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Bilateral Proprioceptive Evaluation in Individuals With Unilateral Chronic Ankle Instability

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Context: Despite extensive research on chronic ankle instability, the findings regarding proprioception have been conflicting and focused only on the injured limb. Also, the different components of proprioception have been evaluated in isolation.

Objective: To evaluate bilateral ankle proprioception in individuals with unilateral ankle instability.

Design: Cohort study.

Setting: Research laboratory center in a university.

Patients or Other Participants: Twenty-four individuals with a history of unilateral ankle sprain and chronic ankle instability (mechanical ankle instability group, n = 10; functional ankle instability [FAI] group, n = 14) and 20 controls.

Main Outcome Measure(s): Ankle active and passive joint position sense, kinesthesia, and force sense.

Results: We observed a significant interaction between the effects of limb and group for kinesthesia ($F = 3.27$, $P = .049$). Increased error values were observed in the injured limb of the FAI group compared with the control group ($P = .031$, Cohen d = 0.47). Differences were also evident for force sense ($F = 9.31$, $P < .001$): the FAI group demonstrated increased error versus the control group (injured limb: $P < .001$, Cohen d = 1.28; uninjured limb: $P = .009$, Cohen d = 0.89) and the mechanical ankle instability group (uninjured limb: $P = .023$, Cohen d = 0.76).

Conclusions: Individuals with unilateral FAI had increased error ipsilaterally (injured limb) for inversion movement detection (kinesthesia) and evertor force sense and increased error contralaterally (uninjured limb) for evertor force sense.

Key Words: functional ankle instability, mechanical ankle stability, joint position sense, kinesthesia, force sense

Key Points

- Participants with functional ankle instability presented bilateral decreased evertor force sense.
- They also displayed decreased kinesthesia sense in the injured limb.
- In addition, bilateral proprioceptive impairments were evident.

Even for simple tasks, motor control is a plastic process that undergoes constant review and modification based on the integration and analysis of sensory input, efferent motor commands, and resultant movements. Proprioceptive information stemming from joint and muscle receptors plays an integral role in this process.[1] Specifically, the role of proprioceptive information from the ankle muscles has been highlighted.[2] *Proprioception* includes joint position sense, kinesthesia, and force sense, and each component can be impaired by an ankle sprain.[3]

It has been claimed that impaired proprioception contributes to chronic ankle instability (CAI).[4] However, the results have been contradictory. Increased error in the joint position sense of the chronically unstable ankle over that of the uninjured group[5,6] (between groups) and over the contralateral healthy side (within group)[7] has been demonstrated. Yet considerable evidence has demonstrated no side-to-side differences in individuals with unilateral CAI[8,9] and no differences between individuals with CAI and healthy controls.[10,11] Even though the movement-detection threshold for ankle inversion and eversion was delayed in the injured limb compared with the contralateral uninjured limb in individuals with CAI,[7] no side-to-side differences were seen.[12] In addition, no differences have been reported between individuals with CAI and healthy controls.[13] One reason for these divergent findings could be discrepancies in participant inclusion criteria and the definitions of CAI, mechanical instability, and functional instability used in the literature.[14]

In the healthy ankle, a conscious sense of passive joint motion is in part attributed to the type II mechanoreceptors embedded in the capsular, ligamentous, and adipose structures of the joint complex.[15] The finding of a diminished sense of passive movement into inversion after a supination injury supports the belief that an acute inversion sprain causes trauma and loss of function of these mechanoreceptors.[16] More recent studies have demonstrated that injecting a local anesthetic into these structures does not affect kinesthesia or active joint position sense[4] but decreases passive joint position sense.[11] These results, together with evidence that injecting an anesthetic into the ankle ligaments failed to alter postural stability,[17] indicate that healthy individuals seem to rely on neuromuscular spindles, which act as receptors related to muscle length, to guarantee joint stability.

In CAI, the sensitivity of the muscle spindles can be impaired. It has been demonstrated that joint afferents, together with muscle afferents and descending supraspinal

Table 1. Group Characteristics

Variables	Group			*P* Value
	Control (n = 20)	Functional Ankle Instability (n = 14)	Mechanical Ankle Instability (n = 10)	
Age, y, mean ± SD	21.8 ± 2.21	20.4 ± 2.92	20.8 ± 2.34	.08
Height, cm, mean ± SD	178.0 ± 9.0	175.0 ± 10.0	177.0 ± 8.0	.72
Mass, kg, mean ± SD	73.8 ± 11.5	69.0 ± 12.3	70.5 ± 11.1	.49
No. of previous ankle sprains	NA	3.5 ± 1.76	2.7 ± 1.34	.70
Frequency of giving way, No.				.22
Rarely	NA	4	4	
Frequently	NA	7	3	
Often	NA	3	3	
Severity of ankle sprain, No.				.30
Severe	NA	0	1	
Moderate	NA	13	9	
Mild	NA	1	0	
Time since last sprain, mo, mean ± SD	NA	7.7 ± 4.08	10.4 ± 1.72	.14

Abbreviation: NA, not applicable.

commands, increase γ motoneuron activation.[18] In this sense, decreased ankle-joint afferents could lead to decreased γ motoneuron activation and consequent decreased muscle-spindle sensitivity.[3] Besides the decreased unilateral joint afferents, decreased bilateral muscle-spindle sensitivity after a unilateral ankle sprain can be hypothesized. This hypothesis is supported by evidence of a group of interneurons that receive not only supraspinal input from the vestibulospinal and reticulospinal pathways and the pyramidal tract but also bilateral input from group Ia and group II neurons and joint afferents.[19] Based on this information, we could expect that decreased unilateral joint afferents would also lead to decreased muscle-spindle sensitivity in the contralateral ankle. However, despite this possibility, the contralateral limb has been used as a reference. Furthermore, considering that muscle and tendon damage is also possible during an ankle sprain,[20] muscle spindles and Golgi organ tendons can be damaged, too. Damage to these receptors leads to a distorted sense of muscle length and tension,[3] affecting joint stability. The studies in this area have shown increased error in eversion force sense in individuals with CAI compared with healthy controls[21,22] and increased error in the chronically unstable ankle compared with the contralateral uninjured limb.[9,23,24]

All of these receptors and the corresponding afferent input may allow a modulation of postural activity in relation to muscle length and tension variation, but only a combination of afferent inputs can provide the necessary information to control body equilibrium. To the best of our knowledge, no authors have evaluated the different components of proprioception in an integrated way.

The purpose of our study was to evaluate bilateral ankle proprioception in individuals with unilateral CAI. Based on the findings of previous studies and on neurophysiological foundations, bilateral increased errors in active joint position sense, kinesthesia, and force sense would be expected in individuals with CAI. Despite extensive clinical and basic science research, the injury-recurrence rate remains high and the reasons why sprains tend to recur are unclear; thus, successful rehabilitation is difficult. The results of our study will help to clarify the sensory deficits related to CAI.

METHODS

Participants

A total of 24 university student-athletes (6 women, 18 men) with unilateral CAI and 20 uninjured athletes (3 women, 17 men) participated in this study (Table 1). The CAI group was divided into 2 subgroups: one was composed of individuals presenting functional ankle instability (FAI) but not mechanical ankle instability (MAI), and the other was composed of individuals with FAI and MAI. Participants assigned to the CAI groups met the criteria set by the International Ankle Consortium.[25] For inclusion in the CAI groups, individuals had to meet the following criteria: (1) history of at least 1 significant unilateral ankle sprain; (2) the initial sprain must have occurred at least 12 months before enrollment in the study; (3) at least 1 ankle sprain was associated with inflammatory symptoms; (4) at least 1 ankle sprain resulted in at least 1 interrupted day of desired physical activity; (5) the most recent injury must have occurred more than 3 months before enrollment in the study; and (6) history of the previously injured ankle joint giving way, recurrent sprain, or feelings of instability. To meet this last criterion, individuals must have answered *yes* to question 1 ("Have you ever sprained an ankle?") and *yes* to at least 4 questions related to perceived ankle instability and giving-way episodes: "(2) Does your ankle ever feel unstable while walking on a flat surface? (3) Does your ankle ever feel unstable while walking on uneven ground? (4) Does your ankle ever feel unstable during recreational or sport activity? (5) Does your ankle ever feel unstable while going up stairs? (6) Does your ankle ever feel unstable while going down stairs?"[25] Individuals were included in the MAI subgroup if they presented 1 or more of the following conditions: (1) pain or changes in talocrural-joint mobility greater than 3 mm on anterior drawer and posterior glide manual stress tests compared with the uninjured side[26] or (2) talar tilt greater than 7° together with a difference greater than 0° in relation to the contralateral (uninjured) ankle.[27] Individuals with negative tests were included in the FAI subgroup. The exclusion criteria for the FAI and MAI subgroups met those set by the International Ankle

Consortium[25]: (1) history of previous surgery to the musculoskeletal structures in either limb of the lower extremity; (2) history of fracture in either limb of the lower extremity requiring realignment; (3) acute injury to musculoskeletal structures of other joints of the lower extremity in the previous 3 months, which affected joint integrity and function, resulting in at least 1 interrupted day of desired physical activity; and (4) history of bilateral ankle sprain. Healthy control participants were selected according to the same exclusion criteria applied to the CAI groups and were also excluded if they had a history of ankle sprain. All volunteers were athletes practicing sports with a high risk of ankle sprain, including basketball, handball, soccer, and volleyball. Before testing, individuals were asked to identify the *dominant limb*, which was described as the leg that he or she would use to kick a ball. Because in healthy individuals, short latency responses are shorter in the nondominant limb,[28] this limb was selected for evaluation. In the FAI and MAI groups, both limbs were evaluated.

The study was approved by the local ethics committee and was implemented according to the Declaration of Helsinki. All individuals gave their written consent.

Instrumentation

The Ankle Instability Instrument was designed to classify patients with FAI and has been shown to be a reliable and valid tool.[29] The instrument presents high test-retest reliability (intraclass correlation coefficient = 0.95). Internal consistency reliability estimates (α coefficients) for each factor and the total measure range from 0.74 to 0.83. Decreased proprioception is related to both self-reported giving-way episodes and perceived ankle instability.[23] Ankle proprioception was assessed using an isokinetic dynamometer (model 4 Pro; Biodex Medical Systems, Inc, Shirley, NY).

Procedures

Each participant was seated with a backrest angle of 100° and knee flexion of 60°. The test foot was positioned on the footplate, with the ankle joint positioned at 15° of plantar flexion and the axis of rotation of the dynamometer aligned with the lateral malleolus. The nontest foot rested on a support bench and the participant was stabilized using straps across the hips and knee. Fixation around the ankle joint was avoided to minimize additional sensory information. The volunteers were blindfolded before starting the proprioceptive evaluation to eliminate visual clues that could influence the results. All tests were performed barefoot, and the testing order, test positions, and side of body tested were randomly chosen.

Joint Position Sense. Active and passive joint position sense were evaluated in 2 positions, 5° and 15° of supination, selected to avoid the extremes of the range of movement, thereby minimizing additional sensory input from the cutaneous and joint receptors (Ruffini endings).[30] In these positions, the muscle spindle provides the major information regarding joint position sense.[30] Our protocol followed the protocols of previous studies.[31,32] For passive testing, the participant's foot was first passively moved to maximal eversion and then to 1 of the 2 test positions. Each test position was maintained for 10 seconds, while the participant was instructed to concentrate on the position of the foot. The foot was then passively brought to maximal eversion and moved passively back toward inversion at a constant speed of 1°/s. The participant was instructed to push a stop button when he or she thought the test position had been reached. Each participant was tested 3 times at each of the 2 test positions. The active test was performed in the same manner, except that after having the foot passively placed in the test position during 10 seconds and then moved to maximal eversion, the participant was asked to actively move the foot back to the test position. The participant was again asked to push the stop button when he or she thought the test position was reached. The mean of the difference between the position chosen by the participant and the test position angle was used for analysis. Konradsen et al[33] validated a comparable method of measuring ankle position sense and found it to be accurate, repeatable, and precise.

Kinesthesia. The ankle was positioned in the middle of its inversion-eversion range of movement. From this initial position, 2 series of passive movements into inversion were imposed on the ankle: one at a velocity of 0.25°/s and another at 1°/s. We selected these velocities to reduce the role of the musculotendinous mechanoreceptors (muscle spindles and Golgi tendon organs) in providing feedback to the central nervous system regarding limb position, highlighting the role of the articular receptors.[34] The passive movement was applied at random time intervals between 1 and 10 seconds. Participants were instructed to push a stop button when movement was first felt. Three trials were performed at each velocity and a 1-minute rest was provided between trials. The degree at which the movement was perceived was used for analysis. Using similar protocols, high to very high reliability values have been reported for kinesthesia.[7]

Force Sense. Maximum voluntary isometric torque of the evertor muscles was evaluated with the ankle positioned at 5° and 15° of inversion. In this test, straps were placed around the forefoot. After a warm-up consisting of submaximal isometric contractions, each participant was instructed to perform maximal isometric contraction of the evertor muscles 3 times, maintain each contraction for 5 seconds, and rest for 2 minutes. The individual was asked to reproduce 20% of the mean value of torque attained in the maximal isometric contractions. This load was chosen based on previous research reporting force-sense deficits in participants with FAI at loads $\leq$30% of maximal isometric contraction[35] and the relevance of this value in the demands of functional activity, such as walking. Visual feedback was provided initially and the test torque was maintained for 10 seconds. Individuals were then asked to reproduce the same torque (3 trials in each position) and maintain it for 5 seconds without feedback. A 1-minute rest period was provided between trials. The mean torque was calculated from the middle 3 seconds of data for each trial in an attempt to ensure that the participant had reached a constant torque level. The outcome measure was the difference between the test and reproduced torques (absolute error). High reliability values in eversion-force measures have been obtained using this instrumentation and protocol.[35]

Table 2. Absolute Error in Passive Joint Position Sense for Each Group

Position	Group	Uninjured Limb			Injured Limb			Between-Participants Effect			Within-Participant Effect		
		Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	*F* Value	*P* Value	η^2 Value	*F* Value	*P* Value	η^2 Value
5° Inversion	Control	3.05 ± 1.84	0.39	1.08	NA	NA	NA	0.019	.98	0.02	1.513	.36	0.078
	Functional ankle instability	3.58 ± 2.70	0.85	2.36	2.65 ± 2.50	0.79	2.19						
	Mechanical ankle instability	3.08 ± 1.37	0.43	1.19	3.28 ± 1.72	0.54	1.50						
15° Inversion	Control	3.30 ± 1.32	0.28	0.78	NA	NA	NA	1.685	.20	0.08	1.685	.20	0.059
	Functional ankle instability	4.50 ± 3.53	1.11	3.06	3.28 ± 2.19	1.00	2.77						
	Mechanical ankle instability	4.45 ± 2.20	0.70	1.94	4.83 ± 2.32	0.73	2.02						

Abbreviation: NA, not applicable.

Statistical Analysis

The data were analyzed using SPSS software (IBM Corp, Armonk, NY). Absolute error of active and passive joint position sense, force sense, and kinesthesia was analyzed by way of mixed-effects analyses of variance. Each analysis of variance had 2 independent factors, limb (injured or uninjured) and group (FAI, MAI, or control). The limb was modeled as a within-group factor, and FAI, MAI, or control was modeled as a between-groups factor. The least significant difference test was used to make post hoc comparisons. We used a .05 significance level for inferential analysis. The standard error of measurement (SEM) was calculated by taking the square root of the error variance of each proprioceptive variable. The SEM was used to calculate the minimal detectable difference (MDD). To compute the MDD as the 95% confidence interval limits of the SEM, the SEM has to be multiplied by 1.96 (for the 95% interval) and by the square root of 2 for the difference scores ($1.96 \times \sqrt{2} \times$ SEM). The magnitude of the effects of the differences between groups was assessed using the Cohen d.

RESULTS

No differences between groups were observed in ankle active or passive joint position sense (Tables 2 and 3). A main effect of ankle position was noted for passive joint position sense ($F = 8.216$, $P = .007$, $\eta^2 = 0.17$). In all groups, increased error was observed at the 15° position (Tables 2 and 3).

A main effect of limb was observed for kinesthesia at 1°/s. A significant interaction was present between the effects of limb and group for this proprioceptive variable ($F = 3.27$, $P = .049$, $\eta^2 = 0.14$; Table 4). Significant differences were evident between the injured limb of the FAI group and the control group ($P = .031$, Cohen d = 0.47). Higher error values were demonstrated in the FAI group (Table 4).

A main effect of limb was observed for force sense at 15° and differences occurred between groups (Table 5). Post hoc analysis revealed that, in this position, both the injured and uninjured limbs differed between the FAI group and the control group (uninjured: $P < .001$, Cohen d = 1.28; injured: $P = .009$, Cohen d = 0.89) and between the FAI group and the MAI group ($P = .023$, Cohen d = 0.76). Increased error was seen in the FAI group compared with the control and MAI groups (Table 5).

DISCUSSION

Despite extensive research, the mechanism behind CAI remains unknown. Evidence regarding proprioception is contradictory, and the components of proprioception have been evaluated in a segmented way. We aimed to evaluate the components of proprioception within a single population of individuals with CAI.

The replication errors for healthy individuals have been reported as being between 1° and 3°.[6] In our study, absolute error was 3.13° for active joint position sense and 3.05° for passive joint position sense at the 5° of inversion position, which agrees with previous reports. For the 15° of inversion position, absolute error was 3.93° for active joint position sense and 3.30° for passive joint position sense. In both positions, the MDD value was close to 1. The same

Table 3. **Absolute Error in Active Joint Position Sense for Each Group**

Position	Group	Uninjured Limb			Injured Limb			Between-Participants Effect			Within-Participant Effect		
		Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	*F* Value	*P* Value	η^2 Value	*F* Value	*P* Value	η^2 Value
5° Inversion	Control	3.13 ± 1.88	0.40	1.11	NA	NA	NA	0.181	.84	0.01	0.648	.53	0.03
	Functional ankle instability	3.49 ± 2.29	0.70	1.94	3.41 ± 1.78	0.56	1.55						
	Mechanical ankle instability	2.72 ± 1.33	0.42	1.16	3.35 ± 2.66	0.54	1.50						
15° Inversion	Control	3.93 ± 2.20	0.47	1.30	NA	NA	NA	0.580	.57	0.03	0.433	.65	0.02
	Functional ankle instability	4.09 ± 3.70	1.17	3.24	3.84 ± 1.51	0.48	1.33						
	Mechanical ankle instability	5.16 ± 2.66	0.84	2.33	4.49 ± 2.87	0.78	2.16						

Abbreviation: NA, not applicable.

Table 4. **Absolute Error in Kinesthesia for Each Group**

Velocity	Group	Uninjured Limb			Injured Limb			Between-Participants Effect			Within-Participant Effect		
		Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	*F* Value	*P* Value	η^2 Value	*F* Value	*P* Value	η^2 Value
0.25°/s	Control	1.45 ± 0.91	0.19	0.53	NA	NA	NA	2.745	.08	0.12	0.615	.55	0.03
	Functional ankle instability	2.36 ± 2.19	0.69	1.91	2.66 ± 1.94	0.61	1.69						
	Mechanical ankle instability	1.91 ± 1.09	0.34	0.94	2.31 ± 1.04	0.33	0.91						
1°/s	Control	1.06 ± 0.99	0.21	0.58	NA	NA	NA	1.237	.30	0.06	7.103	.01	0.15
	Functional ankle instability	2.05 ± 1.49	0.88	2.44	2.66 ± 1.79[a]	0.38	1.05						
	Mechanical ankle instability	1.33 ± 1.12	0.35	0.97	2.15 ± 0.88	0.28	0.78						

Abbreviation: NA, not applicable.

[a] Different from the control group ($P < .05$).

Table 5. Absolute Error in Force Sense for Each Group

Position	Group	Uninjured Limb			Injured Limb			Between-Participants Effect			Within-Participants Effect		
		Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	Mean ± SD	Standard Error of Measurement	Minimal Detectable Difference	*F* Value	*P* Value	η^2 Value	*F* Value	*P* Value	η^2 Value
5° Inversion	Control	0.78 ± 0.74	0.16	0.44	NA	NA	NA	1.822	.18	0.08	1.507	.23	0.07
	Functional ankle instability	0.96 ± 0.86	0.27	0.75	1.51 ± 0.70	0.22	0.61						
	Mechanical ankle instability	0.82 ± 1.03	0.32	0.89	0.96 ± 0.44	0.14	0.39						
15° Inversion	Control	0.88 ± 0.44	0.09	0.25	NA	NA	NA	9.313	<.001	0.32	5.330	.03	0.12
	Functional ankle instability	1.84 ± 1.46[a,b]	0.26	0.72	2.59 ± 1.83[a,b]	0.48	1.33						
	Mechanical ankle instability	0.87 ± 1.04	0.33	0.91	1.59 ± 1.35	0.43	1.19						

Abbreviation: NA, not applicable.
[a] Different from the control group ($P < .05$).
[b] Different from the mechanical ankle instability group ($P < .05$).

tendency was shown by the FAI and MAI subgroups. As in previous studies,[8–11] no differences were found in joint position sense among the control and FAI and MAI subgroups for either injured or uninjured limbs.

The kinesthesia results revealed proprioceptive deficits in the injured limb. Increased error values were present in the injured limb of the FAI group compared with controls, demonstrating increased errors in the information provided by articular receptors in this limb.[34] Lentell et al[7] noted that the amount of motion necessary to register movement was increased by 1° in unstable ankles. In the current study, the FAI group detected movement at 0.91° and 1.21° later in the uninjured and injured limbs, respectively, whereas no differences were evident in the MAI group compared with controls. It has been argued that if ligaments are disrupted by trauma and then heal in an elongated state, ligament tension for a given angle of ankle inversion will be reduced and, subsequently, the inversion mechanoreceptors will misinterpret the angle of inversion.[4] According to this perspective, a higher degree of error should be expected in the MAI group. However, we found differences in only the FAI group. These results point to decreased sensitivity of the peroneal muscle spindles in this group. This hypothesis is supported by a previous study[6] indicating that replication error was not correlated with the degree of mechanical ankle instability. In our research, to be included in the chronic instability group, participants must have had giving way of the previously injured ankle joint or recurrent sprain or feelings of instability. No differences in kinesthesia were observed when the definition of CAI was based on the number of ankle-sprain episodes (at least 3 ankle-inversion sprains).[13] Considering that all of our participants described at least 3 ankle-inversion–sprain episodes but also giving-way episodes, the observed differences could have resulted from these criteria.[25]

Increased error in force sense was seen in the injured and uninjured limbs of the FAI group compared with controls at the 15° of inversion position. These findings indicate that the peroneal muscles of individuals with FAI decrease their contribution to regulation of force production[23] and stiffness[36] in the injured limb[21,22,29] but also in the uninjured limb. Force sense is mediated locally by the Golgi tendon organs, which may be damaged at the time of initial injury, explaining the deficit we noted. In fact, evertor-muscle strains occur in 15% of ankle sprains, and 2% of patients with ankle sprains report maximal tenderness over the peroneal muscles or tendons rather than the ligaments.[20] Increased force-sense error could reduce the role of the peroneal muscles in stabilizing against ipsilateral injurious inversion forces but also in accelerating the center of pressure in the direction of the center of the base of support to dampen the contralateral ankle-sprain mechanism. This deficit provides evidence for the increased risk of injuring the uninjured limb in individuals with unilateral FAI.[37] However, it should be noted that we evaluated force sense in a non–weight-bearing position. Future authors should evaluate force sense during weight-bearing activities to confirm our results. The association between larger errors in force sense and CAI was previously demonstrated[23] as they were related to both self-reported giving-way episodes and perceived ankle instability. From a more global postural-control perspective, the increased error provided by the Golgi tendon organ leads to less accuracy in detecting the projection of the body's center of mass within the base of support,[38] impairing postural adjustments. Our findings corroborate those of previous investigators[21,22] who used the same inclusion criteria to define CAI.

Because γ motoneuron activation is largely influenced by peripheral afferent input, decreased proprioceptive input leads to decreased γ motoneuron activation. If γ activation is suppressed in patients with ankle instability, then a lack of activation or tone in many or all of the muscles surrounding the injured joint (but also in the contralateral limb) may lead to decreased joint stiffness, potentially contributing to instability. In this circumstance, the joint would be more susceptible to injury without appropriate levels of dynamic joint stability through muscle contraction. As suggested by Hertel,[39] the key to treating FAI may be to find an intervention strategy that will enhance γ activation, probably by increasing the quantity and quality of proprioceptive input.

Individuals with FAI demonstrated greater proprioceptive deficits than individuals with MAI. Considering that participants with MAI also presented with episodes of ankle-joint giving way or feelings of instability, our results seem to indicate that these residual symptoms could be a consequence of mechanical instability rather than proprioceptive deficits. However, considering the η^2 values, future studies with larger samples are required to confirm the lack of differences in proprioceptive variables between individuals with MAI and healthy controls.

CONCLUSIONS

Individuals with unilateral FAI had increased error in ipsilateral inversion-movement detection (kinesthesia) and bilateral evertor force sense. Proprioceptive impairments of the injured limb may increase the risk of injury through inappropriate bilateral force sense and ipsilateral movement detection.

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