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Frontal and Sagittal Plane Lower Extremity Mechanics during Single-Limb Squatting in Chronic Ankle Instability

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Background

Chronic ankle instability (CAI) is a common sequelae to the lateral ankle sprain (1).

Individuals with CAI have a higher risk of developing osteoarthritis and reporting lower quality of life scores (2,3).

Biomechanical variations have been observed in individuals with CAI during ambulation and landing (4,5).

The single-limb squat (SLS) is a commonly used clinical assessment. However, to the authors' knowledge there are no studies investigating the biomechanical profile of the SLS in individuals with CAI.

Purpose

The purpose of this study was to perform a bilateral comparison of sagittal and frontal plane joint angles and moments during a SLS in individuals with unilateral CAI.

Hypothesis

We hypothesized that inter-limb biomechanical differences would be observed in individuals with unilateral CAI.

Participants

All participants were recruited from a university setting and provided written informed consent.

Individuals were included if they reported a history of at least 1 ankle sprain > 3 months prior to participation and scored > 10/37 (6) on the Identification of Functional Ankle Instability (IdFAI) scale (Figure 1).

Participants were excluded if they had a recent ankle sprain (within the last 3 months), had a history of lower extremity surgery, or had any current lower extremity or spinal injury.

Methods

All participants completed a single data collection in a laboratory setting. Weight-bearing (WB) dorsiflexion (DF) range of motion (ROM) was assessed bilaterally using established methods (7) (Figure 2).

Individuals were then prepared for motion analysis using 47 reflective markers. Makers were placed on the L5-S1 interspinous space and bilaterally on iliac crests, anterior superior iliac spines, greater trochanters, lateral and medial femoral condyles, lateral and medial tibial plateaus, lateral and medial malleoli, distal foot, and first and fifth metatarsal heads. Tracking clusters were placed on the thigh, shank, and heel.

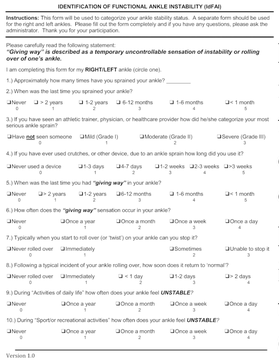
Data were collected using an 8-camera motion analysis system (Vicon, Centennial, CO, 150 Hz) with a floor-mounted force plate (Bertec Corp, Columbus, OH, 1500 Hz).

Table 1: Descriptive data expressed as mean (standard deviation) or frequencies

Sex (F:M)	Age (yrs)	BMI (kg/m^2)	IdFAI	Leg Dominance (R:L)	Side of CAI (Dom:Nondom)
9:6	23.6 (2.1)	24.34 (2.87)	17.07 (4.76)	14:1	10:5

Table 2: Bilateral joint angles (degrees), internal moments (Nm/(kg*m)), and ground reaction forces (body weights) expressed using mean (standard deviation)

	Involved	Uninvolved	*p*-value
Weight-Bearing Dorsiflexion ROM	42.0 (6.2)	45.5 (4.3)	***0.050***
Peak Hip Flexion Angle	80.7 (9.8)	79.3 (9.6)	0.418
Peak Hip Adduction Angle	21.3 (5.7)	22.3 (3.2)	0.513
Peak Knee Flexion Angle	73.0 (9.1)	76.2 (7.6)	0.127
Peak Knee Abduction Angle	2.2 (3.1)	2.3 (3.1)	0.973
Peak Ankle Dorsiflexion Angle	26.5 (6.6)	29.9 (5.5)	***0.010***
Peak Ankle Eversion Angle	13.1 (3.3)	13.0 (3.1)	0.917
Peak Hip Extension Moment	0.92 (0.33)	0.88 (0.26)	0.547
Peak Hip Abduction Moment	0.60 (0.11)	0.62 (0.09)	0.459
Peak Knee Extension Moment	0.69 (0.20)	0.74 (0.16)	0.212
Peak Knee Abduction Moment	0.38 (0.09)	0.37 (0.10)	0.660
Peak Ankle Plantarflexion Moment	0.55 (0.13)	0.63 (0.09)	***0.008***
Peak Ankle Inversion Moment	0.09 (0.02)	0.10 (0.03)	0.055
Vertical Ground Reaction Force	1.33 (0.42)	1.32 (0.40)	0.549



IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? _____

2.) When was the last time you sprained your ankle?
❑Never ❑> 2 years ❑1-2 years ❑6-12 months ❑1-6 months ❑< 1 month
0 1 2 3 4 5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?
❑Have not seen someone ❑Mild (Grade I) ❑Moderate (Grade II) ❑Severe (Grade III)
0 1 2 3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?
❑Never used a device ❑1-3 days ❑4-7 days ❑1-2 weeks ❑2-3 weeks ❑>3 weeks
0 1 2 3 4 5

5.) When was the last time you had **"giving way"** in your ankle?
❑Never ❑> 2 years ❑1-2 years ❑6-12 months ❑1-6 months ❑< 1 month
0 1 2 3 4 5

6.) How often does the **"giving way"** sensation occur in your ankle?
❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day
0 1 2 3 4

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?
❑Never rolled over ❑Immediately ❑Sometimes ❑Unable to stop it
0 1 2 3

8.) Following a typical incident of your ankle rolling over, how soon does it return to "normal"?
❑Never rolled over ❑Immediately ❑< 1 day ❑1-2 days ❑> 2 days
0 1 2 3 4

9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE***?
❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day
0 1 2 3 4

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE***?
❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day
0 1 2 3 4

Version 1.0

Figure 1: IdFAI tool

Figure 2: Weight-bearing DF ROM using smartphone inclinometer

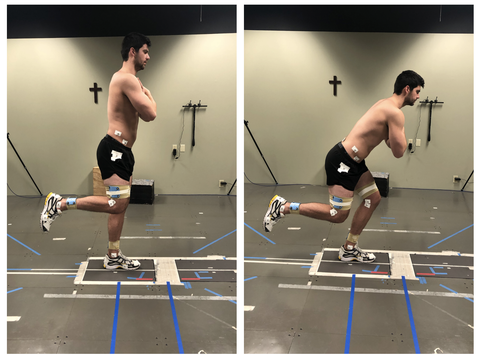


Figure 3: Example of SLS starting and peak descent positions. Participants maintained arms across chest and contralateral knee flexion.

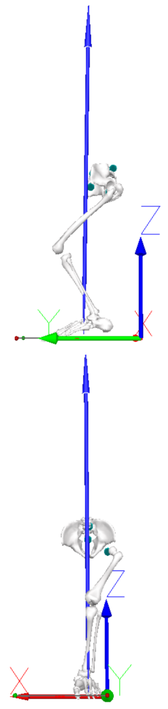


Figure 4: Example of SLS rendering in Visual 3D

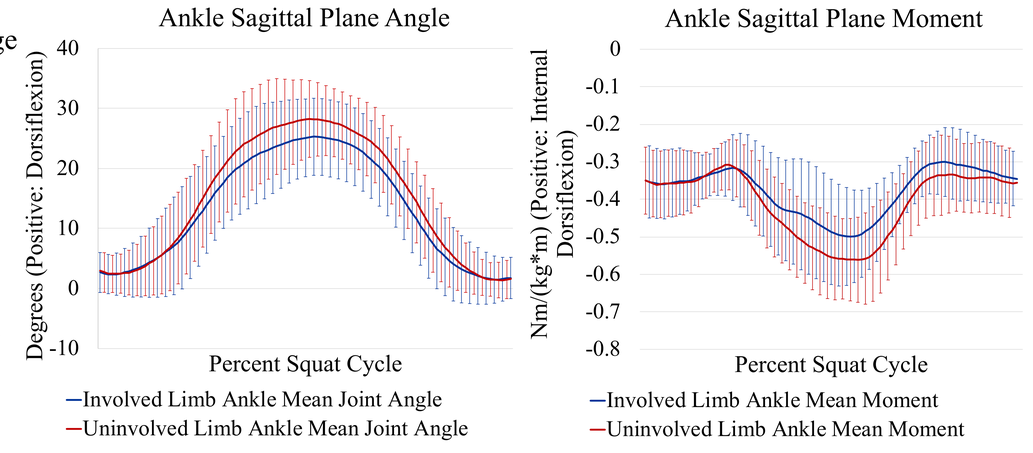


Figure 5: Sagittal plane ankle angles and moments demonstrated peak differences during the SLS task

Methods (continued)

Participants performed the SLS with their stance limb on the force plate, arms crossed, and their non-stance limb knee flexed to 90 degrees with their thigh vertical (Figure 3). A trial was defined as 3 continuous repetitions at a free speed to maximum depth. Five SLS trials were collected bilaterally.

For the middle squat from each trial, marker trajectories were identified and gap-filled in Vicon Nexus software. Data were then exported as C3D files for analysis in Visual 3D software (Figure 4) (C-motion, Germantown, MD).

Variables of interest included peak hip, knee, and ankle sagittal and frontal plane joint angles and internal moments, as well as peak vertical ground reaction force.

Paired t-tests were performed between limbs using α=0.05.

Results

Descriptive data are presented in Table 1, and dependent variables in Table 2.

There was approximately 3 degrees less WB DF ROM (p=0.050) and peak DF angle on the involved limb (p=0.010). The peak plantarflexion moment was approximately 13% less (p=0.008).

Post-hoc correlation of WB DF and peak ankle DF showed a moderate relationship (r=0.66).

Discussion/Conclusions

Individuals with CAI demonstrated reduced ankle DF during both clinical ROM assessment and during the SLS task.

The reduced internal ankle plantarflexion moment supports previous results seen in single-leg landing in those with CAI (5).

Frontal plane angles and moments did not differ between limbs.

Clinical Relevance

The clinical assessment of WB DF coincided with reduced DF mechanics during the SLS. The data suggest that interventions to increase DF ROM may facilitate improvement in SLS symmetry.

The unexplained variance between WB DF and SLS ankle mechanics suggests that factors such as strength, neuromuscular control and kinesiophobia may also affect SLS performance.

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