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Short communication

Four-way-leaning test shows larger limits of stability than a circular-leaning test

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ABSTRACT

Introduction: Limits of stability (LOS) have extensive clinical and rehabilitational value yet no standard consensus on measuring LOS exists. LOS measured using a leaning or a circling protocol is commonly used in research and clinical settings, however differences in protocols and reliability problems exist.
Objective: This study measured LOS using a four-way-leaning test and a circular-leaning test to test which showed larger LOS measurements. Furthermore, number of adaptation trials needed for consistent results was assessed.
Method: Limits of stability were measured using a force plate (Metitur Good Balance System®) sampling at 50 Hz. Thirty healthy subjects completed 30 trials assessing LOS alternating between four-way-leaning test and circular-leaning test.
Results: A main effect of methods (ANOVA:$F(1,28) = 45.86$, $P < 0.01$) with the four-way-leaning test showing larger values than the circular-leaning test (NK, $P < 0.01$). An interaction between method × directions was found (ANOVA:$F(3, 84) = 24.87$, $P < 0.01$). The four-way-leaning test showed larger LOS in anterior (NK, $P < 0.05$), right (NK, $P < 0.01$) and left direction (NK, $P < 0.01$). Analysis of LOS for the four-way-leaning test showed a difference between trials (ANOVA:$F(14,392) = 7.81$, $P < 0.01$). Differences were found between trial 1 and 7 (NK, $P < 0.03$), trial 6 and 8 (NK, $P < 0.02$) and trial 7 and 15 (NK, $P < 0.02$). Four-way-leaning test showed high correlation (ICC > 0.87) between first and second trial for all directions.
Conclusion: Four-way-leaning test yields larger LOS in anterior, right and left direction making it more reliable when measuring LOS. A learning effect was found up to the 8th trial, which suggests using 8 adaptation trials before reliable LOS is measured.

1. Introduction

Balance can be defined as capacity to maintain the projected center of mass within limits of stability (LOS), without changing the base of support [1]. Elderly's LOS have been of interest as authors postulate that LOS may help understanding balance impairments [2,3]. However no standard consensus on measuring LOS exists [2,4] as different protocols and number of trials are used [2,4,3,5–9].

Different systems are used to assess LOS. The NeuroCom Balance Master measures LOS using an eight-way leaning protocol [6] showing high reliability [3]. Biodex Balance System™ uses a suspended movable circular force plate that tilts in any direction [4,6], showing good reliability [6], although NeuroCom Balance Master® yields better LOS measures using a leaning protocol [4]. Regular force plates outputting center of pressure (COP) have also been used when assessing LOS, using leaning [2,3,5] and circling [7,8] protocols, showing better results than aforementioned systems [5].

Despite the leaning protocols popularity, recent studies have used a circling protocol [6–8] emphasizing the lack of a standardized LOS measuring protocol [2,4]. The objective of this study is to investigate whether a circular-leaning or

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four-way-leaning test yields the larger LOS measurements and reliability between trials.

2. Method

2.1. Participants

Thirty healthy subjects (16 males) aged 23.0 ± 2.2 years, height 178.1 ± 11.4 cm, weight 75.2 ± 12.7 kg, without neural and muscular deficits volunteered and signed an informed consent. The study was in accordance with the Helsinki Declaration, approved by the local Ethics Committee (N-20120077).

2.2. Setup

A force plate (Metitur Good Balance System®) was placed 3 m from a wall. The force plate, an equilateral triangle (800 mm), had four strain gauge transducer signals converted by a three-channel DC amplifier and transformed to digital data (50 Hz) and subsequently filtered digitally, using a three-point median filter and IRR filter, with 20 Hz cut-off frequency. Subjects positioned heels 25 cm apart [8] and feet angled 8°. Subjects focused on a wall-mounted cross (10 × 10 cm) at height 170 cm, and leaned without lifting their feet.

2.3. Protocol

Subjects performed 30 trials alternating between the four-way-leaning and circular-leaning test after completing one familiarization of both. Subjects stood with arms crossed and hands resting on their shoulders. The four-way-leaning test involved a voice guided 8 s self-paced erect lean in anterior, right, posterior and left direction, returning to center after each direction. The circular-leaning test involved a 35 s self-paced clockwise circular erect lean exploring LOS initiated by leaning anterior and circling until time passed [8]. Trials were discarded and repeated if subjects lost ground contact (visually inspected). Subjects were asked to reach for their maximum distance from the starting position.

2.4. Statistical analysis

The COP position was calculated from the vertical forces and LOS was quantified as the maximum COP displacement for each direction [2]. A three-way Repeated Measures ANOVA analyzed LOS [factors: methods (four-way-leaning vs. circular-leaning test),

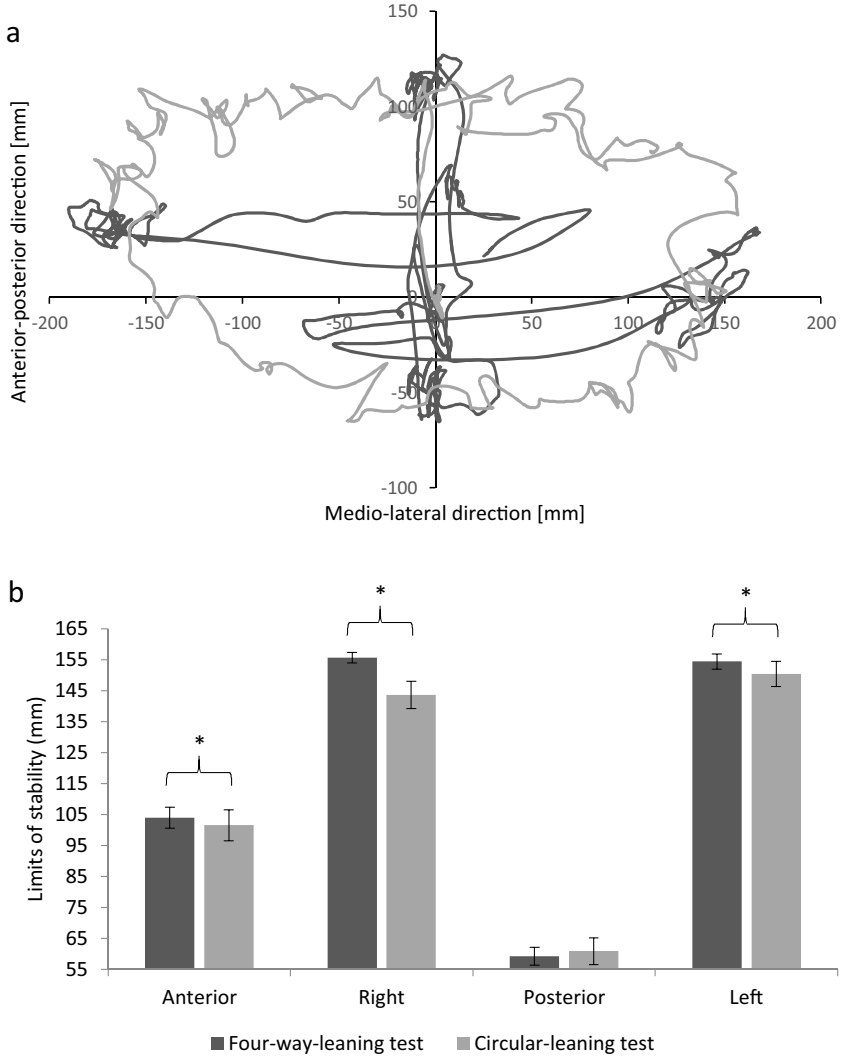

Fig. 1. Limits of stability measurements for the four-way-leaning test and the circular-leaning test. A) Example of bidimensional center of pressure trajectory for a representative subject during the four-way-leaning test (dark grey) and the circular-leaning test (light grey). B) Mean (±standard deviation) limits of stability for all subjects in each direction. * = indicates significant difference between methods ($P < 0.05$).