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

Running title: Predictors of CAI following ankle sprain

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26 **Abstract**

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

29 **Design:** Cohort study

30 **Setting:** University biomechanics laboratory

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

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

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

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

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

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51 Lateral ankle sprain (LAS) is one of the most common acute musculoskeletal injuries; its
52 high prevalence pervades across many different populations and activities¹. Despite its
53 ubiquity, LAS is typically considered an innocuous injury that resolves quickly with minimal
54 treatment². Unfortunately, this is not the case, as pain and swelling are commonplace
55 following acute LAS³, contributing to reduced functional capacity³ and occupational absence⁴
56 in many individuals. The development of these symptoms, which also include “giving-way”
57 of the ankle joint, ankle joint instability and recurrent ankle sprain are representative of a
58 condition known as chronic ankle instability (CAI)⁵. It has been proposed that only after a 12-
59 month time interval does the risk of recurrence recede to that of a first-time injury⁶.

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61

62 Recent literature highlights the high prevalence of CAI following LAS. A recent systematic
63 review identified that approximately 33% of patients still experience pain and instability,
64 34% report at least one re-sprain, and up to 64% state that they have not recovered fully from
65 their initial injury at a 1-year follow up after conventional treatment⁷. Furthermore, in a cross-
66 sectional survey of an Australian community population aged between 18-65 years, chronic
67 ankle disorders affected almost 20% of the sample, with the majority of participants
68 attributing their disorder to a previous ankle sprain injury⁸.

69

70 To expedite recovery and prevent CAI after LAS, it is important to devise a treatment plan
71 tackling the impairments identified during clinical assessment in the acute period of injury⁹.

72 A recent recognition paradigm has suggested a three-tiered approach to assessing functional
73 impairment and disability in CAI populations⁹. In this paradigm, self-assessment outcomes in
74 which the person reports what they can and cannot do (usually via a questionnaire) are
75 combined with clinical and laboratory outcomes. Cumulatively, these metrics quantify a

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

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84 It is possible that deficits in clinical outcomes, including ankle-joint swelling³, range-of-
85 motion (ROM)^{3,10} impairment, arthrokinematic restriction (posterior talar glide)¹¹ and hyper-
86 or hypomobility¹²⁻¹⁴ may relate to the eventual development of CAI. Unfortunately, while
87 there are numerous cross-sectional investigations of CAI populations which have identified
88 its associated deficits, longitudinal research investigating the predictors of CAI in populations
89 with first-time ankle sprain is sparse¹⁵. Such investigations stand to elucidate the coping
90 mechanisms that lead to recovery following first-time LAS.

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93 Recently published work undertaken in our laboratory presented instrumented motion
94 analyses of participants with acute, first-time LAS completing a battery of movement tasks
95 during a 12-month follow-up¹⁶. This investigation identified that deficits in dynamic balance
96 performance and self-reported function 6-months following a first-time acute LAS can be
97 used to predict CAI development¹⁶. Unfortunately, the implementation of these findings in a
98 clinical context is hindered by the lack of portability of the data acquisition methods, the high
99 cost of the necessary equipment and the time required to analyze the acquired data. On this

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

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

110

111 MATERIALS AND METHODS

112 Design: Cohort study

113 Participants

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

121

122

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

125

126

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

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131

132 Outcome measures

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

135

136

137 In a series of separately published papers, the LAS cohort were evaluated as a whole during a
138 series of postural control, gait and jumping/landing tasks¹⁶. In addition to the biomechanical
139 evaluation of these tasks, the primary author (XX) evaluated the cohort using a battery of
140 clinical tests at the 2-week time-point to explore their potential predictive value for CAI or
141 LAS 'coper' status at the 12-month time-point. As such, this investigation details one part of
142 a wider exploratory analysis of the clinical and/or laboratory outcomes that can be utilised to
143 predict long-term CAI outcome. None of the data for the postural control, gait and
144 jumping/landing tasks¹⁶ have been utilised in the present report.

145

146

147 Participants' designation as CAI or LAS coper status was completed according to recently
148 published guidelines¹⁷⁻²⁰: participants with a Cumberland Ankle Instability Tool (CAIT)
149 score of <24 were designated as having CAI while participants with a CAIT score ≥ 24 were

150 designated as LAS copers¹⁷, to avoid the potential for false positives in this group²¹.

151 Furthermore, to be designated as a LAS coper, participants also must have returned to pre-
152 injury levels of activity and function, and to have reported no instances of “giving way” at
153 their ankle joint²².

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157 Clinical assessment procedures

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

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168 Data analysis

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

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

178

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180

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182 report.

183

184 RESULTS

185 Descriptive statistics for the clinical tests are presented in Table 3. Results of preliminary
186 correlation analyses are presented in Table 4. The potential predictors were entered into a
187 direct logistic regression model in one block. Scores on the knee-to-wall test, figure-of-eight
188 test, eversion ROM and inversion ROM were then removed sequentially from the model
189 using a backward elimination technique in the optimisation of its predictive capacity. The
190 regression analysis was then repeated with the remaining predictors (scores on the posterior
191 talar glide test [PTGT], anterior-drawer test, talar-tilt test and plantarflexion ROM). This
192 model was statistically significant $\chi(2, N = 68) = 15.63, p = 0.008$, and explained between
193 21.7% (Cox and Snell R square) and 29.0% (Nagelkerke R squared) of the variance in
194 outcome (i.e. CAI vs Coper) and correctly classified 68.8% of cases. The sensitivity and
195 specificity of the final model was 64.3% and 72.2% respectively. The results of this logistic
196 regression analysis (with associated standardised beta-weights) are presented in Table 5.
197 Based on the standardised beta-weights, the PTGT explained the greatest variance in outcome
198 (CAI vs coper) in the final regression equation.

199

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 here¹⁶. 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 investigation¹⁶, findings from the current study, although significant, must be taken with
214 caution.

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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

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

227

228

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

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240 Overall, we conclude that these findings are not clinically meaningful, as the sensitivity and
241 specificity of the final model corresponded to a likelihood ratio of approximately 0.9,
242 denoting that participants with better scores on these clinical outcomes only have a ‘slight’
243 decrease in their risk of developing CAI²⁴. Furthermore, the exploratory nature of the
244 statistical model increases the risk for type 1 error, further belying its potential clinical value.
245 Despite this, we consider these findings to be a valuable addition to the literature as they

246 should inform current classification paradigms for CAI²⁵, encourage future research efforts
247 and direct clinicians' assessment protocols for acute ankle sprain and CAI.

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249

250 With regards to the classification paradigms, three primary categorical constructs are
251 considered to contribute to CAI: mechanical insufficiency, self-reported instability and
252 recurrent sprains. CAI may result from any, all or different combinations of these constructs.

253 On this basis, the self-report outcome that was used to diagnose CAI in the current study may
254 have masked the contribution of these underlying constructs to the overall condition. For the
255 purposes of the present study, the CAIT was used to diagnose individuals as having CAI or
256 not, which is in line with the recommendations of the International Ankle Consortium²⁵.

257 However, it is entirely possible that grouping participants according to the extent of their self-
258 reported disability as determined by the CAIT undermined the statistical power of the
259 regression model, as members of each group may have presented with different combinations
260 of the underlying constructs of CAI. Alternatively, it is possible that mechanical impairments
261 (local arthrokinematic restriction and hypomobility) are weakly associated with CAI, and our
262 results can be taken at face value. However, we would consider the former hypothesis as
263 more likely, on the basis that previous authors have investigated mechanical impairment as an
264 explanatory factor for CAI in a cross-sectional manner, with no definitive association
265 between ankle laxity and the wider paradigm of CAI²⁶⁻³¹. While an acute ankle sprain
266 typically threatens the integrity of ligamentous structures, and some authors have reported
267 lingering hypomobility and hypermobility following the acute injury²⁶⁻³¹, these outcomes do
268 not appear to be observed consistently in CAI patients.

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270

271 This lends towards the hypothesis that the arthrokinematic restrictions (as assessed through
272 the PTGT) and hypomobility (as determined using the anterior-drawer and talar-tilt tests)
273 contribute more to a sub-group model that falls under a wider paradigm of CAI-our results
274 suggest that mechanical instability may predicate CAI in some patients, and not in others. In
275 particular, the unique contribution of the PTGT test to our regression model would suggest
276 that arthrokinematic restriction should be investigated further as part of a sub-group analysis
277 of CAI patients. This arthrokinematic restriction was seemingly independent of dorsiflexion
278 ROM despite the fact that previous research has identified that dorsiflexion ROM (as
279 assessed using the knee-to-wall test) is moderately correlated with talar glide when measured
280 with the PTGT³². Importantly, this correlation was identified in a non-injured cohort of
281 participants³². Findings from the current study point to an apparent dissociation between
282 these outcomes in patients with acute LAS. While the PTGT has been used in the literature to
283 assess restrictions in arthrokinematics at the talocrural joint in patients suffering from
284 recurrent ankle sprains^{11,33}, there is an absence of such investigation in cohorts in the acute
285 phase of injury.

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

295 present study. In light of the recruitment time for the current study, which extended for >18-
296 months¹⁶ from a catchment area population of approximately 350,000, it is likely that a multi-
297 centre research study is required to achieve large enough sample sizes to represent the
298 different CAI constructs. We consider this to be a priority for future research if efforts are to
299 be made to reduce the potential consequences of the high incidence and prevalence of ankle
300 sprain across a wide variety of populations and activities¹. For researchers conducting cross-
301 sectional analyses of CAI cohorts, we echo the sentiments of the International Ankle
302 Consortium, who have recommended that CAI classification should relate specifically to the
303 research question²⁵. They have suggested that if investigators are interested in the deficits
304 present in participants with CAI, such as mechanical insufficiency, measures of self-reported
305 function or disability may not be a necessary inclusion criterion to answer the research
306 question. However, if functional impairment is relevant to the proposed project or
307 intervention, then validated ankle specific questionnaires that are designed to evaluate self-
308 reported function should be used to create the necessary inclusion criterion, and tasks with
309 established validity for the specific construct should be employed. For instance, the Star
310 Excursion Balance Test has demonstrated predictive value for acute ankle sprain incidence³⁴
311 and CAI development¹⁶, thus qualifying it as a valid measure for functional impairment. In
312 contrast, it remains unclear exactly what tests should be used to quantify the mechanical
313 insufficiencies underpinning CAI. The available longitudinal data suggest that ankle-joint
314 laxity³⁵ and ROM^{35,36} do not relate to ankle sprain incidence, and the current study is the first
315 to suggest that their predictive value for CAI is significant, but limited. This may change with
316 appropriate segmentation of the sub-groups of CAI into its underlying constructs. On this
317 note, it is encouraging that researchers have begun to adopt this approach, wherein the
318 subgroups of CAI are being analysed, rather than being aggregated together³⁷. However, to
319 the authors' knowledge, currently no longitudinal data are available for each CAI subgroup.

320

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 cohort¹⁶). 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

345 the sub-groups of the CAI paradigm (ie mechanical insufficiency, self-reported instability and
346 recurrent sprains, with different combinations of these three) would improve their predictive
347 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

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

time-point 3 (12-months following injury).

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
Laxity	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	
			0	70	56.1	
			1	26.7	26.8	
			2	3.3	14.6	
		3	0	0		
	Ant Drawer (0-3)	0	90	75.6		
		1	10	17.1		
		2	0	2.4		
		3	0	0		
	Tilt (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

		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

test) to final outcome (CAI vs LAS coper) determined at the 1-year time-point.

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
Tilt	-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° – maximum plantar – 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 subtalar 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 wall¹¹.

Ankle swelling was assessed using the figure-of-eight method²². 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 inversion¹¹. 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 measure¹¹.

ACCEPTED MANUSCRIPT