Prism adaptation improves postural imbalance in neglect patients

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Several studies have found a negative relation between neglect and postural imbalance. The aim of the current study was to investigate the influence of a single session of prism adaptation on balance [i.e. mediolateral and anteroposterior center of pressure (CoP)] and postural sway (i.e. mean variance of displacement in horizontal and vertical planes) in neglect patients. CoP and postural sway were measured in a single session while sitting unaided on a Wii Balance Board. With respect to mediolateral as well as anteroposterior CoP, there was an improvement in postural imbalance after prism adaptation when measurements were performed with the eyes open, but not with the eyes closed. With respect to postural sway, only horizontal sway was significantly reduced after prism adaptation, but no changes were found for vertical sway. Prism adaptation may produce the recalibration of disturbed representation of space as well as higher-level representations of extrapersonal and internal body space (i.e. internal body midline). Given the important role of postural control in daily life functioning in stroke patients, this study might open possibilities for a successful rehabilitation procedure to alleviate deficits in postural imbalance. *NeuroReport* 00:000–000 © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

One prominent deficit resulting from stroke is visuospatial neglect, commonly referred to as neglect. Neglect is characterized by a failure to orient toward, respond to, and report stimuli that occur in the contralesional side of space. It can result from a lesion to either hemisphere, but is more severe and enduring after right hemisphere damage [1]. In the (sub)acute phase, about 50% of stroke patients show neglect [2]. The time course of spontaneous neurological recovery of neglect shows a natural logistic curve up to the first 12–14 weeks poststroke, after which neglect severity becomes invariant [2]. Neglect has been associated with slower and more attenuated recovery patterns of sensory–motor impairment [3]. Several studies have found a negative relation between neglect and postural balance [4,5]. Although a uniform definition is lacking, balance has been described as the capacity to maintain, achieve, or restore a state of equilibrium during any posture or activity [6], and is one of the most important factors that determine independency in activities of daily living (ADLs). It is therefore an important factor within rehabilitation in the subacute phase after stroke.

In recent decades a number of rehabilitation procedures have been set up to ameliorate neglect symptoms. Prism adaptation [7], in which a visual scene is laterally displaced, appears a promising technique: noninvasive, easy to administer, and improving a wide range of neglect-related deficits, varying from improvement on neuropsychological neglect tests (e.g. object cancellation tests) to improvement on ADL assessment [e.g. functional independence as measured with the Barthel Index (BI) [8] and the Functional Independence Measure [9]] or wheel chair driving [10].

As a distorted balance can lead to significant problems in daily life functioning [11] and as neglect has been negatively associated with postural balance, a direct comparison between neglect, postural imbalance, and potential beneficial effects of prism adaptation is needed, especially in the subacute phase. Therefore, the aim of the current study was to investigate the influence of prism adaptation on balance and postural sway in neglect patients.

Methods

Participants

The criteria for admission in a rehabilitation center in the Netherlands are: (a) the patient cannot be discharged home, but is expected to return home in view of the prognosis and availability of the caregivers; (b) the patient is able to learn and is sufficiently motivated; (c) the patient has sufficient vitality; (d) the rehabilitation goals are complex and need a multidisciplinary approach; (e) return to work may be possible; and (f) a relatively high rate of rehabilitation is possible.

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Stroke patients consecutively admitted for inpatient rehabilitation to De Hoogstraat Rehabilitation (April–July 2012) were included when they met the following criteria: (a) a brain lesion as revealed by computed tomography or MRI; (b) presence of spatial neglect as assessed with a short screening including line bisection, object cancellation, and letter cancellation; (c) aged between 18 and 80 years; (d) able to understand and carry out the test instructions; and (e) written or verbal informed consent and sufficient motivation to participate. The exclusion criterion was inability to sit unaided.

All patients received multidisciplinary standard stroke care and treatment and their participation in the study did not interfere with daily routines. In addition, all patients received visual scan training, which was the current intervention used for rehabilitation of neglect in this rehabilitation center.

Procedure

Within the first 2 weeks of admission to 'De Hoogstraat' Rehabilitation Center, neuropsychological neglect screening took place as standard stroke care. Balance was also measured as part of this screening. Patients with neglect on the neuropsychological neglect screening were subsequently asked to participate in a study on feasibility of prism adaptation in the subacute phase [12]. Informed consent was obtained. The average time between the neglect screening and prism adaptation was 10 days. The study was approved by the Ethics Review Boards of the University Medical Center Utrecht.

Neglect screening

A neglect screening was administered to all patients. This screening included a shape cancellation test and a line bisection test.

The shape cancellation test consisted of a field of 54 target shapes ($0.6 \times 0.6^\circ$) among 75 distractor shapes of various sizes (with widths ranging from 0.95 to 2.1° and heights ranging from 0.45 to 0.95°). The stimulus presentation was $\sim 18.5^\circ$ wide and 11° high. Patients were instructed to find all the target shapes presented on the screen and click on them. A circle appeared on the screen around the location of each mouse click and remained on screen during the test. The difference in number of crossed targets on the contralesional and ipsilesional side was used to indicate neglect (i.e. an asymmetry of at least two omissions between contralesional and ipsilesional sides [2]).

The line bisection task consisted of three horizontal lines that were vertically evenly distributed, but were not aligned horizontally. The middle line was presented in the horizontal and vertical center of the screen, the top line was presented above the vertical center of the screen and shifted to the right, and the bottom line was presented below the vertical center of the screen and shifted to the left. The amount of vertical shift was always 28% of the line length and the amount of horizontal shift was always 15% of the line length in both near and far space. Lines were $\sim 22^\circ$ long and 0.2° thick. Patients were asked to indicate the center of each line by moving the cursor with the mouse and clicking on the subjective midpoint of each line, starting at the topmost line and working their way down. This task was performed four times in a row, resulting in a total of 12 lines. Patients with an average score outside the range of healthy controls (average + 3 SD = 0.553 cm left and right from the actual center) were categorized as having neglect.

Prism adaptation procedure

The prism adaptation procedure was adapted from Rossetti *et al.* [7] and was performed with a pair of goggles fitted with wide-field point-to-point prismatic lenses, inducing a rightward optical shift of 10°.

The distance between the visual stimuli and the body midline was ~ 65 cm. Patients were presented with three visual targets (red, yellow, blue) on a horizontal axis. The left and right visual targets were both 11.5 cm away from a central visual stimulus. Exposure consisted of 100 fast, repetitive pointing movements. In random order, half of the pointing movements were made to the left (red) visual target and the other half were made to the right (blue) visual target. When patients experienced difficulties in distinguishing between left and right, the color of the visual stimulus was used. Occasionally, patients were instructed to point to the central (yellow) visual stimulus, thereby preventing automatic pointing in a sequence of motor acts to either the left or the right target.

After the adaptation phase (i.e. repetitive pointing), prisms were withdrawn and the after-effect was measured. Conventionally, the strength of the adaptation can be obtained by measuring the spatial deviation from a target stimulus. Here, after prism removal, patients were instructed to look carefully at the central (yellow) visual stimulus. After a few seconds they were instructed to point to the target with eyes closed to prevent online adjustments and visual feedback. For after-effects, the mean error displacement from the central stimulus was calculated and should have been at least 3 cm, otherwise the prism adaptation procedure was continued.

Balance and postural sway

Balance and postural sway were measured in a single session. The patients were instructed to keep their hand loose in their lap while sitting unaided on a Wii Balance Board (WBB) placed on a stool. Two runs were performed: one with eyes open and one with eyes closed. The WBB was placed ~ 1 m in front of an overall white wall. In a recent study, the validity and reliability of the WBB were assessed in comparison with a force plate and exhibited good-to-excellent test–retest reliability of center of pressure (CoP) path length and between devices [13].

Measures

Mediolateral CoP (i.e. side-to-side, y-axis) and anteroposterior CoP (i.e. forward and backward, x-axis) were used to measure balance in a horizontal and vertical plane, respectively. Shifts in CoP were seen as a measure of postural sway, or the patient's ability to maintain balance. In addition, horizontal and vertical postural sway (i.e. mean variance of displacement in horizontal and vertical planes separately) were calculated.

In addition, the patient's medical record was reviewed. The following admission to rehabilitation data were captured: demographic data (i.e. age, sex), stroke characteristics (i.e. time poststroke onset, hemisphere, and subtype of stroke), and data on function and activity at admission [i.e. BI, Motricity Index, and Mini–Mental State Examination (MMSE)].

The BI [14] measures the extent to which stroke patients can function independently in their ADLs (i.e. feeding, bathing, grooming, dressing, bowel and bladder control, toileting, chair transfer, ambulation, and stair climbing). Scores range from 0 (completely dependent) to 20 (completely independent).

The Motricity Index [15] was used to determine the motor functions. There are three items for the arms (i.e. pinch grip, elbow flexion, shoulder abduction) as well as three items for the legs (i.e. ankle dorsiflexion, knee extension, hip flexion). Scores range from 0 (no activity, paralysis) to 33 [maximum (normal) muscle force] for each dimension, with a maximum total score of 100.

Cognitive status was measured with the MMSE [16]. It is a 30-point questionnaire used for screening orientation, memory, attention, calculation, language, and construction functions. Scores vary from 0 (severe cognitive impairments) to 30 (noncognitive impairments).

Statistical analyses

First, paired sample *t*-tests were performed to compare mediolateral CoP, anteroposterior CoP, and horizontal and vertical postural sway 1 week and directly before prism adaptation. Second, paired sample *t*-tests were performed to compare mediolateral CoP, anteroposterior CoP, and horizontal and vertical postural sway directly before and after prism adaptation.

Results

Demographic and stroke characteristics

An overview of demographic and stroke characteristics of the 10 neglect patients is given in Table 1. All of the patients had lesions in the right hemisphere. Seventy percent of patients suffered from cortical ischemic stroke, whereas 30% suffered from intracerebral hemorrhage. On average, patients were moderately disabled, given the average score of 12 on the BI and the average score of 24.40 on the MMSE.

Table 1 Demographical and stroke characteristics at admission

Clinical variables	Average (SD)
Age (years)	58.43 (12.63)
Sex (male)	40%
Time poststroke (days)	47.00 (37.21)
Hemisphere of stroke (R)	100%
Subtype of stroke (%)	
Cortical ischemic	70
Intracerebral hemorrhage	30
BI (0–20)	12.5 (4.59)
MI UE (0–100)	69.43 (44.05)
MI LE (0–100)	79.29 (19.36)
MMSE (0–30)	24.40 (4.51)

BI, Barthel Index; MI LE, Motricity Index Lower Extremities; MI UE, Motricity Index Upper Extremities; MMSE, Mini–Mental State Examination.

There were no statistical differences between the mediolateral and anteroposterior CoPs or postural sway at the time of the neuropsychological neglect screening and directly before prism adaptation [$t(8) < -0.458$, $P > 0.659$]. In other words, a stable baseline measure was obtained.

With respect to mediolateral CoP, there was a significant difference between preprism and postprism adaptation when measurements were performed with the eyes open [$t(9) = -3.206$, $P = 0.011$ (Fig. 1a)], indicating a shift toward the actual body midline (represented as '0' in Fig. 1a) after prism adaptation. With the eyes closed, however, no significant shift was found [$t(9) = -1.891$, $P = 0.091$ (Fig. 1b)].

With respect to anteroposterior CoP, there was a significant difference between preprism and postprism adaptation when measurements were performed with the eyes open [$t(9) = -3.884$, $P = 0.004$ (Fig. 1c)], indicating a shift forward after prism adaptation. With the eyes closed, however, no significant shift was obtained [$t(9) = -1.478$, $P = 0.174$ (Fig. 1d)].

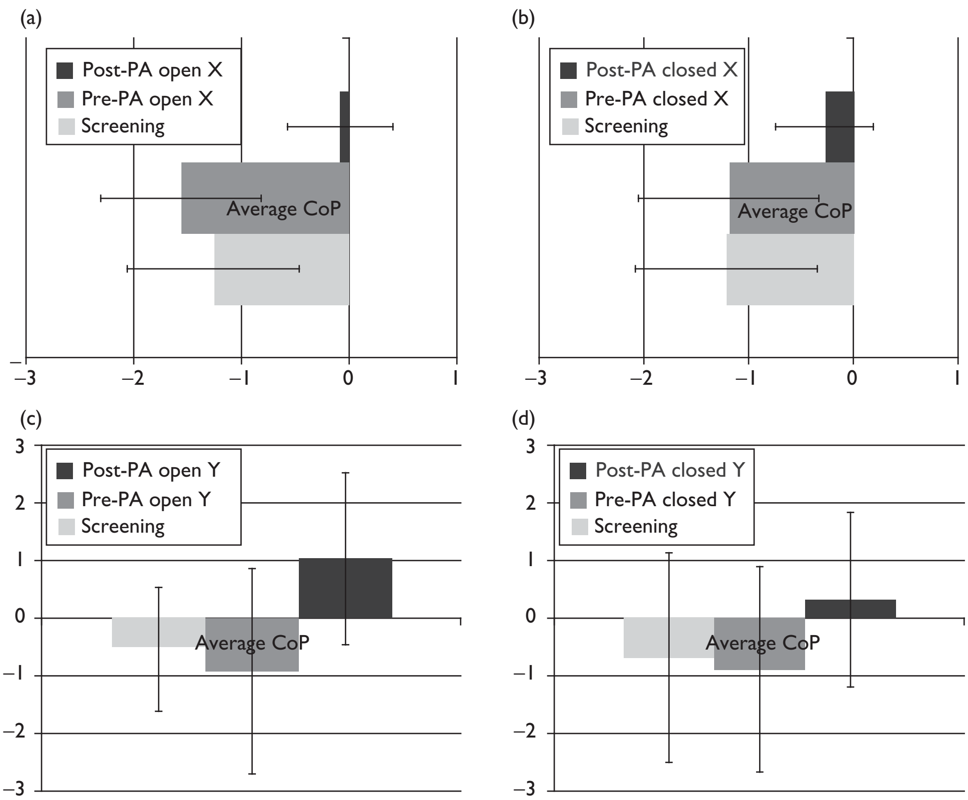
With respect to postural sway, only horizontal sway was significantly reduced after prism adaptation [eyes open: $t(9) = 2.582$, $P = 0.030$; eyes closed: $t(9) = 3.238$, $P = 0.010$], but no changes were found for vertical sway [$t(9) < 1.088$, $P > 0.305$].

Discussion

The aim of the current study was to investigate the influence of prism adaptation on balance and postural sway in subacute neglect patients. The rationale was that in prism adaptation, visual images are shifted toward one side and pointing accuracy decreases. Pointing accuracy is re-established as visual, proprioceptive, and motor reference frames are realigned to shift pointing movements in the opposite direction of the visual distortion, which might restore balance and postural sway.

The results indicated that the mediolateral CoP was shifted toward the actual body midline, the anteroposterior CoP was shifted forward, and horizontal postural sway was reduced, after prism adaptation. Prism adaptation therefore might be

Fig. 1



(a) Eyes open and (b) eyes closed: negative values represent a shift of center of pressure (CoP) to the contralesional side (here leftwards), whereas positive values represent a shift of CoP to the ipsilesional side. (c) Eyes open and (d) eyes closed: negative values represent a backward shift of CoP, whereas positive values a forward shift of CoP.

an instrument to enhance balance in patients with neglect in the subacute phase after stroke. These results are in line with an earlier study in chronic neglect patients (more than 12 months after stroke onset), which showed that postural imbalance improved up to 6 weeks after an 8-week intervention using prism adaptation [8].

Among other factors, deficits in postural balance have been attributed to lesions to the areas in the right parietal cortex responsible for the processing of sensory information for the control of body postural activities [5]. As spatial neglect is commonly found after lesions to the inferior parietal lobe, in particular to the right hemisphere, there is a large overlap in the neural areas contributing to the attentional deficits observed in neglect and the disorders of balance frequently observed after stroke. It is therefore perhaps not surprising that disorders of balance frequently coexist with spatial neglect (for a review, see Wee and Hopman [17]). Interestingly, prism adaptation is known to activate parietal areas in both healthy individuals and brain-lesioned patients [8,18]. It might therefore be the case that prism adaptation improves postural imbalance through modulation of the parietal cortex. In the parietal cortex, prism adaptation might recalibrate the spatial representations, resulting in a decreased distortion of the internal postural map [19].

Two levels of postural difficulty were measured in this study and a striking difference between the measurements with eyes open and closed was obtained; prism adaptation significantly influenced CoP measured with the eyes open, but not when measured with the eyes closed. There are several possibilities to explain this result. First, it might be that the beneficial effect of prism adaptation lies primarily in visual feedback or in the combination of visual and proprioceptive feedback more than the proprioceptive feedback alone. For example, significant improvements in eye movements toward the neglected side have been observed previously [8,20,21], which have been interpreted as ‘a resetting of the oculomotor system’. Second, it has been observed that older adults in general tend to sway more and rely more on visual information to maintain balance, which might be the result of decreases in sensory or motor system functions or cognitive tasks (for a review, see Woollacott and Shumway-Cook [22]). Therefore, it might be that this age-related decrease in motor system functions requires more or longer prism adaptation sessions to indicate a comparable effect. Given the sample size, it was not feasible to investigate the influence of age on the magnitude of the changes after prism adaptation.

We found that the mediolateral shift in both sessions before prism adaptation was toward the contralesional side. Interestingly, this is opposite to the results found in a study by Tilikete *et al.* [19], who found that in patients with hemiplegia, an ipsilesional bias was apparent before prism adaptation. This difference between patients with hemiplegia and patients with neglect might be the result of a distorted central representation of body gravity in patients with neglect, especially 'ignoring' body signals coming from the contralesional side. Postural imbalance in patients with neglect has been described as the result of impairment in the multimodal (visual, tactile) orientation of the body in space [4,23], due to a cognitive disorder in somesthetic processing, leading to a disturbed body scheme [4]. As such, patients may fail to notice that they are tilting too much toward the contralesional side. This might be in line with the results of Kerkhoff [23], who found that nearly all patients with (left-sided) neglect showed a counterclockwise (i.e. overshoot to the left) rotation of vertical, horizontal, and oblique orientations in both the visual and tactile domain. Prism adaptation may produce the recalibration of disturbed representation of space as well as higher-level representations of extrapersonal and internal body space (i.e. internal body midline).

In addition, the anteroposterior CoP was shifted forward after prism adaptation [8]. This forward displacement has also been observed in healthy individuals after prism adaptation [24]. In that study, the effect was attributed to postural compensation for the pointing movements required during adaptation. It might be that a similar compensation is responsible for the anteroposterior shift observed in our study, yet this would not explain the differences between eyes open and eyes closed (i.e. no shift). We therefore feel that prism adaptation has a genuine effect on anteroposterior CoP, most likely due to alarming and updating of an internal model of body structure [19,24].

Conclusion

This study has revealed that (postural) imbalance in patients with neglect can improve after prism adaptation. Given the important role of postural control in daily life functioning in stroke patients, this study might open possibilities for a successful rehabilitation procedure to alleviate deficits in postural imbalance.

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Conflicts of interest

There are no conflicts of interest.

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