RESEARCH PAPER

Effects of 5 minutes of neck-muscle vibration immediately before occupational therapy on unilateral spatial neglect

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Abstract
Purpose. To evaluate the effects of neck-muscle vibration for 5 min before occupational therapy (OT) on unilateral spatial neglect (USN).
Method. In this multiple-baseline design study for 6 weeks (A1-B-A2 design: A1, A2; conventional OT without neck-muscle vibration, B; neck-muscle vibration before OT together with conventional OT), we examined 11 right brain-damaged patients in the post-acute phase of stroke who showed USN. Sessions A1 and A2: conventional OT for 40 min once daily for 5 days a week. Session B: the left posterior neck muscles of the patient were subjected to vibration for 5 min, without confirming the appearance of a kinaesthetic illusion, immediately before OT, and then the same OT programme as in sessions A1 and A2 was performed. Each session lasted 2 weeks. USN and activities of daily living (ADL) were evaluated at 2-week intervals by the Behavioural Inattention Test (BIT) and Functional Independence Measure (FIM), respectively.
Results. Significant increases in the total scores in both the conventional subtest and behavioural subtest of the BIT were only seen during session B. FIM scores increased significantly during both sessions A1 and B.
Conclusions. The application of neck-muscle vibration before OT may have positive effects on USN, but the specific effect on the improvement of ADL is not clear.

Keywords: Unilateral spatial neglect, muscles, vibration

Introduction

Unilateral spatial neglect (USN) due to a right-hemisphere lesion is observed in 40% of stroke patients with left hemiplegia [1]. The exploratory behaviour in these patients is shifted toward the right side, resulting in a neglect of stimuli situated on the left. Patients with USN perform worse on tests of activities of daily living (ADL) at both admission and discharge, and typically spend significantly longer in rehabilitation hospitals, compared to patients without neglect [2–5].

Various approaches for the treatment of USN in stroke rehabilitation have been examined, including vestibular stimulation [6,7], trunk rotation [8,9], neck-muscle vibration [10–13], prism adaptation [14,15], eye patching [16] and visual scanning [17], and any improvements during such treatments for USN have been evaluated with simple tests, such as a cancellation test or a copy-drawing test. In some studies with prism adaptation or neck-muscle vibration, the positive effect has lasted for more than 1 month [13,14].

The application of neck-muscle vibration for 20 min to the optimal site on the neck results in a kinaesthetic illusion and can improve task performance in a cancellation test and copying [10–13]. Schindler et al. evaluated the long-term efficacy of visual exploration training alone or in combination with neck-muscle vibration in two matched groups of
10 patients with spatial neglect [12]. In this combination treatment, the patients performed visual exploration while the contralateral neck muscles were vibrated. The results showed that the combined treatment gave superior results, and a specific and lasting reduction in the symptoms of neglect was evident 2 months after the completion of treatment. Furthermore, neck-muscle vibration for 20 min without concurrent training for 10 consecutive days induced a significant amelioration of spatial neglect after vibration was discontinued [13]. In these studies, to determine the optimal position of the vibrator on the left posterior neck muscles, each patient was asked to fixate straight ahead on a red light-emitting diode (LED), which was located just in front of the sagittal body midline at a distance of 2 m, in a completely darkened room. The position of the vibrator was varied on the neck until the patients consistently reported horizontal movement of the stationary LED to the right. This optimal location was then stimulated for 20 min. However, the appearance of a kinaesthetic illusion is not proportional to the improvement of USN [11,12], and neck-muscle vibration for 30 s can change the posture of normal subjects and amputees [18,19]. If neck-muscle vibration for a shorter duration could be shown to have an effect similar to that with neck-muscle vibration for 20 min with an illusion, neck-muscle vibration would be more useful and applicable in rehabilitation for USN. Therefore, the effects of neck-muscle vibration for a short duration on the symptoms of neglect and ADL need to be clarified.

In the present study, we investigated whether 5 min of neck-muscle vibration immediately before occupational therapy (OT) would promote a reduction in the symptoms of neglect and the recovery of ADL compared to conventional OT without neck-muscle vibration in a single group of patients with USN.

### Methods

#### Subjects

Eleven right brain-damaged patients with stroke who showed USN in the Japanese version of the Behavioural Inattention Test (BIT) [20] were recruited from among in-patients who had been admitted to a rehabilitation centre at a university hospital. The subjects demonstrated impaired performance on at least one of the 6 conventional subtests in the BIT. None of the patients met any of the following exclusion criteria: (1) severe pain or skin disease at the posterior neck; (2) severe atherosclerosis of carotid arteries by an ultrasonic evaluation and (3) dementia or inability to understand the meaning of the study.

Patients were 68.2 ± 8.2 years old (mean ± SD) with a range of 54–79 years. The duration after onset was 7.5 ± 4.1 weeks, with a range of 4–17 weeks. The diagnoses of the patients consisted of four cerebral haemorrhages and seven cerebral infarction, and all of the patients were right-handed (Table I). This study was approved by the Ethical Committee of the university hospital and written informed consent was obtained from all of the subjects.

#### Experimental design and exercise protocol

A multiple-baseline design [A1–B–A2 design: A1,A 2; conventional OT treatment without neck-muscle vibration, B; neck-muscle vibration before OT together with conventional OT treatment] across individuals was used (Figure 1). The study period was 6 weeks and each session lasted 2 weeks.

Interventions for each session were as follows:

- Sessions A1, A2: conventional OT for 40 min once daily for 5 days a week. OT included

### Table I. Demographic and clinical data for the participating patients with unilateral neglect.

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Time from CVA (weeks)</th>
<th>Visual field defect</th>
<th>Aetiology</th>
<th>Lesion sites</th>
<th>BIT (conventional) (total/146)</th>
<th>BIT (behavioural) (total/81)</th>
<th>FIM (total/126)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79</td>
<td>M</td>
<td>7</td>
<td>Hemianopia</td>
<td>Infarct</td>
<td>O,Th</td>
<td>35</td>
<td>20</td>
<td>74</td>
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<tr>
<td>2</td>
<td>73</td>
<td>F</td>
<td>5</td>
<td>No</td>
<td>Infarct</td>
<td>P,CR-CN</td>
<td>120</td>
<td>74</td>
<td>87</td>
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<tr>
<td>3</td>
<td>65</td>
<td>M</td>
<td>6</td>
<td>Hemianopia</td>
<td>Hem</td>
<td>P,Cr,BG</td>
<td>111</td>
<td>44</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
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<td>M</td>
<td>5</td>
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<td>Put</td>
<td>70</td>
<td>51</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>56</td>
<td>F</td>
<td>5</td>
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<td>Infarct</td>
<td>F</td>
<td>131</td>
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<td>115</td>
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<tr>
<td>6</td>
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<td>Hem</td>
<td>Th</td>
<td>99</td>
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</tr>
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<td>79</td>
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<td>4</td>
<td>No</td>
<td>Infarct</td>
<td>IC-CR</td>
<td>138</td>
<td>75</td>
<td>84</td>
</tr>
<tr>
<td>8</td>
<td>70</td>
<td>F</td>
<td>5</td>
<td>No</td>
<td>Infarct</td>
<td>Put-CR</td>
<td>128</td>
<td>81</td>
<td>103</td>
</tr>
<tr>
<td>9</td>
<td>73</td>
<td>F</td>
<td>10</td>
<td>Hemianopia</td>
<td>Infarct</td>
<td>BG,Pu,th</td>
<td>40</td>
<td>6</td>
<td>72</td>
</tr>
<tr>
<td>10</td>
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<td>M</td>
<td>6</td>
<td>Hemianopia</td>
<td>Hem</td>
<td>Put</td>
<td>107</td>
<td>58</td>
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</tr>
<tr>
<td>11</td>
<td>64</td>
<td>F</td>
<td>17</td>
<td>Hemianopia</td>
<td>Infarct</td>
<td>T,P</td>
<td>132</td>
<td>59</td>
<td>120</td>
</tr>
</tbody>
</table>

T = temporal lobe; P = parietal lobe; O = occipital lobe; F = frontal lobe; BG = basal ganglia; Th = thalamus; Put = putamen; CR = corona radiata; IC = internal capsule; CN = caudate nucleus; BIT = Behavioural Inattention Test; FIM = Functional Independence Measure.
ADL, vocational, perceptual and functional activity training using the constructional task of copy-drawing and an attentional task.

- Session B: neck-muscle vibration was applied immediately before OT, and then the same OT programme as in sessions A1 and A2 was performed. Neck-muscle vibration was delivered for 5 min/day on the left posterior neck muscles while the individuals were sitting with their eyes closed in a normally lit room. During stimulation, the patients did not perform any specific activities. A handheld vibrator (Thrive MD-01: Thrive Co., Osaka Japan) was positioned on the left upper posterior neck muscles (about 6–8 cm lateral to the cervical spine: upper sternocleidomastoid muscle, and splenius muscle) (Figure 2). In contrast to the previous method [10–13], we did not confirm the appearance of a kinaesthetic illusion. The tip of the vibrator was 5 cm in diameter, and it oscillated at 91 Hz with an amplitude of 1.0 mm. This vibrator was selected because its frequency (80–100 Hz) was nearly the same as that in previous methods [10–13], and it was readily available because it had been used for physiotherapy at the study site.

All of the subjects received comprehensive rehabilitation including OT and physiotherapy throughout the 6-week study period. In addition to OT, physiotherapy, including passive range-of-motion exercise, mat exercise, standing up and sitting down, and ambulation with assistive devices or support, was performed for 40 min once a day for 5 days a week.

### Evaluation of USN and ADL

USN was evaluated quantitatively using the BIT, which consists of 15 subtests (conventional test: 6 subtests, 146 points total; behavioural test: 9 subtests, 81 points total) and indicates spatial cognitive function as a cumulative score [20]. Severity (mild to severe) in the BIT was classified as follows: mild attentional impairment, below the cut-off point in two or fewer subtests; moderate attentional impairment, below the cut-off point in three or four tests; severe attentional impairment, below the cut-off point in five or six tests [21]. ADL was evaluated with the Functional Independence Measure (FIM, 18–126 points) which consists of 18 items rated on a 7-level ordinal scale [22]. The BIT and FIM were assessed four times, every 2 weeks, during the 6-week study period (Figure 1). The BIT was evaluated strictly by occupational therapists who provided the OT (not blinded). The FIM was evaluated in a blinded manner by nurses, physical therapists and physicians during the study.
Statistics

To determine (1) whether changes in the BIT and FIM occurred during each of the 2-week sessions A1, B and A2, and (2) whether the changes during 2-week session B were greater than those in sessions A1 and A2, the data were analysed using Friedman’s test and the Wilcoxon signed-rank test with the Bonferroni correction for post hoc comparisons, since the data had a wide and discontinuous distribution. A conservative level of significance with a value of 0.05/n was chosen by the Bonferroni correction, where n was the number of comparisons that were made in all the measurements [i.e. the level of significance was set at \( p = 0.008 \) (0.05/6)].

Results

BIT

Table II summarises the changes in mean scores for the BIT during each of the three sessions. The subjects did not show an increase in conventional test scores in the BIT during sessions A1 and A2, however they did show a statistically significant increase during session B (from 67 to 67; \( p = 0.003 \)). After session A2, the subjects showed a slight decrease in the average score from 67 to 62. In subtests of the behavioural test, the increases in ‘map navigation’, ‘telling and setting the time’ and ‘picture scanning’ during session B were statistically significant (all \( p = 0.004 \)).

The number of subtests in the BIT for which the score was below the cut-off, where a larger number indicates more severe USN, decreased only during session B. Improvements in the severity of USN during session B were as follows: severe to moderate (4 cases), moderate to mild (4 cases), moderate to normal (1 case) and no change (1 severe and 1 moderate). Statistically significant decreases relative to pre-treatment (0 week) were observed after session B and session A2 (both \( p = 0.007 \)).

FIM

Table II summarises the changes in the mean scores for the FIM during each of the three sessions. The improvements in the FIM total score during sessions A1 and B were statistically significant (\( p = 0.003 \) and \( p = 0.005 \), respectively). Statistically significant improvements in the FIM between pre-treatment (0 weeks) and post-treatment were observed after sessions A1, B and A2 (all \( p = 0.003 \)). With regard to changes in the FIM subscores during session B, only self-care improved significantly (\( p = 0.005 \)). Subscores for self-care, sphincter, transfer and locomotion showed significant increases (all

<table>
<thead>
<tr>
<th>Table II. Summary of changes in scores for the Behavioural Inattention Test (BIT) and the Functional Independence Measure (FIM) during the 6-week study period.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIT</strong></td>
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<tr>
<td><strong>FIM</strong></td>
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<tr>
<td>Conventional test</td>
</tr>
<tr>
<td>Behavioural test</td>
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<tr>
<td>Severity of USN</td>
</tr>
<tr>
<td><strong>FIM</strong></td>
</tr>
<tr>
<td>Self-Care</td>
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<tr>
<td>Sphincter</td>
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<tr>
<td>Transfer</td>
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<tr>
<td>Locomotion</td>
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<tr>
<td>Cognition</td>
</tr>
<tr>
<td>Total score</td>
</tr>
</tbody>
</table>

Values are mean ± SD. The severity of unilateral spatial neglect (USN) is indicated by the number of subtests of the BIT with scores below the cut-off point.

*Indicates statistically significant changes (\( p < 0.008 \)) during the 2-week session.
†Indicates statistically significant changes compared with the pre-treatment evaluation (0 weeks) (\( p < 0.008 \)).
Furthermore, the improvements in session B only seen during session B, and not during session A2. We followed-up 2 subjects (Patients 5 and 8) who achieved full marks in the BIT at discharge (about 6 months from onset) for 2 months after discharge. The FIM scores from discharge to 2 months after discharge were as follows; Patient 5, from 120 to 121; Patient 8, from 117 to 119. These patients were independent after discharge.

Discussion

In the current study of patients with USN in the post-acute phase after stroke, statistically significant improvements in both the BIT-conventional test and the BIT-behavioural test were observed only during session B, and the FIM scores significantly improved during both session A1 and session B. Thus, simple neck-muscle vibration for 5 min before OT may enhance the improvement in the BIT and ADL for patients with USN.

Effects of 5 min of neck-muscle vibration before OT on unilateral spatial neglect

The mean duration after onset in the current study was 7.5 weeks (range 4–17 weeks). The possibility of natural recovery should be considered because it has been reported that a 90% improvement in USN was seen at 20 weeks from onset [23]. However, significant improvements in the BIT scores were only seen during session B, and not during session A1. Furthermore, the improvements in session B might be considered to be a carryover effect from the preceding session A1. However, it is reasonable to expect that neck-muscle vibration before OT may lead to greater neurological improvement, since the duration after stroke onset is inversely related to neurological recovery [23]. The greater improvements in the BIT following session B suggest that the reduction in the symptoms of neglect may have been promoted by neck-muscle vibration before OT.

The activity of the posterior insula is increased by neck-muscle vibration, and the posterior insula contributes to improved spatial perception [24]. Neck-muscle vibration for 5 min may also primarily influence the egocentric representation of space, since, among the subtests of the BIT, significant improvements were mainly observed in visual scanning ability, such as in the cancellation test, telling and setting time test and picture scanning test, which are related to egocentric space, but not in a test of constructional ability such as a copying task.

Mechanism by which neck-muscle vibration improves unilateral spatial neglect

The mechanisms by which neck-muscle vibration reduces the symptoms of neglect might be related to specific anatomical features and functions. Neck muscles have a very high spindle index compared to muscles of the limbs and contain many types of fibres, which transmit positional information regarding posture [25, 26]. Information regarding somatic sensation from the neck is integrated with eye movements for gazing at an object and postural reaction by visual information [27]. The discharge of muscle spindles in neck muscles induced by vibration may influence the direction of attention. If this influence is strong enough, neck-muscle vibration might induce a kinesthetic illusion. Percutaneous vibration also activates spindles and other receptors since muscle spindle primary endings (Ia fibers) are most sensitive to mechanical vibration [28]. Mane et al. proposed that somatosensory areas including the insula and temporoparietal junction contribute to the egocentric representation of space [29]. If the insula participates in the synthetic integration of information about the external world and the body, it is reasonable to speculate that neck-muscle vibration could influence the directions of both attention and visual scanning.

Effects of 5 min of neck-muscle vibration before OT on the BIT and ADL

Few previous studies have examined the effects of intervention for USN on ADL [30]. The BIT is the principal outcome measure for USN and is widely used. In the present study, the BIT was chosen because it was the first standardised test for USN and uses conditions that are closely related to ADL [20]. However, few studies have used the BIT to evaluate USN after intervention [30]. Wiart et al. [8] reported that the Bon Saint Come method seems to significantly improve recent and chronic USN, as well as the FIM score. In this method, however, patients with USN have to train for 1 h/day while standing. This may be especially difficult for patients with severe USN, since such patients tend to have little ability to maintain a standing position due to the disturbance of attention, poor durability and severe hemiplegia. While right half-field eye-patching [16] has been shown to improve the BIT score, there was no significant difference in improvement in FIM scores between patients in the control and experimental groups.

In the present study, improvements in ADL were observed after all of the sessions, but only the changes in sessions A1 and B were statistically significant. The exact influence of neck-muscle vibration on ADL is unknown due to the present study design. Further, it
may be difficult to determine the long-term effect of 5 min of neck-muscle vibration before OT since neither improvement nor continuation of an effect was observed in the BIT-behavioural test in session A2.

**Limitations**

This study may be limited by a rater bias because many assessors were involved in evaluating the FIM and BIT. Further, a blind evaluation was not performed in the BIT due to the limited number of staff. However, the measurements were thought to be reliable because (1) the parameter used in this study could be measured objectively; (2) all evaluations were discussed in advance to minimise intra-evaluator discrepancy and conducted following the description in the assessment manual and (3) the evaluator/patient pairs were not changed throughout the study.

Some improvements in the performance of the BIT might be due to testing effects, i.e. test-enhanced learning, since four evaluations were performed every 2 weeks during the 6-week study period. To minimise these effects, a more stringent \( p \) value by the Bonferroni correction was adopted in the present study.

In the present study, instead of a randomised control design, a multiple-baseline design (A1–B–A2) was used because there were not enough patients to exclude heterogeneity between study groups. Further research is needed to confirm the effectiveness of 5 min of neck-muscle vibration on neglect symptoms and ADL using a study design that compares the results to those in control groups that do not receive the intervention of neck-muscle vibration.

**Conclusions**

In the current A1–B–A2 design study for patients with USN in the subacute phase after stroke, significant improvements in both the BIT-conventional test and the BIT-behavioural test were only seen in session B, which involved 5 min of neck-muscle vibration immediately before OT, but not in sessions A1 and A2, which involved conventional OT without neck-muscle vibration. ADL significantly improved in sessions A1 and B, but not in session A2. Thus, the application of neck-muscle vibration before OT may have a positive effect on USN, but the specific effect on the improvement of ADL is not clear.

**Declaration of interest**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

**References**


