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Clinical movement assessments do not differ between collegiate athletes with and without chronic ankle instability



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ABSTRACT

Objectives: To determine if overall Landing Error Scoring System-17 (LESS-17) and Fusionetics scores differ between collegiate athletes with and without chronic ankle instability (CAI). We also aimed to determine if the rate of specific movement errors during the LESS-17 and Fusionetics differed between the groups.

Design: Case-Control.

Setting: Clinical Sports Medicine Facility.

Participants: Ninety-nine athletes from six Division I NCAA sports were eligible for the investigation. Forty-nine of those participants were classified as having CAI and fifty were classified as uninjured controls.

Main outcome measures: An overall Lower Extremity Fusionetics score and individual task scores were calculated based on movement errors made during a double limb, double-limb with heel lift, and single limb squat. A LESS-17 score was calculated based on movement errors made during a 30 cm drop jump. **Results:** No differences were found between groups for the LESS-17 ($p = 0.51$), overall Lower Extremity Fusionetics ($p = 0.49$), and individual Fusionetics tasks ($p > 0.36$). More individuals with CAI made an uncontrolled trunk movement during a single-limb squat than uninjured controls ($p < 0.01$).

Conclusions: Overall movement quality, as assessed by the LESS-17 and Fusionetics, did not differ between collegiate athletes with and without CAI. The rate of making specific movement errors also did not differ between groups.

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Lateral ankle sprains (LAS) are one of the most common injuries in sport (van Rijn et al., 2008). Among the general public, over 900,000 LAS were seen in United States emergency departments in 2010 alone (Shah, Thomas, Noone, Blanchette, & Wikstrom, 2016). These events resulted in excess of \$1.1 billion in healthcare charges (Shah et al., 2016). However, contemporary figures suggest that the true incidence rate in the general population is around 5.5 times higher than figures derived from emergency department data as many LAS go untreated (Kemler, van de Port, Valkenberg, Hoes, & Backx, 2015). Unfortunately, LAS are not an innocuous injury as prospective evidence demonstrates that at least 40% of individuals who sustain a first time ankle sprain develop residual symptoms, often defined as chronic ankle instability (CAI). (Doherty et al., 2016).

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CAI is associated with a variety of sensorimotor and biomechanical alterations. For example, those with CAI have significant postural control impairments (Wikstrom, Naik, Lodha, & Cauraugh, 2009). Those with CAI also have altered sagittal and frontal plane kinematics at the ankle (Caulfield & Garrett, 2002; Drewes, McKeon, Kerrigan, & Hertel, 2009) and more proximally (Caulfield & Garrett, 2002; Gribble & Robinson, 2009) during jump landings and other dynamic activities. Kinetic alterations such as higher vertical ground reaction forces and greater loading rates during such activities have also been observed (Bigouette et al., 2016; Caulfield & Garrett, 2004). Cumulatively, these alterations are hypothesized to contribute to the increased risk of musculoskeletal injury observed following LAS. Indeed, LAS have the highest recurrence rates of all lower limb musculoskeletal injuries (Hootman, Dick, & Agel, 2007) and a link between a history of a LAS and an increased risk for an ACL injury has been established (Kramer, Denegar, Buckley, & Hertel, 2007). These alterations, particularly the biomechanical alterations, are thought to contribute to the development of ankle post-traumatic

osteoarthritis (Golditz et al., 2016). Clearly, a need exists to be able to identify biomechanical adaptations in those with CAI in order to funnel those individuals into interventions to enhance movement quality, reduce the risk of recurrent injury, and slow the progression of post-traumatic osteoarthritis.

The gold standard for detecting biomechanical alterations remain lab based force platforms and motion analysis systems but the associated time and cost constraints limit their ability to scale and screen large numbers of individuals in an efficient manner (Padua et al., 2009). As a result, multiple movement assessments have been developed to detect biomechanical alterations in the clinical setting. The Landing Error Scoring System-17 (LESS) (Padua et al., 2009), Functional Movement Screen (FMS) (Functional Movement, 2018), and Fusionetics (Fusionetics: Performance Health System, 2018) are movement assessment tools currently available to practitioners. Evidence suggests that the LESS and FMS are associated with anterior cruciate injury (ACL) and broad lower extremity injury risk to varying degrees (Everard, Lyons, & Harrison, 2018; Padua et al., 2015) but conflicting evidence does exist (Fox, Bonacci, McLean, Spittle, & Saunders, 2016). In those with CAI, research has quantified movement quality changes, via Fusionetics, after fatigue and after a 4-week intervention (Bagherian, Rahnama, Wikstrom, & Clark, 2018; Bagherian, Rahnama, & Wikstrom, 2017). However, only the FMS has been used to compare movement quality between those with CAI and uninjured controls and no differences were noted between the groups (Choi & Shin, 2015; Choi & Shin, 2016).

Therefore, the primary purpose of this investigation was to determine if movement quality, as assessed via the LESS-17 and Fusionetics, differs between collegiate athletes with and without CAI. The secondary purpose, was to determine if a higher proportion of those with CAI make specific movement errors within the LESS-17 and Fusionetics assessments relative to uninjured controls. We hypothesize that overall LESS-17 and Fusionetics scores would not differ between the groups. We further hypothesize that collegiate athletes with CAI would be more likely to make specific errors associated with both the LESS-17 and Fusionetics assessments.

1. Methods

1.1. Design & participants

A case-control design was used to determine if LESS-17 and Fusionetics assessment scores differed between collegiate athletes with and with CAI. All UNC Chapel Hill athletes who participated on a varsity team that included LESS-17 and Fusionetics movement assessments as part of their 2017–2018 pre-season physical exam ($n = 221$) were asked to participate. Those interested ($n = 205$, 92.7%) read and signed the university approved informed consent document prior to their movement assessments. Of those that provided written consent, 99 (48.3%) athletes from six Division I NCAA sports were deemed eligible for the study. Forty-nine of those participants were classified as having CAI and fifty were classified as uninjured controls. Participant demographics can be seen in Table 1.

Inclusion criteria for the control group included no previous ankle sprain and no serious lower leg injury or surgery prior to enrollment. The inclusion criteria for the CAI group was determined by the International Ankle Consortium (Gribble et al., 2013). More specifically, the criteria consisted of a history of at least one significant ankle sprain that occurred at least 12 months prior to enrolling in the study, at least two episodes of giving way in the six months prior to study enrollment, and scoring > 10 on the Identification of Functional Ankle Instability (IdFAI). Exclusion criteria for both groups included a history of previous surgery to either lower extremity, a history of lower

Table 1
Participant demographics.

	CAI (n = 49)	Control (n = 50)
IdFAI	15.63 ± 3.86	1.20 ± 2.30
Number of previous sprains	2.69 ± 2.22	0.00 ± 0.00
Sex (Male; %)	20, 41%	26, 52%
Age (years)	19.86 ± 1.24	19.64 ± 1.08
Height (cm)	159.41 ± 25.67	159.82 ± 25.94
Weight (kg)	68.59 ± 3.14	69.82 ± 3.54
FAAM-S (%) ^a	94.58 ± 9.61	98.82 ± 5.42
Sport (n, (%))		
Women's Crew	10 (20.4%)	9 (18%)
Men's Soccer	9 (18.5%)	12 (24%)
Women's Soccer	4 (8.1%)	3 (6%)
Men's Lacrosse	11 (22.3%)	14 (28%)
Women's Lacrosse	9 (18.5%)	4 (8%)
Field Hockey	6 (12.2%)	8 (16%)

^a Indicates a statistically significant difference between the groups.

extremity fracture requiring realignment, and/or an acute lower extremity joint injury in the previous 3 months resulting in an interruption of one day of physical activity. Participants younger than 18 and older than 35 were also excluded from the study.

1.2. Procedures

After reading and signing the university approved informed consent form, participants were asked to complete the IdFAI and the Foot and Ankle Ability-Measure-Sport (FAAM-S) to determine group assignment and quantify self-reported function respectively. The IdFAI ($ICC_{2,1} = 0.959$) (Gurav, Ganu, & Panhale, 2014) and the FAAM-S ($ICC_{2,1} = 0.87$) (Martin, Irrgang, Burdett, Conti, & Van Swearingen, 2005) have good to excellent test-retest reliability. Next, participants completed the LESS-17 (prevalence- and bias-adjusted $\kappa = 0.71$) (Mauntel et al., 2017) and the Fusionetics movement assessments ($ICC_{2,1}$ range = 0.55–0.71) (Cornell & Ebersole, 2018). The UNC Chapel Hill sports medicine staff who were trained in both assessments and blinded to group assignment, completed assessments. The order of test completion was determined by the sports medicine staff but was not recorded.

All three of the Fusionetics' lower extremity movement assessments were completed. This included five trials of the double leg overhead squat (DLS), double leg overhead squat with heel lift (DLS-HL), and five trials of a single leg squat (SLS) on each limb (Bagherian et al., 2018; Bagherian et al., 2017). The DLS was completed barefoot with feet should-width apart. Participants raised their arms straight up over their head with elbows extended. Participants squatted to the height of a chair before returning to the starting position. Each phase (descent, ascent) lasted about 2 s. The DLS-HL was performed in an identical manner, with one exception; that participants completed this task with a 5.1-cm plate under their heels. The SLS was conducted with hands on hips and to a depth of roughly 45–60° of knee flexion while barefoot. The movement assessment of the right and left SLS was merged to generate the SLS score (Fusionetics: Performance Health System, 2018). Movement errors for all tasks were recorded as “yes” (i.e. this error was made) or “no” (i.e. this error was not made). Identification of movement errors during these tasks has been shown to have a moderate to high inter-rater reliability (Frank, Stanley, & Padua, 2016; Stanley, Frank, & Padua, 2016). Visual depictions, instructions, and movement compensations (i.e. errors representing poor movement quality) for each task have been published elsewhere (Bagherian et al., 2018). The Fusionetics Scoring System calculated the overall Lower Extremity Fusionetics score based on a participants performance during all three tasks. The same system calculated scores for the DLS, DLS-HL, and SLS. Scores, ranging

between 0 and 100, are based on the number, type, and body region within which an error occurred and generated by a proprietary scoring algorithm (Bagherian et al., 2018). Overall scores for the tasks were interpreted as poor (0–49.99), moderate (50–74.99), and good movement efficiency (75–100) based on the Fusionetics Scoring System (Fusionetics: Performance Health System, 2018).

To complete the Landing Error Scoring System (LESS), athletes completed three trials after a minimum of 1 practice trial (Padua et al., 2009). Each participant jumped down off a 30 cm tall box to a designated landing area located 90 cm in front of them. Upon landing, athletes immediately completed a maximal vertical jump before again landing in the target area. A trial was discarded and repeated if the participant (1) failed to jump off the box with both feet at the same time; (2) missed the target landing area; (3) failed to jump vertically upon their initial landing; or (4) failed to complete the task in a smooth motion (Padua et al., 2009). The LESS trials were recorded by a Kinect sensor (i.e. depth camera) (Version 1; Microsoft Corp, Redmond, WA) (Mauntel et al., 2017) which was connected to a standard laptop computer which was running Athletic Movement Assessment software (PhysiMax Technologies Ltd, Tel Aviv, Israel). The LESS-17 is a valid and reliable movement assessment tool (Padua et al., 2009) with larger scores indicative of poorer movement quality. The software used the Kinetic sensor to automatically score 16 of the 17 LESS items. The primary author (JH) upon review of the recorded trials scored overall impression, the final LESS item. The automated scoring system used in this investigation is as reliable as the criterion standard of LESS scoring (i.e. scoring by expert raters). (Mauntel et al., 2017).

1.3. Statistical analysis

Group demographics (e.g. age, height, weight) and FAAM-S scores were compared using independent sample t-tests. To achieve the primary purpose of this investigation, between group comparisons were made for the following dependent variables: overall LESS score, overall Lower Extremity Fusionetics score, DLS score, DLS-HL score, and SLS score. The data associated with these variables were not normally distributed, based on Komogorov-Smirnov normality tests ($p < 0.05$). Therefore, separate Mann Whitney U tests were used to compare dependent variable scores between the groups. Hedge's g effect sizes and 95% confidence intervals (CI) for the overall assessment scores were calculated and interpreted as small (< 0.3), moderate (0.31–0.70), and large (> 0.71) (McKeon & Wikstrom, 2016). A frequency distribution of each group's Fusionetics scores (i.e. Good, Moderate, Poor) for all Fusionetics related dependent variables was analyzed using Chi Square analyses. To achieve the secondary purpose of this investigation, Fisher's exact tests were used to determine if the proportion of errors made during the LESS-17 and Fusionetics assessments differed between the CAI and control groups. An alpha level of 0.05 was used for all analyses.

2. Results

No differences were found between groups for the overall LESS-17 ($p = 0.51$), overall Lower Extremity Fusionetics ($p = 0.49$), DLS

($p = 0.81$), DLS-HL ($p = 0.73$), or the SLS score ($p = 0.36$). Group means and standard deviations for each test can be seen in Table 2. Further, there was no difference between the proportions of those with CAI and uninjured controls who were deemed to have poor, moderate, or good movement quality during the overall Lower Extremity Fusionetics ($\chi^2 = 0.72$), DLS ($\chi^2 = 0.07$), DLS-HL ($\chi^2 = 0.68$), and SLS ($\chi^2 = 0.32$) as seen in Table 3.

The proportion of individuals with CAI and uninjured controls that made specific errors did not differ for any of the individual items within the LESS-17, overall Lower Extremity Fusionetics, DLS, and DLS-HL assessments ($p > 0.05$). However, the proportion of individual's who made an uncontrolled trunk movement during the SLS was higher in the CAI group ($p < 0.01$). No other differences were noted during the SLS. Tables 4 and 5 list the proportion of participants in each group that made individual item errors during the Fusionetics and LESS assessments respectively.

3. Discussion

The purpose of this study was to compare overall clinical movement assessment scores between collegiate athletes with and without CAI. Overall LESS-17 and Fusionetics scores did not differ between the groups, supporting our a priori hypothesis. We also aimed to determine if a higher proportion of CAI participants, relative to uninjured controls, made a specific error during the LESS-17 or Fusionetics assessments. Our results largely contradicted our a priori hypothesis as only one difference was noted. More specifically, those with CAI were more likely to have uncontrolled trunk motion during the SLS which we believe is representative of the postural control deficits common to those with CAI (Wikstrom et al., 2009).

Previous biomechanical research using instrumented equipment has shown both distal (i.e. ankle) and proximal (i.e. knee) kinematic alterations as well as altered kinetic patterns during a variety of single and double limb landing tasks in recreational athletes with CAI (Bigouette, Simon, Liu, & Docherty, 2016; Caulfield & Garrett, 2002; Caulfield & Garrett, 2004; Drewes et al., 2009; Gribble & Robinson, 2009). With some exceptions (e.g. inversion), the LESS-17 is capable of identifying the movement errors that were previously noted in CAI participants using laboratory based motion capture instrumentation. Task and assessment differences likely explain the contrary findings. For example, the LESS-17 is a double limb drop landing task and includes an immediate countermovement jump. However, the majority of CAI investigations have used some version of a single limb hop stabilization task. As a result, it is likely that different motor control strategies are required to complete the tasks (i.e. stabilization vs. countermovement jump) and that double limb landings mask potential single limb deficiencies. Further, the countermovement jump would not stress the postural control system to the same extent as a hop stabilization task which is commonly used in the CAI literature because postural control is commonly impaired in this population (Wikstrom et al., 2009) and linked to injury risk (Wang, Chen, Shiang, Jan, & Lin, 2006). Thus, the movement task associated with the LESS-17 may not be the most robust to identify altered biomechanics in individuals with CAI in the clinical setting.

Table 2
Means and standard deviations for overall movement assessment scores.

	LESS-17	LE Fusionetics	DLS	DLS-HL	SLS
CAI	4.94 ± 1.93	65.39 ± 12.33	66.41 ± 18.22	82.38 ± 13.61	49.20 ± 21.91
Control	4.80 ± 1.99	67.01 ± 15.10	67.60 ± 16.61	80.33 ± 16.58	54.00 ± 24.06
Effect Sizes (95% CI)	.05 (–.34 to .44)	–.08 (–.48 to .31)	–.05 (–.44 to .35)	.09 (–.3 to .49)	–.15 (–.54 to .25)

LE: Lower Extremity, DLS: Double Limb Squat, HL: Heel Lift, SLS: Single Limb Squat, CI: Confidence Intervals.

Table 3
Frequency distribution of overall movement quality during Fusionetics movement assessments.

	Group	Poor	Moderate	Good
Lower Extremity Fusionetics	CAI	7 (14.3%)	29 (59.2%)	13 (26.5%)
	Control	6 (12%)	27 (54%)	17 (34%)
Double Limb Squat	CAI	9 (18.4%)	20 (40.8%)	20 (40.8%)
	Control	3 (6%)	30 (60%)	17 (34%)
Double Limb Squat- Heel Lift	CAI	1 (2.1%)	13 (26.5%)	35 (71.4%)
	Control	2 (4%)	16 (32%)	32 (64%)
Single Limb Squat	CAI	22 (44.9%)	22 (44.9%)	5 (10.2%)
	Control	16 (32%)	25 (50%)	9 (18%)

However, it is important to note that the LESS-17 aims to detect the presence of a movement error and not quantify the magnitude of the error. Thus, the double-limb countermovement jump may elicit aberrant biomechanics in those with CAI but a measure of error magnitude is needed to elucidate group differences.

To date, no investigation has compared squat biomechanics between those with CAI and uninjured controls using instrumented equipment. However, Webster and Gribble demonstrated that those with CAI had lower gluteus maximus activation during a single limb rotation squat relative to uninjured controls (Webster & Gribble, 2013). Despite this apparent neuromuscular control impairment, our results are consistent a previous investigation that

Table 4
Frequency distribution of specific movement compensations (errors) made by each group during the Fusionetics Double Limb Squat, Double Limb Squat- Heel Lift, and Single Limb Squat assessments.

Checkpoint	Movement compensations	Control (n = 50)	CAI (n = 49)	p-value
Double Limb Squat Foot/Ankle	Foot Turns Out	27 (54%)	27 (55.1%)	0.54
	Foot Flattens	14 (28%)	11 (22.4%)	0.34
	Heel of Foot Lifts	3 (6%)	3 (6.1%)	0.65
Knee	Knee Valgus	8 (16%)	8 (16.3%)	0.59
	Knee Varus	15 (30%)	18 (36.7%)	0.31
L-P-H-C	Excessive Forward Lean	34 (68%)	32 (65.3%)	0.47
	Low Back Combined	21 (42%)	23 (46.9%)	0.39
	Asymmetrical Weight Shift	24 (48%)	21 (42.8%)	0.38
Shoulder	Arms Fall Forward	32 (64%)	29 (59.2%)	0.39
Double Limb Squat- Heel Lift				
Foot/Ankle	Foot Turns Out	11 (22%)	7 (14.3%)	0.23
	Foot Flattens	7 (14%)	5 (10.2%)	0.39
Knee	Knee Valgus	3 (6%)	0 (0.0%)	0.13
	Knee Varus	15 (30%)	16 (32.6%)	0.47
L-P-H-C	Excessive Forward Lean	21 (42%)	13 (26.5%)	0.08
	Low Back Combined	11 (22%)	15 (30.6%)	0.23
	Asymmetrical Weight Shift	19 (38%)	15 (30.6%)	0.29
Shoulder	Arms Fall Forward	23 (46%)	24 (49.0%)	0.46
Single Limb Squat				
Foot/Ankle	Foot Flattens	21 (42%)	19 (38.8%)	0.45
Knee	Knee Valgus	34 (68%)	37 (75.5%)	0.27
	Knee Varus	7 (14%)	6 (12.2%)	0.52
L-P-H-C	Uncontrolled Trunk Motion	25 (50%)	37 (75.5%)	0.01
	Loss of Balance	17 (34%)	12 (24.5%)	0.21

L-P-H-C: Lumbo-pelvic-hip complex.

Table 5
Frequency distribution of specific movement compensations (errors) made by each group during the Landing Error Scoring System assessment.

Checkpoint	Error	Control (n = 50)	CAI (n = 49)	p-value
Foot/Ankle	IC Plantar flexion Angle	19 (38%)	21 (42.8%)	0.39
	Asymmetrical Foot Contact	9 (18%)	18 (36.7%)	0.07
	Wide Stance	0 (0%)	0 (0%)	–
	Narrow Stance	38 (76%)	36 (73.5%)	0.48
	Foot Internal Rotation	0 (0%)	1 (2%)	0.50
	Foot External Rotation	21 (42%)	25 (51%)	0.24
Knee	IC Knee Flexion	4 (8%)	8 (16.3%)	0.17
	Medial Knee Position	7 (14%)	11 (22.4%)	0.20
	Knee Displacement	10 (20%)	7 (14.3%)	0.31
	Maximum Medial Knee Displacement	16 (32%)	16 (32.6%)	0.56
Hip	IC Hip Flexion	0 (0%)	0 (0%)	–
	Hip Displacement	7 (14%)	5 (10.2%)	0.39
Trunk	IC Trunk Flexion	1 (2%)	2 (4.1%)	0.49
	Lateral Trunk Flexion	17 (34%)	17 (34.7%)	0.56
	Excessive Trunk Flexion at Displacement	32 (64%)	34 (69.4%)	0.36

noted no differences between those with CAI and healthy controls during the FMS deep squat task (Choi & Shin, 2015; Choi & Shin, 2016). Like the LESS-17, it is possible that the task itself may not be robust enough to elucidate group differences. Two of the current squat tasks and the FMS deep squat task are double limb in nature, which reduces the stress placed on the participant's postural control system. The Fusionetics assessments do include a single limb squat but scores from both limbs are averaged to create an overall score, potentially masking impairments on the involved limb. While speculative, it is also possible that the task is appropriate but the binary nature of the assessment is not robust enough. Future research is needed to determine if instrumented assessments can detect group differences in both recreational and athletic CAI samples during a squat maneuver to test this hypothesis.

It is also important to note that the current FAAM-S scores were much higher than most reported in the literature. The high FAAM-S scores are likely related to our sample consisting of collegiate athletes while the majority of the CAI literature assesses recreationally active individuals with CAI. While speculative, elite athletes may be able to compensate differently or better after an initial and/or recurrent ankle sprain than those defined as recreational athletes. This may explain the higher FAAM-S scores (i.e. less perceived disability) and the lack of movement quality differences. Consistent with our results, Division I athletes with and without CAI did not differ on an instrumented dynamic postural control assessment (Liu et al., 2013). Cumulatively, the data suggest that recreational and elite athletes may have different impairment patterns, which is consistent with the heterogeneous nature of CAI. However, this is potentially problematic if clinical assessments (movement or otherwise) are developed based on impairments detected in recreational athletes with CAI. Therefore, future research needs to better characterize the perceptual, structural, and/or sensorimotor adaptations present in elite athletes with CAI relative to their uninjured counterparts.

While the LESS-17 and Fusionetics assessments could not detect movement quality differences between the groups, they have a role in clinical practice. The Fusionetics assessments could be a metric for rehabilitation progress as it detected movement quality improvements in collegiate athletes with CAI following an intervention (Bagherian et al., 2017). The LESS-17 can be used to identify those at an increased risk of lower extremity musculoskeletal injuries broadly. However, future research is needed to determine if the LESS-17 and/or the Fusionetics assessment scores can successfully identify those with an increased risk of sustaining an initial and/or recurrent ankle sprains. To date, the Star Excursion Balance Test has demonstrated early success in predicting ankle sprain risk (Gribble et al., 2016). This appears to support the result that more collegiate athletes with CAI had uncontrolled trunk movement (i.e. poor balance) during the SLS than uninjured controls. However, more research is needed to confirm this result given the number of statistical analyses performed.

4. Conclusions

Overall, movement quality as assessed by the LESS-17 and Fusionetics, did not differ between collegiate athletes with and without CAI. Similarly, collegiate athletes with CAI made specific movement errors on both clinical assessments at the same rate as uninjured controls with one exception. Those with CAI were more likely to have uncontrolled trunk movement, which we interpret as representative of poor balance, than uninjured controls.

Conflicts of interest

None.

Ethical approval

The work has been approved by the appropriate ethical committees related to the institution at which it was performed and all participants gave written informed consent prior to participation.

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