Immediate effect of adding mirror visual feedback to lateral weight-shifting training on the standing balance control of the unilateral spatial neglect model

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Abstract. [Purpose] This study aimed to clarify the immediate effect of adding mirror visual feedback to lateral weight-shifting training on the standing balance control of the left unilateral spatial neglect model. [Participants and Methods] We included 64 healthy participants to create left unilateral spatial neglect models and divided them into four subgroups. Each subgroup received opposite lateral weight-shifting training with or without mirror visual feedback. We then evaluated the static and dynamic standing balance by measuring the center of pressure point alterations in the medial-lateral and anterior-posterior planes. We further evaluated the center of pressure length and bilateral load ratio. [Results] The center of pressure was significantly stable upon performing the eyes-open static standing balance test in the left weight-shifting training subgroup with mirror visual feedback. When participants performed the left dynamic standing balance test, the center of pressure moved significantly rightward and became significantly stable in the right weight-shifting training subgroup with mirror visual feedback. The left load ratio significantly decreased in the right weight-shifting training of subgroups that either did or did not receive mirror visual feedback upon performing the left dynamic standing balance test. [Conclusion] We concluded that adding mirror visual feedback to lateral weight-shifting training affected some measurements of standing balance control of the left unilateral spatial neglect model.

Key words: Mirror visual feedback, Weight-shifting training, Unilateral spatial neglect

INTRODUCTION

Unilateral spatial neglect (USN) is a common disabling condition following right brain damage, is typically characterized by a failure to respond to stimuli and realize on the contralateral side and unable to use extremities opposite the lesion1–3). This neglect condition caused impaired mobility, decreased long-term functional outcomes, limited ability to complete daily activities, and restricted social participation4, 5). Various training modalities and therapeutic interventions have been devel-
Several studies indicated that mirror visual feedback (MVF) on neglect conditions has a positive and negative effect. Visual feedback training can improve the postural balance control problems in an upright position and affect visual perception in hemiparesis chronic stroke patients. Furthermore, mirror therapy (MT) that increased cognitive function then significantly affected motor function, balance capacity, walking velocity, daily living activities, and pain. MT is a simple treatment that improves USN and may positively affect visuospatial neglect. In contrast, the MVF indicated a reverse effect of postural control and behavioral response in severe neglect and confuses some patients, especially in recognizing mirror image in mirror agnosia case. Hence, the continuity effect of the MVF was temporal and further investigation for alleviating neglect is needed.

Moreover, weight-shifting training (WST) was often used clinically to improve balance function in stroke patients. A compelled body weight-shift approach could result in a long-lasting improvement of weight-bearing symmetry in individuals with acute and chronic stroke. However, several studies elucidated that the training was not affected weight distribution. Additionally, there is a strong association between postural disorders and spatial neglect in stroke patients. Therefore, we propose combining the MVF and WST approaches to improve postural balance ability in USN patients.

On the other hand, head-mounted display (HMD) device modifications and adjustments were introduced as an instrument for clinical evaluation and can be a potential treatment strategy for USN patients. In addition, healthy participants have been involved in determining the physiological effects of the training developed. Moreover, an increase of postural sway during the eye-opened quiet upright standing task was affected by wearing the HMD for virtual reality (VR). HMD modification as the USN model use procedure was explored in healthy participants. The prism glass, which was substituted by a web camera and HMD modification in healthy participants, can project a more appropriate visual orientation direction and optically shift more to the right emulated the left USN patients. Its use modulated the postural balance control change due to deviations of the web camera’s visual direction that resembled an actual USN situation. Thus, the present study applied HMD modification with a tilted web camera on healthy participants as the USN model.

In order to understand physiological mechanisms of the affected standing balance control when performing the adding of MVF to lateral WST in low clinical risk, we preliminarily investigate the immediate effect of that combined training on the postural balance control changes on the USN model through examining the static standing balance (SSB) and dynamic standing balance (DSB) tests. Accordingly, the present study aimed to clarify the immediate effect of adding MVF training to lateral WST on the standing balance control of the left USN model. We analyzed postural balance responses set on the SSB and DSB tests of the left USN model by measuring the center of pressure (COP) alterations displayed on the monitor in an upright standing position after the WST to the left (L) or right (R) with MVF and without MVF. We hypothesized that this combined training affects COP alterations, stabilizes postural stability, and may affect postural orientation in the standing balance control of the left USN model.

PARTICIPANTS AND METHODS

Sixty-four healthy participants were involved in this study (26 females and 38 males; mean age, 27.9 ± 4.9 years; weight, 59.9 ± 7.9 kg; height, 166.1 ± 6.3 cm). All participants gave written informed consent and provided sufficient explanation before the intervention. The study conforms to the Declaration of Helsinki and obtains approval from the Tokyo Metropolitan University ethical committee (No. 19075). We conducted a non-clinical quasi-experimental design with single-blind allocation concealment. Participants were randomly allocated into two MVF treatment groups and two treatment groups without MVF as control groups consisting of 16 people in each subgroup. The first treatment and control subgroups received the WST to the left with MVF (L-MVF) and without MVF (L-Non-MVF). The second treatment and control subgroups received the WST to the right with MVF (R-MVF) and without MVF (R-Non-MVF). All participants were confirmed without neurological dysfunctions and musculoskeletal disorders history, especially in visual ability, spinal posture, and lower extremities.

During the pre-test, training task, and post-test, all participants wearing the USN model of HMD (Virtual reality headset for mobile phone with 3D glasses) and smartphone (Galaxy S6 edge, SCV31, Samsung Electronics Japan Co., Ltd) with a web camera (SVPro VR 3D camera) mounted on the head and covered the eyes. This USN model procedure is adopted and the same as the previous study protocol. The USN model used a modification of visual direction web camera on HMD of 10 degrees to the right to resemble a mild USN situation (Fig. 1). All participants were not informed about that direction modification in this experiment. A COP platform (SR Vision by Sumitomo Riko Co. Ltd, Nagoya, Japan) was used to quantify variables of the COP point alterations in the medial-lateral (ML) and anterior-posterior (AP) plane, COP-length, and bilateral body load ratio in the SSB and DSB to the left (L) and right (R). These variables indicated postural sway adaptation, postural stability, and postural orientation. During the lateral WST task with MVF, a full standing mirror (210 cm high, 110 cm wide) is positioned in front of the participant at a distance of 150 cm with the symmetrical vertical line attached to the center mirror (Fig. 2). During the task without MVF, the mirror was covered by a black cloth in full.

Two physical therapists administered these trials in a quiet laboratory environmental situation. The experiment begins by assessing COP variables in pre-test before the training. In the first SSB test, participants were asked to stand upright with
both arms folded across the front of the chest and both feet resting on top of the COP platform with eyes opened (EO) and eyes closed (EC) alternately for 30 seconds each. Then, in the DSB test, participants were requested to sway their posture in the ML plane (leftward and rightward) as possible by keeping an idle position perpendicular and stable alternately for 30 seconds each. All SSB and DSB measurements were then performed in the post-test in the same order as the pre-test (Fig. 2).

In the first two treatment subgroups (L-MVF and R-MVF), the MVF training was performed through WST to the left or to the right of 50 times repetition following a metronome rhythm of 60 bpm in front of an adult-sized mirror set. Participants were asked to stand upright with a sight facing the mirror while observing the body’s movements reflected and focusing...
on the symmetrical vertical line attached to the mirror’s center. In the second two control subgroups (L-Non-MVF and R-Non-MVF), participants were asked to stand upright in front of the covered mirror. The same WST was performed without MVF, reflecting the body’s movements when participants try to swing laterally with the same number of repetitions. Two physical therapists as observers guided participants during the trial to ensure that motor tasks were executed correctly and synchronously.

The COP-ML, COP-AP, and COP-length in the SSB and DSB tests were collected in centimeters. The bilateral body-load ratio was obtained in percentage (%). The COP data were composed using Microsoft Excel software after file format conversion from SR Vision platform original software. Pre-and post-test results are shown in Mean ± SD. Difference (Diff) results between pre-and post-test showed in Mean ± SEM. Changing ratio (CR) results showed in percentage (%). Paired sample t-test and Wilcoxon signed ranks test were performed after the data normality test of Shapiro-Wilk test to calculate comparison between pre-and post-test data within-participant effects in each subgroup. The statistical power of the corrected effect size of Cohen’s d was estimated for within-participants of each subgroup and calculated with Hedges’s g formula. Statistical software (IBM Corp.; SPSS V. 26, Armonk, NY, USA) was used, and the significance level was set at p<0.05.

RESULTS

Participant demographics of each subgroup are shown in Table 1. All participants completed trials and no participant reported fatigue after the training.

The COP-ML, COP-AP, COP-length, and left load ratio results of the MVF and non-MVF subgroup of the SSB and DSB tests in two different WST directions were presented in Tables 2 and 3. CR negative and positive values in the COP-ML indicated that COP point moves further leftward and rightward direction in the frontal plane. CR negative and positive values in the COP-AP indicated that COP point moves further backward and forward direction in the sagittal plane. CR negative and positive values in the COP-length indicated that postural stability is becoming more stable and unstable. The left load ratio’s negative and positive values indicated that postural orientation inclined rightward and leftward. The bodyweight ratio to the left and right side of the body is assumed to be opposite and vice versa, so that data displayed on the table is only the left load ratio.

Based on the results, the COP-length became significantly stable (−13.35%) in the L-MVF subgroup on performing the EO-SSB test (p<0.05) with an effect size between small to medium (Table 2). When participants were performing the DSB-L test, the COP-ML moved significantly rightward (4.01%) in the R-MVF subgroup (p<0.05), the COP-length became significantly stable (−13.64%) in the R-MVF subgroup (p<0.05), and the left load ratio significantly decrease (−1.68% and −2.17%) in the R-MVF and R-Non-MVF subgroups (p<0.05) with an effect size between small to medium, respectively (Table 3).

DISCUSSION

The present study explored the immediate effect of adding the MVF to lateral WST on the standing balance control of the USN model by comparing the training with MVF and without MVF on each different lateral WST direction. This preliminary investigation is the first study to test an exercise performed in healthy participants conditioned as the USN model. We used the COP monitor to evaluate the standing balance control indicated by the COP-ML, COP-AP, COP-length and left load ratio. A previous study revealed changes in the postural balance control after participants used the USN model. Clinically, the left USN occurs more frequently than the right USN, so that the left USN model was chosen in the present study. Moreover, this left USN model situation may differ from the pathophysiological conditions in actual USN patients. However, the USN models’ postural response to a designed training may explain at least characteristics and physiological effect mechanisms analogous to the USN patients as an initial consideration in a rehabilitation program with minimal risk.

Mirror training has been implemented clinically for hemiparesis patients. The mirror was placed vertically in front of the participant in the sideway position to observe upper or lower limb respond to imitate the opposite non-affected limb move.
| Subgroup          | WST to the left | WST to the right |
|-------------------|-----------------|------------------|
|                   | With MVF        | Without MVF      | With MVF        | Without MVF      |
|                   | (Treatment group 1) | (Control group 1) | (Treatment group 2) | (Control group 2) |
| EO–SSB            |                 |                  |                 |                  |
| COP–ML            |                 |                  |                 |                  |
| Pre               | 15.87 ± 1.30    | 16.12 ± 0.60     | 15.97 ± 0.67    | 15.88 ± 0.88     |
| Post              | 15.74 ± 0.80    | 15.84 ± 0.74     | 16.06 ± 0.59    | 15.84 ± 0.66     |
| Diff              | −0.13 ± 0.36    | −0.28 ± 0.24     | 0.09 ± 0.13     | −0.04 ± 0.13     |
| CR                | −0.83%          | −1.71%           | 0.59%           | −0.28%           |
| Hedges’ g         | 0.117           | 0.405            | −0.138          | 0.050            |
| COP–AP            |                 |                  |                 |                  |
| Pre               | 16.92 ± 1.66    | 16.53 ± 1.31     | 17.31 ± 1.56    | 17.34 ± 1.85     |
| Post              | 16.68 ± 1.64    | 16.75 ± 1.33     | 17.40 ± 1.77    | 17.31 ± 2.04     |
| Diff              | −0.24 ± 0.17    | 0.22 ± 0.18      | 0.09 ± 0.19     | −0.03 ± 0.14     |
| CR                | −1.44%          | 1.32%            | 0.51%           | −0.18%           |
| Hedges’ g         | 0.141           | −0.162           | 0.053           | 0.015            |
| COP Length        |                 |                  |                 |                  |
| Pre               | 17.14 ± 5.43    | 14.09 ± 2.63     | 14.58 ± 3.21    | 14.69 ± 4.89     |
| Post              | 14.85 ± 6.79    | 13.61 ± 2.67     | 14.38 ± 2.97    | 15.78 ± 4.82     |
| Diff              | −2.29 ± 1.32*   | −0.48 ± 0.36     | −0.21 ± 0.65    | 1.08 ± 0.96      |
| CR                | −13.35%         | −3.41%           | −1.41%          | 7.36%            |
| Hedges’ g         | 0.363           | 0.176            | 0.063           | −0.218           |
| Left load ratio   |                 |                  |                 |                  |
| (%)               |                 |                  |                 |                  |
| Pre               | 49.69 ± 6.89    | 49.50 ± 2.41     | 50.46 ± 3.26    | 51.08 ± 3.60     |
| Post              | 50.97 ± 4.40    | 50.69 ± 3.54     | 49.68 ± 2.92    | 50.86 ± 2.90     |
| Diff              | 1.28 ± 1.72     | 1.19 ± 1.08      | −0.78 ± 0.55    | −0.22 ± 0.56     |
| CR                | 2.57%           | 2.40%            | −1.55%          | −0.43%           |
| Hedges’ g         | −0.215          | −0.383           | 0.245           | 0.065            |
| EC–SSB            |                 |                  |                 |                  |
| COP–ML            |                 |                  |                 |                  |
| Pre               | 15.81 ± 0.52    | 15.93 ± 0.59     | 16.14 ± 0.61    | 16.10 ± 0.80     |
| Post              | 15.66 ± 0.79    | 15.91 ± 0.69     | 15.93 ± 0.67    | 15.86 ± 0.70     |
| Diff              | −0.14 ± 0.12    | −0.03 ± 0.16     | −0.21 ± 0.17    | −0.24 ± 0.16     |
| CR                | −0.91%          | −0.16%           | −1.32%          | −1.48%           |
| Hedges’ g         | 0.218           | 0.030            | 0.319           | 0.311            |
| COP–AP            |                 |                  |                 |                  |
| Pre               | 16.96 ± 1.51    | 16.89 ± 1.15     | 17.69 ± 1.48    | 17.81 ± 1.76     |
| Post              | 16.94 ± 1.64    | 17.11 ± 1.40     | 17.63 ± 1.79    | 17.53 ± 1.97     |
| Diff              | −0.28 ± 0.22    | −0.14 ± 0.19     | −0.29 ± 0.25    | −0.51 ± 0.24     |
| CR                | −0.07%          | 1.26%            | −0.39%          | −1.58%           |
| Hedges’ g         | 0.012           | −0.167           | 0.035           | 0.146            |
| COP Length        |                 |                  |                 |                  |
| Pre               | 13.03 ± 3.26    | 13.23 ± 3.87     | 12.80 ± 3.17    | 15.13 ± 5.12     |
| Post              | 13.92 ± 6.12    | 13.13 ± 4.58     | 14.01 ± 2.93    | 14.54 ± 5.88     |
| Diff              | 0.89 ± 1.01     | −0.11 ± 1.41     | 1.21 ± 0.74     | −0.59 ± 0.83     |
| CR                | 6.86%           | −0.80%           | 9.42%           | −3.88%           |
| Hedges’ g         | −0.176          | 0.022            | −0.386          | 0.104            |
| Left load ratio   |                 |                  |                 |                  |
| (%)               |                 |                  |                 |                  |
| Pre               | 50.78 ± 2.91    | 50.47 ± 2.47     | 49.71 ± 2.12    | 50.40 ± 3.31     |
| Post              | 51.58 ± 4.62    | 50.42 ± 3.42     | 50.39 ± 3.58    | 50.76 ± 3.21     |
| Diff              | 0.80 ± 0.69     | −0.05 ± 0.85     | 0.67 ± 0.97     | 0.36 ± 0.57      |
| CR                | 1.58%           | −0.10%           | 1.36%           | 0.71%            |
| Hedges’ g         | −0.201          | 0.016            | −0.225          | −0.107           |

WST: Weight shifting training; MVF: Mirror visual feedback; L: Left; R: Right; Static standing balance (SSB); Eyes opened (EO); Eyes closed (EC); COP: Center of pressure; ML: Medial–Lateral; AP: Anterior–Posterior; Diff: Difference; CR: Changing ratio. The Pre and Post values are presented as mean ± standard deviation (cm). Diff values are presented as mean ± standard error of the mean. *p<0.05 (indicates a significant difference between Pre and Post).
### Table 3. Pre-test, post-test, and difference test comparison between MVF and non-MVF subgroup on the dynamic standing balance (DSB)

| Subgroup       | Variables | WST to the left | WST to the right |
|----------------|-----------|-----------------|------------------|
|                |           | With MVF (Treatment group 1) | Without MVF (Control group 1) | With MVF (Treatment group 2) | Without MVF (Control group 2) |
|                | L−MVF (n=16) | L−Non−MVF (n=16) | L−MVF (n=16) | L−Non−MVF (n=16) |
| FOR−R         | COP−ML Pre | 21.83 ± 1.03 | 21.75 ± 2.39 | 22.87 ± 1.48 | 22.73 ± 1.53 |
|               |           | 22.12 ± 1.23 | 21.85 ± 2.25 | 22.67 ± 1.90 | 22.63 ± 1.58 |
|               | Diff 0.29 ± 0.19 | 0.10 ± 0.21 | −0.20 ± 0.28 | −0.11 ± 0.20 |
|               | CR 1.32% | 0.43% | −0.93% | −0.49% |
|               | Hedges’ g | −0.249 | −0.041 | 0.144 | 0.062 |
|               | COP−AP Pre | 15.2 ± 1.83 | 16.86 ± 1.59 | 17.01 ± 1.56 | 16.96 ± 2.01 |
|               |           | 16.31 ± 1.25 | 16.40 ± 1.74 | 16.4 ± 1.67 | 16.83 ± 2.09 |
|               | Diff −0.20 ± 0.20 | −0.07 ± 0.20 | 0.14 ± 0.14 | −0.13 ± 0.17 |
|               | CR −1.28% | −0.33% | 0.92% | −0.81% |
|               | Hedges’ g | 0.102 | 0.035 | −0.09 | 0.061 |
|               | COP Length Pre | 29.08 ± 7.72 | 21.02 ± 7.17 | 25.04 ± 10.29 | 25.29 ± 10.88 |
|               |           | 21.52 ± 10.83 | 21.17 ± 8.66 | 24.24 ± 8.81 | 24.86 ± 12.15 |
|               | Diff 0.54 ± 1.07 | −0.14 ± 1.08 | −0.80 ± 1.26 | −0.43 ± 0.98 |
|               | CR 2.53% | 0.62% | −3.27% | −1.65% |
|               | Hedges’ g | −0.055 | −0.018 | 0.081 | 0.036 |
|               | Left load ratio Pre | 20.40 ± 3.61 | 21.60 ± 10.54 | 16.61 ± 5.64 | 18.03 ± 5.14 |
|               |           | 20.06 ± 3.79 | 21.53 ± 10.03 | 17.97 ± 6.90 | 17.95 ± 5.98 |
|               | Diff −0.34 ± 0.72 | −0.07 ± 0.91 | 1.37 ± 0.84 | −0.08 ± 0.90 |
|               | CR −0.62% | −0.40% | 8.15% | −0.42% |
|               | Hedges’ g | 0.089 | 0.006 | −0.210 | 0.013 |
| FOR−L         | COP−ML Pre | 9.71 ± 1.60 | 10.24 ± 2.47 | 9.02 ± 1.77 | 9.46 ± 1.81 |
|               |           | 9.84 ± 1.62 | 10.11 ± 2.31 | 9.38 ± 1.52 | 9.65 ± 1.95 |
|               | Diff 0.13 ± 0.28 | −0.13 ± 0.20 | 0.36 ± 0.15* | 0.19 ± 0.17 |
|               | CR 1.28% | −1.34% | 4.01% | 1.84% |
|               | Hedges’ g | −0.078 | 0.052 | −0.212 | −0.098 |
|               | COP−AP Pre | 16.96 ± 2.01 | 17.13 ± 1.73 | 17.80 ± 1.84 | 17.65 ± 1.85 |
|               |           | 17.05 ± 1.76 | 17.15 ± 1.77 | 17.78 ± 2.20 | 17.58 ± 1.97 |
|               | Diff 0.09 ± 0.21 | 0.02 ± 0.12 | −0.02 ± 0.21 | −0.06 ± 0.19 |
|               | CR 0.52% | 0.11% | −0.07% | −0.35% |
|               | Hedges’ g | −0.046 | −0.011 | 0.009 | 0.035 |
|               | COP Length Pre | 22.80 ± 7.48 | 21.55 ± 7.84 | 26.56 ± 9.70 | 25.39 ± 11.61 |
|               |           | 22.13 ± 7.45 | 20.59 ± 8.20 | 22.94 ± 7.51 | 23.65 ± 10.09 |
|               | Diff −0.66 ± 0.94 | −0.96 ± 0.83 | −3.61 ± 1.65* | −1.73 ± 1.21 |
|               | CR −2.88% | −4.46% | −13.64% | −6.81% |
|               | Hedges’ g | 0.087 | 0.116 | 0.406 | 0.155 |
|               | Left load ratio Pre | 80.06 ± 6.49 | 77.90 ± 10.73 | 83.89 ± 7.32 | 82.21 ± 6.76 |
|               |           | 79.82 ± 6.72 | 78.17 ± 9.93 | 82.49 ± 7.27 | 80.44 ± 7.79 |
|               | Diff −0.24 ± 1.08 | 0.27 ± 1.04 | −1.40 ± 0.55* | −1.78 ± 0.67* |
|               | CR −0.29% | 0.34% | −1.68% | −2.17% |
|               | Hedges’ g | 0.035 | −0.025 | 0.187 | 0.236 |

WST: Weight shifting training; MVF: Mirror visual feedback; L: Left; R: Right; Dynamic standing balance (DSB); COP: Center of pressure; ML: Medial–Lateral; AP: Anterior–Posterior; Diff: Difference; CR: Changing ratio. The Pre and Post values are presented as mean ± standard deviation (cm). Diff values are presented as mean ± standard error of the mean. *p<0.05 (indicates a significant difference between Pre and Post).
In that procedure, mirror neurons’ function in the brain works to improve neuroplasticity performance, hypothesized to restore the impaired brain’s function and effectively improve motor function and ADL on stroke survivor. In contrast, our study implemented the MVF on the front side to determine whether the participants could rely on their reflected body alignment in the whole-body mirror to maintain their upright postural control. We expected participants might fix their postural balance and shift their visual attention based on that experimental setting. The MVF can enhance the neurophysiological response and increase cognitive activation to be helpful in neuro-rehabilitation and stroke recovery. However, our results corroborate a review showing weak evidence and inconsistent studies that mirror training affects healthy individuals’ motor performance. These outcomes may be due to participants, unlike patients with neglect who do not use the same clues and cannot modify their procedures to recalibrate their spatial representations.

On the other hand, the WST has been investigated to improve balance performance and was often used to encourage the COP transferring stability in stroke patients. Visual feedback effects could be observed in patients presenting weight-bearing asymmetries. Furthermore, the visual feedback rhythmic WST may improve the dynamic balance function for hemiplegic stroke patients. The left USN condition leads COP point to move to the body’s right side. Accordingly, our results showed that COP-ML moved laterally following WST to the right once the MVF was added when performing the opposite DSB test.

The present study revealed that postural stability was modulated by adding MVF following participants on performing the WST to the left in the EO-SSB test and WST to the right in the DSB-L test. Our results confirm a previous study that indicated postural stability was affected by visual feedback when participants intend to control the movement. Moreover, our result showed that postural balance oriented laterally following the WST to the right with nor without MVF in the DSB-L test. In line with a previous study, these weight-bearing alterations indicated asymmetric loading on both legs modifies the postural control adjustment, and weight distribution on opposite feet supports undisturbed stance upright of healthy participants.

As we know, former studies reported that actual USN patients were confused with MVF. In comparison, the USN model condition with its HMD interferes and makes it difficult for the individual to process visual information that affected the postural balance. Accordingly, the significant difference between the MVF and non-MVF subgroup only showed in some variables. The potential benefits of our findings for the physical therapy clinical setting are that it was necessary to consider whether there is a cognitive load increase resulting from the exercise given that might affect training outcomes. Adding MVF to the lateral WST also requires a specific consideration before implementing it on the USN patients to improve balance control in a standing position. Admittedly, some studies reported that COP in the USN patients tends to rely more on the right leg’s non-paretic side. Our results indicated the decreased left load ratio in the DSB-L in the right WST group. We suggested that these results appear to be influenced by the predominance of left-leg stability on standing position in healthy right-handed participants. Hence, we concluded that the over-performing of the right WST on the USN patients seems counterproductive to produce the postural balance stability.

This preliminary study has several limitations. First, the small number of participants in each subgroup may affect the study findings. In theory, the other results of the measurement variables may be significantly different if the number of participants is increased. Second, although there were two control subgroups without adding MVF on lateral WST, we did not have the non-USN and right USN model participants as the other control groups. Thus, it requires further investigation whether participants using the same HMD with and without camera modification had a similar postural response in the trials. Third, since the setup is a USN model in healthy participants, it does not precisely match an actual clinical case accompanied by other neurological symptoms such as hemiparesis and cognitive decline, so that it needs to be careful in construing the outcomes. Hence, further studies are needed to observe the long-term adaptation effect when the training is implemented continuously by involving more participants and control groups with secondary measurements to complement the necessary interpretation in advanced analysis.

In conclusion, indeed, the MVF training is recognized to induce postural adjustment, and lateral WST increases proprioceptive stimulation of the lower extremity to stabilize the postural balance in healthy participants and hemiparesis patients. However, in the present study, the COP-AP did not alter in all subgroups. Our findings revealed that the left WST with MVF affects the postural stability in the EO-SSB test. The Right WST with MVF affects COP-ML, postural stability, and right WST with and without MVF altered left load ratio significantly in the DSB-L test. Our results seem to prove that adding MVF to both lateral WST can immediately affect the standing balance control of the left USN model in some postural balance measurements. The WST in a different lateral direction with MVF or without MVF generally maintains the COP points position, postural stability, postural orientation consistently in both SSB and DSB tests of the left USN model. As a clinical implication, we suggested further study involving actual patients by considering these specific postural responses before applied this combined training to actual hemiparesis and USN patients. Further studies are needed to explore the effects of multimodal treatment on the USN model before implementing it to an actual patient.
Conference presentation
Several parts of our study were presented at three conferences. Firstly, at the 23rd International Society of Electrophysiology and Kinesiology Congress 2020, Nagoya, Japan, abstract number R2-3. Secondly, at the 18th Japanese Society of Neurological Physical Therapy 2020, Kyoto, Japan, abstract number EW-1. Thirdly, at the 25th Japanese Society of Physical Therapy Fundamental Science 2020, Sendai, Japan, abstract number 2G28-03.

Conflict of interest
There are no conflicts of interest to declare.

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REFERENCES
1) Heilman KM, Valenstein E, Watson RT: Neglect and related disorders. Semin Neurol, 2000, 20: 463–470. [Medline] [CrossRef]
2) Kerkhoff G, Schenk T: Rehabilitation of neglect: an update. Neuropsychologia, 2012, 50: 1072–1079. [Medline] [CrossRef]
3) Ting DS, Pollock A, Dutton GN, et al.: Visual neglect following stroke: current concepts and future focus. Surv Ophthalmol, 2011, 56: 114–134. [Medline] [CrossRef]
4) Spacecavento S, Cellamare F, Falcone R, et al.: Effect of subtypes of neglect on functional outcome in stroke patients. Ann Phys Rehabil Med, 2017, 60: 376–381. [Medline] [CrossRef]
5) Conti RP, Arnone JM: Unilateral neglect: assessment and rehabilitation. Int J Neurosci Behav Sci, 2016, 4: 1–10. [CrossRef]
6) Lisa LP, Jughters A, Kerckhofs E: The effectiveness of different treatment modalities for the rehabilitation of unilateral neglect in stroke patients: a systematic review. NeuRehabilitation, 2013, 33: 611–620. [Medline] [CrossRef]
7) Median AC, Wagyuddin, Amimoto K: Rehabilitation interventions of unilateral spatial neglect based on the functional outcome measure: a systematic review and meta-analysis. Neuropsychyl Rehabil, 2020, 1–30. [Medline] [CrossRef]
8) Azouvi P, Jaccouin-Courtois S, Luauté J: Rehabilitation of unilateral neglect: evidence-based medicine. Ann Phys Rehabil Med, 2017, 60: 191–197. [Medline] [CrossRef]
9) Liu KP, Hanly J, Fahey P, et al.: A systematic review and meta-analysis of rehabilitative interventions for unilateral spatial neglect and hemianopia poststroke from 2006 through 2016. Arch Phys Med Rehabil, 2019, 100: 956–979. [Medline] [CrossRef]
10) Lee SW, Shin DC, Song CH: The effects of visual feedback training on sitting balance ability and visual perception of patients with chronic stroke. J Phys Ther Sci, 2013, 25: 635–639. [Medline] [CrossRef]
11) In TS, Cha YR, Jung JH, et al.: Effects of visual feedback with a mirror on balance ability in patients with stroke. J Phys Ther Sci, 2016, 28: 181–185. [Medline] [CrossRef]
12) Hwang SS, Lee JH, Choi YJ: The effects of visual feedback self exercise on postural control in stroke patients. J Korean Soc Phys Med, 2017, 12: 105–112. [Medline] [CrossRef]
13) Imaiizumi S, Asai T, Hiromitsu K, et al.: Voluntarily controlled but not merely observed visual feedback affects postural sway. PeerJ, 2018, 6: e4643. [Medline] [CrossRef]
14) Deconinck FJ, Smorenburg AR, Benham A, et al.: Reflections on mirror therapy: a systematic review of the effect of mirror visual feedback on the brain. Neurorehabil Neural Repair, 2015, 29: 349–361. [Medline] [CrossRef]
15) Broderick P, Horgan F, Blake G, et al.: Mirror therapy for improving lower limb motor function and mobility after stroke: a systematic review and meta-analysis. Gait Posture, 2018, 63: 208–220. [Medline] [CrossRef]
16) Louie DR, Lim SB, Eng JJ: The efficacy of lower extremity mirror therapy for improving balance, gait, and motor function poststroke: a systematic review and meta-analysis. J Stroke Cerebrovasc Dis, 2019, 28: 107–120. [Medline] [CrossRef]
17) Thieme H, Morkisch N, Mehrholz J, et al.: Mirror therapy for improving motor function after stroke. Cochrane Database Syst Rev, 2018, 7: CD008449. [Medline] [CrossRef]
18) Thieme H, Bayn M, Wurg M, et al.: Mirror therapy for patients with severe arm paresis after stroke—a randomized controlled trial. Clin Rehabil, 2013, 27: 314–324. [Medline] [CrossRef]
19) Pandian JD, Arora R, Kaur P, et al.: Mirror therapy in unilateral neglect after stroke (MUST trial): a randomized controlled trial. Neurology, 2014, 83: 1012–1017. [Medline] [CrossRef]
20) Beis JM, André JM, Barre A, et al.: Mirror images and unilateral spatial neglect. Neuropsychologia, 2001, 39: 1444–1450. [Medline] [CrossRef]
21) Ramachandran VS, Altschuler EL, Hillyer S: Mirror agnosia. Proc Biol Sci, 1997, 264: 645–647. [Medline] [CrossRef]
22) Daprati E, Siriga A, Pradat-Diehl P, et al.: Recognition of self-produced movement in a case of severe neglect. Neurocase, 2000, 6: 477–486. [CrossRef]
23) Chandra SR, Issac TG: Neurodegeneration and mirror image agnosia. N Am J Med Sci, 2014, 6: 472–477. [Medline] [CrossRef]
24) Ramachandran VS, Altschuler EL, Stone L, et al.: Can mirrors alleviate visual hemineglect? Med Hypotheses, 1999, 52: 303–305. [Medline] [CrossRef]
25) Watanabe S, Amimoto K: Mirror approach for the patients with unilateral spatial neglect and mirror agnosia. J Phys Ther Sci, 2007, 19: 73–76. [CrossRef]
26) Ramachandran VS, Altschuler EL: The use of visual feedback, in particular mirror visual feedback, in restoring brain function. Brain, 2009, 132: 1693–1710.
27) Mohapatra S, Eviota AC, Ringquist KL, et al.: Compelled body weight shift technique to facilitate rehabilitation of individuals with acute stroke. ISRN Rehabil, 2012, 2012: 1–7. [Medline] [CrossRef]
28) Aruin AS, Rao N, Sharma A, et al.: Compelled body weight shift approach in rehabilitation of individuals with chronic stroke. Top Stroke Rehabil, 2012, 19: 556–563. [Medline] [CrossRef]
29) Tsaklis PV, Grooten WJ, Fränzen E: Effects of weight-shift training on balance control and weight distribution in chronic stroke: a pilot study. Top Stroke Rehabil, 2012, 19: 23–31. [Medline] [CrossRef]
30) Jung K, Kim Y, Chung Y, et al.: Weight-shift training improves trunk control, proprioception, and balance in patients with chronic hemiparetic stroke. Tohoku J Exp Med, 2014, 232: 195–199. [Medline] [CrossRef]
31) Andersson P, Fränzen E: Effects of weight-shift training on walking ability, ambulation, and weight distribution in individuals with chronic stroke: a pilot study. Top Stroke Rehabil, 2015, 22: 437–443. [Medline] [CrossRef]
32) Liao WC, Lai CL, Hsu FS, et al.: Different weight shift trainings can improve the balance performance of patients with a chronic stroke: a randomized controlled trial. Medicine (Baltimore), 2018, 97: e13207. [Medline] [CrossRef]
33) Pérennou D: Postural disorders and spatial neglect in stroke patients: a strong association. Restor Neurol Neurosci, 2006, 24: 319–334. [Medline] [CrossRef]
34) Tanaka T, Sugihara S, Nara H, et al.: A preliminary study of clinical assessment of left unilateral spatial neglect using a head mounted display system (HMD) in rehabilitation engineering technology. J Neuroeng Rehabil, 2005, 2: 31. [Medline] [CrossRef]
35) Tanaka T, Ifukube T, Sugihara S, et al.: A case study of new assessment and training of unilateral spatial neglect in stroke patients: effect of visual image transformation and visual stimulation by using a Head Mounted Display system (HMD). J Neuroeng Rehabil, 2010, 7: 20. [Medline] [CrossRef]
36) Kim JH, Lee BH, Go SM, et al.: Improvement of hemispatial neglect by a see-through head-mounted display: a preliminary study. J Neuroeng Rehabil. J Neuroeng Rehabil, 2015, 12: 1–6. [CrossRef]
37) Lee HM, Li PC, Fan SC: Delayed mirror visual feedback presented using a novel mirror therapy system enhances cortical activation in healthy adults. J Neurol Physiol Clin, 2017, 47: 305–314. [Medline] [CrossRef]
38) Rougier PR, Boudrahem S: Interaction between postural asymmetry and visual feedback effects in undisturbed upright stance control in healthy adults. Neuropsychophy Clin, 2011, 47: 305–314. [Medline] [CrossRef]
39) Chen Y, Wang P, Bai Y, et al.: Effects of mirror training on motor performance in healthy individuals: a systematic review and meta-analysis. BMJ Open Sport Exerc Med, 2015, 9: e000590. [Medline] [CrossRef]
40) Horlings CG, Carpenter MG, Kühn UM, et al.: Influence of virtual reality on postural stability during movements of quiet stance. Neurosci Lett, 2009, 451: 227–231. [Medline] [CrossRef]
41) Imai Y, Polastri PF, Penedo T, et al.: Virtual reality head-mounted goggles increase the body sway of young adults during standing posture. Neurosci Lett, 2020, 737: 13533. [Medline] [CrossRef]
42) Robert MT, Ballaz L, Lemay M: The effect of viewing a virtual environment through a head-mounted display on balance. Gait Posture, 2016, 48: 261–266. [Medline] [CrossRef]
43) Numata T, Fujita Y, Ichikawa K, et al.: Leftward optical shift induces bias in line bisection: a study with healthy subjects using a head-mounted display. Prog Rehab Med, 2019, 4: 20190008. [Medline] [CrossRef]
44) Miedlan AC, Yige S, Amimoto K: The influence of using the head-mounted display with modified web camera as left unilateral spatial neglect model on static and dynamic standing balance in the healthy subjects. In: Proceedings of ISEK XXIII Virtual Congress. 2020, p 66–67, R2:3.
45) Ellis PD: Effect size calculators. 2009. https://www.polyu.edu.hk/mm/effectsizefaqs/calculator/calculator.html (Accessed Jun. 23, 2021).
46) Meidian AC, Yige S, Amimoto K: The influence of using the head-mounted display with modified web camera as left unilateral spatial neglect model on static and dynamic standing balance in the healthy subjects. In: Proceedings of ISEK XXIII Virtual Congress. 2020, p 66–67, R2:3.
47) Rothgangel AS, Braun SM, Beurskens AJ, et al.: The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature. Int J Rehabil Res, 2019, 42: 330–336. [Medline] [CrossRef]
48) Lee SA, Cha HG: The effect of motor imagery and mirror therapy on upper extremity function according to the level of cognition in stroke patients. Int J Rehabil Res, 2012, 35: 227–231. [Medline] [CrossRef]
49) Gandhi DB, Sterba A, Khatter H, et al.: Mirror therapy in stroke rehabilitation: current perspectives. Ther Clin Risk Manag, 2020, 16: 75–85. [Medline] [CrossRef]
50) Bartur G, Pratt H, Frenkel-Toledo S, et al.: Neuropsychological effects of mirror visual feedback in stroke patients with unilateral hemispheric damage. Brain Res, 2018, 1700: 170–180. [CrossRef]
51) Wang W, Zhang X, Ji X, et al.: Mirror neuron therapy for hemispatial neglect patients. Sci Rep, 2015, 5: 1–5. [CrossRef]
52) Nojima I, Mima T, Koganemaru S, et al.: Human motor plasticity induced by mirror visual feedback. J Neurosci, 2012, 32: 1293–1300. [Medline] [CrossRef]
53) Cheng PT, Wang CM, Chung CY, et al.: Effects of visual feedback rhythmic weight-shift training on hemiplegic stroke patients. Clin Rehabil, 2004, 18: 747–753. [Medline] [CrossRef]
54) Genthon N, Rougier P: Influence of an asymmetrical body weight distribution on the control of undisturbed upright stance. J Biomech, 2005, 38: 2037–2049. [Medline] [CrossRef]
55) Wang W, Zhang X, Ji X, et al.: Mirror neuron therapy for hemispatial neglect patients. Sci Rep, 2015, 5: 1–5. [CrossRef]