Clinical Tests Have Limited Predictive Value for Chronic Ankle Instability When Conducted in the Acute Phase of a First-Time Lateral Ankle Sprain Injury

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Clinical tests have limited predictive value for Chronic Ankle Instability when conducted in the acute phase of a first-time lateral ankle sprain injury

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Running title: Predictors of CAI following ankle sprain

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Abstract

Objective: To evaluate whether a battery of clinical assessments for acute lateral ankle sprain (LAS) can be used to predict long-term recovery.

Design: Cohort study

Setting: University biomechanics laboratory

Participants: Eighty-two individuals were assessed using a clinical test battery within two-weeks of incurring a first-time LAS.

Main Outcome Measures: The clinical test battery included scores on the 'talar-glide' (deg), anterior-drawer, talar-tilt, figure-of-eight [figure8] for swelling (mm), knee-to-wall (mm) and hand-held goniometric range-of-motion [inversion; eversion; plantar-flexion (in degrees)]. Scores on the the Cumberland Ankle Instability Tool (CAIT) taken 12-months after the clinical test battery were used to classify participants as having Chronic Ankle Instability (CAI) or as being LAS 'copers'

Results: Forty percent of participants were designated as having CAI with 60% being designated as LAS copers. A logistic regression analysis revealed that a combined model using scores from the talar-glide, talar-tilt and anterior-drawer tests in addition to plantar-flexion ROM was statistically significant ($p < 0.01$) and correctly classified cases with moderate accuracy (68.8%). The final model had moderate sensitivity (64%) and good specificity (72%).

Conclusions: The clinical tests utilised in this investigation have limited predictive value for CAI when conducted in the acute phase of a first-time lateral ankle sprain injury.

Key terms: Ankle/physiopathology [MeSH]; Ankle injuries/physiopathology; Joint Instability [MeSH]; Sprains and strains/physiopathology [MeSH].

Lateral ankle sprain (LAS) is one of the most common acute musculoskeletal injuries; its high prevalence pervades across many different populations and activities[1]. Despite its ubiquity, LAS is typically considered an innocuous injury that resolves quickly with minimal treatment[2]. Unfortunately, this is not the case, as pain and swelling are commonplace following acute LAS[3], contributing to reduced functional capacity[3] and occupational absence[4] in many individuals. The development of these symptoms, which also include "giving-way" of the ankle joint, ankle joint instability and recurrent ankle sprain are representative of a condition known as chronic ankle instability (CAI)[5]. It has been proposed that only after a 12-month time interval does the risk of recurrence recede to that of a first-time injury[6].

Recent literature highlights the high prevalence of CAI following LAS. A recent systematic review identified that approximately 33% of patients still experience pain and instability, 34% report at least one re-sprain, and up to 64% state that they have not recovered fully from their initial injury at a 1-year follow up after conventional treatment[7]. Furthermore, in a cross-sectional survey of an Australian community population aged between 18-65 years, chronic ankle disorders affected almost 20% of the sample, with the majority of participants attributing their disorder to a previous ankle sprain injury[8].

To expedite recovery and prevent CAI after LAS, it is important to devise a treatment plan tackling the impairments identified during clinical assessment in the acute period of injury[9]. A recent recognition paradigm has suggested a three-tiered approach to assessing functional impairment and disability in CAI populations[9]. In this paradigm, self-assessment outcomes in which the person reports what they can and cannot do (usually via a questionnaire) are combined with clinical and laboratory outcomes. Cumulatively, these metrics quantify a

patient's perception of their impairment and evaluate how the 'organismic constraints' (which evolve following the initial LAS) underpin this perception. Unfortunately, it is not clear what combination of clinical assessment procedures can be used to forecast the risk of CAI development as no investigation is currently available which has evaluated the diagnostic accuracy of 'traditional' clinical assessment procedures completed soon after incurrence of a first-time LAS for CAI 12-months later.

It is possible that deficits in clinical outcomes, including ankle-joint swelling[3], range-of-motion (ROM)[3,10] impairment, arthrokinematic restriction (posterior talar glide)[11] and hyper- or hypomobility[12-14] may relate to the eventual development of CAI. Unfortunately, while there are numerous cross-sectional investigations of CAI populations which have identified its associated deficits, longitudinal research investigating the predictors of CAI in populations with first-time ankle sprain is sparse[15]. Such investigations stand to elucidate the coping mechanisms that lend to recovery following first-time LAS.

Recently published work undertaken in our laboratory presented instrumented motion analyses of participants with acute, first-time LAS completing a battery of movement tasks during a 12-month follow-up[16]. This investigation identified that deficits in dynamic balance performance and self-reported function 6-months following a first-time acute LAS can be used to predict CAI development[16]. Unfortunately, the implementation of these findings in a clinical context is hindered by the lack of portability of the data acquisition methods, the high cost of the necessary equipment and the time required to analyze the acquired data. On this

basis, a prospective cohort investigation of a 'traditional' clinical test battery (those typically used for LAS injury diagnosis) for eventual CAI diagnosis is warranted.

Therefore, the purpose of this exploratory prospective cohort analysis was to evaluate the predictive accuracy of a 'traditional' clinical test battery which included assessments of ankle joint swelling, ROM, arthrokinematic impairment and hyper/hypomobility for CAI development in a cohort with acute first-time LAS. Due to the absence of research in this population, we did not formulate specific hypotheses as to which tests would be of value in a predictive model for CAI.

MATERIALS AND METHODS

Design: Cohort study

Participants

Eighty-two participants were recruited at convenience from a University-affiliated hospital emergency department (ED) within 2-weeks of sustaining an acute first-time LAS injury. All participants were provided with basic advice on applying ice and compression for the week on discharge from the Emergency Department. Activities of daily living were encouraged: participants were instructed to weight-bear and walk within the limits of pain when possible. All participants were recreationally active, which was defined as "habitually completing a minimum of 1.5hours of moderate or physical activity per week."

Participant demographics for the entire LAS group are detailed in Table 1. Exclusion criteria for participants of the current study are presented in Table 2.

The Human Research Ethics Committee of the university where the study was completed approved this research. All participants signed an informed consent form prior to testing.

Outcome measures

Participants attended the University research centre within 2-weeks of injury and then 12-months (+/- 1 week) following injury.

In a series of separately published papers, the LAS cohort were evaluated as a whole during a series of postural control, gait and jumping/landing tasks[16]. In addition to the biomechanical evaluation of these tasks, the primary author (XX) evaluated the cohort using a battery of clinical tests at the 2-week time-point to explore their potential predictive value for CAI or LAS 'coper' status at the 12-month time-point. As such, this investigation details one part of a wider exploratory analysis of the clinical and/or laboratory outcomes that can be utilised to predict long-term CAI outcome. None of the data for the postural control, gait and jumping/landing tasks[16] have been utilised in the present report.

Participants' designation as CAI or LAS coper status was completed according to recently published guidelines[17-20]: participants with a Cumberland Ankle Instability Tool (CAIT) score of <24 were designated as having CAI while participants with a CAIT score ≥24 were

designated as LAS copers[17], to avoid the potential for false positives in this group [21]. Furthermore, to be designated as a LAS coper, participants also must have returned to pre-injury levels of activity and function, and to have reported no instances of "giving way" at their ankle joint[22].

Clinical assessment procedures

The clinical evaluation included assessments of ankle joint ROM (including goniometric assessment of plantarflexion, inversion, eversion and dorsiflexion using the knee-to-wall test), swelling (using the figure-of-8 method), hyper/hypomobility (using the anterior-drawer and talar-tilt tests) and arthrokinematic integrity (using the posterior-talar glide test). All tests were conducted using instrumentation that would normally be available in a 'real-world' clinical scenario. The specific details of the protocol for conducting the clinical test battery are available in the supplemental documents of this article.

Data analysis

Outcomes from the eight clinical tests were subjected to univariate statistical analysis to evaluate their potential predictive value. Specifically, the correlation of the outcomes for ROM (4), laxity (2), swelling (1) and athrokinematic integrity (1) to status at the 12-month time-point (CAI vs LAS coper) as determined by the CAIT was evaluated using Pearson's r. A preliminary logistic regression analysis using all eight variables was then performed, and was repeated with backwards elimination of variables which were deemed to explain the least

variance in the overall model (on the basis of the correlation analysis). This exploratory approach was deemed the most appropriate mechanism to evaluate the individual contribution of each predictor variable, and to optimise the predictive capacity of the model.

Source of funding

This study was supported by the Health Research Board. There are no conflicts of interest to report.

RESULTS

Descriptive statistics for the clinical tests are presented in Table 3. Results of preliminary correlation analyses are presented in Table 4. The potential predictors were entered into a direct logistic regression model in one block. Scores on the knee-to-wall test, figure-of-eight test, eversion ROM and inversion ROM were then removed sequentially from the model using a backward elimination technique in the optimisation of its predictive capacity. The regression analysis was then repeated with the remaining predictors (scores on the posterior talar glide test [PTGT], anterior-drawer test, talar-tilt test and plantarflexion ROM). This model was statistically significant χ (2, N = 68) = 15.63, p = 0.008, and explained between 21.7% (Cox and Snell R square) and 29.0% (Nagelkerke R squared) of the variance in outcome (i.e. CAI vs Coper) and correctly classified 68.8% of cases. The sensitivity and specificity of the final model was 64.3% and 72.2% respectively. The results of this logistic regression analysis (with associated standardised beta-weights) are presented in Table 5. Based on the standardised beta-weights, the PTGT explained the greatest variance in outcome (CAI vs coper) in the final regression equation.

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200

201 DISCUSSION

202 Findings from this study have revealed that several clinician-oriented outcomes demonstrate
203 statistically significant predictive value for CAI development. These outcome measures were
204 administered on a cohort of individuals within two weeks of incurring a first-time LAS
205 injury. The cohort was subsequently stratified into CAI and LAS 'coper' groups 12-months
206 later. This cohort were simultaneously evaluated across a 'spectrum' of movement patterns as
207 part of another investigation, whereby biomechanical outcomes were entered into a logistic
208 regression model in a similar fashion to what has been reported here[16]. To the authors
209 knowledge, these are the only investigations currently available detailing a longitudinal
210 evaluation of participants in the acute stage of a first-time LAS injury with sufficient follow-
211 ups to allow subsequent classification into CAI or LAS 'coper' status. However, while a
212 series of predictor variables with good diagnostic accuracy were identified in the former
213 investigation[16], findings from the current study, although significant, must be taken with
214 caution.

215

216

217 Specifically, as shown in Table 5, only one variable-the PTGT-made a uniquely statistically
218 significant contribution to the regression model, which also included the anterior-drawer and
219 talar-tilt tests, and plantar-flexion ROM. The final model had medium overall accuracy (69%)
220 with moderate sensitivity (64%) and good specificity (72%)[23]. On this basis, it is therefore
221 likely to produce a large number of false positives-it is at risk of over-classifying the number
222 of participants who are at higher odds of developing CAI. The strongest predictor variable in

the regression model (based on the semi-standardized beta weights) was indeed the PTGT, recording an odds ratio of 1.73 (Table 5). This indicated that participants with a restriction in posterior glide of the talus as determined by the PTGT were 1.73 times more likely to develop CAI than those who eventually became LAS 'copers'.

For the anterior-drawer and talar-tilt tests, having a score of 0 (indicating "hypomobility") increased the odds of developing CAI by 1.87 and 1.52 times respectively, controlling for the other factors in the model. This finding is belied by the fact that no participants were scored as having "gross laxity" (i.e. a score of 3) on either of these tests, so the predictive capacity of the model is limited by a lack of representative data for this sub-group. Finally, while plantar-flexion ROM was included in the model to optimise its overall predictive capacity (the model had 62.2% accuracy in classifying cases without this predictor variable), the 95% CI's for the OR included 0. Thus, the indication that a reduction in plantar-flexion ROM is linked with CAI development is inconclusive.

Overall, we conclude that these findings are not clinically meaningful, as the sensitivity and specificity of the final model corresponded to a likelihood ratio of approximately 0.9, denoting that participants with better scores on these clinical outcomes only have a 'slight' decrease in their risk of developing CAI[24]. Furthermore, the exploratory nature of the statistical model increases the risk for type 1 error, further belying its potential clinical value. Despite this, we consider these findings to be a valuable addition to the literature as they

should inform current classification paradigms for CAI[25], encourage future research efforts and direct clinicians' assessment protocols for acute ankle sprain and CAI.

With regards to the classification paradigms, three primary categorical constructs are considered to contribute to CAI: mechanical insufficiency, self-reported instability and recurrent sprains. CAI may result from any, all or different combinations of these constructs. On this basis, the self-report outcome that was used to diagnose CAI in the current study may have masked the contribution of these underlying constructs to the overall condition. For the purposes of the present study, the CAIT was used to diagnose individuals as having CAI or not, which is in line with the recommendations of the International Ankle Consortium[25]. However, it is entirely possible that grouping participants according to the extent of their self-reported disability as determined by the CAIT undermined the statistical power of the regression model, as members of each group may have presented with different combinations of the underlying constructs of CAI. Alternatively, it is possible that mechanical impairments (local arthrokinematic restriction and hypomobility) are weakly associated with CAI, and our results can be taken at face value. However, we would consider the former hypothesis as more likely, on the basis that previous authors have investigated mechanical impairment as an explanatory factor for CAI in a cross-sectional manner, with no definitive association between ankle laxity and the wider paradigm of CAI[26-31]. While an acute ankle sprain typically threatens the integrity of ligamentous structures, and some authors have reported lingering hypomobility and hypermobility following the acute injury[26-31], these outcomes do not appear to be observed consistently in CAI patients.

This lends towards the hypothesis that the arthrokinematic restrictions (as assessed through the PTGT) and hypomobility (as determined using the anterior-drawer and talar-tilt tests) contribute more to a sub-group model that falls under a wider paradigm of CAI-our results suggest that mechanical instability may predicate CAI in some patients, and not in others. In particular, the unique contribution of the PTGT test to our regression model would suggest that arthrokinematic restriction should be investigated further as part of a sub-group analysis of CAI patients. This arthrokinematic restriction was seemingly independent of dorsiflexion ROM despite the fact that previous research has identified that dorsiflexion ROM (as assessed using the knee-to-wall test) is moderately correlated with talar glide when measured with the PTGT [32]. Importantly, this correlation was identified in a non-injured cohort of participants [32]. Findings from the current study point to an apparent dissociation between these outcomes in patients with acute LAS. While the PTGT has been used in the literature to assess restrictions in arthrokinematics at the talocrural joint in patients suffering from recurrent ankle sprains [11,33], there is an absence of such investigation in cohorts in the acute phase of injury.

To answer the question posited by the available body of research as to the contribution of mechanical insufficiencies to the CAI paradigm, a cohort study of individuals who proceed to develop representative datasets for the different constructs of CAI (i.e mechanical insufficiency, self-reported instability and recurrent sprains, with different combinations of these three) is required. Such an analysis could elucidate the different exposures that lend towards the development of these constructs as inter-linked contributors to CAI. Such an investigation would necessitate a larger sample of participants than was recruited in the

present study. In light of the recruitment time for the current study, which extended for >18-months[16] from a catchment area population of approximately 350,000, it is likely that a multi-centre research study is required to achieve large enough sample sizes to represent the different CAI constructs. We consider this to be a priority for future research if efforts are to be made to reduce the potential consequences of the high incidence and prevalence of ankle sprain across a wide variety of populations and activities[1]. For researchers conducting cross-sectional analyses of CAI cohorts, we echo the sentiments of the International Ankle Consortium, who have recommended that CAI classification should relate specifically to the research question[25]. They have suggested that if investigators are interested in the deficits present in participants with CAI, such as mechanical insufficiency, measures of self-reported function or disability may not be a necessary inclusion criterion to answer the research question. However, if functional impairment is relevant to the proposed project or intervention, then validated ankle specific questionnaires that are designed to evaluate self-reported function should be used to create the necessary inclusion criterion, and tasks with established validity for the specific construct should be employed. For instance, the Star Excursion Balance Test has demonstrated predictive value for acute ankle sprain incidence[34] and CAI development[16], thus qualifying it as a valid measure for functional impairment. In contrast, it remains unclear exactly what tests should be used to quantify the mechanical insufficiencies underpinning CAI. The available longitudinal data suggest that ankle-joint laxity [35] and ROM[35,36] do not relate to ankle sprain incidence, and the current study is the first to suggest that their predictive value for CAI is significant, but limited. This may change with appropriate segmentation of the sub-groups of CAI into its underlying constructs. On this note, it is encouraging that researchers have begun to adopt this approach, wherein the subgroups of CAI are being analysed, rather than being aggregated together[37]. However, to the authors' knowledge, currently no longitudinal data are available for each CAI subgroup.

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321 Study Limitations

322 While our results are important, several limitations should be noted. First, it is likely that the
323 two-week window of eligibility for assessment undermined the homogeneity of our sample
324 further increasing the chance of sampling error. However, recruiting patients with a first-time
325 LAS is compounded by the high prevalence of this injury among the general population-
326 many potential recruits were excluded from our study because they had a previous history of
327 ankle sprain injury. Having to assess our cohort within a pre-determined 24-hour interval
328 would therefore have threatened the feasibility of the study. Another limitation of this
329 research is that we did not have access to instrumentation that would have improved the
330 objectivity of our test battery, such as arthrometers, arthrograms or ultrasonography.
331 However, we would argue that our test battery reflected real-world practice, wherein the
332 majority of clinicians do not have routine access to these tools. We also could not control for
333 the type of rehabilitation protocols undertaken by the cohort, however whether our cohort
334 undertook rehabilitation or not did not associate with outcome (this was investigated in our
335 previous biomechanical analysis of this cohort[16]). Finally, because the LAS cohort were
336 recruited after the initial injury, it is unknown as to whether the deficits identified either in
337 the in this prospective analysis preceded or were caused by the first instance of LAS.

338

339 CONCLUSIONS

340 This is the first analysis in which the predictive value of a clinical test battery for ankle sprain
341 injury for determining CAI has been investigated. While our results showed that some of
342 these clinical tests demonstrate predictive value, the accuracy at which they identify
343 individuals at risk of developing CAI is moderate. Further research is required to determine
344 whether performing these tests in a less heterogenous sample of individuals, representative of

the sub-groups of the CAI paradigm (ie mechanical insufficiency, self-reported instability and recurrent sprains, with different combinations of these three)would improve their predictive value.

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Table 1. Demographics for all LAS participants at the time of recruitment (within 2-weeks of injury), and for CAI and LAS coper participants at time-point 3 (12-months following injury).

Demographic:	Gender		Age (years)		Body mass (kg)		Height (m)	
	n	Male	Female	Mean	95% CI	Mean	95% CI	Mean	95% CI
LAS	82	54	28	22.78	21.89 to 23.67	76.6	73.66 to 79.54	1.72	1.70 to 1.74
CAI	28	17	11	23.21	21.62 to 24.81	75.53	70.14 to 80.91	1.72	1.69 to 1.75
LAS coper	42	26	16	22.74	21.42 to 24.07	73.43	69.66 to 77.20	1.73	1.70 to 1.76

Abbreviations: CAI = Chronic Ankle Instability; CI = confidence interval; LAS = lateral ankle sprain.

Exclusion criteria
1. No previous history of LAS injury on either limb (excluding the initial acute episode)
2. No other severe lower extremity injury in the last 6 months
3. No history of ankle fracture
4. No previous history of major lower limb surgery
5. No history of neurological disease, vestibular or visual disturbance or any other pathology that would impair their motor performance

Table 2. Exclusion criteria for the LAS group

Abbreviations: LAS = lateral ankle sprain

Table 3. Descriptive statistics (% cases for categorical variables; mean and SD for non-categorical variables) of the clinical outcomes delineated by group (CAI vs LAS coper).

Construct	Outcome		CAI		Coper	
			Mean	SD	Mean	SD
Swelling	Figure-of-8 (mm)		12.17	11.36	11.85	8.36
	Knee-to-wall (mm)		57.47	39.67	56.88	42.56
ROM	Inversion (deg)		9.40	5.10	9.15	5.61
	Eversion (deg)		8.80	3.81	8.65	3.71
	Plantar-flexion (deg)		28.21	8.88	31.49	11.35
Arthrokinematics	PTGT (deg)		0.77	0.94	1.43	1.34
			Percent of cases		Percent of cases	
Laxity	Ant Drawer (0-3)	0	70		56.1	
		1	26.7		26.8	
		2	3.3		14.6	
		3	0		0	
	Ttilt (0-3)	0	90		75.6	
		1	10		17.1	
		2	0		2.4	
		3	0		0	

Abbreviations: Ant Drawer = Anterior Drawer Test; CAI = Chronic Ankle Instability; LAS = Lateral Ankle Sprain; PTGT = Posterior Talar Glide Test; Ttilt = Talar Tilt Test

Table 4. Pearson's correlation coefficients of clinical outcomes related to swelling (the figure-of-8 test), ankle joint ROM (including plantarflexion, dorsiflexion, inversion, eversion), laxity (as assessed using the anterior-drawer and talar-tilt tests) and arthrokinematic integrity (using the posterior-talar glide test) to final outcome (CAI vs LAS coper) determined at the 1-year time-point.

		Swelling	ROM				Laxity		Arthrokinematics
		Figure-of-8 (mm)	Plantar-flexion (deg)	Knee-to-wall (mm)	Inversion (deg)	Eversion (deg)	Ant Drawer	Ttilt	PTGT (deg)
Outcome	r	-0.017	0.157	-0.007	-0.023	-0.20	0.178	0.156	0.269
(CAI/coper)	p-value	0.893	0.212	0.953	0.849	0.870	0.139	0.201	0.024

Abbreviations: Ant Drawer = Anterior Drawer Test; CAI = Chronic Ankle Instability; LAS = Lateral Ankle Sprain; PTGT = Posterior Talar Glide Test; Ttilt = Talar Tilt Test.

Table 5. Results of the logistic regression analysis (with associated standardized beta weights) for the input variables at the 2-week time point.

Variable	$\hat{b}$	SE $\hat{b}$	$\hat{\beta}$	Wald t	Prob.	OR	95% CI of the OR	
							Lower	Upper
PTGT	0.55	0.25	0.12	4.66	0.03	1.73	1.05	2.84
PF ROM	0.02	0.03	0.04	0.49	0.48	1.02	0.96	1.08
Ant Drawer	-0.63	0.49	0.07	1.61	0.21	1.87	0.71	4.94
Ttilt	-0.65	0.89	0.03	0.22	0.64	1.52	0.26	8.71
Constant	-1.26	0.92	--	1.85	0.17	0.28		

$\hat{\beta}$ = semi-standardized beta weight using the mean predicted probability of 0.23 as a reference value; *OR* = odds ratio; CI = confidence interval; SE = standard error.

CLINICAL TESTS

Ankle joint range-of-motion was assessed using a handheld goniometer (Lafayette Instrument Company, Lafayette, Indiana). Ankle joint plantarflexion was assessed with participants lying prone on a plinth with the knee flexed to 90°; the centre of the goniometer was placed on the lateral malleolus with its stable arm parallel to the fibula and its movable one parallel to the fifth metatarsal. Participants were then instructed to actively "point your toe away from your body as far as you can"; the plantarflexion angle was calculated as - $(90° - \text{maximum plantar} - \text{flexion angle})$.

Ankle inversion and eversion were assessed with the patient in the supine position. A rolled-towel was placed under the knee to maintain a position of approximately 10° flexion. A piece of paper adhered to a plexi-glass surface was placed at the posterior aspect of the calcaneus of the injured limb. A line was then drawn along the plexi-glass with the ankle placed in a sub-talar neutral position by the examiner. The participant was then instructed to invert or evert their ankle, as previously demonstrated prior to the assessment, and a second line was then drawn along the plexi-glass surface, thus creating two intersecting lines. A goniometer was then used to measure the acute angle created.[21]

Ankle dorsiflexion was assessed using a knee-to-wall test. Participants completed this test in a standing position. The lower limb was placed in a standardized position: the second toe, centre of the heel, and knee were kept in a plane perpendicular to an opposing wall, with the heel firmly in contact with the ground. Participants were then required to lunge forward until the anterior aspect of the patella contacted the wall and maximum dorsiflexion was obtained without the ipsilateral heel coming off the ground. A tape measure was used to measure the distance between the great toe and the wall [11].

Ankle swelling was assessed using the figure-of-eight method [22]. Participants began seated on a plinth with their knee flexed and the test limb hanging freely above the ground, several

landmarks were first marked using a skin pencil: the tuberosity of the navicular; the base of the 5th metatarsal; the distal tip of the medial malleolus; the distal tip of the lateral malleolus; the tibialis anterior tendon. A tape measure was then placed beginning midway between the tibialis anterior tendon and lateral malleolus, drawn medially across the instep and placed distal to the tuberosity of the navicular, pulled across the arch and up just proximal to the base of the 5th metatarsal, finally crossing the tibialis anterior tendon (sub-talar measurement). The tape was then continued around the distal tip of the medial malleolus, pulled across the achilles tendon and at the distal tip of the lateral malleolus (talar measurement) [22]. Both the injured and non-injured limbs were measured, and the difference between the two was calculated to estimate swelling (mm) on the injured limb.

Ligamentous laxity at the ankle joint was assessed using the anterior drawer and the talar tilt tests. Each test was conducted with participants seated on a plinth with their knee flexed and the test limb hanging freely above the ground. For the anterior drawer test, the lower leg was stabilised with the foot at approximately 20° of ankle plantar flexion. The examiner then gripped the posterior-inferior aspect of the calcaneus and applied a posterior-anterior force to "draw the talus forward in the ankle mortise" [11]. For the talar tilt test, the foot was held in a neutral sagittal plane position. The examiner again gripped the posterior-inferior aspect of the calcaneus and subsequently tilted the rearfoot into inversion[11]. The 'end-feel' for both tests was graded on a scale from 0 to 3 (0 = hypomobile, 1 = normal, 2 = mild laxity, 3 =gross laxity).

The arthrokinematics of the talus were assessed using the posterior talar glide test. In this test, passive knee flexion during DF ROM, while the foot is placed in subtalar neutral is used as an assessment of posterior talar glide. This test was conducted with participants seated on a plinth with their knee flexed and the test limb hanging freely above the ground. A bubble inclinometer (Baseline®, Fabrication Enterprises, White Plains, NY) was fastened approximately 6 cm above the participant's lateral malleolus. After positioning the inclinometer, the participant's foot was placed into a subtalar neutral position and the talus was pushed posteriorly, and the ankle into dorsiflexion, until a firm capsular end-feel was

encountered. At the endpoint, the glide was stopped and the angle of knee flexion was recorded. Measurements were repeated 3 times with the mean of the 3 repetitions to serve as an outcome measure [11].