DISABILITY OF WEIGHT SHIFT TOWARD NON-PARETIC LEG IN STROKE PATIENTS WITH NON-DOMINANT HEMISPHERE

FUMIYASU ISHII, NORIYUKI MATSUKAWA, MITSUYA HORIBA, IKUO WADA, TAKEHIKO YAMANAKA, MANABU HATTORI, TAKEMORI YAMAWAKI, KOSEI OJIIKA

1) Department of Neurology, Nagoya City University Medical School, Mizuho-ku, Nagoya 467-8601, Japan
2) Division of Rehabilitation Medicine, Nagoya City University Medical Center, Mizuho-ku, Nagoya 467-8602, Japan
3) Department of Information Technology for Human Welfare, Nihon Fukushi University, Toumi-chou, Handa 475-0012, Japan

(Accepted for publication February 2, 2009)

SUMMARY

Postural disorders seen in individuals with strokes are related to asymmetric weight bearing. However, the precise function of the dominant or non-dominant hemisphere in controlling static standing posture or bearing weight remains unclear. To examine whether there is a significant difference in the ability to balance between dominant and non-dominant hemisphere-lesioned patients, quantitative evaluation of the percentage of weight-shift was performed to determine the ability to control balance in static posture and on maximum voluntary weight-shift toward the paretic or non-paretic leg. Participants were registered from a consecutive series of stroke patients attending a rehabilitation program (n = 53, male 34, female 19, 68.5 ± 10.0 yr old). Age matched normal controls were recruited from the family of patients as volunteers (n = 12, male 4, female 8, 67.9 ± 4.9 yr old). Patients with right hemisphere lesion could not perform maximum voluntary shift weight toward the non-paretic leg, in
comparison with those with dominant hemisphere lesion \( (p < 0.05) \). We suggest that patients with a non-dominant lesion should practice weight shift toward the non-paretic leg to improve their static or gait balance.

**Key words:** Instability; Posture; Weight shift; Stroke; Non-dominant hemisphere

**INTRODUCTION**

Stroke is one of the most common causes of death in advanced countries. While therapeutic advances in the treatment of stroke in the acute stage has reduced stroke mortality, stroke results in severe neurological disability for patients \( (1) \). In particular, deficit in motor control, abnormal synergistic organization of movements, impaired force regulation, muscle weakness, sensory deficit, and loss of range of motion reduces the quality of life in patients with stroke \( (2-5) \).

While rehabilitation with physical therapy can help to reestablish motor function in stroke patients, postural unbalance may impede functional recovery in gait \( (6) \). It is conceivable that this asymmetry in static and dynamic position is associated with impairments causing the bearing of most weight through the non-paretic limb when significant paresis exists \( (6-9) \). As weight shifting is a necessary prerequisite to ambulation, improving this ability is one of foremost treatment goals for gait in the physical treatment of the stroke patients \( (10-12) \). In fact, supportive training of the paretic leg to bear weight, for example with treadmill, shoe wedge or lifts, can effectively ameliorate gait disturbance \( (13-16) \). However, reluctance to bear weight on the paretic leg may continue and cause disturbance of gait, despite conventional physical therapy to correct asymmetrical standing posture \( (17) \). Moreover, this asymmetric posture could foster further disuse, and hinder recovery of motor function in lower limbs during the motor convalescent stage \( (18) \).

At the same time, there is a group of patients with stroke, indicative instability of gait and a tendency to fall to the paretic side repeatedly from the early stage \( (19) \). Patients with lesions in the right hemisphere have shown a larger sway area and more lateral displacement than patients with left hemisphere lesions, indicating the importance of the right hemisphere for instability in standing and gait \( (20) \). This instability is considered to relate to anosognosia, and patients with right hemisphere lesions may suffer from a persistent distortion of spatial postural representation \( (21) \). Each hemisphere, right or left, might play a different role in the control of standing posture \( (20) \). However, the precise function of the right or left hemisphere in controlling static standing posture or bearing weight remains unclear.

In this study, to determine whether there is a significant difference in the ability to balance between dominant and non-dominant hemisphere-lesioned patients, we examined the percentage of weight bearing through the non-paretic leg in static standing and maximum voluntary weight shift to-
Postural instability in right brain-damaged patients

METHODS

Participants

Japanese patients with clinically and neuroradiologically diagnosed stroke were recruited in the metropolitan area of Nagoya city, central Japan \((n = 53, \text{ male } 34, \text{ female } 19, 68.5 \pm 10.0 \text{ yr old})\). Participants were medical admission patients from Nagoya City University Medical Center, and registered as a consecutive series of stroke patients attending a rehabilitation program. The characteristics of these patients and age matched normal controls are summarized in table 1. Briefly, 31 patients had a left hemisphere lesion \((20 \text{ male, } 11 \text{ female, } 68.1 \pm 9.4 \text{ yr old})\), and 22 patients had a right hemisphere lesion \((14 \text{ male, } 8 \text{ female, } 69.1 \pm 11.3 \text{ yr old})\). Age matched normal controls were recruited from the family of patients as volunteers \((n = 12, \text{ male } 4, \text{ female } 8, 67.9 \pm 4.9 \text{ yr old})\). To establish regularity in the background of patients, the standard for registration was restricted as follows: (i) right-handed; (ii) younger than 80 years of age; (iii) neuroradiologically verified single vascular lesion in the territory of the middle cerebral artery of one hemisphere, and (iv) stroke no earlier than one week before the experimental testing session. There was no significant difference in duration time of examination from the time of stroke \((\text{left lesion: } 15.8 \pm 7.1 \text{ days, right lesion: } 16.2 \pm 7.6 \text{ days})\) (Table 1). To eliminate the involvement of the degree of neurological dysfunction, including motor

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LH (n=31)</th>
<th>RH (n=22)</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects (Male / Female)</td>
<td>31 (20 / 11)</td>
<td>22 (14 / 8)</td>
<td>12 (4 / 8)</td>
</tr>
<tr>
<td>Age, years</td>
<td>68.1±9.4</td>
<td>69.1±11.3</td>
<td>67.9±4.9</td>
</tr>
<tr>
<td>Duration of illness, days</td>
<td>15.8±7.1</td>
<td>16.2±7.6</td>
<td>-</td>
</tr>
<tr>
<td>B.S.stage</td>
<td>IV 4</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>V 15</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VI 12</td>
<td>12</td>
<td>-</td>
</tr>
</tbody>
</table>

There is no significant difference in age, the period after stroke and motor function, Brunnstrome stage score. All subjects are right-handed, and are able to stand.

LH: patients with left hemisphere lesion,
RH: patients with right hemisphere lesion
function, sensory function and cerebellar function, the registered participants were limited within Brunnstrom stage IV - VI, with little or no neurological sensory and cerebellar dysfunction (Table 1). This study was approved by the medical ethical committee of Nagoya City University Graduate School of Medical Sciences.

**Apparatus**

Weight bearing of participants was assessed by using a foot scan computerized force platform system (F scan, Nitta Ltd, Japan). This system consists of a single platform connected to a personal computer allowing independent measurement of vertical force between the feet and the surface of the platform.

**Procedure**

Three series of weight bearing measurements were performed. This procedure was repeated in three different standing positions. In the first series, the participants were asked to stand with level stance, wide-shouldered and with eyes open (Fig. 1a), and their weight bearing distribution was recorded at 10 seconds, 30 seconds or 60 seconds after starting the static position. In the second series,

![Fig. 1. Schematic presentation of static posture and maximum voluntary weight shift. Subjects maintain the basic position during rest. Subsequently, they shift their weigh maximally toward the stronger leg, and then change the side of weigh-shift toward the weaker leg. The percentage of weight shift on left leg during static position, and on each leg during maximum voluntary shift, is evaluated by foot scan computerized force platform system.

a) Static position   b) Maximum voluntary shifting position toward left leg   c) Maximum voluntary shifting position toward right leg](image-url)
participants were encouraged to shift their weight maximally on to the non-paretic lower extremity, with the remaining paretic leg on the platform (Fig. 1 b, c). The percentage of forced weight was measured in the same way as static standing measurement. In the third series, participants were encouraged to bear weight maximally on the paretic lower extremity and keep this forced position, and the percentage of weight bearing was calculated as described above (Fig. 1 b, c). Two to three minute rest periods were allowed between each position. The order of the positions was the same as above for every participant. Testing in three positions was repeated on three consecutive days, and mean results of three measurements in each position were used for statistical analysis.

**Statistical analysis**

In order to determine statistical differences in percentage of weight shifting through the affected leg and in the characteristics of each group examined, data were analyzed by a one-way ANOVA followed by Turkey’s post hoc tests. Statistical significance was preset at p < 0.01.

**Results**

All participants with stroke demonstrated asymmetrical weight bearing with static posture. Age matched control participants divided weight equally to each leg in static position (left leg; 10 seconds: 49.9 ± 1.9%, 30 seconds: 49.2 ± 3.2%, 60 seconds: 49.6 ± 3.8%). Participants with a left hemisphere lesion bore weight toward the non-paretic leg more than 50% in static standing posture (10 seconds: 53.8 ± 3.7%, 30 seconds: 53.0 ± 4.5%, 60 seconds: 53.4 ± 5.1%) (Fig. 2). Conversely, participants with a right hemisphere lesion bore weight dominantly on the paretic leg in static standing posture (10 seconds: 48.8 ± 5.4%, 30 seconds: 49.6 ± 3.1%, 60 seconds: 48.4 ± 3.1%) (Fig. 2). There was a significant difference in duration from the initiation of standing between patients with left lesion and those with right lesion (p < 0.01).

We next evaluated the ability of maximum voluntary weight-shift toward the paretic or non-paretic leg. In the evaluation of the ability to consciously transfer weight to the non-paretic leg, patients with left hemisphere lesion could transfer more of their body weight to the non-paretic leg than those with right hemisphere lesion. There was a significant difference in the forced weight shift on the non-paretic between the left lesioned group (10 seconds: 82.2 ± 8.7%, 30 seconds: 80.1 ± 10.0%, 60 seconds: 77.8 ± 13.2%) and right lesioned group (10 seconds: 70.4 ± 10.6%, 30 seconds: 68.7 ± 11.0%, 60 seconds: 64.9 ± 13.8%) (p < 0.01) (Fig. 3a). However, there was no significant difference in the ability to force weight shift on the paretic leg between the two groups (left lesioned; 10 seconds: 78.7 ± 12.8%, 30 seconds: 79.9 ± 10.6%, 60 seconds: 78.2 ± 12.1%, right lesioned; 10 seconds: 78.8 ± 10.9%, 30 seconds: 77.4 ± 11.2%, 60 seconds: 77.7 ± 10.5%) (Fig. 3b). In the age matched control group, participants could shift weight-bearing toward each leg more than 80% (right leg; 10 seconds: 88.1 ± 4.0%, 30 seconds: 86.8 ± 5.2%, 60 seconds: 87.5 ± 5.7%, left leg;
In this study, we showed that all participants with stroke demonstrated asymmetrical weight bearing during static standing posture, with wide-shoulders and open eyes, compared with age matched controls. However, there was a significant difference in the percentage of body-weight shifting to the non-paretic leg between patients with lesions on the left or right side. In brief, there was more than 50% shift on non-paretic leg in left hemisphere-lesioned patients and less than 50% shift on that leg in right hemisphere-lesioned patients. With respect to maximum voluntary weight shifting ability toward non-paretic legs, there was also a significant difference between patients with a left lesion and those with a right hemisphere lesion. In sum, patients with right hemisphere lesion could not weight shift consciously toward the non-paretic leg, compared with those with left hemisphere lesion, indicative of the importance of the right hemisphere for standing stability and consciously shifting weight to the non-paretic leg.

10 seconds: 88.1 ± 5.9%, 30 seconds: 84.6 ± 7.8%, 60 seconds: 84.4 ± 7.6%.

Discussion

In this study, we showed that all participants with stroke demonstrated asymmetrical weight bearing during static standing posture, with wide-shoulders and open eyes, compared with age matched controls. However, there was a significant difference in the percentage of body-weight shifting to the non-paretic leg between patients with lesions on the left or right side. In brief, there was more than 50% shift on non-paretic leg in left hemisphere-lesioned patients and less than 50% shift on that leg in right hemisphere-lesioned patients. With respect to maximum voluntary weight shifting ability toward non-paretic legs, there was also a significant difference between patients with a left lesion and those with a right hemisphere lesion. In sum, patients with right hemisphere lesion could not weight shift consciously toward the non-paretic leg, compared with those with left hemisphere lesion, indicative of the importance of the right hemisphere for standing stability and consciously shifting weight to the non-paretic leg.
Fig. 3. Comparisons of the weight shifting percentage toward non-paretic or paretic leg between dominant hemisphere damage and non-dominant hemisphere damage

Patients with stroke revealed the exacerbation tendency of sustaining ability on non-paretic leg, compared with age-matched control individuals. In particular, participants with non-dominant hemisphere damage denoted the impairment of weight sustaining ability on non-paretic leg in comparison with those with dominant hemisphere damage (a). In contrast, there is no significant difference in the weight-shifting ability toward paretic leg among those with dominant hemisphere damage, those with non-dominant hemisphere damage and age-matched control individuals (b).

*p<0.01
The ability to remain balanced in static standing and preserve upright posture is maintained by an interplay between the motor, sensory and cognitive systems (22). Impairment of the mechanism responsible for postural control can lead to unsteadiness and instability in standing posture (23). In this study, to exclude the involvement of motor dysfunction and sensory dysfunction, we recruited only patients with the ability to stand independently without an assistive device. In fact, there was no significant difference in the scores for motor function and sensory function among evaluated groups.

In this study, we also demonstrated that patients with right hemisphere lesion present more weight shift onto the paretic leg in static standing. In contrast, patients with left hemisphere lesion did not show a significant difference in the percentage of body weight on the paretic leg. This result could indicate that the right hemisphere may be important in shifting body weight toward the paretic leg unconsciously, and in affecting instability in static posture.

Recent reports have emphasized the important role of space exploration disturbance, such as hemi-neglect in imbalance after stroke (24). Balance instability is more frequent, and it requires more time to recover that imbalance after right hemisphere lesion than after left hemisphere lesion (25). In addition, the role of trunk apraxia is indicated in association with the preservation of standing posture (26).

In this study, we demonstrated that patients with right hemisphere lesion could not perform a maximum voluntary shift of body weight toward the non-paretic leg. There are few reports regarding the ability of voluntary weight-shift toward the non-paretic leg. Goldie PA et al reported that the ability of maximum voluntary weight bearing by the non-paretic leg in stroke patients decreases more than that of age matched controls (control subjects: 95%, stroke patients: 80-85%) (7). Our data may suggest that the instability of patients with right hemisphere damage is reflected in this reduction in the conscious ability to shift voluntarily, as well as in the unconscious inclination toward the paretic leg.

Conclusion

To improve balance in static standing posture and gait posture, our data would suggest that the physical therapist should attempt to get patients to practice conscious weight-shifting toward the non-paretic leg, and to avoid unconscious weight-shifting toward the paretic leg.

REFERENCES

Postural instability in right brain-damaged patients


20. Spinazzola L, Cubelli R, Della Sala S Impairments of trunk movements following left or right hemisphere lesions: dissociation between apraxic errors and postural instability. Brain 2003; 126 : 2656-2666.


24. Rode G, Tiliket C, Charlopaion P, Boisson D. Postural asymmetry reduction by vestibular caloric stimulation in
