Background and Purpose—It is unknown whether hemiparetic individuals are aware of their weight-bearing asymmetry during sit-to-stand tasks. This study compared the error between hemiparetic and healthy individuals’ perception of weight-bearing and their actual weight-bearing distribution during the sit-to-stand task and analyzed the association between the knee extensor muscle strength and the weight-bearing distribution and perception.

Methods—Nineteen unilateral hemiparetic subjects and 15 healthy individuals participated in the study. They performed the sit-to-stand transfer on force platforms under different foot placements (spontaneous and symmetrical) and had to rate their perceived weight-bearing distribution at the lower limbs on a visual analog scale. The strength of the knee extensors was assessed with a Biodex dynamometer.

Results—The hemiparetic individuals presented greater weight-bearing asymmetry and errors of perception than the healthy individuals. Although no significant association was found between strength and weight-bearing perception, moderate associations were found between strength and weight-bearing distribution for both the spontaneous ($r=0.75$, $P<0.01$) and symmetrical ($r=0.71$, $P<0.01$) foot position conditions.

Conclusions—This study revealed that individuals with hemiparesis after a stroke do not perceive themselves as asymmetrical when executing the sit-to-stand transfer and that the knee extensor strength is a factor linked to their weight-bearing asymmetry, not to their perception. (Stroke. 2010;41:1704-1708.)

Key Words: perception $\bullet$ stroke $\bullet$ weight-bearing

After a stroke, hemiparetic individuals rise from a chair by placing more weight on their nonparetic foot, although they have the capacity to perform more symmetrically on demand, with visual feedback, or by altering the foot position. The asymmetrical performance has been associated with motor weakness and loss of postural control. It is not well known whether hemiparetic subjects are aware of this asymmetry of weight-bearing (WB) and if they perceive it adequately. Few studies have focused on the perception of WB distribution during functional tasks. For upright stance, when healthy subjects (mean age: 43.6±18.0 years) were asked to bear 25%, 50%, and 75% of their weight on 1 of their lower limbs, the mean absolute errors of WB perception (absolute difference between actual WB distribution and perception) were 7.3% ($\pm 4.7\%$), 3.3% ($\pm 3.7\%$), and 7.7% ($\pm 4.8\%$), respectively. Using the same protocol with poststroke individuals revealed greater errors (WB target 25%: 9.6% [±7.0%]; WB target 50%: 5.2% [±4.0%]; WB target 75%: 9.8% [±4.0%]) of WB perception in patients than in healthy subjects. In sit-to-stand (STS), 1 study reported that the association between the hemiparetic individuals’ own estimation of WB distribution on a visual analog scale (VAS) and the actual WB distribution while rising was low ($r=0.36$). The authors concluded that their subjects were only slightly aware, if at all, of their weight distribution during the STS transfer. However, they also could not eliminate the fact that their VAS or their instructions on how to use it might not have been clear enough.

Several training interventions aimed at improving symmetry in functional tasks such as standing, walking, or STS require the ability to perceive WB adequately. Our first objective, therefore, was to compare the error between hemiparetic and healthy individuals’ perception of WB and their actual WB distribution during the STS task using a VAS with clear instructions. The second objective was to analyze possible relationships between the muscle strength of the knee extensors and the WB distribution and perception. It was hypothesized that the errors of perception for the hemiparetic participants during the STS task would be greater than those obtained for healthy individuals and that a good linear association would be found between the knee extensor strength and the WB perception and distribution for the hemiparetic participants.

Methods

Participants

To be included in this study, participants in both groups had to have a minimal activity tolerance of 3 hours with rest and be able to rise...
from a standard-height chair (45 to 50 cm) without using their arms. The hemiparetic participants had to present a residual motor impairment in the lower limb (score of ≤6 out of 7 on the Chedoke McMaster Stroke Assessment). Those presenting with comprehensive aphasia, a significant cognitive deficit (score <25 out of 30 on the Folstein Mini-Mental examination), evidence of a cardiopulmonary disease, nonstroke-related disabilities, hemineglect assessed with the Bells Test, and/or hemianopsia evaluated with the clinical test of the object moving in the visual field were excluded. The subjects in the control group had to be free of any health problems affecting the accomplishment of STS tasks. The experiment was approved by the local ethics committee and followed institutional guidelines. All subjects gave written informed consent for their participation.

### Clinical Assessment

Demographic data on all subjects were gathered. The physical examination for the hemiparetic participants was done by a physiotherapist experienced in neurology and included the Chedoke-McMaster Stroke Assessment, Index of Spasticity of Levin and Hui-Chan, and Berg Balance Scale to determine the level of motor impairment, muscle tone, and balance ability, respectively. For the control group, the last task of the Berg Balance Scale was used to evaluate balance. Subjects were asked to maintain unipedal standing for 10 seconds and the time was recorded. In both groups, place 4 identical cylinders of different weights in increasing order and perceive different weights, the subjects in both groups were asked to increase their effort to their maximal strength level for each maximal static contraction. The mean of 2 trials (values in Nm) with increase in the lower limb (score of ≤6 out of 7 on the Chedoke McMaster Stroke Assessment). Those presenting with comprehensive aphasia, a significant cognitive deficit (score <25 out of 30 on the Folstein Mini-Mental examination), evidence of a cardiopulmonary disease, nonstroke-related disabilities, hemineglect assessed with the Bells Test, and/or hemianopsia evaluated with the clinical test of the object moving in the visual field were excluded. The subjects in the control group had to be free of any health problems affecting the accomplishment of STS tasks. The experiment was approved by the local ethics committee and followed institutional guidelines. All subjects gave written informed consent for their participation.

### STS Task Assessment

To assess the STS tasks, a height-adjustable instrumented chair without a back or armrest was used to record the forces under each thigh (Figure 1A; for details, see Roy et al). The chair level was placed at 100% of the subject’s leg length. Two AMTI force plates (OR6-7 to 1000) were used to record the forces under each foot (Figure 1A). This experimental setup allowed the forces under the thighs and feet to be recorded for the entire STS task. All signals were collected at 600 Hz with a customized Labview program.

Subjects were asked to stand up at natural speed under 2 conditions of WB distribution at the lower limbs with their arms crossed on their chest: (1) a STS as they usually do (spontaneous condition). No instructions were given regarding the initial foot position; and (2) a STS with a verbal instruction to put equal WB on each side (left/right: 50%/50%) with both feet placed symmetrically at 15° of dorsiflexion (symmetrical condition). Marks on the thighs and on the ground ensured the subjects kept constant seat and foot positions between trials in a given foot condition. Two trials for each condition were executed for a total of 4 STS transfers.

Additional conditions with visual feedback were tested for the controls. The feedback represented a specific weight distribution on the right side presented on a computer screen facing the subjects. While executing the STS, the subjects were asked to place a cursor, initially at zero, in the target zone, which represented a specific WB unknown to the subject. The imposed percentages of WB, assigned randomly, were 30%, 40%, 50%, 60%, and 70% on the right leg. For each WB condition, 2 successive trials were done and each condition was performed twice randomly.

On completing each trial, the hemiparetic and healthy subjects rated their perceived WB distribution on a 10-cm VAS provided on a portable computer (Figure 1A–B). The extreme left part of the scale indicated 100% WB on the left side and the extreme right referred to 100% WB on the right side. The middle part of the line designated equal weight distribution (50%/50%). The subjects were asked to place the cursor according to their weight distribution on a computer screen facing the subjects. While executing the STS, the subjects were asked to place a cursor, initially at zero, in the target zone, which represented a specific WB unknown to the subject. The imposed percentages of WB, assigned randomly, were 30%, 40%, 50%, 60%, and 70% on the right leg. For each WB condition, 2 successive trials were done and each condition was performed twice randomly.

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### Table 1. Characteristics of the Subjects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Hemiparetic Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>57.1±13.7</td>
<td>65.0±3.8</td>
<td>0.04</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.71±0.07</td>
<td>1.67±0.1</td>
<td>0.65</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>79.8±23.3</td>
<td>76.5±17.2</td>
<td>0.23</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27.2±7.6</td>
<td>27.3±5.0</td>
<td>0.97</td>
</tr>
<tr>
<td>Male/female</td>
<td>15/4</td>
<td>7/8</td>
<td></td>
</tr>
</tbody>
</table>
the scale. All hemiparetic participants were able to rate their WB distribution themselves using their nonparetic hand.

Data Analysis
For each STS transfer, the vertical ground reaction forces on both sides were analyzed for the 2 groups. The WB distribution on each side, expressed in percent of total WB, was determined using the vertical ground reaction forces of the seat and foot averaged over a 1-second time interval (from −0.5 second before the seat-off event to 0.5 second after; Figure 1 C). This interval was chosen because it covers the largest efforts during the STS task. The seat-off event corresponded to the time when the forces on the force plates of the seat were null. The distributions of WB on the nonparetic side for the hemiparetic participants and the right side for the control subjects produced during the STS tasks were compared with the perceived WB distribution scores on the VAS.

To determine whether the healthy and hemiparetic subjects were able to judge their WB distribution accurately when they performed the STS spontaneous or symmetrical transfers, the error of perception was expressed with different references and thus characterized 4 types of error: (1) the raw error (difference between the real WB distribution and the perception) to see if the subjects underestimated or overestimated the weight under their nonparetic or right side (healthy individuals); (2) the absolute error (absolute difference between the real WB distribution and the perception) to provide the magnitude of the error of perception without considering the direction (overestimations and underestimations); (3) the normalized raw error (raw error%/of real WB distribution); and (4) normalized absolute error (absolute error%/ of real WB distribution) to allow comparison of errors within conditions, between subjects, and groups without having the influence of the magnitude of the WB distribution of each subject.

To assess the association between the knee extensor strength and the WB distribution during STS transfers, the strength values on the nonparetic or right side (healthy individuals) were expressed as a percentage of the total bilateral strength, like for the real WB distribution. All hemiparetic participants were able to rate their WB distribution accurately when they performed the STS tasks (mean score of 13 out of 15 on the Geriatric Depression Scale; all presented no sign of major depression. One rated his pain level in the lower limbs at rest as 5.5 out of 10 on the VAS and 6 rated their pain level on activity between 2.6 and 5.7 out of 10; all the others presented a pain level of ≤2 on the VAS.

Results

Characteristics of the Participants
Nineteen individuals with a chronic hemiparesis (3 to 27 years poststroke; 11 with a left hemiparesis) participated in this study (Table 1). They had a moderate level of motor impairment with a mean score of 5.2 out of 7 (±1.1) for the leg and 3.6 out of 7 (±1.4) for the foot on the Chedoke McMaster Stroke Assessment. Except for 1 that had a score of 13 out of 15 on the Geriatric Depression Scale, all presented no sign of major depression. One rated his pain level in the lower limbs at rest as 5.5 out of 10 on the VAS and 6 rated their pain level on activity between 2.6 and 5.7 out of 10; all the others presented a pain level of ≤2 on the VAS.

Table 2. WB and Errors of Perception (%) for the Hemiparetic Individuals and Healthy Subjects (Nonparetic and Right Sides, Respectively) in the Spontaneous (SP) and Symmetrical (S) Conditions

<table>
<thead>
<tr>
<th>Groups</th>
<th>Conditions</th>
<th>Mean (SD)</th>
<th>Types of Error</th>
<th>Raw</th>
<th>Normalized Raw</th>
<th>Absolute</th>
<th>Normalized Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemiparetic</td>
<td>SP</td>
<td>56.8 (6.9)</td>
<td>3.3 (8.1)</td>
<td>4.8 (13.8)</td>
<td>6.2 (6.0)</td>
<td>10.7 (9.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>55.6 (6.7)</td>
<td>4.7 (5.7)</td>
<td>7.7 (9.9)</td>
<td>6.1 (4.1)</td>
<td>10.7 (6.4)</td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>SP</td>
<td>50.0 (2.7)</td>
<td>−1.1 (3.3)</td>
<td>−2.5 (6.7)</td>
<td>2.7 (2.2)</td>
<td>5.5 (4.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>49.7 (3.5)</td>
<td>−0.5 (3.7)</td>
<td>−1.5 (7.6)</td>
<td>2.8 (2.4)</td>
<td>5.7 (5.0)</td>
<td></td>
</tr>
</tbody>
</table>

Statistical Analyses
Descriptive statistics were computed on all variables. Because the WB distribution and perception data did not differ significantly between the first and second trials, the mean of 2 trials was used in further analyses. The errors (real WB versus perception) between the 2 groups were compared with independent Student t tests. Intraclass correlation coefficients were used to evaluate the level of absolute agreement between the real WB distribution on the right side or the nonparetic side and the perceived WB as assessed by the VAS in the spontaneous and symmetrical tasks for the hemiparetic individuals and for the conditions with a visual feedback for the control group.

Pearson correlation coefficients were used to quantify the association between the knee extensor muscle strength and the WB distribution and perception in the spontaneous and symmetrical STS. The difference between sides in each group was tested with paired Student t tests. All statistics were performed with the 13th version of SPSS software and the level of significance was fixed at 0.05.

Figure 2. Scatterplot presenting the associations between the VAS scores (%) and WB at the seat-off event under the nonparetic side (%) for the hemiparetic individuals in the spontaneous (diamonds) and symmetrical (squares) STS transfer conditions. The line of identity is presented.
Perception of WB Distribution During STS Tasks

Subjects with chronic hemiparesis had a more asymmetrical WB distribution (P<0.01; Table 2) and also presented greater errors of perception than the healthy individuals (P<0.05; Table 2). The positive sign of the raw errors indicates an underestimation of the weight under their nonparetic foot (or overestimation under their paretic foot; see also Figure 2). For both groups, the mean values generally increase between the raw and the normalized absolute errors.

In the hemiparetic group, poor to moderate levels of association between the real WB distribution (force plate data) and the perceived WB (VAS scores) in the spontaneous and symmetrical STS transfer tasks were found (intraclass correlation coefficient=0.199, P=0.179 and intraclass correlation coefficient=0.393, P=0.011, respectively; Figure 2). For the control group, a very good level of association between the real and perceived WB distributions was found (intraclass correlation coefficient=0.755, P<0.001; Figure 3).

Discussion

Our hemiparetic participants presented greater errors of WB perception and their intraclass correlation coefficients between their real WB distribution and their perception were much lower than those obtained for the control group. These results support those of Bohannon and Tinti-Wald for upright stance. They found that hemiparetic individuals made significantly greater errors (5.2±4.0%) in WB than healthy subjects (3.3±3.7%). Our study also determined that the magnitude of the errors varies with the calculation method used and that each of these different ways of expressing the error of perception reveals important information. Nevertheless, all methods indicated greater errors in the hemiparetic than in the healthy individuals.

A thorough explanation for the greatest errors found in the hemiparetic group is still lacking. A plausible explanation would be...
be that they rated their perceived effort distribution rather than their weight distribution. According to previous studies, the asymmetries observed in hemiparetic subjects seem to be related to the desire to produce symmetrical levels of effort. Bertrand et al. proposed the principle of bilateral matching effort to explain the strategy chosen by hemiparetic individuals when performing bilateral matching tasks at the upper limbs. Also, Simon and Ferris demonstrated in hemiparetic subjects that, during an isometric force-matching task on a leg press machine, there was no significant difference between limbs when normalizing the forces produced by those obtained in bilateral maximum voluntary contractions. In addition, Milot et al. found that poststroke individuals during gait presented similar bilateral levels of effort estimated by a muscular utilization ratio, an index that expresses the relative involvement of a muscle in a functional task according to its maximal strength. These results suggest that the effort rather than the loading could be a dominant factor guiding muscle activation in hemiparetic individuals during functional tasks. Therefore, in the presence of muscle weakness, hemiparetic individuals who base their motor strategies on producing similar levels of effort will inevitably perform asymmetrically.

We found associations between the asymmetry of the maximal knee extensor strength and the WB in the hemiparetic group for both the spontaneous and symmetrical STS transfers. In a previous study, associations (r>0.70) were also revealed between the asymmetry of the knee extensor strength and the mechanical moments during the STS tasks. These results suggest that parietic and nonparietic knee strength play a role in the STS loading strategy. Finally, I could also argue that clinical characteristics other than strength could interfere with perception such as the location of the lesion, the presence of sensory deficit, depression, and high levels of pain. Our results do not support this idea. However, we had only a few subjects presenting these characteristics and further studies are clearly required before concluding on that aspect.

Summary

Our results revealed greater WB asymmetry and errors of WB perception in hemiparetic participants compared with healthy individuals during the STS task. We also found that the asymmetry of the knee extensor strength was associated with the WB asymmetry in hemiparetic participants but not with their perception. Nevertheless, before assuming that these individuals cannot perform symmetrically and do not perceive themselves as asymmetrical, other factors such as the sense of effort need to be studied.

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Disclosures

None.

References

Perception of Weight-Bearing Distribution During Sit-to-Stand Tasks in Hemiparetic and Healthy Individuals

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