A Calligraphy Exercise for Improving Upper Limb Functions in Subacute Stroke Patients: A Pilot Randomized Control Study

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Research Article

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Abstract

Background: Self-administered rehabilitation exercises can improve upper limb (UL) function in stroke patients, but their effects depend on successful integration of fundamental principles of neurorehabilitation. This study aimed to validate the effect of a modified calligraphy exercise for improving UL function in subacute stroke patients.

Methods: 30 subacute stroke patients were randomized into experimental and control groups. Patients in the experimental group received three-week calligraphy interventions. Patients in the control group received education protocol. Fugl-Meyer Assessment for UL (FMA-UL), Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire, and Modified Barthel Index (MBI) assessment were performed before and after the interventions.

Results: Both groups got significantly higher FMA-UL scores after the interventions (P < 0.001), but no significant improvement was found in the DASH assessment in the experimental (P = 0.336) or the control group (P = 0.024). For the MBI assessment, significant improvements after the interventions were found in the experimental (P = 0.001) and the control groups (P < 0.001). It was also found that patients in the experimental group had significantly better performance in the post-intervention FMA-UL assessment than patients in the control group (P = 0.001). However, patients in the experimental group did not get significantly higher scores in the post-intervention MBI assessment than patients in the control group (P = 0.243).

Conclusions: The outcomes indicated that the modified calligraphy exercise improved the motor impairments in the patients’ UL, suggesting its potential as a self-administered exercise for facilitating UL function recovery in subacute stroke patients.

Trial Registration

This study was registered at Chinese Clinical Trial Registry on Feb. 4, 2021, and was assigned of a trial registration number: ChiCTR2100043036.

Introduction

Stroke is one of the primary reasons leading to long-term movement disabilities in older adults, and some 55–85% of stroke patients suffer from functional impairments in the upper limb (UL) as a result of upper motor neuron syndrome, somatosensory dysfunction on the contralateral side of the brain lesion, and cognitive impairment [1–3]. After the initial treatment of acute stroke [4, 5], 30–66% of subacute/chronic stroke patients still possess limitations in UL motor function [6, 7], especially the difficulty in coordinating the movements of arm, hand, and fingers [8]. These prolonged UL motor impairments limit the patients in their abilities in activities of daily living [9, 10], affect their social interaction [11], and reduce their quality of life [12]. Therefore, it has become a wide consensus that rehabilitation of UL motor impairments
should be extended to the subacute or even chronic phase of stroke to provide patients with continuous therapeutic effects [12–14].

Self-administered exercises for rehabilitation have greatly drawn public attention, since it is cost-effective and flexible [15, 16]. Such exercises are thus particularly suitable for home-based rehabilitation for subacute and chronic stroke patients. However, a recent systematic review indicated that existing self-administered exercises are not more effective than no intervention when being applied to chronic and severe stroke patients [17]. One reason may be that patients have low adherence to self-administered exercises due to the lack of supervision or loss of interest. In addition, it has been suggested that several key principles of stroke neurorehabilitation, including sufficient intensity, goal-oriented practice, and increasing difficulty, etc., should characterize an effective rehabilitation exercise [18–21]. These principles can facilitate patients’ motor learning and brain plasticity, which are highly demanded in stroke rehabilitation, but they may be considerably ignored in previous self-administered exercises.

In a recent research proposal [22], we proposed a self-administered exercise involving traditional Chinese calligraphy. Chinese calligraphy is a visually guided practice of artistic writing, during which individuals use a “brush” pen to apply ink on a paper. Through pen gripping and UL joint movements during calligraphy practicing, stroke patients are expected to gain favourable training effects on their UL motor function. In addition, copybooks with character frames have been developed to exert self-administered and goal-oriented characteristics to the calligraphy exercise. With the view to validating its feasibility and optimizing its design, this study aimed to evaluate the effect of the calligraphy exercise on the recovery of UL motor impairments and disability in activities of daily living in subacute stroke patients. We hypothesized that patients would perform significantly better in the assessments of UL motor function after receiving the calligraphy exercise intervention compared to their counterparty.

**Materials And Methods**

**Subject recruitment and randomization**

30 patients, diagnosed with stroke using brain computer tomography or magnetic resonance imaging by neurologists, were recruited in this study. The following inclusion criteria were applied: 1) within the subacute phase of stroke (14 days to six months after the stroke occurred), 2) able to sit without UL supporting, 3) sufficient active range of joint motions (≥ 90° of shoulder flexion, ≥ 90° of elbow flexion, ≥ 30° of wrist pronation/supination, ≥ 30° of wrist flexion), 4) able to hold the calligraphy brush with the affected hand, and 5) no serious visual field defect. Patients were excluded if they had: 1) other neurological diseases or UL surgical histories, 2) severe communication deficits, and 3) shoulder pain that hinders UL movement (subjects’ should pain during UL movement was assessed using a numerical rating scale from 0 (no pain) to 10 (worst pain imaginable) [23], and those who reported a score over 3 were excluded). This study was approved by the Ethics Committee prior to the subject recruitment. All the recruited patients were informed about the study and signed informed consent.
All the patients were randomized into two groups (experimental vs. control) using envelopes [24] by a statistician. Here, 30 envelopes were prepared, each labelled with an external series number from “0” to “30” and an internal group number: # 1 — experimental group or # 0 — control group. Once a patient was recruited, the statistician randomly opened an envelope and allocated the patient into one of the two groups according to the internal number. The external series number was also used as the patient’s ID for data management throughout the study. Demographic and clinical information was collected from each patient after subject randomization.

**Study protocol**

Subjects in this study received rehabilitation interventions according to the experimental or control group protocols (Fig. 1). As all the patients were based in the hospital during the study, conventional occupational therapy and daily nursing were routinely applied. Outcomes regarding subjects’ UL motor functions were measured before and after the interventions.

**Intervention protocols**

Patients in the experimental group received three-week calligraphy exercise interventions (Fig. 2a). Custom-designed copybooks with character frames were applied for the calligraphy exercise. Here, three different copybooks were developed, each containing straight, dot, or curve frames (Fig. 2b). Each copybook was used in the calligraphy exercise for one week. During the exercise, the patient was instructed to sit steadily in front of a desk and hold a calligraphy brush using the thumb, index finger, and middle finger of the affected hand. The patient soaked the brush head with water and was instructed to write within the character frames on the copybook as accurately as she/he could, but the patient’s UL movement patterns were not regulated. The calligraphy exercise lasted 30 mins a day for five days per week.

Patients in the control group received lectures on stroke recovery and general health education twice per week for three weeks. The patients met with the study coordinator three time per week to review the information of the lectures, ensuring that both groups received the same amount of time from the study coordinator over the intervention period.

**Outcome measures**

Before and after the interventions, UL functions of the patients were assessed as follows:

- *Fugl-Meyer Assessment for UL (FMA-UL):* This assessment provides a numeric score for motor function of the UL after stroke. The FMA-UL has a 3-point ordinal scale: 0 (no function), 1 (partial function), and 2 (perfect function). The maximum score is 66.

  - *Disabilities of Arm, Shoulder, and Hand (DASH):* This measure is a 30-item self-report questionnaire designed to assess individually rated UL impairments and impacts on activities for individuals with musculoskeletal disorders in the UL [25].
• Modified Barthel Index (MBI): This is a 100-point scale that measures an individual’s ability to perform 10 activities of daily living, including bathing, feeding, and dressing, etc, with each activity scored based on the individual’s level of need for assistance. Lower scores indicate poorer independence, while higher scores indicate greater independence. The MBI is a reliable and responsive measure of disability in stroke patients [26].

Data processing and statistical methods

Descriptive statistics was applied to present the outcomes. Paired sample t-test was used to examine any difference between the baseline and post-intervention outcomes. Analysis of covariance (ANCOVA) was performed to examine any group difference for the three outcome measures, with the baseline score being used as the covariate. Bonferroni correction was applied to correct for multiple comparisons. Effect size (ES) was calculated using Cohen’s d measure [27], and interpreted as: small (d = 0.2), medium (d = 0.5), and large (d = 0.8). All the statistical analysis was performed using SPSS 24.0 (SPSS Inc, Chicago, IL, USA). The significant level was set at 0.05.

Results

All the 30 patients completed the study without any dropout or missing value. Demographic and clinical characteristics of the patients, as well as outcomes of based assessments, were illustrated in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Experimental group (n = 15)</th>
<th>Control group (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male/female), n</td>
<td>9/6</td>
<td>11/4</td>
</tr>
<tr>
<td>Age (mean ± SD), yr.</td>
<td>59.3 ± 7.8</td>
<td>60.5 ± 10.9</td>
</tr>
<tr>
<td>Side of paresis (left/right), n</td>
<td>8/7</td>
<td>9/6</td>
</tr>
<tr>
<td>Dominant hand affected, n</td>
<td>7 (46.7%)</td>
<td>6 (40%)</td>
</tr>
<tr>
<td>Type of stroke (Ischemic/Haemorrhagic), n</td>
<td>10/5</td>
<td>11/4</td>
</tr>
<tr>
<td>Time of stroke till study started (mean ± SD), day</td>
<td>95.8 ± 48.6</td>
<td>92.1 ± 57.6</td>
</tr>
<tr>
<td>Fugl-Meyer Assessment for Upper Limb (mean ± SD), max = 66</td>
<td>34.7 ± 4.3</td>
<td>36.9 ± 6.5</td>
</tr>
<tr>
<td>Disabilities of Arm, Shoulder, and Hand (mean ± SD), max = 100</td>
<td>80.5 ± 12.4</td>
<td>75.5 ± 10.4</td>
</tr>
<tr>
<td>Modified Barthel Index (mean ± SD), max = 100</td>
<td>34.7 ± 11.1</td>
<td>38.4 ± 7.2</td>
</tr>
</tbody>
</table>
The outcomes of baseline and post-intervention assessments were compared. Specifically, patients in the experimental group achieved significantly higher scores in the post-intervention FMA-UL assessment compared to the baseline assessment ($P < 0.001, ES = 1.233$; Table 2). Similarly, patients in the control group achieved significantly higher scores in the post-intervention FMA-UL assessment compared to the baseline assessment ($P < 0.001, ES = 0.397$). No significant change was found in the DASH score between the baseline and post-intervention assessments in neither the experimental ($P = 0.336, ES = 0.243$) nor the control group ($P = 0.024, ES = 0.261$). Significantly higher MBI score after the intervention period was found in both the experimental ($P = 0.001, ES = 1.456$) and the control ($P < 0.001, ES = 2.259$) groups.

Table 2
Comparisons between the baseline and post-intervention assessments.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Baseline values</th>
<th>Post-intervention values</th>
<th>Change in scores (95% CI)</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fugl-Meyer Assessment for Upper Limb</td>
<td>Experimental</td>
<td>34.7 ± 4.3</td>
<td>41.0 ± 5.8</td>
<td>6.3 (4.6–8.0)</td>
<td>7.948</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>36.9 ± 6.5</td>
<td>39.5 ± 6.6</td>
<td>2.6 (1.4–3.8)</td>
<td>4.516</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Disabilities of Arm, Shoulder, and Hand</td>
<td>Experimental</td>
<td>80.5 ± 12.4</td>
<td>77.3 ± 13.9</td>
<td>3.2 (-3.7–10.1)</td>
<td>0.997</td>
<td>0.336</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>75.5 ± 10.4</td>
<td>72.5 ± 12.5</td>
<td>3.0 (0.5–5.5)</td>
<td>2.527</td>
<td>0.024</td>
</tr>
<tr>
<td>Modified Barthel Index</td>
<td>Experimental</td>
<td>34.7 ± 11.1</td>
<td>53.1 ± 14.0</td>
<td>18.4 (9.1–27.7)</td>
<td>4.246</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>38.4 ± 7.2</td>
<td>59.4 ± 11.0</td>
<td>21.0 (14.3–27.7)</td>
<td>6.761</td>
<td>&lt; 0.001*</td>
</tr>
</tbody>
</table>

* denoted statistical significance after adjustment using Bonferroni correction.

The results of ANCOVA for the outcome measures were illustrated in Table 3. There was a significant difference in the post-intervention FME-UL score between the two groups. Here, the experimental group achieved a significantly higher FMA-UL score compared to the control group ($P = 0.001, ES = 0.335$). Compared to the control group, the experimental group did not achieve a significantly higher DASH score after the intervention ($P = 0.862, ES = 0.001$). Finally, no significant difference in the post-intervention MBI score was found between the experimental and control groups ($P = 0.243, ES = 0.050$).
### Table 3
ANCOVA results of the outcome measures

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group</th>
<th>Baseline values</th>
<th>Post-intervention values (95% CI)</th>
<th>Estimated post-intervention values (95% CI)</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fugl-Meyer assessment for upper limb</td>
<td>Experimental</td>
<td>34.7</td>
<td>41.0 (37.8–44.2)</td>
<td>42.1 (40.7–43.6)</td>
<td>13.592</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>36.9</td>
<td>39.5 (35.8–43.1)</td>
<td>38.4 (36.9–39.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disabilities of Arm, Shoulder, and Hand</td>
<td>Experimental</td>
<td>80.5</td>
<td>77.3 (69.6–85.0)</td>
<td>75.2 (70.2–80.2)</td>
<td>0.031</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>75.5</td>
<td>72.5 (65.5–79.4)</td>
<td>74.6 (69.5–79.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Barthel Index</td>
<td>Experimental</td>
<td>34.7</td>
<td>53.1 (45.3–60.8)</td>
<td>53.4 (46.6–60.2)</td>
<td>1.422</td>
<td>0.243</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>38.4</td>
<td>59.4 (53.3–65.5)</td>
<td>59.1 (52.3–65.9)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* denoted statistical significance after adjustment using Bonferroni correction.

### Discussion

Previous studies have reported that Chinese calligraphy is able to improve individuals’ cognitive well-being [28], and is curative to several neuropsychiatric disorders such as autism, depression, and posttraumatic stress [29]. This is the first study investigating the effect of calligraphy for improving UL motor function for stroke patients. The most important finding of this study was that compared to stroke patients who received no intervention, stroke patients had significantly better performance in the FMA-UL assessment after receiving the calligraphy intervention.

FMA-UL assessment is a gold standard clinical approach that has been widely used to evaluate a stroke patient’s UL sensorimotor impairments [30–32]. In this study, patients achieved an average baseline FMA-UL score of 34.7 in the experimental group and 36.9 in the control group, which were within the range of 29–43 reported in previous studies involving subacute/chronic stroke patients [30, 31, 33]. Importantly, the outcomes also indicated that patients who received the calligraphy intervention achieved significantly higher FMA-UL scores compared to their counterparts who received no intervention, suggesting that the calligraphy exercise may be effective for promoting UL motor recovery in subacute stroke patients. Using calligraphy for UL motor rehabilitation after stroke is very new. Therefore, no previous studies could be compared for outcome interpretation. Our explanation is that the calligraphy exercise exerted a unique movement style in patients’ UL. Here, continuous coordinative movements of the three UL joints (wrist, elbow, and shoulder) were essential during the calligraphy writing, which rendered intensive training to the patients’ affected arm. In addition, the patients were required to keep consistent character thickness as
consistent as they can during the calligraphy practicing. As brush pens with a soft head were used in this study, the patients might strive to maintain UL stability to follow the instructions. This might stimulate their neuromuscular control and improve muscle strength in their UL.

The modified calligraphy exercise was designed by following several key principles for neuromuscular rehabilitation of stroke, which may be another reason leading to the favourable effect of the calligraphy intervention. First, it has been suggested that goal-oriented rehabilitation programs, where attention is focused on the performance of the exercise rather than on the exercise itself, can lead to higher motor learning performance [20, 34]. As it is difficult to evaluate performance in traditional Chinese calligraphy, we developed copybooks for the patients to practice calligraphy writing. These copybooks contained character frames, and the patients were required to write within the frames at their best (the goal). Patients would strive to reach the goal rather than pay attention to the coordinative movements of their UL. Therefore, such a design made our calligraphy exercise a goal-oriented rehabilitation program. Second, increasing difficulty is another key principle of neuromuscular rehabilitation after stroke, which has been used in rehabilitation programs leveraging robot-assisted therapy [35] or VR-based systems [36]. Rehabilitation programs with increasing difficulty have also been indicated to be more suitable for less impaired stroke patients or those who have reached to the later phase of stroke, e.g., subacute stroke patients [37]. In this study, copybooks with three difficulty levels were developed and applied for the calligraphy intervention. Using these copybooks, the patients wrote short straight characters in the first week so that their motor learning performances would not be impeded by difficult tasks that surpassed their ability at the early stage [38]. With the subjects’ UL motor function improved, they wrote circles and curves during the rest of the intervention to exert more complicated movement patterns in their UL. Here, such an increase in the training difficulty might further balance the error processing demands on the subjects during calligraphy practice with their improved performance, which is optimal for motor learning [39]. On the other hand, personalized difficulty levels may result in better motor learning performance compared to when increases in the difficulty level are fixed [40]. Thus, further research may prescribe the difficulty levels of calligraphy exercise for specific stroke populations based on their baseline BMI, physical activity level, and motivational traits. With the optimization of the rehabilitation protocol, further studies may also focus on evaluating the effect of calligraphy on stroke patients’ motor learning performance. Here, testing the regulative change of UL motor variability has been indicated to be able to predict the improvement in their motor learning ability [41].

Low-cost self-administered exercises for home-based rehabilitation are ideal for subacute or chronic stroke patients, especially given that living too far away and transportation difficulty can greatly affect patients’ participation in supervised hospital-based rehabilitation programs [42]. The cultural element in calligraphy exercise may encourage stroke patients from east Asia to participate or even develop it as a hobby for long-term insistence. In addition, the copybook used in the calligraphy exercise could be modified by involving characters from different languages, in order to facilitate its popularization among stroke patients worldwide.
Several limitations of this study should be announced. First, the length of the intervention was relatively short. Further studies may investigate stroke patients’ UL motor performance during a longer period of calligraphy intervention, in order to improve the study quality. In addition, investigations on stroke patients’ motor learning performance and brain plasticity were missed in this study, which however, may reveal the neurological mechanisms underlying the change in patients’ UL motor function after calligraphy intervention. Finally, considering that the study was performed in the hospital and lasted for a short period, subjects; adherence to the calligraphy exercise was not measured in this study. As individuals’ adherence is important to the effectiveness of a rehabilitation exercise, further studies should report adherence rates, especially in long-period study designs.

Conclusions

In conclusion, the modified calligraphy exercise might have a positive effect on the UL sensorimotor function in subacute stroke patients. This study provided a preliminary clinical basis and theoretical support for the calligraphy exercise as a self-administered rehabilitation approach to be initiated by stroke patients in the subacute or chronic phase.

Declarations

**Ethical Approval and Consent to participate:** This study was approved by the Ethics Committee prior to the subject recruitment. All the recruited patients were informed about the study and signed informed consent.

**Human and Animal Ethics:** Human ethics regulations were strictly obeyed during the execution of the study.

**Consent for publication:** A written informed consent for publication have been obtained from the participant illustrated in Figure 2, which could be provided upon request.

**Availability of supporting data:** Data will be provided upon request.

**Competing interests:** The authors have no competing interests to disclose.

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**Authors’ contributions:** Conceptualization: Qiang Zhang, Xie Wu; Methodology: Qiang Zhang, Xiaodi Wu; Formal analysis and investigation: Qiang Zhang, Xiaodi Wu, Jun Qiao; Writing - original draft preparation: Qiang Zhang, Xiaodi Wu; Writing - review and editing: Xie Wu; Funding acquisition: Nan Chen; Resources: Jun Qiao, Nan Chen; Supervision: Xie Wu.
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References


Figures
Figure 1

Consort diagram from subject recruitment to data analysis.
Figure 2

The calligraphy intervention. a) The subject performs calligraphy exercise, b) Design of calligraphy copybooks with increasing difficulty.