A NEW METHOD TO QUANTIFY MULTIDIRECTIONAL SEATED POSTURAL STABILITY IN INDIVIDUALS WITH SPINAL CORD INJURY

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SUMMARY
Reaching an optimal level of multidirectional seated postural stability figures among the key milestones of the rehabilitation process for individuals with spinal cord injury (SCI). Despite the importance of this goal, quantitative assessment of multidirectional seated postural stability among this population has received limited attention. The objective of this study was to quantify multidirectional seated postural stability in individuals with SCI using new outcome measures obtained using a new method. Fourteen individuals with a SCI were instructed to randomly lean as far as possible in eight directions, set apart by 45° intervals, while seated on an instrumented chair with their feet placed on force platforms. Eight direction-specific stability indices, representing the ratio between the absolute COP excursion and the maximal potential COP distance, and a global stability index, representing the area defined by an ellipse fitting the mean peak COP excursion in each of the eight specific directions normalized against the area of the BOS were calculated. The direction-specific stability indices ranged from 21.2±8.5% (anterior) to 40.2±15.6% (posterior) whereas the global index of stability was 9.6±5.6% with values ranging between 2.1% (minimum) and 21.0% (maximum). These new method allows to quantify multidirectional seated postural stability in clinical practice and research protocols.

METHODS
Fourteen individuals (male/female=13/1; age = 43.07±12.94 yrs; height = 1.76±0.09 m; weight = 84.69±21.9 kg), who sustained a complete or incomplete sensori-motor SCI (AIS=A to D) located between C3 and L4 vertebral levels 10.0 ±11.4 years before the study and use a wheelchair as their primary source of mobility (>4 hrs per day in a wheelchair), participated in this study. All participants reviewed and signed an informed consent form before entering the study (CRIR-456-0809).

Participants were positioned on an instrumented height-adjustable seat with their feet on the force platforms embedded into the floor (Figure 1) [1]. Their thighs were parallel to one another with 75% of the length of the thighs in contact with the instrumented seat; their knees were flexed at ~75° and their hands were resting on their thighs. Kinematic parameters of the head, trunk, upper and lower extremities were recorded at a sampling frequency of 60 Hz, using five synchronized Optotrak motion analysis camera bars. Participants were instructed to randomly lean as far as possible in eight different directions, set apart by 45° intervals, using their natural movement strategies especially in terms of movement amplitude and velocity (Figure 2A). Two 15-second trials were recorded in each direction. To assure proper trunk movement displacement during the tasks, real-time center-of-pressure (COP) visual feedback was provided on a computer screen to highlight the target direction of the COP displacement and the requested COP trajectory.

INTRODUCTION
Many individuals with spinal cord injury (SCI) experience sensory-motor impairments that can affect their lower extremities (L/Es), trunk or upper extremities (U/Es) to a various extent. The complex synergies required to control multidirectional seated postural stability are disturbed to a various extent among individuals with SCI. These individuals are exposed to an increased risk or fear of instability or even falls, when maintaining a sitting posture or carrying out seated functional activities (e.g., reaching, weight-relief lifts, transfers, manual wheelchair propulsion, etc.). Surprisingly, quantitative assessment of multidirectional seated postural stability among individuals with SCI has received insufficient and unspecific attention to date and explains, in part, why therapists still rely almost exclusively on observational and qualitative measures for the assessment of seated postural stability. The main objective of this study was to quantify multidirectional seated postural stability in individuals with SCI using new outcome measures: eight direction-specific and a global stability indices.
Direction-specific stability indices, expressed as a percentage (%) representing the ratio between the absolute distance traveled by the COP (numerator) and the maximal potential distance the COP would have needed to travel in order to reach the BOS in the direction of the COP displacement (denominator), were computed for the two trials completed in the eight specific directions studied (Figure 2B). A global stability index, expressed as a percentage (%) representing the area defined by an ellipse fitting the mean peak COP excursion in each of the eight specific directions (numerator) normalized against the area of the BOS (denominator), was calculated (Figure 2B). These two stability indices range from 0 to 100%. Theoretically, as these stability indices increase, the closer an individual may get to the margin of stability defined by the BOS, the greater leaning capabilities or better compensatory strategies an individual may have. Alternatively, in this situation, one also needs to consider that the same individual may also become less stable when moving in a specific direction as they approach the margin of stability (safety margin). Both factors need consideration when interpreting the results and provide valuable insight on multidirectional seated postural stability.

The mean global stability index was 9.6±5.6% with values ranging between 2.1% (minimum) and 21.0% (maximum). The lowest global stability index was observed in an individual classified as having a complete C6 sensori-motor tetraplegia (last preserved sensory and motor segments = 6th cervical vertebra), whereas the highest global stability index was found in an individual classified with an incomplete L4 sensori-motor paraplegia (last preserved motor and sensory segments = 4th lumbar vertebra and 2nd sacral vertebra, respectively). These findings suggest that the level and completeness of the SCI, closely linked to the severity of the sensori-motor impairments, may be key determinants of the multidirectional seated postural stability among individuals with SCI. Moreover, these results confirmed that the capability to lean in eight different directions while seated is drastically reduced in individuals with SCI in comparison to healthy individuals who were recently found to have a global stability index of 32.7±0.4% [3].

CONCLUSIONS
This study proposes a new method to quantify multidirectional seated postural stability. The direction-specific and global stability indices may become useful outcome measures of multidirectional seated postural stability for rehabilitation professionals to characterize change over time or the impact of various treatments on multidirectional seated postural stability in clinical practice or research projects, for example. Ongoing research challenges include defining the reliability, validity and responsiveness of these measures within a large cohort of manual wheelchair users with various impairments and disabilities and healthy counterparts.

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