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Double-leg stance and dynamic balance in individuals with functional ankle instability

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ABSTRACT

To investigate whether double-leg stance could reveal balance deficits in subjects with functional ankle instability (FAI) and whether such an assessment of static balance would be correlated with measures of dynamic instability, 16 individuals with FAI and 16 healthy controls participated in this study. Static postural control was tested using double-leg stance (either with the eyes open (EO) or closed (EC)) on a dual-plate force platform. Dynamic balance was evaluated using the Multiple Hop Test (MHT) and a weight-shifting task. FAI subjects were significantly less stable in the anteroposterior direction during double-leg stance (as assessed by velocity of centre of pressure, VCP), both for the EO and EC condition. In the mediolateral direction the VCP values were also higher in FAI, but significance was only found for the EC condition ($p = .02$). FAI subjects made significantly more balance errors compared to healthy controls ($p < .001$) on both the affected and less affected leg during MHT. There were no significant differences between FAI and healthy subjects during the weight-shifting task. No relationship was found between double-leg stance and MHT measures (all correlations (r_s) less than .30). This study suggests that static postural control during double-leg stance is impaired in FAI subjects. Although dynamic balance during MHT is also affected, no significant relationship was found between static and dynamic measurements, which indicate that they are most probably related to different aspects of postural control.

1. Introduction

After suffering an initial lateral ankle sprain, within a period of 3 years, as much as 34% of the patients will report at least one re-sprain with many more reporting other continual residual symptoms [1]. In the literature inconsistencies exist regarding the exact percentage of individuals who develop chronic ankle instability (CAI), ranging from approximately 20% up to 70% [2–4]. Residual symptoms after an initial ankle sprain incident, which include recurrent sprain, episodes of ankle joint "giving way", pain, swelling, and decreased function, have been termed CAI [5]. CAI may be attributed to mechanical instability or functional ankle instability (FAI) or to a combination of both [5,6]. Mechanical instability is defined as joint motion beyond the normal physiological range of motion [5]. FAI is the phenomenon of recurrent persistent symptoms in the absence of aberrant mechanical laxity [5].

Although the basis for FAI is still unknown, most evidence points towards a central mechanism [7,8] which includes deficits in sensorimotor control and neuromuscular control [3,9,10]. Supraspinal adaptations to motor control may be an important contributor to the underlying neurophysiologic mechanism of CAI [7]. One strong argument is that both the involved and the uninvolved leg are affected during single-leg stance [9,10]. If indeed the basic deficit for unilateral sprain is bilateral, also double-leg stance is expected to be affected. However, an early study has failed to show significant differences between CAI subjects and healthy controls during double-leg stance using the sway index (a numerical value of the standard deviation of the time and distance the subject spent away from his/her centre of balance) [11]. Subsequent studies have investigated single-leg stance when comparing the affected ankle to either the less affected ankle or to the ankles of healthy controls [5,12–15]. For single-leg stance individuals with CAI showed impaired single-leg stance for some parameters while not for others. A meta-analysis [16] revealed that the category "area" for centre of pressure (COP) parameters in CAI was not sensitive enough to detect differences,

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whereas other measurement categories which are time and velocity dependent have all shown significant differences between FAI subjects and healthy controls. Furthermore, different inclusion criteria among the studies has also led to differences in outcome [5,16]. Therefore, one may wonder whether the choice of balance outcome measures in earlier studies was related to the failure to detect differences in double-leg stance between CAI and controls. Furthermore, because the question of central changes and bilateral impairments after ankle sprains is especially interesting for subjects without mechanical instability, the focus should be on the FAI subgroup rather than the CAI group as a whole.

Hence the first goal of this study was to reevaluate double-leg stance for FAI subjects using the velocity of centre of pressure (VCP) as outcome parameter [17,18]. We hypothesized that double-leg stance would be less stable in FAI subjects, even those affected unilaterally, and would result in an increased VCP compared to healthy controls.

The second question relates to the need for dynamic testing. Recently, it has been argued that dynamic balance is possibly more relevant than static balance because most ankle sprains occur during dynamic conditions [14,19,20]. However, others have suggested that static measures are more sensitive to detect differences [16]. Therefore, the present study compared static and dynamic measures in the same subjects using two promising new methods to evaluate dynamic balance. The simple weight-shifting paradigm, used by Van Deun et al. [19] and Levin et al. [21], showed that CAI subjects were consistently slower than controls in activating their muscles to initiate the weight shift needed to change from a double to a single-leg stance and needed more time to stabilize while shifting weight. In our laboratory a similar approach had been used in a previously developed weight-shifting task on a dual-plate force platform [17].

The second dynamic measure is the Multiple Hop Test (MHT) proposed by Eechaute et al. [22,23]. Performing multiple hops significantly challenges the postural control system and has been shown to be a reliable and valid instrument for assessing dynamic postural control: it is able to detect differences between FAI subjects and controls [22,23].

Hence the second goal of the present study was to determine the relation between the performance during static double-leg stance and the dynamic postural control tests in FAI subjects. We hypothesized that dynamic postural control will be affected during both the weight-shifting task and the MHT. However, because static and dynamic tests evaluate different aspects of postural control [13], we hypothesized that a strong correlation between the two measures may not be found.

2. Methods

Sixteen young adults with a self-reported history of FAI (seven unilateral and nine bilateral) and 16 healthy adults (Table 1) participated. The inclusion of FAI subjects was based upon the completion of a questionnaire containing the FAI criteria. FAI was defined as a history of a traumatic lateral ankle sprain without mechanical ankle instability, which resulted in recurrent episodes of giving way and ankle sprains, in daily life or during sports activities. In the past two years these occurred at least three times per year. A subject was considered to be bilaterally affected if both ankles met the FAI criteria. The anterior drawer test was used to determine mechanical ankle instability [24]. Exclusion criteria for both groups were pathologies other than ankle sprains. All subjects performed sports activities at least 1.5 h per week. If a subject reported bilateral ankle instability, the self-reported worst limb with most episodes of giving way was considered to be the affected leg. Leg dominance was determined by using a kicking preference test. All subjects were informed about the purpose of the study and gave their written informed consent prior to participation. The Arnhem–Nijmegen Medical Ethics board approved the protocol.

2.1. Double-leg stance

Double-leg stance was measured using a dual-plate force platform, as previously described [25]. Subjects stood barefoot with the feet against a foot frame [25]. During the double-leg stance task, subjects were asked to stand as quietly as possible for a 30-s period. This was repeated three times during both the eyes open (EO) and the eyes closed (EC) conditions. Between the trials there was a rest period of 1 min.

2.2. Weight shifting

For the weight-shifting task, the subjects stood on the same force platform as previously described [17]. The COP position was displayed on a monitor in front of the subject. Two stationary targets (3 cm × 3 cm) were presented on either side of the virtual vertical in the middle of the screen which corresponded to the sagittal midline of the body. The position of the centres of the two targets was scaled to the base of support of the subject. In this way approximately 65% of the body weight on one limb was required to bring the cursor from the sagittal midline to the middle of the target. In practice the distance between the two centres of the targets (in cm) on the screen was (0.15 × stance width) × 2. Subjects were asked to perform as many successful weight shifts as possible in a 30-s period. During these 30 s the subjects had to bring their weight from one target to the other as quickly and smoothly as possible. Once the subject reached the target and the cursor was held within it for at least one second, the targets changed colours and the subject had to move to the other target.

Three repeats were performed, with one-minute rest periods in between.

2.3. Multiple Hop Test

For the MHT described by Eechaute et al. [22,23], a numbered floor pattern was marked with 11 pieces of 2 cm by 2 cm white, inelastic tape (Fig. 1A). Subjects had to try to maintain their balance when hopping and to avoid any postural correction or balance errors. Subjects were only allowed to continue hopping to the next tape marker after they regained balance. During the tests, subjects were videotaped. Subjects performed the hop test on one leg with a 30-s rest before switching to the other leg. This was repeated three times with a 3-min rest period between the repeats. The order of the starting leg was randomized for the first repeat and then alternated per repeat.

2.4. Analysis and statistics

The force platform data (sample frequency: 500 Hz) were amplified and filtered with a cut-off frequency of 30 Hz. The COP data were low-pass filtered with a cut-off frequency of 6 Hz. In double-leg stance the outcome parameters were the VCP's in mediolateral (ML) and anteroposterior (AP) direction (based on the root mean square). For each subject the median VCP in both directions over three trials was used for further analysis. Outcome parameters for the weight-shifting task were the number of correct weight shifts and the disfluency amplitude in ML direction during weight shifts (disfluency is a measure of the deviation (mm) from the shortest path between the two targets) [26].

The primary outcome for the MHT was the number of balance errors [27]. Balance errors were also classified as either change in support strategy errors (CSS-errors) or fixed support strategy errors (FSS-errors). CSS-errors include falling,

Table 1
Subject characteristics (mean ± SD).

	FAI group ($n = 16$)			Healthy control group ($n = 16$)
	Total ($n = 16$)	Uni ($n = 7$)	Bi ($n = 9$)	
Sex	4M, 12F	2M, 5F	2M, 7F	4M, 12F
Age (years)*	22.4 ± 2.9	21.7 ± 1.8	23.1 ± 3.7	24.6 ± 3.1
Height (cm)	176 ± 10	181 ± 10	172 ± 7	174 ± 6
Weight (kg)	73.13 ± 10.13	72.82 ± 8.73	73.40 ± 11.77	70.53 ± 9.50
Body mass index (kg m^{-2})	23.57 ± 3.48	22.15 ± 2.15	24.83 ± 4.06	23.16 ± 2.67
Sport activity (h/week)	5.1 ± 2.8	6.6 ± 1.7	3.7 ± 2.9	3.6 ± 1.7

Subject characteristics (mean ± SD) of the functional ankle instability (FAI) group (unilateral (uni) and bilateral (bi) FAI) and healthy control group.
* Significant difference between FAI and healthy controls ($p = .02$).