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Literature review

# Determinants of sit-to-stand tasks in individuals with hemiparesis post stroke: A review

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ABSTRACT

*Background and purpose:* The ability to rise from a chair to reach a standing position is impaired after stroke. This paper aims to review for the first time the factors that impact the ability to rise from a chair and identify recommendations for post-stroke rehabilitation.

*Methods:* In order to analyse relevant scientific publications (French and English), the search terms "stroke", "rehabilitation" and "sit-to-stand" (STS and its variations) were used. The initial literature search identified 122 titles and abstracts for full review and 46 were retained because both the junior and senior researchers agreed that they were aligned with the objectives of this review.

*Results and conclusion:* During STS, most individuals with hemiparesis able to stand independently presented several changes such as lateral deviation of the trunk towards the unaffected side (ipsilesional side), asymmetrical weight bearing (WB) and asymmetry of knee moment forces. Interestingly, the WB asymmetry was observed even before seat-off, when subjects with hemiparesis still had their thighs in contact with the chair suggesting a planned strategy. Among other interesting results, the time to execute the STS was longer than in controls and influenced by the sensorimotor deficits. A greater risk of falling was observed with a need for more time to stabilize the body during STS and especially during the extension phase. Some rehabilitation interventions may be effective in improving STS duration, WB symmetry and the ability to stand independently with repeated practice (mentally or physically) of STS tasks. However, more research is essential to further investigate effects of specific training protocols and pursue better understanding of this complex and demanding task, particularly for stroke patients who need assistance during this transfer.



## 1. Introduction

Stroke is the third cause of mortality in the world [1]. As one of the most common causes of long-term disability, stroke imposes an enormous economic burden in several countries [2–4] and caring for stroke survivors put social, emotional, health and financial burdens and strains on the informal caregivers [5]. After stroke, patients usually present sensorimotor impairments contralateral to the cerebral lesion that contribute to limiting their ability to perform functional activities such as walking [6], standing [7] and sit-to-stand (STS) [8,9]. STS, which is considered a fundamental prerequisite for daily activities, is commonly compromised and individuals post-stroke do not easily recover this ability to rise safely from a chair [10]. Therefore, it is important to have a better understanding of how STS is accomplished and to know the important factors to consider in order to improve the patients' performance.

The most important determinants to consider during a STS task were already reviewed for healthy subjects [11] but not for hemiparetic individuals. Some of these determinants have been studied extensively in hemiparetic individuals and are commonly accepted, while others still need further research. The objective of this topical review is to present advances in research and clinical topics relevant to factors that may affect the ability to execute STS after stroke and to identify recommendations for post-stroke rehabilitation.

## 2. Methods

A literature review was conducted to identify relevant scientific publications concerning STS execution by people affected by

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stroke. The literature search was carried out in Medline. The search terms "stroke", "rehabilitation" and "sit-to-stand" (and its variations) were used. There was a restriction for French and English language but no restrictions for publication date or study design. From the initial literature search, 122 titles and abstracts were appraised to identify papers for full review. Among these articles, only 29 were retained because they were consistent with the objectives of this review. The reference section from each initially selected article was searched manually and 17 other relevant publications were added. Finally, the study results from 46 articles were extracted and a narrative synthesis was compiled. The content of these 46 articles was validated by a senior researcher expert with STS literature.

### 2.1. STS description

Roebroeck et al. [12] described STS as a movement of the body's center of mass (CoM) upward from a sitting position to a standing position without losing balance. Similarly, Vander Linden et al. [13] added that it is a transitional movement to the upright posture requiring movement of CoM from a stable position to a less stable position over extended lower extremities. For Galli et al. (2008) [14], STS requires skills, such as coordination between trunk and lower limb movements, muscle strength, control of equilibrium and stability.

To simplify its analysis, authors divided STS into phases that depend on kinematic variables, ground forces and CoM movement. Schenkman et al. [15] distinguished four phases. The seat-off, which refers to the moment when only the feet are in contact with the ground and no force is applied on the seat, is often used to identify STS phases. The first phase is the flexion momentum phase, which begins with the initiation of movement and ends just before the thighs lift off from the chair. The second phase, the momentum-transfer phase, begins with seat-off and continues with the anterior and upward CoM displacement. The anterior displacement of the CoM brings it close to the center of pressure (CoP) to reach a quasi-static stability position. The third phase is designated as the extension phase. It is initiated just after maximal ankle dorsiflexion is reached and continues until hips ceases to extend. The stabilization phase is the last phase of STS. It begins just after hip extension velocity reaches 0°/s and continues until all motion associated with stabilization from rising is achieved.

Other authors [12,16,17] simplified STS by referring to only two phases: STS begins with the preparatory phase defined as onset of an anterior-posterior force beneath the thighs and lasts until seat-off. The second phase is the rising or extension phase, which lasts from seat-off until CoM vertical velocity decreases to zero (Fig. 1). As it is the most recent description, we will distinguish only two phases in our review of STS determinants in the next sections. However, specific events of STS namely onset, the transition phase, the seat-off and the end of the task will also be used. These events corresponded respectively to the first perceptible changes of the vertical force on feet or thighs, almost similar forces under both feet and thighs, the point where the subject is just leaving the seat and the beginning of a stable extension of the hips in the standing position [18].

### 2.2. STS determinants in healthy individuals

STS determinants in healthy individuals have been described in a review by Janssen et al. [11]. In this section, we voluntarily limited the review to concepts that are important for the analysis in individuals post stroke.

### 2.3. Angular displacements of lower limbs and trunk

In order to rise from a chair, Nuzik et al. [19] reported that hips bent during the first 40% of the STS cycle, and then, continued with

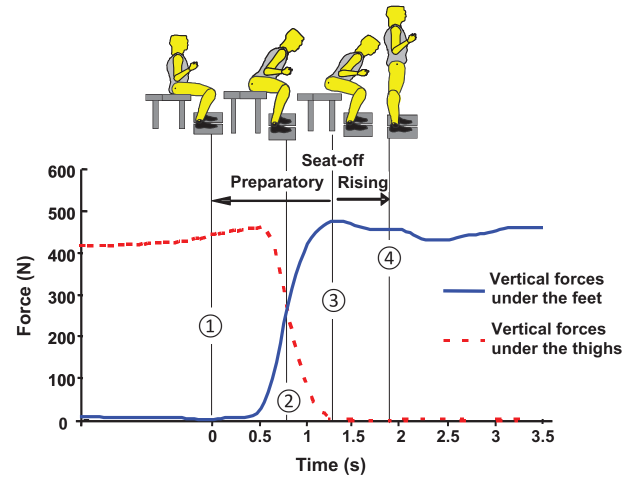


**Fig. 1.** STS phases and events. Phases: preparatory and rising: events: 1: onset, 2: transition, 3: seat-off and 4: end of STS. STS begins with the preparatory phase, defined as onset of an anterior-posterior force beneath the thighs, and lasts until seat-off. The second phase is the rising or extension phase, which lasts from seat-off (3) until center of masse (CoM) vertical velocity decreases to zero (4).

extension for the last 60%. Knees moved in extension during the whole cycle. The dorsal flexion of ankles occurred at 20% of cycle and then a plantar flexion movement was observed. When healthy subjects rose from a chair with feet placed in spontaneous (no instructions given on the initial foot position) and symmetrical (both feet placed at 15° of dorsiflexion) positions, the trunk was near the neutral position on the frontal plan during STS [9]. However, when the feet were placed asymmetrically, healthy subjects rose with the trunk deviated towards the foot placed behind [9]. On the sagittal plan, the trunk initially moved forward during the first 53.3% of the STS movement cycle with a mean distance of 489.6 mm, then upright for 49.8% of the cycle and finally backward to attain stable standing [20].

### 2.4. Muscular activation pattern of lower limbs

A bilateral specific muscular activation sequence in a concentric mode, is required to reach the standing posture from the seated position. Tibialis anterior muscles were activated first in order to stabilize the feet before beginning the forward body movement [12,13,21,22]. Tibialis anterior activation was followed by knee and hip extensor muscles, which reached their peak of activity at seat-off [23]. First, iliopsoas initiated hip flexion [22] then quadriceps, as a biarticular muscle, continued hip flexion, stabilized the knees and allowed their extension [12,21,22]. After seat-off, hamstrings decelerated the initial hip flexion and therefore promoted hip extension in order to initiate the extension phase of STS [21]. In order to balance the forward movement, the tibialis anterior provided dorsiflexion torques at the ankles to maintain the CoP in a posterior position under the feet [24]. At the end of STS, the activation of the gastrocnemius and soleus muscles enhanced control of the body's forward transition [22].

### 2.5. CoM behaviour

To rise from a chair, an individual needs to bring his CoM from a relatively large and stable base of support in sitting to a considerably smaller base of support in standing [25]. To achieve this transition, CoM must first move forward then reach its maximal velocity at the preparatory phase [12]. At seat-off, CoM switches into vertical movement and its velocity continues to accelerate until it reaches a maximum at the middle of the