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# Effects of Weight-Shift Training on Balance Control and Weight Distribution in Chronic Stroke: A Pilot Study

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**Purpose:** The objective was to evaluate the effect of weight-shift training on functional balance, weight distribution, and postural control measures during standing and forward reach tasks in subjects with chronic stroke. **Methods:** Nine male subjects (mean age, 66 years; range, 60–75 years) who experienced a stroke 3 to 13 years previously participated in a 4-week training program consisting of static and dynamic balance exercises with visual feedback and gait training with wall support. Balance control was assessed before and after the intervention with clinical measures (Berg Balance Scale) and with a pressure platform for registering the center of pressure (CoP) during quiet stance (weight distribution, CoP sway area, and velocity), and during a forward reach task at shoulder and knee levels. Intervention effects were evaluated with the Wilcoxon matched-pairs test. **Results:** After training, the group improved their Berg Balance Scale median score from 42 (range, 14–54) to 46 (20–55) ( $P = .01$ ), CoP sway area [10.6 (5.0–31.4) to 3.0 (1.8–10.8) cm<sup>2</sup>;  $P = .01$ ], and mean velocity [3.5 (2.4–8.0) to 1.7 (0.9–3.7) mm/s;  $P = .01$ ] during quiet standing but not weight distribution ( $P = .59$ ). During the forward reach tasks, most of the postural control measures such as movement time, CoP displacement, and CoP velocity were significantly ( $P < .05$ ) improved after the training period for both the affected and nonaffected sides as compared to before the training period. **Conclusion:** A weight-shift training program improved balance control but not weight distribution in a group of chronic stroke subjects. Larger, randomized, and controlled studies are necessary. **Key words:** center of pressure, exercise, gait, postural control, postural stability, reach, visual feedback

Stroke is one of the most disabling chronic conditions, and its motor sequelae are a primary reason for the disabling effect.<sup>1,2</sup> The rate and extent of recovery post stroke depends largely upon the initial degree of impairment, on an intact cortex adjacent to the lesion, and on the timing and intensity of the rehabilitation.<sup>3,4</sup> Initially, improvement of motor activity may occur post stroke because of the recovery of marginally functional neurons and later due to reorganization or relearning of neural functions (ie, neuroplasticity).<sup>4,5</sup> Earlier, stroke deficits were alleged to be permanent after 3 to 6 months, and rehabilitation was terminated. However, currently there is some evidence that subjects with stroke improve their motor function even in the chronic state (longer than 6 months) due to neuroplasticity.<sup>6,7</sup>

The ability to transfer body weight from one leg to the other is a basic aspect of human locomotion and everyday activities. The transfer requires postural adjustments and is central to gait<sup>8</sup> as well as to maintaining balance during reaching

tasks.<sup>9</sup> Individuals with stroke are asymmetric; they place more weight on the nonaffected leg and have decreased ability to transfer weight within their base of support without loss of balance.<sup>10–12</sup> Biofeedback systems are designed to provide visual or auditory feedback regarding the locus of the center of pressure (CoP), and training protocols seek to enhance weight distribution, steadiness, and dynamic stability.<sup>13–15</sup> Several studies have shown improved weight distribution and/or static and dynamic balance control in acute or subacute stroke after visual feedback training.<sup>16–19</sup> However, Van Peppen et al showed no such improvements.<sup>20</sup> Little is known about the effect of visual feedback training on chronic stroke<sup>7</sup> and even less about stroke suffered several years previously. Although visual feedback training standing on a force

plate might not train all aspects of functional balance,<sup>7,18</sup> a combination of such training during static and dynamic balance exercises including weight transfers during gait might be preferable for increasing functional balance. Transferring weight to the affected side is difficult in subjects with chronic stroke,<sup>10,11</sup> and wall support might enable these people to transfer their weight toward the side. However, this hypothesis has not been investigated.

Thus, the present aim was to evaluate the effect of weight-shift training, consisting of visual feedback in standing, and gait training with wall support on functional balance tasks, weight distribution, and postural control measures during standing and forward reach tasks, in subjects with chronic stroke.

## Material and Methods

### Subjects

Nine male subjects with chronic stroke (3 to 13 years since insult) participated in this pilot study (**Table 1**). All subjects were recruited from an outpatient physical therapy clinic in Stockholm, Sweden. Subjects were included if they had experienced their stroke more than 3 years previously, had remaining gait difficulties, were able to walk at least 20 m, and were able to follow verbal and visual instructions. Subjects were excluded if they needed a walking stick or crutches, received any other exercise/training or physical therapy treatment (including home exercises) during the intervention period, or were not approved by a physician to take part in the exercise due to other disorders or injuries such as mental disorders, recent lower limb injuries, and low back pain. Subjects were also excluded if they had a history of multiple strokes or any other neurological disorder. Informed consent was obtained from each subject before the study, and the project was approved by the ethics committee in Stockholm.

Clinical and laboratory measures were performed on all subjects before and within 3 days of the end of the intervention by the same test leader/physical therapist. The intervention was performed at the outpatient clinic by a physical

**Table 1.** Subjects' characteristics

Subject	Age, years	Affected side	Years since stroke, years
1	75	L	3
2	63	L	13
3	67	R	13
4	71	L	5
5	62	R	3
6	66	L	3
7	70	L	7
8	59	R	4
9	60	R	8
Mean (SD)	66 (5.4)	5L and 4R	6.6 (4.1)

Note: L = left; R = right.

therapist with neurologic specialist certification, while the clinical and laboratory measures were carried out at a motor control laboratory in Stockholm.

### Intervention

The subjects performed the following 3 activities 4 times a week over 4 weeks (16 sessions).

1. *Static balance control.* The subjects stood barefoot on a vertical posturographic digital platform (see the section, Laboratory outcome measures, for details). They were to stand as still as possible controlling their CoP through visual feedback from a PC monitor for 30 s in 3 different standing positions. These were (a) normal bipedal stance, (b) a modified tandem stance with the affected leg in front of the nonaffected (big toe of rear foot touching instep of foot in front), and (c) a modified tandem stance with the nonaffected leg in front of the affected leg. The subjects performed this sequence 3 times with 2 minutes rest between each sequence.
2. *Dynamic balance control.* The subjects adopted a barefoot, quiet bipedal stance on the platform, with arms relaxed by their sides and looking straight forward at a PC monitor for visual feedback of their CoP position on the platform. They then performed a sequence of moving the CoP to 7 different positions (center, left side, right side, left forefoot, right forefoot, left heel, and right heel) within their base of support while

keeping their trunk still. The whole sequence took 35 s, consisting of 5 s in each position. The sequence was performed 3 times with 2 minutes rest between each sequence.

3. *Walking with wall support.* The subjects walked with the affected side closest to a wall. During walking, the subjects were instructed to place the foot of the affected leg on a 3-cm wide and 10-m long line running 20 cm from the wall. During the stance phase of the affected leg, the subjects were instructed to shift their trunk so that the shoulder of the affected side touched the wall. Wearing regular shoes, the subjects walked along the wall in this manner 10 times in 3 sets with 2 minutes rest between each set.

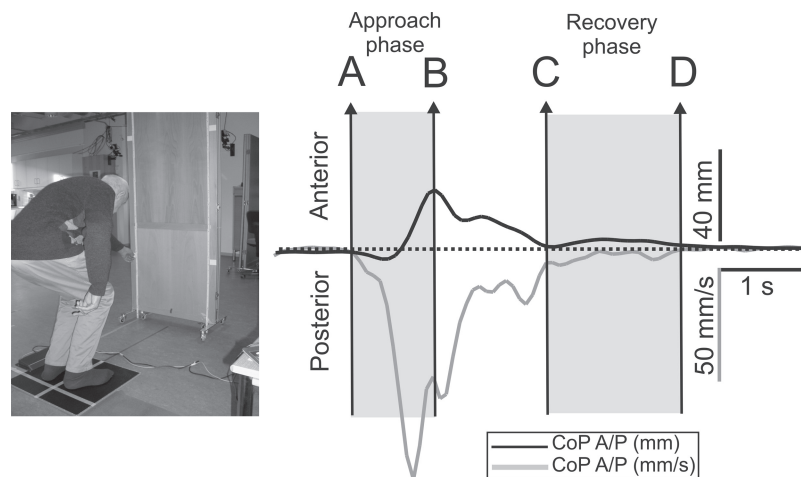
### Clinical outcome measures

To evaluate functional performance and balance, the subjects performed the Berg Balance Scale (BBS) before and after the intervention.<sup>21,22</sup> Each of the 14 BBS items is graded on a 5-point ordinal scale (0–4), yielding a total of 56 points. The protocol assesses balance during various daily activities. These activities include sit-to-stand,

stand-to-sit, quiet standing (eyes opened and eyes closed), sitting without back support, transfers, reaching forward when standing, picking up an object from the floor when standing, looking over the left and right shoulder while standing, turning 360°, placing alternate feet on a footstep, tandem stance for 30 s, and one-leg stance for 10 s. The scale is scored according to degree of difficulty, with lower values for poor task performance and higher values indicating full ability to perform the task. A total score was calculated for data analysis.

### Laboratory outcome measures

To evaluate weight distribution and stability in standing and during forward reach tasks, foot pressure was recorded and analyzed on an electronic pressure platform (EPS; Foot Checker 3.2; Comex S.A. / LorAn Engineering Srl, Castel Maggiore, Bologna, Italy) on the floor. The 700 × 500 mm platform contained 2,304 resistive sensors with a measuring accuracy of 0.001 kPa, sampled at a frequency of 60 Hz. For the platform measurement, the subjects stood upright on the platform in their socks and were instructed to stand with their feet in a comfortable position. Their foot



**Figure 1.** The left panel shows a subject with chronic stroke reaching forward with the nonaffected (left) arm to a target at knee level. The right panel shows raw data of the anterior/posterior (A/P) displacement of the center of pressure (CoP) as well as the velocity of the A/P CoP. Analysis of the CoP was divided into an approach and a recovery phase (shaded area). The approach phase was defined between the first continuous decrease in the CoP relative to baseline (line A) and the peak value of the CoP displacement (line B) and the recovery phase as the time between the instant that the CoP returned to baseline (line C) and the instant where the CoP velocity stabilized (line D).

position was standardized in the anterior/posterior (A/P) direction by aligning the heels to a tape on the platform (see **Figure 1**, left panel). The distance between the first metatarsal heads was measured for accurate reproduction in the follow-up measurements. The subjects' arms hung loosely at their sides, and they were told to stand in a relaxed position and breathe normally. Visual feedback was given through a 17-in. PC monitor placed at eye level 50 cm in front of the subjects.

The subjects performed the following static standing and forward reach tasks on the platform.

1. Quiet standing in normal bipedal stance for 15 s while standing as still as possible, with visual feedback to control their CoP.
2. Forward reach tasks: The subjects performed 4 reaching movements, reaching forward for 2 targets with the affected arm and 2 with the nonaffected: (a) 2 target points were placed at shoulder level, and (b) 2 target points were placed at knee level. The horizontal distance between the targets was the same as the width of the subjects' shoulders. Target distance was determined individually, according to the subjects' upper limb length, plus the maximum distance reached during a trial to touch the wall with the nonaffected arm while keeping their balance (ie, subjects' maximum reach distance with their nonaffected arm). This distance was the same before and after the intervention. For the reach tasks, the subjects faced the targets and were ready to move and reach forward to touch the target or reach as far as possible when the tester randomly indicated a target with a laser pointer. Because all the subjects had limited range of motion in the affected arm due to spasticity, they were unable to touch the target but were instructed to reach as far as possible toward it. All the subjects were familiarized with the reaching procedure and practiced reaching all 4 target positions. Two trials for each target were then performed. Note that the postural control measures (as described below) were the outcomes of interest and not the reaching distance.

During data analysis, the A/P displacement (mm), the sway area (cm<sup>2</sup>), and the mean velocity (mm/s) of the CoP were calculated. The

A/P starting position was standardized with a similar posture before and after the intervention. Weight distribution of both legs during quiet stance was calculated from the vertical force and normalized as percent body weight (%BW). In addition, the sway area (cm<sup>2</sup>) and the velocity (mm/s) of the total CoP during quiet standing were calculated in an integrated software module, SKG stabilometry software (LorAn Engineering Srl, Castel Maggiore, Bologna, Italy). For the analysis of the forward reach tasks, data from the platform were exported into ASCII files and analyzed in Axograph (Axon Instruments, Union City, California), a software package designed for Macintosh personal computers. From the curves generated, the maximum anterior displacement and temporal aspects of the A/P CoP were determined manually. The temporal measurements were analyzed during an approach phase and a recovery phase (**Figure 1**, right panel). Line A in **Figure 1** refers to the time when the displacement of the CoP was detected as the first continuous decrease (anticipation) in the CoP relative to baseline. The approach phase was defined between line A and the maximum value of the CoP displacement (line B), and CoP displacement and duration were analyzed. The recovery phase representing the ability to stabilize after the voluntary reach was defined as the time between the instant when the CoP returned to baseline (line C) and the instant when the CoP velocity stabilized (line D). The mean velocity of the CoP in the A/P direction during the approach phase was calculated by dividing the CoP A/P displacement by the time of the approach phase in each trial. For each subject and each task, the mean of 2 trials was then calculated.

### Statistical analysis

Given the few subjects in this pilot study, the Wilcoxon matched pairs test with a significance of  $P < .05$  was chosen to evaluate the effects of the intervention program concerning all the outcome measures (BBS, CoP displacement, CoP velocity, %BW) and the temporal measures during all phases and in all tasks. Statistical analyses were performed using the STATISTICA computer statistical package (Version 9.1; Statsoft Inc, Tulsa, Oklahoma).

## Results

All the subjects completed the training sessions 4 times a week during the 4-week intervention period (100% compliance).

### Functional balance performance

Although chronic, all subjects improved their total BBS score after the intervention period ( $P = .01$ ; median score, 42 [14–54] to 46 [20–55]; see **Figure 2**). Eight of 9 subjects reached further during the functional reach task (item 8), 6 subjects stood longer during the tandem stance task (item 13), 4 subjects stood longer during the one-leg stance task (item 14), and 3 performed faster during the alternate foot placement task (item 12).

### Weight distribution and postural stability

#### Quiet standing tasks

At baseline, the subjects stood slightly, but not significantly, asymmetrically with on average 44.3% of their body weight on their affected side during quiet stance. After the intervention period, there was no change in weight distribution ( $P = .59$ ; **Table 2**). Sway area was reduced from 10.6 to 3.0 cm<sup>2</sup> ( $P = .01$ ), and the mean velocity of the

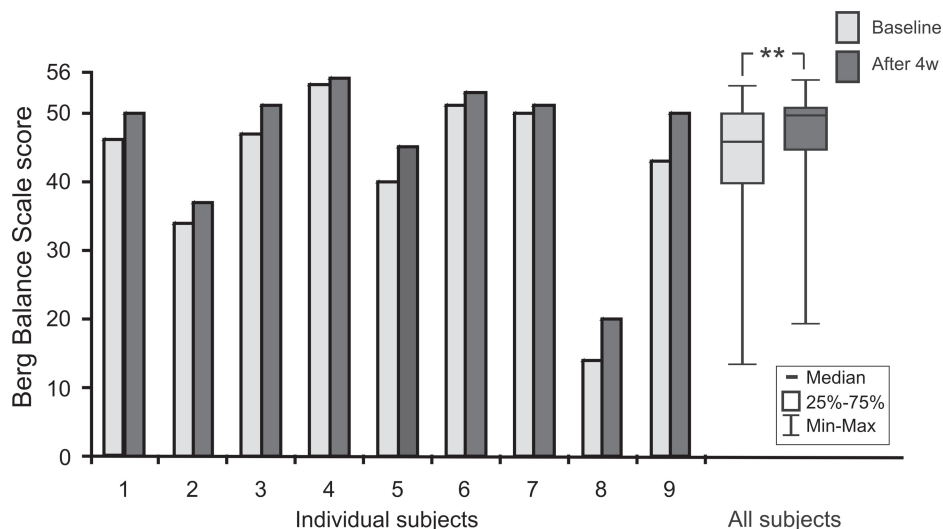
CoP during quiet standing decreased significantly from 3.5 to 1.7 mm/s in quiet bipedal stance after the intervention compared to before ( $P = .01$ ).

#### Forward reach task at shoulder level

CoP displacement in the A/P direction was more than double after the intervention during reach at shoulder level with the arm on the affected side from 13.8 to 32.2 mm ( $P = .02$ ) and on the nonaffected side from 16.6 to 33.9 mm ( $P = .04$ ; **Table 2** and **Figure 3**). Moreover, a decrease from 4.6 to 4.2 s in the duration of the approach phase was seen after the intervention in the nonaffected side ( $P = .03$ ). This increase in displacement and decrease in duration gave an increased mean velocity during the approach phase in the affected side from 5.8 to 19.7 mm/s ( $P = .04$ ) and in the nonaffected side from 3.8 to 11.4 mm/s ( $P = .02$ ). During the recovery phase, there were no significant differences in the time to stabilize before or after the intervention in either side (**Table 2**).

#### Forward reach task at knee level

CoP A/P displacement during the forward reach task at knee level increased (from 12.6 to 29.3 mm) after the intervention only in the nonaffected side.



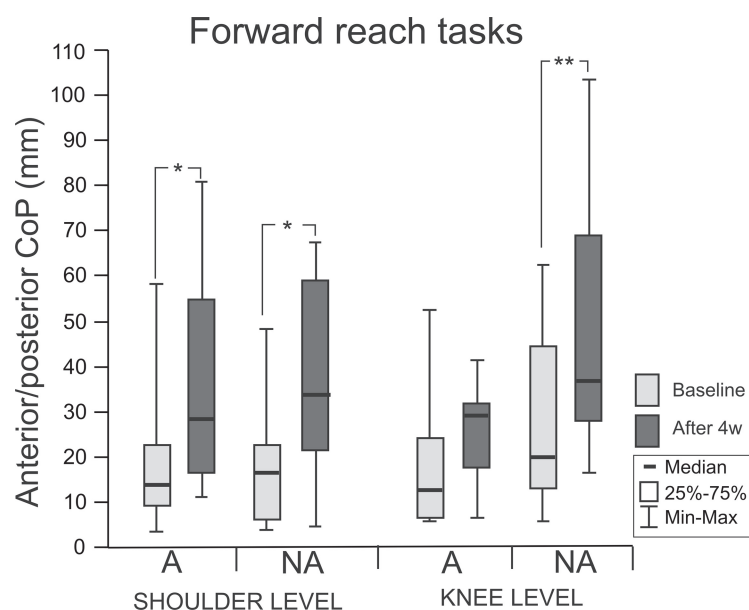
**Figure 2.** Total Berg Balance Scale score of each subject at baseline (light grey) and after the 4-week intervention (dark grey), and a box-plot of the median, 25%–75% confidence interval, and range for the whole group at baseline and after the intervention.

\*\*Denotes  $P < .01$ .

**Table 2.** Outcome measures during quiet standing and forward reach tasks at shoulder and knee level

Variables	Baseline	After 4 weeks	P
	Median (range)	Median (range)	
<b>Quiet standing task</b>			
Weight distribution on affected leg, % body weight	44.3 (24.6–52.8)	44.0 (25.0–57.0)	.59
Quite bipedal stance, CoP sway area, cm <sup>2</sup>	10.6 (5.0–31.4)	3.0 (1.8–10.8)	.01
Quite bipedal stance, CoP mean velocity, mm/s	3.5 (2.4–8.0)	1.7 (0.9–3.7)	.01
<b>Forward reach task - shoulder level</b>			
Affected A/P CoP displacement, mm	13.8 (3.6–58.1)	32.2 (11.2–81.0)	.02
Nonaffected A/P CoP displacement, mm	16.6 (3.8–48.4)	33.9 (4.7–67.5)	.04
Affected approach phase, seconds	3.5 (2.6–6.2)	3.8 (2.2–5.3)	.34
Nonaffected approach phase, seconds	4.6 (3.2–9.6)	4.2 (2.2–6.0)	.03
Affected recovery phase, seconds	3.3 (1.5–5.2)	1.8 (1.0–4.6)	.06
Nonaffected recovery phase, seconds	4.7 (2.1–5.9)	2.9 (1.1–4.5)	.09
Affected CoP mean velocity, mm/s	5.8 (3.6–12.9)	19.7 (7.5–28.4)	.04
Nonaffected CoP mean velocity, mm/s	3.8(2.5–6.7)	11.4 (9.5–43.2)	.02
<b>Forward reach task - knee level</b>			
Affected A/P CoP displacement, mm	12.6 (5.8–52.6)	29.3 (6.6–41.3)	.11
Non-affected A/P CoP displacement, mm	20.0 (5.8–62.3)	36.9 (16.3–103.7)	.01
Affected approach phase, seconds	3.7 (1.9–5.9)	3.1 (1.8–4.3)	.67
Nonaffected approach phase, seconds	4.6 (1.9–6.5)	2.6 (1.3–5.0)	.02
Affected recovery phase, seconds	4.0 (1.5–9.1)	2.2 (1.7–4.8)	.01
Nonaffected recovery phase, seconds	4.2 (1.7–6.5)	3.3 (0.9–4.9)	.20
Affected CoP mean velocity, mm/s	9.9 (3.94–11.1)	13.6 (12.8–39.6)	.05
Nonaffected CoP mean velocity, mm/s	7.0 (2.2–12.8)	22.4 (8.5–15.1)	.01

Note: Wilcoxon matched pairs test was used.  $P < .05$  shown in bold. CoP = center of pressure; A/P = anterior/posterior.



**Figure 3.** Anterior/posterior (A/P) displacement of the center of pressure (CoP) for the affected (A) and nonaffected (NA) sides when reaching forward for a shoulder-level target at baseline (light grey) and after the 4-week intervention (dark grey).

\*Denotes  $P < .05$ . \*\*Denotes  $P = .01$ .



In the nonaffected side, the approach phase duration decreased (**Table 2** and **Figure 3**). Thus, the mean velocity of the approach A/P CoP increased in the nonaffected side from 7.0 to 22.4 mm/s after the intervention ( $P = .01$ ) and tended to increase in the affected side (9.9 to 13.6 mm/s) after the intervention ( $P = .05$ ). During the recovery phase, the time to stabilize decreased in the affected side from 4.0 s before the intervention to 2.2 s after ( $P = .01$ ).

## Discussion

This pilot study showed that weight-shift training improved functional balance score, stability during quiet stance, and postural control measures during forward reach in chronic stroke subjects. On the other hand, the weight-shift training showed no changes in weight distribution during quiet standing. Moreover, it seems that the improvement in balance control was due mainly to improved control of the nonaffected side, because more of the parameters (6 out of 8) studied on the nonaffected side during a reaching task were improved than were those on the affected side (3 out of 8).

Functional balance measured with the BBS improved statistically. However, it is questionable whether the improvement is clinically important, because the median group score improved only by 4 points. Steffen and Seney<sup>23</sup> calculated the minimum detectable change score from Berg's el al<sup>21</sup> study and found that the difference should be 5 points for 24 elderly subjects with or without stroke, whereas another study<sup>24</sup> suggests 6 BBS points for a clinically significant change. On the other hand, our BBS improvement tallies with that in other studies of visual feedback training 3 to 59 months post stroke<sup>7</sup> as well as during task-specific training 2 to 20 years post stroke.<sup>6</sup> Walking interventions in stroke have little effect on BBS total score, probably because the scale has no items that require walking,<sup>25</sup> so it seems that the increase in BBS was due mainly to the first 2 parts of the training program. Our findings contradict a review by Barclay-Goddard et al<sup>18</sup> of 7 randomized controlled studies. They found that visual feedback after stroke did not improve sway in standing, functional balance (BBS), or measures of independence, but it improved weight

distribution. Opposed to this, a recent meta-analysis of visual feedback training in standing in acute and subacute stroke subjects showed no effect on weight distribution, postural sway, or gait compared to conventional therapy.<sup>20</sup> The present study could not confirm a more symmetrical weight distribution after the intervention, although a more stable posture during standing and reaching was found. The lack of improvement in weight distribution might be related to the fact that this chronic stroke group was not very "asymmetrical" at baseline. Moreover, during simple functional movements such as standing, walking, and reaching, the central nervous system coordinates both the postural components that stabilize the body and the prime mover components that relate to the particular motor task. This coordination is based on an internal representation of body posture that is upgraded continuously by feedback mechanisms.<sup>26</sup> However, the slightly asymmetrical body reference seen in this study had been developed and used for several years, and these chronic stroke subjects might need more than 4 weeks to adapt to a new body position. Others have reported a defective sensorimotor integration in stroke subjects<sup>27,28</sup> that might affect the internal reference.<sup>28</sup> A final explanation of the lack of positive effect on the weight-bearing asymmetry in this study might be that the asymmetry is not the principle cause of postural instability in chronic stroke.<sup>29</sup> Our results show decreased postural sway during quiet stance with visual feedback after a training period. This was not surprising, though, because quiet standing with visual feedback was part of the intervention. This corresponds with other intervention studies of acute and subacute stroke subjects that included sway area.<sup>14,30</sup> However, our sway values are not comparable with other studies, perhaps due to differences in the severity of stroke or in the validity of the measurement system that should be evaluated further.

Our forward reach tasks were studied bilaterally during 2 phases, approach and recovery, using the parameters CoP displacement and movement time, which together defined the mean CoP velocity. Increased mean velocity during the approach phase may represent higher stability and greater confidence in balance. The results



show an improvement in balance function (ie, expanding the limits of stability<sup>31</sup>) mainly due to improved function of the nonaffected side, but it was surprising to find improvement in the affected side also after such a long time since stroke. We expected that increased CoP displacement and mean velocity during the approach phase would result in a longer recovery phase, because the postural disturbance would be greater. However, this was not the case and again shows improved function of both sides. The reach task at both levels improved, although a reach at knee level may require more balance control and muscle strength. Some exercise studies<sup>32</sup> of subjects with stroke have also found improvement in reaching ability while others have not.<sup>33</sup>

To our knowledge, this pilot study is the first to investigate postural control by examining the CoP during forward reach tasks in this way; it seems that the parameters used are suitable for studying postural control after internal balance disturbances. We investigated reaching tasks to evaluate whether increased balance control as a result of a specific training program could be transferred to tasks in daily life. Many studies of the effects of feedback training following stroke have provided clear evidence that only those abilities specific to the training are enhanced.<sup>17,34,35</sup> On the other hand, Barclay-Goddard et al<sup>18</sup> showed that feedback training improved stance symmetry but not sway in standing or clinical measures of balance or measures of independence. These contradictory results indicate a need for more studies on the effects of poststroke feedback training on motor function in general, such as whether a program based on dynamic balance

tasks only (such as gait) affects static balance tasks and vice versa and whether static balance training improves function during dynamic balance tasks. In our study, the combined program affected both balance in general and specific tasks, and it was therefore impossible to isolate the effects from each other.

This pilot study indicated that the training program and the parameters used are suitable for further studies in this area. A limitation in the platform software precluded standardization of the starting position of the CoP before and after the intervention in the medial/lateral direction, and this measure was therefore excluded from analysis. The lack of information on the CoP in the medial/lateral direction made it difficult to study weight distribution during the reaching tasks, another interesting parameter. Further studies should be larger, randomized, and controlled and should incorporate more dynamic balance tasks (eg, gait) and should include female subjects.

In conclusion, use of weight-shift training improved functional balance score, stability during quiet stance, and ability to reach forward to a target in a group of chronic stroke subjects. The parameters for identifying stability limits during forward reaching tasks seem to be suitable for further studies.

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