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The effect of weight-bearing asymmetry on dynamic postural stability in healthy young individuals

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ABSTRACT

Background: In people with lateralized disorders, such as stroke, Weight-Bearing Asymmetry (WBA) is common. It is associated with postural instability, however, WBA is one of several abnormalities that may affect postural stability in these disorders. Therefore, we investigated the isolated effects of WBA on dynamic postural stability in healthy individuals.
Methods: Ten young participants were subjected to multidirectional stance perturbations by support surface translations at three levels of WBA (0, 10 and 20% of body weight unloading of one leg). The stepping threshold was determined iteratively for each condition and in four perturbation directions (forward, backward, leftward and rightward). The stepping threshold was defined as the highest perturbation intensity recovered from with a feet-in-place response. The Margin of Stability (MOS) at the stepping threshold was defined as the smallest distance between the vertical projection of the Extrapolated Center of Mass (XCOM) and the edge of the base of support.
Results: WBA decreased the stepping threshold (stability decreased) for perturbations towards the loaded side (translations towards the unloaded side), whereas it increased stepping thresholds for perturbations towards the unloaded side. No significant effects of WBA were found on the MOS. WBA increased the frequency of stepping with the unloaded leg upon forward and backward perturbations.
Conclusion: WBA increased dynamic stability towards the unloaded leg following external balance perturbations and resulted in a greater probability of stepping with this leg. Future studies are needed to evaluate the functional significance of these WBA-related effects on postural stability in people with lateralized disorders.

1. Introduction

Postural instability is a common symptom of lateralized disorders, such as stroke. In addition, these patients often demonstrate weight-bearing asymmetry (WBA) in favor of the unaffected leg [1]. In cross-sectional studies, greater WBA was found to be associated with reduced postural stability during quiet stance [2–4]. In clinical populations, however, WBA is only one of the many deficits that may influence postural instability. Therefore, the functional significance of WBA with regards to postural instability in individuals with lateralized disorders is not fully understood.

Studies that investigated the isolated effects of WBA on postural stability in healthy individuals have already provided important insight. In two previous studies that manipulated WBA in healthy young subjects using a within-subjects design, postural sway during quiet standing was found to increase with greater WBA [5,6]. In addition, WBA resulted in a kinetic regulation asymmetry with a larger contribution of the loaded leg in terms of ankle torques with increased WBA [5,7]. However, these effects of WBA were very small at levels of WBA equivalent to those commonly observed in patients (e.g. 10% extra body weight on the non-paretic leg) [5]. Furthermore, WBA was also found to modulate postural reflexes in response to translational perturbations in healthy subjects [8]. Postural reflex magnitude was larger when more weight was borne on the leg [8], which appears to partly underlie the larger torques that the loaded leg generates under WBA conditions.

An important unanswered question is whether WBA affects dynamic stability following external balance perturbations.

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Usually, low intensity perturbations can be overcome with a feet-in-place response, whereas stepping or grabbing for support becomes necessary to prevent falling following high intensity perturbations. We were particularly interested in the effects of WBA on the transition from feet-in-place to change-in-support reactions, as this so-called 'stepping threshold' has recently been associated with fall risk in daily life [9].

The aim of this study was to evaluate the effect of WBA on stepping thresholds, defined as the maximum perturbation intensity that could be sustained with a feet-in-place response. We expected WBA to result in a higher stepping threshold (i.e. more postural stability) upon perturbations towards the unloaded leg as the initial center of mass (COM) position is shifted towards the other leg, thereby creating a larger safety margin towards the unloaded side. Consequently, the stepping threshold towards the loaded leg was expected to be lower (i.e. less postural stability) with larger WBA. For forward and backward perturbations, we hypothesized that WBA would not have major effects on the stepping thresholds. We also investigated whether, following high intensity perturbations, stepping leg preference was influenced by WBA. As stepping requires a quick unloading of the stepping leg, we expected that WBA would increase the frequency of stepping with the leg that was unloaded prior to the perturbation [10].

2. Methods

2.1. Participants

Ten healthy young individuals (one male, nine females) with a mean age of 25 years (SD 4 years) participated. To be included, they had to be free of neurological, orthopedic or vestibular disorders that could interfere with the test results. All subjects gave written informed consent. The study adhered to the guidelines of the local medical ethical committee and was conducted in accordance with the Declaration of Helsinki.

2.2. Experimental setup

Multidirectional stance perturbations were delivered by a moveable platform (Radboud Falls Simulator, 120 × 180 cm Baat Medical, Enschede, The Netherlands; Fig. 1) with two embedded force plates (AMTI Custom 6 axis composite force platform, Watertown, USA). The platform could suddenly and unexpectedly translate in the forward, backward, leftward or rightward direction [11]. Note that a backward translation resulted in a forward perturbation and vice versa. We will refer to the direction of the perturbations. Perturbations comprised an acceleration (300 ms), constant velocity (500 ms), and deceleration phase (300 ms). The participants were secured by a safety harness attached to a sliding rail on the ceiling, which allowed frictionless movement of the cable in forward and backward directions.

2.3. Experimental protocol

Participants stood on the platform with bare feet in a standardized position (inter-heel distance 17 cm and toes placed outward with a 9° rotation angle with respect to the sagittal midline [1,5]) and with the hands folded at umbilical level. They were instructed to respond naturally to the perturbations, but without grabbing the rails surrounding the platform. Prior to each trial, the investigator provided verbal feedback regarding the weight distribution based on visual inspection of the vertical ground reaction forces. The perturbation direction was unknown in advance and the onset of perturbation was randomly varied between ~2 and 6 s after verbal feedback was given.

Participants were subjected to three conditions of imposed WBA (0, 10 and 20% of body weight unloading of one leg). The unloaded leg was the dominant leg (i.e. the leg that was used to kick a ball) in half of the participants and the non-dominant leg in the other half. For each subject, the stepping threshold was determined in three conditions of WBA and in four perturbation directions (forward, backward, rightward, leftward). The order of the conditions was balanced among participants.

The stepping threshold was determined by gradually increasing the perturbation intensity with increments of 0.125 m/s^2 according to the protocol used in a previous study [12]. For the condition that was performed first, the starting intensity was based on pilot experiments. The starting intensity was set at 0.875 m/s^2 for forward perturbations and at 0.375 m/s^2 for backward perturbations. For lateral perturbations the starting intensity depended on

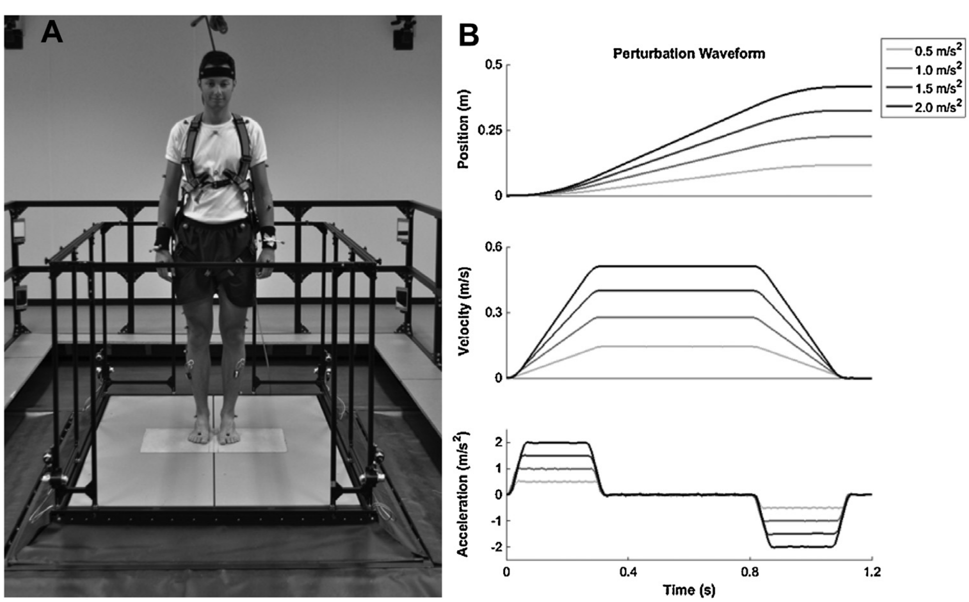

Fig. 1. A: The experimental setup consisted of a moveable platform with two embedded force plates (120 × 180 cm). The platform could translate in the forward, backward and both sideways directions. B: Perturbation profiles. The perturbation waveform consisted of a 300 ms acceleration, 500 ms constant velocity and 300 ms deceleration phase.