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Effects of strength training combined with task-oriented training on upper extremity recovery and enjoyment of individuals with chronic stroke

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KEYWORDS
Cerebrovascular disease; Rehabilitation; Physiotherapy; Arm; Muscle weakness.

ABSTRACT
Only little evidence has assessed the impact of strength training combined with task-oriented training (TOT) on the upper extremity function of patients with chronic stroke. This study investigated the effects of adding strength training to TOT on the upper extremity recovery and enjoyment of individuals with chronic stroke. Nineteen chronic stroke patients were randomly allocated to either a strength training combined with TOT program (experimental group, n = 10) or a TOT-only program (control group, n = 9). Both groups received a 70-minute training program, 5 times a week for 4 weeks-with a total of 3,600 repetitions for all tasks in the training. The outcomes were assessed in terms of upper extremity functions, grip strength, upper extremity motor impairment, shoulder flexion active range of motion (AROM), muscle tone, and physical activity enjoyment as assessed using the Physical Activity Enjoyment Scale (PACES) at baseline and post-intervention. The upper extremity function, upper extremity motor impairment and shoulder flexion AROM of the participants in both groups improved significantly (p-value < 0.05) post-intervention without increasing spasticity. There were no statistically significant differences between the two groups. Grip muscle strength was improved in the experimental group only (p-value < 0.05). The PACES score of the experimental group and the control group were 105.0 (89.0, 118.2) and 91.0 (83.5, 106.0), respectively. The findings suggest benefit of 4-week strength training combined with TOT program on the improvement of upper extremity functions, upper extremity motor impairment and shoulder flexion AROM of the participants similar to the improvement witnessed in the participants of the TOT-only program. However, only the strength training combined with TOT program improved muscle strength. The post-chronic stroke patients seemed to enjoy the strength training combined with TOT program more than the TOT-only program.

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Introduction

Post-stroke, more than 80% of patients suffer upper extremity functional limitations[1]. Upper extremity function is essential for daily-life activities that consist of reaching for and manipulating objects[2]. Stroke patients unable to restore their hemiparetic upper extremity functional ability may compensate by using their sound side[3]. Consequently, the undertaking of daily life activities and/or social interactions might be decreased since many activities require bilateral movement such as the buttoning up of clothing, driving vehicles, or showering oneself [4]. In addition, complications such as muscle atrophy and contractures could occur following such immobility[5]. Thus, the improvement of the hemiparetic arm function is a core aspect of stroke rehabilitation practice.

Muscle weakness is a predominant cause of post-stroke upper extremity functional activity limitation[5], as is defined as an inability of the muscle to produce the necessary tension to maintain, initiate, or control movement[6]. Several factors can cause muscle weakness post-stroke, including a reduction in the number of motor units being used, a decrease in the firing frequency and/or recruitment order of motor units[6], and adaptive length-associated changes of muscle and muscle disuse[7]. Previous research has demonstrated that restoration of upper extremity muscle strength improves upper extremity functional activity[8,9]. The upper extremity strength training program, which consisted of 36 repetitions of upper extremity movement 3 days per week for 5 weeks, was found to be effective in improving upper extremity muscle strength in chronic stroke patients. Furthermore, the strength training program also had a positive effect on upper extremity functions[10]. This finding is in line with a recent systematic review, which suggested that resistance training may be beneficial in improving upper extremity function post-stroke[11].

Task-oriented training (TOT) is a well-established and evidence-based approach that has been proven to effectively restore functional outcomes post-stroke[12]. This specific, intense, engaging, collaborative, self-directed, and patient-centered training has been found to significantly improve upper extremity function in stroke patients[13]. Combining a strength training program with the TOT program appears to be more beneficial than the TOT-only program for chronic stroke patients. Research has shown that the 360-minute TOT program combined with strength training can improve bilateral upper extremity tasks more effectively than the TOT-only program[14]. However, this research provided fixed tasks of training for individual stroke patients. Notably, allowing stroke patients to take part in goal setting and selecting training of their own training tasks can significantly improve their satisfaction with rehabilitation programs[15]. This suggests that the TOT program may be more effective when patients are given the opportunity to involve in the process.

Limited research has been conducted to assess the impact of strength training combined with TOT on the upper extremity function of patients with chronic stroke. Our research team discovered that a combination of strength training and patient-centered goal-setting TOT program (1,800 repetitions of total tasks training within 2 weeks) significantly improved unilateral upper extremity tasks of stroke patients[16]. Despite our previous research, we have not seen a significant improvement in unilateral upper extremity tasks when strength training and TOT are combined, compared to TOT-only program. The evidence is clear that neural plasticity can be promoted through task training repetitions, with a study of chronic stroke patients showing positive results after 3,150 repetitions of total task training[17]. The aim of this study was to evaluate the impact of strength training combined with TOT (3,600 repetitions of total tasks training over a period of 4 weeks) compared to a TOT-only program. This study further explored the level of enjoyment experienced by chronic stroke patients in each program.

Materials and methods

Study design and participants

This study employed a matched-pair, randomized, controlled, and single-blinded design to recruit participants from the community in Mueang District, Phitsanulok Province, Thailand. Eligible participants for this research had experienced a stroke within the 6- to 60-month period prior to the study, were aged between 40 and 70 years old, had a motor recovery score of the upper extremity assessed by the Fugl Meyer Scale between 19 and 58, were able to extend their wrist and fingers, could sit independently for more than 30 minutes, and had the capacity to follow commands. The exclusion criteria for this study were individuals with other neurological conditions and a Modified Ashworth Scale (MAS) score of 3 or greater for shoulder adductors, elbow flexors, wrist flexors, and bilateral hemiplegia. Ethical approval was received from the Naresuan University Institutional Review Board IRB No.0012/62 (COA No.1302019) and Buddhachinaraj Hospital Institutional Review Board IRB No.100/62.

Sample size

A sample of 10 patients per group was necessary at a 5% significance level, 80% power, and 20% dropout rate based on a study by Arya et al[18].

Randomization

According to the wide range of inclusion criteria of this study, the matched pair design was employed to reduce confounding factors[19]. Patients were matched based on their upper extremity function and grip strength and stratified by age, gender, post-stroke duration, and upper extremity function to ensure an equal distribution. To ensure concealed allocation, a person not involved in the patient selection process performed the randomization. A computerized program was utilized to randomly assign patients to either the strength training associated with patient-centered goal-setting TOT program (experimental group) or the patient-centered goal-setting TOT-only program (control group). Outcomes were assessed at the beginning of the intervention and again at the fourth-week post-intervention. A blinded physiotherapist assessed all variables, while the participants were unaware of which group they were assigned to. However, due to the nature of the study, the physiotherapists who trained the patients in each group were not blinded.

Interventions

All of the participants received a 70-minute session, 5 times per week for 4 weeks at their respective homes. The program for each group was provided by 2 individual physiotherapists with an average of 3 years of neurorehabilitation experience. To ensure consistency, the therapists gave the same instructions and verbal cues for TOT training to all participants in both groups. The TOT activities were designed based on daily-life undertakings and consisted of strength-dependent activities relating to the hemiparetic arm, those bimanual and dexterity of the hemiparetic hand. These activities presented in table 1 were originally published in Thai[16].

Table 1 Task-oriented training activities

Task-Oriented Training Activities
1. Strength-dependent activities of the hemiparetic arm
1.1 Reaching for and grasping of a glass
1.2 Swiping a table while extending one's elbow
1.3 Pouring water from the a bottle
1.4 Brushing hair
1.5 Lifting a bottle
1.6 Lifting a mobile phone to one's ear
2. Bimanual activities
2.1 Folding a towel
2.2 Opening drawers
2.3 Twisting a towel
2.4 Lifting a pot
2.5 Swiping a desk
2.6 Picking a ball from a basket
3. Dexterity of the most hemiparetic hand
3.1 Buttoning up a clothing item
3.2 Tying shoelaces
3.3 Turning a key
3.4 Picking up a pencil
3.5 Lifting a spoon
3.6 Grasping and releasing a small ball

The participants in both groups selected six training activities from the three categories outlined in table 1, customizing their goals based on their capacity and individual needs. For instance, they practiced lifting a spoon and bringing it close to their lips. The sequence of training was randomized, and both groups received the same frequency and amount of training. The intensity of the training was designed according to previous studies[14,20]. The participants underwent stretching of their hypertonic upper extremity muscle groups both before and after their training session. The training program consisted of 10 sets repeated 3 times, with a 30-second rest interval between each set and a 1-minute rest interval between each activity[10,14,17]. All activities were performed while the participants were seated on a chair with a backrest, with their hips and knees flexed at 90 degrees. A belt was used to restrict the trunk and prevent any compensatory movements during training. The trainer provided verbal cues to offer feedback on the exercise performance, limit compensatory movements, and reinforce positive behaviors. The participants in the experimental group identified their one-Repetition Maximum (1RM) of shoulder flexor by sitting on a chair with a backrest and raising their hemiplegic arm with a sandbag attached to their wrist. The final weight of the sandbag that allowed each participant to raise their arms to the full range of motion was set as their 1RM. Their 1RM was multiplied by 0.06 to be the target weight. At the 3rd-week milestone, the difficulty of all activities was increased in various ways, such as increasing the range of motion, the size of objects used, and the target weight set according to each participant's capacity. The intervention results for both groups are presented in table 2.

Table 2 Intervention for experiment and control groups

Program	Control group	Duration	Experimental group	Duration
Warm up	Stretching	5	Stretching	5
Training	TOT	60	Strength training and TOT	60
Cool down	Stretching	5	Stretching	5

Outcome measures

Primary outcome measures

The primary outcome measure of this study was the change in upper extremity function over time, as measured by the Streamlined Wolf Motor Function Test for chronic patients (SWMFT-C). This test was streamlined from the widely used 17 items of the Wolf Motor Function Test (WMFT)(21) in order to reduce the burden of administration and provide the most relevant information about recovery potential(22). The SWMFT-C demonstrated excellent predictive validity, concurrent validity, comparable responsiveness(23), excellent test-retest reliability and internal consistency(24). The SWMFT-C consists of six tasks; extend elbow weight, hand to box (front), lift can, lift pencil, turn key in lock, and fold towel. These tasks are evaluated in regard to the performance time witnessed and the patient's functional ability scale. The maximum time allowed to complete a task is 120 seconds. There are six levels of functional ability ranging from zero (does not attempt with involved arm) to five points (movement appears to be normal)(22).

Secondary outcome measures

The secondary outcome measures included grip strength, upper extremity motor impairment, shoulder flexor range of motion, muscle spasticity of the affected side, and the enjoyment of receiving the program as assessed by a hand grip dynamometer, the Fugl Meyer for Upper Extremity (FMA-UE), a goniometer, the modified Ashworth scale (MAS) and the Physical Activity Enjoyment Scale (PACES)(25), respectively.

The participants were seated in a backrest chair with their shoulder abducted and flexed at 10 degrees and their elbow flexed at 80 degrees in order to assess their grip strength and upper extremity motor impairment. The grip strength was selected as an outcome measure due to its strong correlation with upper extremity function in stroke patients(26). The hand grip dynamometer was employed to assess grip strength due to its demonstrated excellent concurrent validity, intra-rater reliability, and test-retest reliability(27,28). Participants were instructed to apply as much grip pressure as possible on the dynamometer for three times, with the highest values recorded(26).

The FMA was used to evaluate motor impairment in stroke patients. It is scored based on direct observation of the patient's performance and has been shown to have good concurrent validity and test-retest reliability(29,30). The FMA-UE consisted of 33 items, out of 155 items of the FMA, including the reflex activity of the elbow flexor and extensor muscles, upper extremity movements (volitional movement with synergies, and volitional movement mixing synergies, volitional movement with little or no synergy), normal reflex activity, wrist movements, hand movements, and coordination/speed of the index finger as it moves from one's knee to one's nose. Here, reflex activities were scored as 0 (none) and 2 (can be elicited) while movement performances were scored on a 3-point ordinal scale (0 = cannot perform, 1 = performs partially, 2 = performs fully). The scores ranged between 0 and 66 points(31).

The shoulder flexion ROM was measured in a supine position with the knee flexed by the universal goniometer, which demonstrated good concurrent validity and test-retest reliability(29). The ROM was chosen as an additional outcome measure due to its ability to predict upper extremity function(32). The normal range of motion (ROM) for shoulder flexion is typically between 160 and 180 degrees. The axis location of the universal goniometer was the middle of the humeral head laterally while the stationary arm was held parallel with the trunk(33).

The muscle tone of the shoulder abductor, the elbow flexor, and the wrist flexor muscles was assessed using the MAS. This scale has been widely used in both clinical and research settings, and has been found to have moderate inter-rater and intra-rater reliability(34). The MAS score ranged from 0 (no increase in tone) to 4 (extremity rigid in flexion or extension)(34).

The 18-item of PACES was used to assess the participant's enjoyment of their physical activity. The PACES had high internal consistency and had high internal consistency(36). A 7-point bipolar Likert scale was here employed, as ranged from 1 (I enjoy it) to 7 (I hate it). The scores of the negative items were reversed, and the summed total scores ranged between 18-126, with higher scores indicating higher enjoyment(25).

Statistical analysis

The SPSS 17.0 statistical software was used for the data analysis of this research. The groups of data have been expressed by means and standard deviations. The normality of the data has been tested using the Shapiro-Wilk test, as is in accordance with the data's non-normal distribution. Descriptive statistics have been presented by means (standard deviation) for the normally distributed variables and medians (IQR) for the non-normally distributed variables. The Wilcoxon Signed-Rank test and Mann-Whitney U test were used to compare all variables within and between the groups. The significance level was set at p-value < 0.05.

Results

A total of 163 patients were screened for eligibility, with 20 ultimately being matched and randomly assigned to either a strength training program associated with TOT (experimental group) or a TOT-only program (control group). The experimental group completed 4 weeks of training, while unfortunately, one participant in the control group dropped out due to relocation to another city. At the end of the study, 19 participants' data were eligible for analysis. The study flow diagram, which outlines the number of participants in the experimental and control groups, is summarized in figure 1.

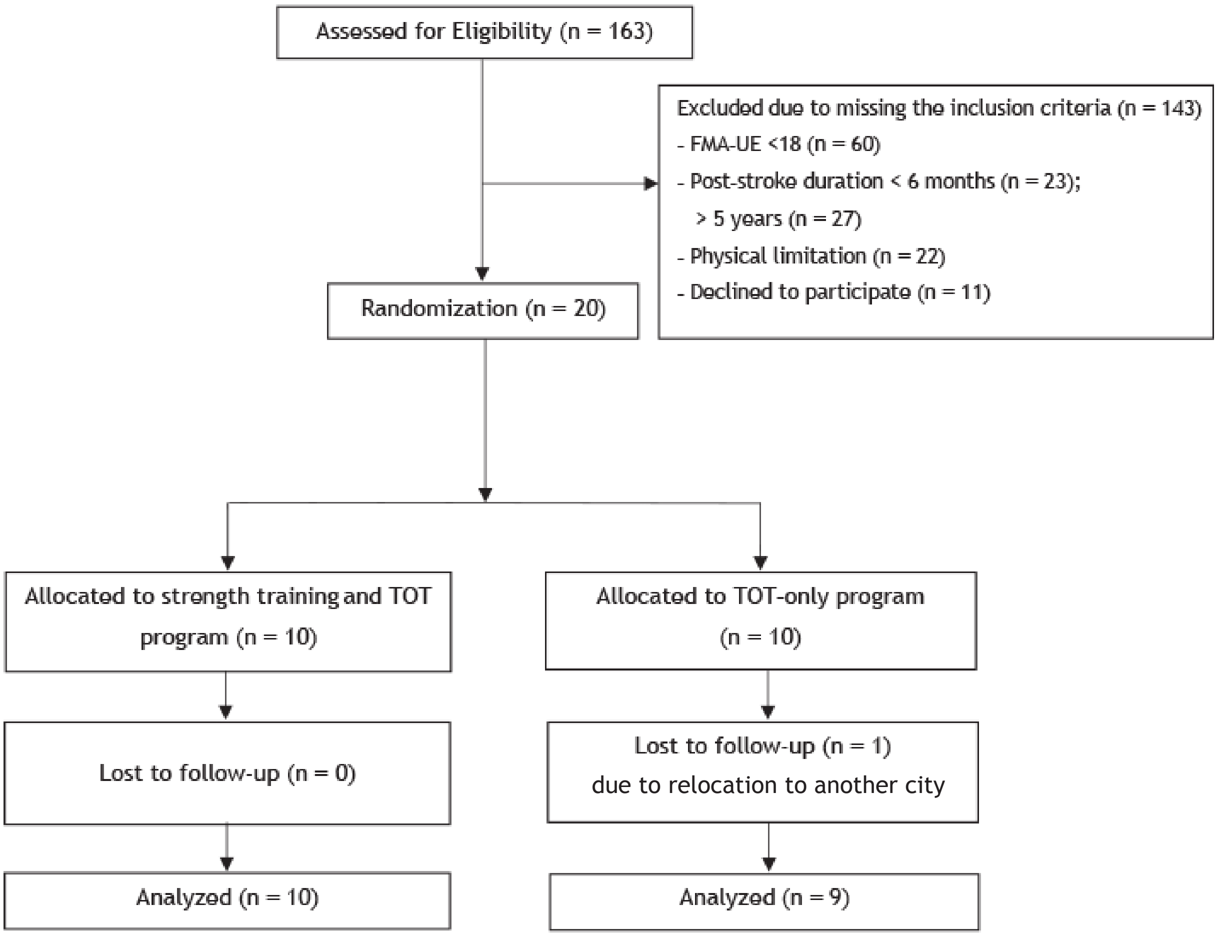

Figure 1 Study flow diagram showing the number of participants in the experimental and control group

Table 3 details the demographic and clinical characteristics of the participants. At the baseline level, there were no significant differences between the two groups. Furthermore, no significant differences were observed in the SWMFT-C-FAS, SWMFT-C-TIME, muscle spasticity grip strength, FMA-UE, shoulder flexor range of motion, and upper extremity muscle spasticity among the participants in each group.

Table 3 Participants' demographics

Variable	**Control group (n = 10)**	**Experimental group (n = 10)**	***p*-value**
Age (years)	61.5 ± 8.5	59.6 ± 8.5	0.47[a]
Gender (male/female)	5/5	6/4	0.63[b]
Hemiparetic side (Right/Left)	4/6	3/7	0.63[b]
Disease duration (month)	26.6 ± 13.5	23.4 ± 19.4	0.14[c]
Pathology (Ischemic/Hemorrhagic)	6/4	8/2	0.32[b]
SWMFT-C-FAS (0-5)	3.00 (1.0, 3.4)	2.4 (1.0, 3.3)	0.70[c]
SWMFT-C-TIME (0-120 second)	7.6 (3.8, 120.0)	5.6 (3.1, 120.0)	0.43[c]
Grip strength (kg)	11.6 (5.1, 18.4)	8.3 (7.4, 18.4)	0.94[c]
FMA-UE (0-66)	38.0 (22.5, 42.0)	32.5 (22.7, 39.0)	0.62[c]
Shoulder flexion ROM (degree)	128.3 (32.5, 145.8)	132.1 (38.4, 149.8)	0.77[c]

Note: Values are presented as number, mean ± standard deviation, or median (interquartile range). [a] Compared between the groups using the independent t-test, [b] Compared between the groups using the chi-square test, [c] Compared between the groups using the Mann-Whitney U test. SWMFT-C-FAS, streamlined wolf motor function test-chronic-functional ability scale; FMA-UE, fugl meyer assessment-upper extremity; ROM, range of motion.

Table 4 illustrates the medians (IQR1,3) and statistics recorded across the 19 participants. Significant within-group differences were observed in the SWMFT-C-FAS, SWMFT-C-TIME, FMA-UE, and shoulder flexion ROM (p-value < 0.05) for both groups, with the experimental group exhibiting a statistically significant difference in grip strength (p-value < 0.05). Neither group experienced an increase in spasticity of the shoulder abductors, elbow flexors, and wrist flexors over time. The experimental group had an enjoyment scale result of 105.0 (89.0, 118.2), while the control group had a result of 91.0 (83.5, 106.0). No statistically significant differences were observed in any of the outcome measurements between the two groups.

Table 4 Outcome measures across 3 assessment occasions

Outcome	Control group (n = 9)	Experimental group (n = 10)	*p*-value*
SWMFT-C-FAS (0-5)			
Baseline	3.00 (1.0, 3.4)	2.4 (1.0, 3.3)	0.70
4th week	3.33 (1.1, 4.1)*	3.0 (1.5, 3.9)*	0.87
SWMFT-C-TIME (0-120 second)			
Baseline	7.6 (3.8, 120.0)	5.6 (3.1, 120.0)	0.43
4th week	4.4 (2.7, 100.7)*	3.3 (2.4, 53.1)*	0.36
Grip strength (kg)			
Baseline	11.6 (5.1, 18.4)	8.3 (7.4, 18.4)	0.94
4th week	11.7 (5.3, 19.1)	11.4 (8.8, 20.3)*	0.65
FMA-UE (0-66)			
Baseline	38.0 (22.5, 42.0)	32.5 (22.7, 39.0)	0.62
4th week	48.0 (30.5, 57.5)*	44.0 (30.7, 54.0)*	0.80
Shoulder flexion ROM (degree)			
Baseline	128.3 (32.5, 145.8)	132.1 (38.4, 149.8)	0.77
4th week	145.0 (51.7, 151.9)*	139.6 (61.2, 156.8)*	0.68
Shoulder abductor spasticity (MAS 0-4)			
Baseline	1.0 (0.0, 1.5)	1.0 (0.0, 2.2)	0.96
4th week	0.0 (0.0, 1.0)	0.0 (0.0, 1.5)	0.56
Elbow flexor spasticity (MAS 0-4)			
Baseline	1.0 (0.0, 2.0)	1.5 (0.0, 3.0)	0.51
4th week	0.0 (0.0, 1.5)	1.0 (0.0, 2.0)	0.10
Wrist flexor spasticity (MAS 0-4)			
Baseline	1.0 (0.0, 2.0)	1.0 (0.7, 3.0)	0.43
4th week	1.0 (0.0, 1.5)	1.0 (0.0, 2.2)	0.43
PACES (0-126)			
4th week	91.0 (83.5.5, 106.0)	105.0 (89.0, 118.2)	0.23

Note: Values are presented as median (interquartile range). *Compared with the baseline within the group using the Wilcoxon Signed-Rank test, *p*-value < 0.05. TOT, task-oriented training; SWMFT-C-FAS, streamlined wolf motor function test-chronic-functional ability scale; FMA-UE, fugl meyer assessment-upper extremity; ROM, range of motion; MAS, modified ashworth scale; PACES, physical activity enjoyment scale.

Discussion

The results of this study indicate that 4-week strength training associated with TOT program did not yield better outcomes than the TOT-only program for chronic stroke patients with mild to moderate motor recovery. However, the strength training associated with the TOT program did improve grip muscle strength. Additionally, neither training program seemed to stimulate spasticity.

This study provides evidence that TOT is effective in improving upper extremity functions and motor impairment[13,14]. Both groups completed 3,600 training repetitions for each task, which is likely enough to promote neural plasticity, or the capacity to modify, restore, or reorganize structurally and functionally[17]. The randomization of the task training provided in both groups resulted in a faster brain reorganization response than that of block training[37]. This allowed for a more efficient and effective reorganization of the brain. Stroke patients can recover rapidly during the first six months post-stroke, however, neural plasticity can be stimulated at any stage post-stroke[38]. This study determined the intensity and duration of training necessary to induce neural plasticity, based on previous research which found that at least 30 hours[39] or more than 3,000 repetitions of task training[17] were required. This finding was supported by both groups, who showed similar neuromuscular adaptation. This study enabled the participants to customize their training tasks within the TOT program in collaboration with their therapist. Before each training session, the participant identified their training activity and established objectives for each task based on their capabilities and needs. Consequently, all training activities were meaningful in that they are likely to sustain their long-term engagement[40]. Participants enjoyed the training program, as evidenced by the enjoyment scale scores of both groups being higher than 80. The scores among the group that combined strength training with the TOT program were notably higher, likely due to their quicker recovery of upper extremity muscle strength, as observed in our previous study[16].

The TOT program's strength training failed to improve grip muscle strength more than the TOT-only program group, as the only muscles being reinforced were the shoulder, the elbow and the wrist muscles. This was due to the strength training consisting of the participants hanging sandbags from their wrists, which did not target the hand muscles.

The findings of this study contradict a prior research, which has demonstrated that strength training with the TOT program had a more marked effect than TOT-only programs[14]. The divergence between the two studies may be attributed to the different outcome measures employed. Da Sil Va et al[14] investigated the effect of TOT and strength training on upper extremity function using the Test d' Evaluation des MembresSuperieu des PersonnAge´es, which includes 4 bilateral and 4 unilateral tasks. In contrast, this current study utilized the SWMFT-C which consists of only one bilateral task and 5 unilateral tasks that address the hemiparetic side.

The strength training associated with TOT program showed a faster improvement in ULFA and grip strength than the TOT-only program, with results seen after just six 70-minute sessions[16]. This finding supported that upper extremity functions are accompanied by strength training[41]. This finding further supported the evidence which found that upper extremity functions can be improved through strength training[26]. Strength training associated with the TOT program has been demonstrated to effectively improve muscle strength, a major cause of upper extremity functional limitation in stroke patients. This finding suggests that strength training should be incorporated into upper extremity rehabilitation programs for chronic stroke patients with moderate to high motor recovery. Strength training associated with TOT program had no effect on muscle spasticity in stroke patients who had either no or mild spasticity at the start of the program, as evidenced by the findings of other studies[41].

This study has provided data that could be further explored through larger sample size to confirm the effectiveness of strength training combined with TOT. It is noted that this study does have some limitations. Firstly, the results cannot be generalized to post-chronic stroke patients with lower upper extremity function, as only those with moderate to high function were recruited. Secondly, it is unclear whether the participants' social activity participation also increased after their functional improvement, so further investigation is needed in this area. Lastly, the study did not assess the retention of the training or the neural plasticity of the participants, which could be addressed in future research. Further research should be conducted to explore the effects of strength training associated with TOT, which focuses on resistance exercises for the hands to improve dexterity.

Conclusion

This study has demonstrated that a 4-week strength training program combined with a TOT program can significantly improve ULFA, upper extremity motor impairment, and shoulder flexion AROM in chronic stroke patients, with similar results to those achieved with the TOT-only program. However, the TOT-only program did not improve upper extremity muscle strength. Furthermore, the participants seemed to prefer the strength training combined with TOT program over the TOT-only program.

Take home messages

The combination of strength training and the TOT program has been shown to improve upper extremity function, motor impairment, and shoulder flexion in chronic stroke patients to a similar degree as the TOT-only program. However, only the combination of strength training and TOT has been found to improve upper extremity muscle strength.

Conflicts of interest

The authors declare no conflict of interest.

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