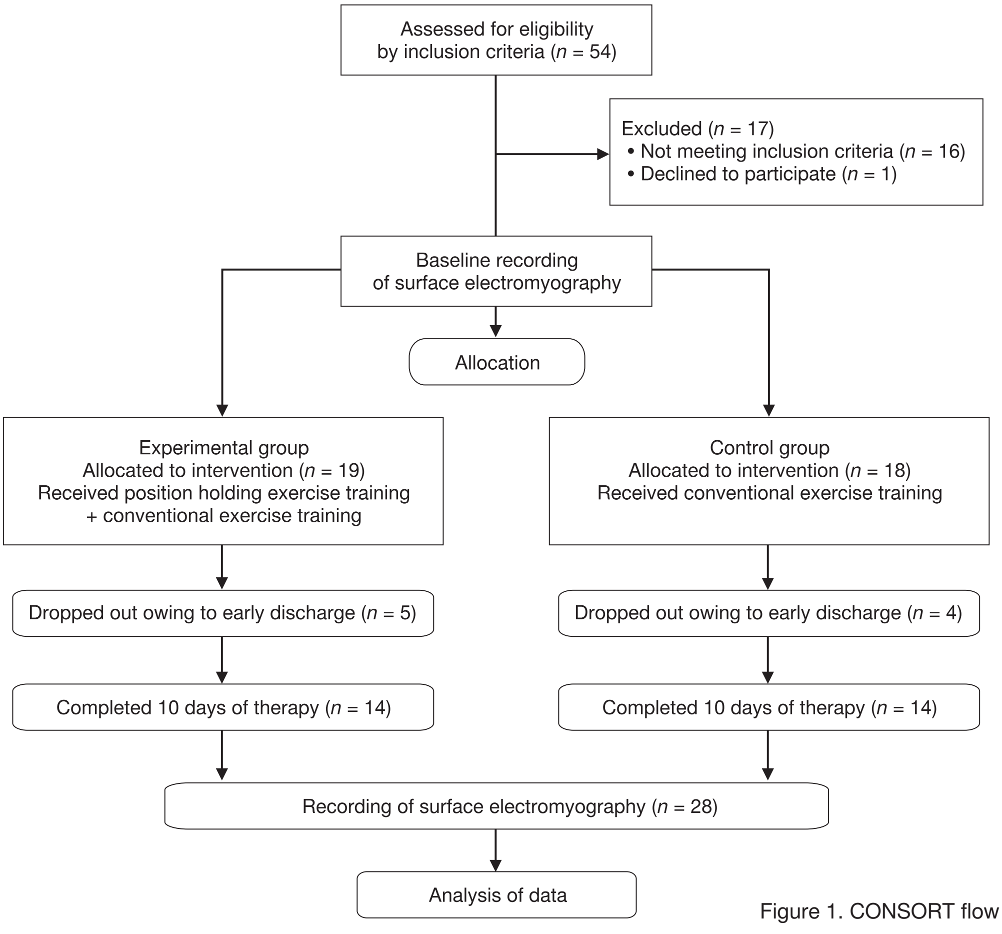

Figure 1. CONSORT flow diagram for patient allotment

Stroke Assessment: motor recovery stage 2 or less in the upper extremity; (4) ability to maintain unsupported sitting in bed or on a chair for 20 minutes. Patients were excluded if they presented with orthopaedic or neurological impairments which affected their ability to undertake the activity.

A total of 54 patients were screened by convenience sampling; 18 were randomly allocated to the control group and 19 to the experimental group by using a 4-block randomization method (Figure 1). The participants in both groups were given impairment-specific exercises [14] (Table 1). In addition to these exercises, the experimental group was trained to maintain their flaccid hand on unstable surfaces in 5 different positions (Table 2, Figure 2). The patients were instructed not to hold the unstable surface but to maintain their hand position on it. The patient's hand was placed in the position and they were asked to sustain the position for 10 seconds in 10 repetitions. Adequate rest was given between the positions and whenever the patient wanted a rest. Initially, assistance was provided to maintain the position; the assistance was gradually reduced as the patient gained control to maintain the position. The individuals were closely monitored to ensure that they did not attempt any compensatory move-

Table 1. Impairment-specific exercises

In lying
- Passive movements of the paretic upper limb and lower limb
- Facilitating techniques by tapping on the muscle belly to improve muscle activity
- Active assisted exercises to the upper and lower limb
- Bed mobility training: pelvic bridging exercises, supine-to-side lying, lying-to-sitting

In sitting
- Weight bearing to the paretic upper limb
- Self-supported shoulder exercises
- Bilateral arm training
- Reaching activities with proper safety measures
- Task-specific training for arm, hand, and lower limbs based on motor sequences relevant to daily life
- Sit-to-stand activities

In standing
- Balance training: static and dynamic activities with therapist's support

Gait training
- Walking facilitated owing to lower extremity control with therapist's guidance

Table 2. Activities to maintain the paretic hand on unstable surface

1. Patient in sitting position on a stable surface (bed side, chair) with a medicine ball placed on a table in the sagittal plane at their chest level, with shoulder in 60–65° flexion
2. Paretic hand placed by the therapist on a medicine ball and the patient asked to maintain the position
3. Patient in sitting position on a stable surface with a medicine ball placed on a table in the scapular plane. Paretic hand placed sidewards on the medicine ball
4. Patient in sitting position on a stable surface with a Swiss ball placed in the sagittal plane at their chest level; paretic hand placed forward on the Swiss ball
5. Patient in sitting position on a stable surface with a Swiss ball placed in the scapular plane; paretic hand placed sidewards on the Swiss ball
6. Patient in sitting position on a stable surface with an empty plastic chair in the sagittal plane at their chest level, with shoulder in 60–65° flexion
7. Paretic hand placed forward on the backrest of a plastic chair

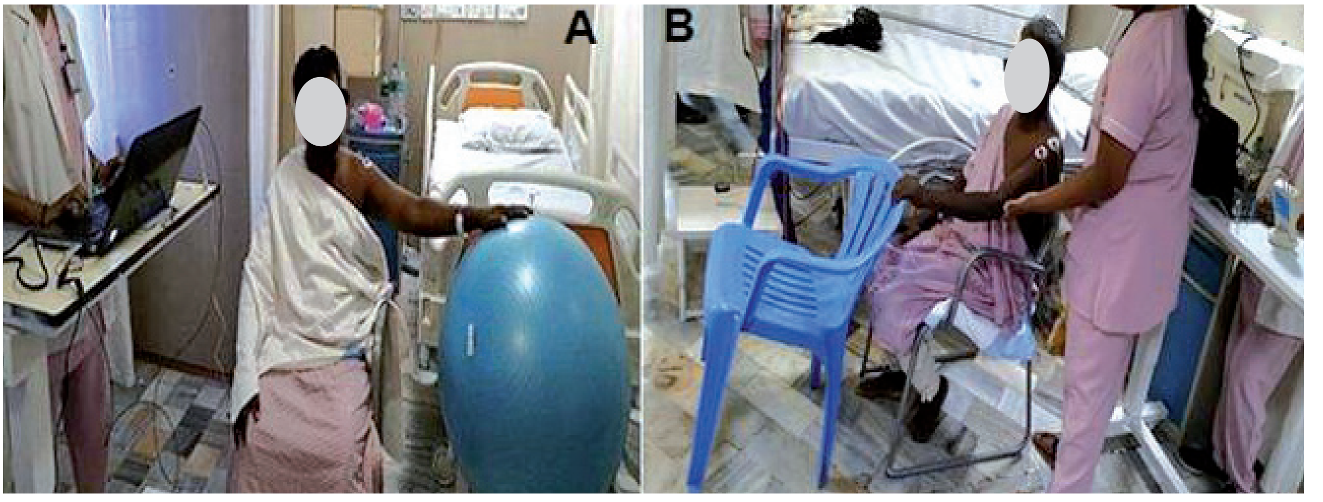

Figure 2. Patient attempts to maintain hemiplegic side hand on a Swiss ball in the scapular plane (A) and on a backward tilted chair (B); recording electromyogram from deltoid after 10 sessions of training

ments. Both groups received 20–25 minutes of therapy for the upper extremity once a day for 10 days as part of 40–45-minute physiotherapy sessions.

During the follow-up, 4 patients dropped out of the study from the control group and 5 from the experimental group because of their discharge from hospital. Finally, 14 patients were analysed in the control group and 14 in the experimental group.

Outcome measure

SEMG was recorded from deltoid and upper trapezius muscles, as these are commonly studied muscles around the shoulder [15] and as they are likely to show activity with minimal effort. The SEMG recordings were performed for both the control and experimental groups before the start of the intervention and on the day after the 10-day intervention program.

SEMG was documented for the upper trapezius, anterior deltoid, middle deltoid, and posterior deltoid by using the NeuroTrac© software 4.0 0f VM (Verity Medical Ltd., United Kingdom). Silver chloride adhesive electrodes were applied. The active electrodes were placed on the muscle belly of the above muscles, with an inter-electrode spacing of 20 mm along an axis parallel to the muscle fibre orientation. Standard skin preparation techniques were utilized; the skin was cleaned with 70% alcohol (ethanol). The ground electrode was placed on the C7 spinous process (seniam.org) [16, 17]. To record the activity of the upper trapezius, the electrodes were placed 50% of the distance along the line from the acromion to the spine on vertebra C7. For the anterior deltoid, the electrodes were placed one-finger width distally and anteriorly to the acromion process. For the middle deltoid, the electrodes were placed from the acromion to the lateral epicondyle of the elbow. For the posterior deltoid, the electrodes were placed in the area about 2 fingerbreadths behind the angle of the acromion.

SEMG was determined with the upper extremity in 5 different positions. Average EMG reading (μV) was recorded for each test position.

Statistical analysis

The output of SEMG recordings for anterior deltoid, posterior deltoid, middle deltoid, and upper trapezius was averaged from 5 different positions for data analysis. A non-parametric test was used as the data were not normally distributed. The Wilcoxon signed rank test was used to analyse the difference in muscle activity of upper trapezius and anterior, middle, and posterior deltoid before and after the intervention in the control group and the experimental group. Between-group analyses were performed with the Mann–Whitney *U* test. Intention-to-treat analysis was not considered as the drop-out from both groups was similar, as was the number of patients analysed in both groups.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Sri Ramachandra Institute of Higher Education and Research Ethical Committee (REF: CSP/18/73/264). Trial registration: Clinical Trails Registry – India (www.ctri.nic.in) (CTRI/2018/11/016430).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 3 shows the profile of the stroke patients who participated in the study. Individuals with right and left stroke were equally distributed across the groups.

Table 3. Profile of the patients

Variables	Control group (n = 14)	Experimental group (n = 14)
Age (years) (mean ± *SD*)	57.71 ± 10.70	55.78 ± 7.52
Males (n)	10	9
Females (n)	4	5
Right cerebrovascular accident (n)	9	10
Left cerebrovascular accident (n)	5	4

Table 4 presents average SEMG recordings of muscle activity for the upper trapezius and anterior, middle, and posterior deltoid. An increase was observed in muscle activity in both the control and experimental groups after the interven-

Table 4. Average electromyography output (μV) (mean ± *SD*) from shoulder muscles in stroke patients

Muscle	Control group			Experimental group			Between groups	
	Before intervention	After intervention	p^a	Before intervention	After intervention	p^a	p^b	p^c
Upper trapezius	3.59 ± 0.85	10.20 ± 1.08	0.001	3.36 ± 1.31	15.11 ± 10.11	0.001	0.92	0.04
Anterior deltoid	3.46 ± 0.38	8.31 ± 0.82	0.001	3.03 ± 0.93	10.23 ± 3.48	0.001	0.05	0.01
Middle deltoid	3.90 ± 0.83	9.78 ± 0.75	0.001	3.57 ± 1.02	12.38 ± 3.57	0.001	0.56	0.002
Posterior deltoid	3.46 ± 0.62	8.47 ± 0.51	0.001	3.18 ± 0.76	9.32 ± 2.27	0.001	0.38	0.01

[a] Wilcoxon signed rank test for pre- and post-analysis within the control and experimental group
[b] Mann–Whitney *U* test for pre-intervention scores between the groups
[c] Mann–Whitney *U* test for post-intervention scores between the groups

tion when tested within the groups. The pre-intervention values did not differ statistically significantly between the groups, whereas the post-intervention results were statistically significantly different ($p < 0.05$). Greater muscle activity was recorded in the experimental group compared with the control group after the intervention.

Discussion

In this study, we found that an effort to sustain the hemiparetic side hand on an unstable surface provoked muscle activity around the shoulder. This form of exercise involves less movement in the shoulder joint, results in minimal risk of soft tissue injury, and will require minimal caregiver assistance to do; moreover, adherence to performing these exercises may be higher than with usual exercises which involve greater movements as the patient can easily undertake this training themselves.

Research in upper limb rehabilitation after stroke has been undertaken predominantly in late sub-acute and chronic phase stroke patients. According to Wattchow et al. [5], rehabilitation techniques at an early stage may enhance learning-related changes and hasten the upper limb recovery. The method of training tested in this study appears to be useful to facilitate proximal muscle activity around the shoulder in early sub-acute stroke patients.

Generally, contribution to and participation in therapy are likely to be better when training mimics functional activities. In this study, the positions we used are part of daily activities that the individuals might find difficult to accomplish. Hence, it is anticipated that patients will accept and participate in this kind of training.

Maintaining proper posture while positioning and transferring a stroke patient is the key to decrease the risk of soft tissue injuries around the shoulder joint [18, 19]. One of the few recommendations to prevent shoulder-hand syndrome is to position the arm forward on a resting surface such as a table to ensure that the hand does not hang down unnoticed [18]. A patient with hemiplegia usually finds it difficult to maintain a static position on resting surfaces. We assume that the training to maintain the hemiparetic side hand on an unstable surface will improve the ability to maintain a static position on resting surfaces. Although the effectiveness of position holding training in preventing shoulder injuries is beyond the scope of this study, the results suggest that administering this training may reduce the risk of soft tissue injuries around the shoulder joint as the patient is more able to maintain a static position on resting surfaces.

Many stroke patients report difficulty adhering to exercises at home. One of the common reasons for poor adherence to exercises is the lack of equipment and infrastructure for training, and the inability of family members to provide guidance and supervision as given by a therapist [20]. The exercises used to sustain the hemiparetic side hand on an unstable surface in order to provoke contractions of muscles around the shoulder that were applied in this study involve a chair, a medicine ball, and a Swiss ball. They are easy to be performed by the patient, require a ball as an instrument, which is simple to procure, and demand less caregiver handling. Different exercises can be developed on the basis of this concept to provide a variety of training and provoke diverse muscle groups.

Limitations

The contraction of upper trapezius and deltoid alone has been studied. Other muscles around the shoulder complex should be tested to understand the effect on other muscles of the shoulder girdle. We could not follow up all patients on whether they were using the training at home; however, a number of patients reported that they were. A long-term follow-up on the feasibility and effectiveness of this exercise approach is required.

Conclusions

An effort to hold the hemiparetic side hand on an unstable surface provokes muscle contraction around the shoulder. This can be used as training with minimal movement to help provoke muscle contraction, and can be applied in patients who are apprehensive to move owing to shoulder pain or are not cooperative for exercise training.

Clinical relevance

This study shows that the use of position holding exercise training is effective in provoking proximal muscle activity around the shoulder. Therefore, it can be utilized as part of training to facilitate upper limb recovery in the early sub-acute phase of stroke rehabilitation.

Recommendations

The SEMG data can be simultaneously recorded from all the proximal muscles. Real-time recording will be helpful to understand the activity of muscles during the training. The effect of such training on functional outcomes can be analysed.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Lawrence ES, Coshall C, Dundas R, Stewart J, Rudd AG, Howard R, et al. Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population. Stroke. 2001;32(6):1279–1284; doi: 10.1161/01.str.32.6.1279.
2. Kwakkel G, Kollen BJ, van der Grond J, Prevo AJH. Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. Stroke. 2003;34(9):2181–2186; doi: 10.1161/01.STR.0000087172.16305.CD.
3. Broeks JG, Lankhorst GJ, Rumping K, Prevo AJ. The long-term outcome of arm function after stroke: results of a follow-up study. Disabil Rehabil. 1999;21(8):357–364; doi: 10.1080/096382899297459.
4. Coupar F, Pollock A, Legg LA, Sackley C, van Vliet P. Home-based therapy programmes for upper limb functional recovery following stroke. Cochrane Database Syst Rev. 2012;2012(5):CD006755; doi: 10.1002/14651858.CD006755.pub2.
5. Wattchow KA, McDonnell MN, Hillier SL. Rehabilitation interventions for upper limb function in the first four weeks following stroke: a systematic review and meta-analysis of the evidence. Arch Phys Med Rehabil. 2018;99(2):367–382; doi: 10.1016/j.apmr.2017.06.014.
6. Van Delden AEQ, Peper CE, Nienhuys KN, Zijp NI, Beek PJ, Kwakkel G. Unilateral versus bilateral upper limb training after stroke: the Upper Limb Training after Stroke clinical trial. Stroke. 2013;44(9):2613–2616; doi: 10.1161/STROKEAHA.113.001969.
7. Harris JE, Eng JJ. Strength training improves upper-limb function in individuals with stroke: a meta-analysis. Stroke. 2010;41(1):136–140; doi: 10.1161/STROKEAHA.109.567438.
8. Saikaley M, Pauli G, Iruthayarajah J, Mirkowski M, Iliescu A, Caughlin S, et al. Evidence-based review of stroke rehabilitation. 10. Upper extremity interventions. Available from: http://www.ebrsr.com/evidence-review/10-upper-extremity-interventions.
9. Abba MA, Muhammad AS, Badaru UM, Abdullahi A. Comparative effect of constraint-induced movement therapy and proprioceptive neuromuscular facilitation on upper limb function of chronic stroke survivors. Physiother Quart. 2020;28(1):1–5; doi: 10.5114/pq.2020.89809.
10. Kim H, Lee G, Song C. Effect of functional electrical stimulation with mirror therapy on upper extremity motor function in poststroke patients. J Stroke Cerebrovasc Dis. 2014;23(4):655–661; doi: 10.1016/j.jstrokecerebrovasdis.2013.06.017.
11. Behm D, Colado Sanchez JC. The effectiveness of resistance training using unstable surfaces and devices for rehabilitation. Int J Sports Phys Ther. 2012;7(2):226–241.
12. Imai A, Kaneoka K, Okubo Y, Shiina I, Tatsumura M, Izumi S, et al. Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. J Orthop Sports Phys Ther. 2010;40(6):369–375; doi: 10.2519/jospt.2010.3211.
13. Karthikbabu S, Nayak A, Vijayakumar K, Misri Z, Suresh B, Ganesan S, et al. Comparison of physio ball and plinth trunk exercises regimens on trunk control and functional balance in patients with acute stroke: a pilot randomized controlled trial. Clin Rehabil. 2011;25(8):709–719; doi: 10.1177/0269215510397393.
14. Carr JH, Shepherd RB. A motor relearning programme for stroke. London: Butterworth-Heinemann; 1990.
15. Wickham J, Pizzari T, Stansfeld K, Burnside A, Watson L. Quantifying ‘normal’ shoulder muscle activity during abduction. J Electromyogr Kinesiol. 2010;20(2):212–222; doi: 10.1016/j.jelekin.2009.06.004.
16. Blanc Y, Dimanico U. Electrode placement in surface electromyography (sEMG) “minimal crosstalk area” (MCA). Open Rehabil J. 2010;3(1):110–116; doi: 10.2174/1874943701003010110.
17. Criswell E, Cram JR. Cram’s introduction to surface electromyography. Sudbury: Jones and Bartlett; 2011.
18. Davies PM. Steps to follow: the comprehensive treatment of patients with hemiplegia, 2nd ed. Berlin: Springer; 2000.
19. Saikaley M, Iruthayarajah J, Pauli G, Iliescu A, Wiener J, Cotoi A, et al. Evidence-based review of stroke rehabilitation. 11. Hemiplegic shoulder pain and complex regional pain syndrome. Available from: http://www.ebrsr.com/evidence-review/11-hemiplegic-shoulder-pain-complex-regional-pain-syndrome.
20. Miller KK, Porter RE, DeBaun-Sprague E, van Puymbroeck M, Schmid AA. Exercise after stroke: patient adherence and beliefs after discharge from rehabilitation. Top Stroke Rehabil. 2017;24(2):142–148; doi: 10.1080/10749357.2016.1200292.