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# The effect of foot position and chair height on the asymmetry of vertical forces during sit-to-stand and stand-to-sit tasks in individuals with hemiparesis

Guylaine Roy [a,b], Sylvie Nadeau [a,b,*], Denis Gravel [a,b], Francine Malouin [c,d], Bradford J. McFadyen [c,d], France Piotte [b]

[a] Centre de recherche interdisciplinaire en réadaptation (CRIR), Institut de réadaptation de Montréal, Canada
[b] École de réadaptation, Université de Montréal, CP 6128, Succursale Centre-ville, Montréal (Québec), Canada H3C 3J7
[c] Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS), Institut de réadaptation en déficience physique de Québec, Canada
[d] Département de réadaptation, Université Laval, Canada

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**Abstract**

*Background*. The asymmetrical motor pattern of persons with hemiparesis influences the performance of activities that require interactions between the two sides of the body.

*Methods*. Twelve subjects with a chronic hemiparesis were asked to stand up and sit down at their natural speed in the following foot positions: (1) spontaneous; (2) symmetrical; (3) asymmetrical with the affected foot placed backward; and (4) asymmetrical with the unaffected foot placed backward. Forces were recorded under each foot using two force plates and under each thigh with an instrumented chair. Each foot position was tested at two chair heights corresponding to 100% and 120% of leg length. For each condition, the duration and the asymmetry of loading expressed by the vertical forces were calculated for four different events: onset, transition (forces under feet and thighs), seat-off or seat-on and at the end of the task.

*Findings*. The time to execute the tasks ranged from 2.31 s to 3.69 s with higher values observed for the stand-to-sit task than for the sit-to-stand task. Overall, the asymmetry of vertical forces was greatest in the middle part of the tasks and was not influenced by the chair height. When the subjects were still in contact with the seat, the loading asymmetry originated from a difference between sides at both the thigh and the foot. The asymmetrical foot position with the affected foot backward promoted loading on the affected side during both tasks.

*Interpretation*. This study shows that loading asymmetry was present before seat-off and after seat-on in sit-to-stand and stand-to-sit tasks, respectively. It shows that positioning the affected foot behind reduces the asymmetry whereas positioning the unaffected foot behind increases the asymmetry. Foot position should be taken into consideration when clinicians assess or train for these mobility tasks.


*Keywords:* Stand; Sit; Kinetics; Instrumented chair; Stroke; Hemiparesis; Limb loading

## 1. Introduction

Rising from a chair and sitting down are common activities yet figure among the most mechanically demanding functional tasks undertaken daily (Riley et al., 1991). In the past two decades, researchers have studied the biomechanics of sit-to-stand (SitTS) and, to a lesser extent, stand-to-sit (StandTS) activities, in young and older

* Corresponding author. Address: École de réadaptation, Université de Montréal, CP 6128, Succursale Centre-ville, Montréal (Québec), Canada H3C 3J7.
*E-mail address:* sylvie.nadeau@umontreal.ca (S. Nadeau).

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healthy subjects (Yoshida et al., 1983; Kralj et al., 1990; Schenkman et al., 1990; Riley et al., 1991). These studies have provided a description of the normal motor pattern and task performance useful for comparison with individuals having physical impairments.

Following a stroke, the ability to perform SitTS and StandTS is reduced. Recent studies assessing these tasks in persons with hemiparesis have been conducted mainly for SitTS. They have shown that persons with a hemiparesis have a SitTS characterized by a longer duration (Yoshida et al., 1983; Engardt and Olsson, 1992; Hesse et al., 1994a; Malouin et al., 2004), by modifications of both the anterior/posterior and medial/lateral displacement of center of mass (Yoshida et al., 1983; Hesse et al., 1994a; Lee et al., 1997; Cheng et al., 1998; Chou et al., 2003) and by an asymmetrical weight-bearing pattern (Engardt and Olsson, 1992; Engardt, 1994a,b; Cheng et al., 1998; Eng and Chu, 2002; Chou et al., 2003; Malouin et al., 2004). The mean difference in body weight distribution between the affected and unaffected limbs ranges from 24% to 53% of total body weight (Hesse et al., 1994a; Cheng et al., 1998; Hesse et al., 1998; Chou et al., 2003) during the SitTS task and were found to be 44% and 48% in stroke nonfallers and fallers (Cheng et al., 1998) during StandTS. Recently, Malouin et al. (2004) found a smaller difference, with a mean limb loading of 41% on the affected limb (deficit of 15% in comparison to control group) for patients with stroke during sitting down. The altered performance has been associated with paralysis, paresis and loss of postural control (Eriksrud and Bohannon, 2003; Lord et al., 2002).

According to Brunt et al. (2002), the asymmetrical weight-bearing pattern in individuals with hemiparesis can be improved by altering the initial foot position of the unaffected limb during SitTS. When the unaffected foot is moved forward, there is no longer any significant difference between the peak vertical reaction forces of the two limbs during SitTS (Brunt et al., 2002). As weight-bearing distribution has mainly been studied under the feet during SitTS, it is not known if foot position affects the weight-bearing distribution before seat-off, when subjects with hemiparesis still have their thighs in contact with the seat of the chair. This would give clinicians information about the moment at which the asymmetry begins for the SitTS task, whether it persists after the subject makes contact with the seat in the StandTS task and, lastly, how it is influenced by foot position.

The study of Hesse et al. (1994a) showed that patients with hemiparesis shifted their center of gravity laterally by 78% more before seat-off and 50% more after seat-off than healthy subjects during the SitTS task. This reflects the strategy used by persons with hemiparesis from the beginning of the SitTS task, not only after the subject leaves the seat. In one study, where forces exerted by each thigh were recorded during SitTS in healthy persons, significant differences between sides were found (Hirschfeld et al., 1999). Thus, it is likely that asymmetry of weight-bearing would be present before seat-off in individuals after stroke but this hypothesis needs to be verified.

Previous studies have also revealed that the SitTS mechanical parameters vary with chair height. A higher chair position creates a decrease in mechanical demand, as demonstrated by lower net extension moments at the knee and hip than those calculated for a lower chair height (Burdett et al., 1985; Rodosky et al., 1989; Schenkman et al., 1996). For example, Rodosky et al. (1989) have reported that the knee extension moment was decreased by 50% by elevating the chair seat height from 65% to 115% of the knee height in healthy subjects. In terms of weight-bearing on the lower limbs during standing up, the maximum value of the vertical component of the ground reaction force decreases with the increase in chair height (Kawagoe et al., 2000). If the elevated chair height tasks are less demanding, are the individuals with hemiparesis able to perform more symmetrically compared to the standard chair height task conditions? What would be the combined effects of chair height and foot position on the level of limb-loading asymmetry during the whole SitTS and StandTS task? It is believed that this information would be relevant to clinicians involved in the rehabilitation of individuals with hemiparesis and would help them identify factors that influence the SitTS and StandTS performance.

The purpose of this study, therefore, was to analyse the effects of varying foot position and chair height on the asymmetry of the vertical reaction forces (VRFs) under the foot and thigh in the SitTS and StandTS tasks performed by individuals with hemiparesis. The asymmetry was calculated for four distinct events, namely onset, transition point that corresponds to almost equal VRFs under the foot and thigh, near-seat contact (just after seat-off in the SitTS task or just before seat-on in the StandTS task) and end of the task. Three hypotheses were verified: (1) asymmetry of the VRFs will vary during the four events, with highest values to be observed at transition (while the thighs are still in contact with seat) and near-seat contact; (2) asymmetry will be modified by the foot position with lowest and highest levels of asymmetry occurring with the affected foot placed backward and forward, respectively and the spontaneous foot condition will show a high level of asymmetry; and, (3) level of asymmetry of the VRFs will be lower for the elevated chair height than for the standard chair height since it has been shown that an elevated chair height reduces moment at lower limbs during the SitTS task.

## 2. Methods

### 2.1. Participants

A sample of convenience of 12 adults (3 females, 9 males) with chronic hemiparesis due to a cerebrovascular accident was studied. Nine presented a left-sided hemiparesis. Their mean age was 49.7 years, ranging from 27 to