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Acute clinical evaluation for the diagnosis of lateral ankle ligament injuries is useful: A comparison between the acute and delayed settings

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Abstract

Purpose: To determine the diagnostic value of seven injury history variables, nine clinical tests (including the combination thereof) and overall clinical suspicion for complete discontinuity of the lateral ankle ligaments in the acute (0–2 days post-injury) and delayed setting (5–8 days post-injury).

Methods: All acute ankle injuries in adult athletes (≥18 years) presenting up to 2 days post-injury were assessed for eligibility. Athletes were excluded if imaging studies demonstrated a frank fracture or 3 T MRI could not be acquired within 10 days post-injury. Using standardized history variables and clinical tests, acute clinical evaluation was performed within 2 days post-injury. Delayed clinical evaluation was performed 5–8 days post-injury. Overall, clinical suspicion was recorded after clinical evaluation. MRI was used as the reference standard.

Results: Between February 2018 and February 2020, a total of 117 acute ankle injuries were screened for eligibility, of which 43 were included in this study. Complete discontinuity of lateral ankle ligaments was observed in 23 (53%) acute ankle injuries. In the acute setting, lateral swelling had 100% (95% confidence interval [CI]: 82–100) sensitivity, haematoma had 85% (95% CI: 61–96) specificity and the anterior drawer test had 100% (95% CI: 77–100) specificity. In the delayed setting, sensitivity for the presence of haematoma improved from 43% (95% CI: 24–65) to 91% (95% CI: 70–98; $p < 0.01$) and the sensitivity of the anterior drawer test improved from 21% (95% CI: 7–46) to 61% (95% CI: 39–80; $p = 0.02$). Clinical suspicion had a positive likelihood ratio (LR) of 4.35 (95% CI: 0.55–34.17) in the acute setting and a positive LR of 6.09 (95% CI: 1.57–23.60) in the delayed setting.

Conclusions: In the acute setting, clinical evaluation can exclude complete discontinuity (e.g., absent lateral swelling) and identify athletes with a high

Abbreviations: ATFL, anterior talofibular ligament; AUC, area under the curve; CFL, calcaneofibular ligament; CI, confidence interval; IQR, interquartile range; IRB, Institutional Review Board; K, Kappa; LR-, negative likelihood ratio; LR+, positive likelihood ratio; MRI, magnetic resonance imaging; NPV, negative predictive value; N.S., not statistically significant; OR, odds ratio; PD-FS, proton-density fat-saturated; PPV, positive predictive value; SE, standard error; T, Tesla; VAS, visual analogue scale.

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probability of complete discontinuity (e.g., positive anterior drawer test) of the lateral ankle ligaments. In the delayed setting, the sensitivity of common clinical findings increases resulting in an improved diagnostic accuracy. In clinical practice, this study underlines the importance of meticulous clinical evaluation in the acute setting.

Level of Evidence: Level III.

KEYWORDS
ankle, clinical assessment, general sports trauma, ligaments, sensitivity and specificity

INTRODUCTION

Acute injuries of the lateral ankle ligaments are the most common injury in sports [9]. Accurate diagnosis is essential for adequate therapy and prevention of chronic ankle instability and post-traumatic osteoarthritis [10]. For the diagnosis, clinical evaluation is considered the mainstay, with advanced imaging techniques (i.e. magnetic resonance imaging [MRI]) predominantly reserved for elite athletes. In the acute setting, of the first 0–2 days post-injury, pain and swelling might negatively affect the reliability of physical examination. Current clinical guidelines therefore recommend delayed physical examination 4–7 days post-injury [15, 23].

The recommendation for delayed physical examination is based on one study [5–7]. In a prospective cohort study of 160 patients presenting to an emergency department after an inversion trauma, a physical examination was performed within 2 days and after 4–7 days. In the acute setting (0–2 days post-injury), the combination of lateral haematoma, tenderness over the anterior talofibular ligament (ATFL) and a positive anterior drawer test had 71% sensitivity and 33% specificity. When performed in the delayed setting (4–7 days post-injury), the diagnostic value for the combination of these three clinical tests improved to 96% sensitivity and 84% specificity. However, only the diagnostic value for these three clinical tests was evaluated and no injury history variables were included. In the athletic setting, where there are important time constraints for return to sport, an early accurate diagnosis and therefore appropriate management are important considerations [13]. Accordingly, understanding the veracity of clinical examination, injury history and the combination thereof is required.

The aim of this study is to determine the diagnostic value of seven injury history variables, nine clinical tests (including the combination thereof) and overall clinical suspicion for complete discontinuity of the lateral ankle ligaments in the acute (0–2 days post-injury) and delayed setting (5–8 days post-injury). The hypothesis of this study is that acute clinical evaluation can be used to diagnose complete discontinuity of the lateral ankle ligaments in athletes.

MATERIALS AND METHODS

Ethics approval was acquired from the Anti-Doping Lab Qatar Review Board (Institutional Review Board [IRB] No. F2016000153). Written informed consent was obtained from all athletes at the time of inclusion. This study was part of a prospective cohort study conducted at Aspetar Orthopaedic and Sports Medicine Hospital from February 2018 until February 2020. The inclusion criteria for this specific study are as follows: all acute ankle injuries in adult athletes (≥18 years), participating in sports at a professional or recreational level and presenting up to 2 days post-injury. Ankle injuries were excluded if imaging demonstrated a fracture, if the 3 T MRI study could not be acquired within 10 days post-injury or if the patient did not undergo delayed physical examination 5–8 days post-injury [1, 2].

Acute clinical evaluation

Initial clinical evaluation was performed up to 2 days post-injury by an Orthopaedic Surgeon or Sports Medicine Physician. Using a standardized form, injury history was recorded and a standardized physical examination was performed.

Delayed clinical evaluation

Patients underwent a second (delayed) evaluation 5–8 days post-injury. The physician was blinded to the results of the initial acute clinical evaluation and MRI findings. To determine the inter-rater reliability, a second physician repeated the clinical evaluation.

Injury history

A total of seven injury history variables were recorded during acute and delayed clinical evaluation using a previously described form [3]: (1) Injury [new/recurrent], (2) Occasion [game/training/non-sports injury], (3)

Contact [contact/non-contact], (4) Mechanism of injury [inversion/eversion/external-rotation/internal-rotation], (5) Perceived presence of swelling [yes/no], (6) Perceived ankle instability [yes/no] and (7) Sensation of pain radiating up the leg [yes/no].

Physical examination

Nine standardized clinical tests were recorded during acute and delayed physical examination using a previously described standardized form [3]: (1) Presence of haematoma [yes/no], (2) Tenderness to palpation [lateral/medial/anterior/posterior], (3) Ability to walk normally [yes/no], (4) Ability to walk on toes [yes/no], Ability to walk on heels [yes/no], (5) Passive range of motion in dorsal flexion, plantar flexion, inversion and eversion [full/restricted/painful], (6) Presence of swelling [yes/no], (7) Swelling site [laterally/medially/anterior/posterior/syndesmosis], (8) anterior drawer test [Grades 0–2] and (9) talar tilt test [Grades 0–2]. The anterior drawer test and the talar tilt test were graded as Grade 0: normal; Grade 1: mild laxity; and Grade 2: moderate to gross laxity [5]. The laxity tests were considered to indicate complete discontinuity when scored Grade 2.

Overall clinical suspicion of lateral ligament injury

Clinical suspicion of lateral ligament injury was recorded by the examining physician once the clinical evaluation had been completed. Clinical suspicion was scored on a four-grade scale: Grade 0: intact ligament, Grade 1: partial discontinuity of a ligament, Grade 2: incomplete discontinuity of a ligament with moderate functional impairment, and Grade 3: complete discontinuity with loss of integrity. The overall clinical suspicion was based on the physicians' overall interpretation of injury history, physical examination and clinical tests. Clinical suspicion was considered positive when scored Grade 3.

Reference standard

MRI was used as the reference standard. Surgical exploration is considered the gold standard for ligamentous ankle injuries. However, this would only be justified in patients with an injury requiring surgical treatment. MRI has a reported 78% sensitivity and 80% specificity for complete discontinuity of the ATFL [21]. For complete discontinuity of the calcaneofibular ligament (CFL), MRI has a sensitivity of 61% and a specificity of 95%. MRI was used as a reference standard as it is the best available alternative to surgical exploration. All patients underwent a 3.0-T MR scan (GE Discovery, GE Healthcare) with an 8-channel receive-only Foot & Ankle array (Invivo, Philips Healthcare). The imaging protocol has been described before [1]. In the sagittal plane, T1-weighted and Proton-Density Fat-Saturated [PD-FS] sequences were acquired, axial T2-weighted and PD-FS sequences were obtained and in the coronal plane, a PD-FS sequence was acquired.

MRI grading of lateral ankle ligaments

Using a standardized scoring form, the MR scans were scored by two radiologists (J.A. & M.A.) with 11 and 3 years of experience in musculoskeletal imaging. Although anatomically closely related, the ATFL and CFL were graded according to the Schneck grading system separately [4, 17, 20]: normal (Grade 0); low-grade sprain (Grade 1: peri-ligamentous high signal/oedema on proton density-weighted sequences and no discontinuity of fibres); partial discontinuity (Grade 2: partial discontinuity but preserved remnant fibres) and complete discontinuity (Grade 3). Previous reports on this cohort demonstrated limited inter-rater reliability for the ATFL ($K = 0.55$) and CFL ($K = 0.31$) when using the Schneck grading system [1]. The radiologists resolved disagreement about the grading of individual ligaments by case discussion during a consensus meeting. To calculate the diagnostic value for complete discontinuity of the lateral ankle ligaments, the Schneck grading system was dichotomized [1]. Acute ankle injuries were considered disease-positive when there was complete discontinuity (Grade 3) of the ATFL and/or CFL.

Dichotomization of injury history and clinical test variables

Variables obtained during injury history and physical examination were dichotomized as previously described [3]. Injury occasion [game/training/non-sports injury] was dichotomized to [game/other]. Mechanism of injury [inversion/eversion/external-rotation/internal-rotation] was dichotomized per individual mechanism of injury, that is, [inversion/other]. Tenderness to palpation [lateral/medial/anterior/posterior] was dichotomized per location, that is, lateral tenderness to palpation [yes/no] and passive range of motion per direction [full/restricted/painful] was dichotomized: that is, passive dorsal flexion painful [yes/no]. The laxity tests were dichotomized as (1) normal [Grades 0–1] and (2) complete discontinuity [Grade 2].

Statistical analysis

Statistical analysis was performed using Rstudio (Rstudio v3.6.3). Descriptive statistics was used to

report demographic data (i.e., gender, age or sport) and injury distribution.

The diagnostic value for injury history (seven variables), physical examination (nine clinical tests) and overall clinical suspicion were calculated using MRI findings as the reference standard. Contingency tables were created to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+) and negative likelihood ratio (LR−). Diagnostic values were calculated for complete discontinuity of the ATFL and/or CFL. For each variable, the area under the curve (AUC) was calculated. To compare the diagnostic value (sensitivity/specificity) of each variable between the acute and delayed settings, McNemar's test was used [22].

The association between the independent variables and the presence of complete discontinuity of the lateral ankle ligaments in the acute and delayed settings were evaluated by univariate logistic regression analyses. Independent variables with a p value < 0.15 in the univariate logistic regression analysis were entered in a multivariate logistic regression analysis. Overall clinical suspicion was not included in the multivariate analyses, as the aim was to determine what combination of objective variables could predict injury. To address quasi-complete separation, Firth's penalized maximum likelihood estimation was used to perform logistic regression analyses using R package logistf [12].

The data analyzed for this study was part of a prospective cohort study on the functional outcome and return to play of athletes with an acute ligamentous ankle injury. Therefore, no a priori sample size calculations were performed for the current study.

Inter-rater reliability for physical examination and overall clinical suspicion in the delayed setting was reported using unweighted kappa statistics and overall agreement. Reliability was interpreted using the Landis and Koch classification: poor if <0, slight 0.00–0.20, fair 0.21–0.40, moderate 0.41–0.60, substantial 0.61–0.80 and almost perfect if 0.81–1.00 [14].

RESULTS

Participants

A total of 117 acute ankle injuries (116 athletes) were assessed for eligibility. Forty-three acute ankle injuries (43 athletes) were included (Figure 1). Most included athletes were male (86%). Of the 43 included athletes, 58% played football, 12% handball, 9% volleyball, 7% basketball and 14% participated in other sports. The median age at time of injury was 24 years (interquartile range [IQR]: 20–28). Clinical evaluation in the acute setting was performed after a median of 1 day (IQR: 1–2). The MR scans were obtained at a median of 3 days (IQR: 2–4) post-injury. The delayed clinical evaluation was performed after a median of 7 days (IQR: 6–8). Using MR imaging as the reference standard, complete discontinuity of the ATFL was observed in 23 (53%) acute ankle injuries. Complete discontinuity of the CFL was observed in 8 (19%) acute ankle injuries. Complete discontinuity of the ATFL and/or CFL was observed in 23 (53%) acute ankle injuries.

Diagnostic value of injury history

The diagnostic value of injury history in the acute and delayed settings is detailed in Table 1. In the acute

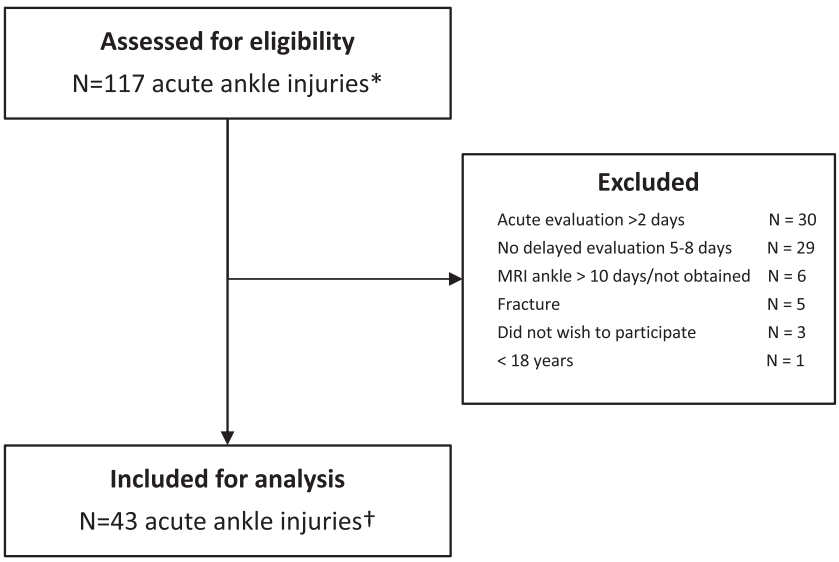

FIGURE 1 Flowchart for in-/exclusion. *In 116 athletes; †In 43 athletes.

TABLE 1 Diagnostic accuracy of injury history for complete discontinuity of the lateral ankle ligaments in 43 athletes.

	Positive findings	Sensitivity%	Specificity%	LR+	LR−	PPV%	NPV%	AUC
Clinical history								
Injury [recurrent]	9/43 (21%)	30 (14–53)	90 (67–98)	3.04 (0.71–13.01)	0.77 (0.58–1.02)	78 (40–96)	53 (35–70)	0.60 (0.43–0.77)
Occasion [game]	25/43 (58%)	65 (43–83)	50 (28–72)	1.30 (0.77–2.22)	0.70 (0.36–1.34)	60 (39–78)	56 (31–78)	0.58 (0.40–0.75)
Contact [contact]	23/41 (56%)	57 (35–76)	44 (22–69)	1.02 (0.59–1.76)	0.98 (0.54–1.79)	57 (35–76)	44 (22–69)	0.51 (0.33–0.69)
Mechanism of injury								
• Inversion	33/43 (77%)	78 (56–92)	25 (10–49)	1.04 (0.75–1.45)	0.87 (0.30–2.53)	55 (37–71)	50 (20–80)	0.52 (0.34–0.69)
• Eversion	4/43 (9%)	9 (2–30)	90 (67–98)	0.87 (0.13–5.62)	1.01 (0.88–1.16)	50 (9–91)	46 (30–63)	0.49 (0.32–0.67)
• External Rotation	3/43 (7%)	0 (0–18)	85 (61–96)	-	1.18 (1.16–1.20)	0 (0–69)	43 (27–59)	0.43 (0.25–0.60)
• Internal Rotation	0/43 (0%)	0 (0–18)	100 (80–100)	-	1.00 (1.00–1.00)	-	47 (31–62)	0.50 (0.33–0.68)
Acute setting								
Perceived swelling	38/43 (88%)	100 (82–100)	25 (10–49)	1.33 (1.04–1.72)	-	61 (43–76)	100 (46–100)	0.63 (0.45–0.80)
Perceived instability	9/37 (24%)	35 (15–61)	85 (61–96)	2.35 (0.69–8.02)	0.76 (0.53–1.10)	67 (31–91)	61 (41–78)	0.60 (0.42–0.79)
Pain radiating up	22/42 (52%)	18 (6–41)	65 (41–84)	0.52 (0.18–1.51)	1.26 (0.98–1.62)	36 (12–68)	42 (25–61)	0.42 (0.24–0.59)
Delayed setting								
Perceived swelling	34/43 (79%)	91 (70–98)	35 (16–59)	1.40 (0.99–1.98)	0.25 (0.06–1.12)	62 (44–77)	78 (40–96)	0.63 (0.46–0.80)
Perceived instability	15/42 (36%)	41 (21–63)	70 (46–87)	1.36 (0.59–3.15)	0.84 (0.57–1.25)	60 (33–83)	52 (32–71)	0.55 (0.38–0.73)
Pain radiating up	16/43 (37%)	22 (8–44)	45 (24–68)	0.40 (0.17–0.94)	1.74 (1.24–2.43)	31 (12–59)	33 (17–54)	0.33 (0.17–0.50)

Note: MR imaging was used as the reference standard. The prevalence of positive findings and diagnostic value of clinical history in the acute and delayed settings are presented. Diagnostic values are presented with a 95% confidence interval (95% CI), positive likelihood ratio (LR+), negative likelihood ratio (LR−), positive predictive value (PPV%), negative predictive value (NPV), and area under the curve (AUC).

Abbreviation: MR, magnetic resonance.

TABLE 2 Diagnostic accuracy of acute physical examination for complete discontinuity of the lateral ankle ligaments in 43 athletes.

	Positive findings	Sensitivity%	Specificity%	LR	LR−	PPV%	NPV%	AUC
Clinical findings								
Presence of haematoma	13/43 (30%)	43 (24–65)	85 (61–96)	2.90 (0.92–9.09)	0.66 (0.46–0.97)	77 (46–94)	57 (38–74)	0.64 (0.48–0.81)
Tenderness to palpation								
• Lateral	39/43 (91%)	100 (82–100)	20 (7–44)	1.25 (1.00–1.56)	-	59 (42–74)	100 (40–100)	0.60 (0.43–0.77)
• Medial	30/43 (70%)	78 (56–92)	40 (20–64)	1.30 (0.86–1.98)	0.54 (0.22–1.37)	60 (41–77)	62 (32–85)	0.59 (0.42–0.76)
• Anterior	19/43 (44%)	57 (35–76)	70 (46–87)	1.88 (0.88–4.03)	0.62 (0.37–1.03)	68 (43–86)	58 (37–77)	0.63 (0.46–0.80)
• Posterior	8/43 (19%)	26 (11–49)	90 (67–98)	2.61 (0.59–11.50)	0.82 (0.64–1.06)	75 (36–96)	51 (34–68)	0.58 (0.41–0.75)
• Syndesmosis	24/43 (56%)	65 (43–83)	55 (32–76)	1.45 (0.82–2.56)	0.63 (0.33–1.20)	63 (41–80)	58 (34–79)	0.60 (0.43–0.77)
– Unable to walk normal	30/43 (70%)	87 (65–97)	50 (28–72)	1.74 (1.09–2.77)	0.26 (0.08–0.83)	67 (47–82)	77 (46–94)	0.69 (0.52–0.85)
– Unable to walk on toes	33/43 (77%)	87 (65–97)	35 (16–59)	1.34 (0.93–1.91)	0.37 (0.11–1.28)	61 (42–77)	70 (35–92)	0.61 (0.44–0.78)
– Unable to walk on heels	30/43 (70%)	87 (65–97)	50 (28–72)	1.74 (1.09–2.77)	0.26 (0.08–0.83)	66 (47–82)	77 (46–94)	0.69 (0.52–0.85)
– Range of motion								
• Pain on dorsal flexion	28/43 (65%)	78 (56–92)	50 (28–72)	1.57 (0.96–2.55)	0.43 (0.18–1.04)	64 (44–81)	67 (39–87)	0.64 (0.47–0.81)
• Pain on plantar flexion	29/43 (67%)	78 (56–92)	45 (24–68)	1.42 (0.91–2.23)	0.48 (0.20–1.18)	62 (42–79)	64 (36–86)	0.62 (0.45–0.79)
• Pain on inversion	31/43 (72%)	78 (56–92)	35 (16–59)	1.20 (0.82–1.77)	0.62 (0.24–1.62)	58 (39–75)	58 (29–84)	0.57 (0.39–0.74)
• Pain on eversion	28/43 (65%)	70 (47–86)	40 (20–64)	1.16 (0.74–1.82)	0.76 (0.35–1.63)	57 (37–75)	53 (27–78)	0.55 (0.37–0.72)
Presence of swelling								
• Lateral	36/43 (84%)	100 (82–100)	35 (16–59)	1.54 (1.12–2.12)	-	64 (46–79)	100 (56–100)	0.68 (0.51–0.84)
• Medial	21/43 (49%)	74 (51–89)	80 (56–93)	3.70 (1.49–9.18)	0.33 (0.16–0.66)	81 (57–94)	73 (50–88)	0.77 (0.62–0.92)
• Anterior	15/43 (35%)	57 (35–76)	90 (67–98)	5.65 (1.45–22.08)	0.48 (0.30–0.78)	87 (58–98)	64 (44–81)	0.73 (0.58–0.89)
• Posterior	4/43 (9%)	9 (2–30)	90 (67–98)	0.87 (0.13–5.62)	1.01 (0.88–1.16)	50 (9-91)	46 (30–63)	0.49 (0.32–0.67)
Laxity tests								
– Anterior drawer test	4/36 (11%)	21 (7–46)	100 (77–100)	Infinity	0.79 (0.63–1.00)	100 (40–100)	53 (35–70)	0.61 (0.42–0.79)
– Talar tilt test	2/33 (6%)	12 (2–38)	100 (76–100)	Infinity	0.88 (0.74–1.05)	100 (20–100)	52 (33–69)	0.56 (0.36–0.76)
Clinical suspicion								
– Complete discontinuity	6/43 (14%)	22 (8–44)	95 (73–100)	4.35 (0.55–34.17)	0.82 (0.66–1.03)	83 (36–99)	51 (35–68)	0.58 (0.41–0.76)

Note: MR imaging was used as the reference standard. The prevalence of positive findings and diagnostic value of physical examination in the acute setting are presented. Diagnostic values are presented with a 95% confidence interval (95% CI), positive likelihood ratio (LR+), negative likelihood ratio (LR−), positive predictive value (PPV%), negative predictive value (NPV), and area under the curve (AUC).

Abbreviation: MR, magnetic resonance.

setting, the patient's perceived swelling had 100% sensitivity and 100% negative predictive value. When the patient reported a recurrence of the injury, this had 90% specificity and a positive LR of 3.04 (95% CI: 0.71–13.01) for complete discontinuity of the lateral ankle ligaments.

Physical examination in the acute setting

The diagnostic value of physical examination in the acute setting is reported in Table 2. At the time of acute clinical evaluation, a median VAS score for pain of 5 (IQR: 3–8) was recorded in 39 patients. Tenderness and swelling over the lateral aspect of the ankle had a 100% sensitivity. The presence of haematoma had 85% specificity with a positive LR of 2.90 (95% CI: 0.92–9.09). The anterior drawer test and talar tilt test demonstrated 100% specificity with a positive predictive value of 100%. The results for the univariate logistic regression analyses are demonstrated in Supporting Information: Supplement 1. In the multivariate logistic regression analysis, swelling on the lateral (OR: 36.74; 95% CI: 2.82–5529.44; $p \leq 0.01$) and medial (OR: 12.06; 95% CI: 2.67–76.74; $p \leq 0.01$) aspect of the ankle were associated with complete discontinuity of the lateral ankle ligaments (Table 3).

Physical examination in the delayed setting

The diagnostic value of physical examination in the delayed setting is reported in Table 4. At the time of delayed clinical evaluation, a median VAS score for pain of 3 (IQR: 1–5) was recorded. The diagnostic value of tenderness over the lateral aspect did not change significantly compared to the acute setting. The sensitivity for the presence of haematoma increased from 43% in the acute setting to 91% in the delayed setting ($p \leq 0.01$). The anterior drawer test demonstrated an improvement in sensitivity from 21% in the acute setting to 61% in the delayed setting ($p = 0.02$). In the multivariate analysis, the presence of haematoma (OR: 10.72; 95% CI: 1.93–83.79; $p \leq 0.01$) and swelling over the posterior aspect of the ankle (OR: 12.77; 95% CI: 2.59–82.74; $p \leq 0.01$) were associated with complete discontinuity of the lateral ankle ligaments - (Table 3). Inter-rater reliability for physical examination in the delayed setting is demonstrated in Supporting Information: Supplement 2.

TABLE 3 Multivariate logistic regression analysis for the association between injury history, physical examination and laxity tests for complete discontinuity of the lateral ankle ligaments.

		Multivariate		
	N	OR (95% CI)	SE	*p* Value
Acute setting				
– Lateral swelling	43	36.74 (2.82–5529.44)	1.80	<0.01
– Medial swelling	43	12.06 (2.67–76.74)	0.84	<0.01
Delayed setting				
– Presence of haematoma	43	10.72 (1.93–83.79)	0.96	<0.01
– Posterior swelling	43	12.77 (2.59–82.74)	0.89	<0.01

Note: The odds ratio (OR) of the predictors associated with complete discontinuity of the lateral ankle ligaments are presented. Values are presented as β-coefficients with corresponding 95% confidence interval (95% CI) and standard error (SE).

DISCUSSION

The most important finding of the present study was that in the acute setting (0–2 days post-injury), physical examination is useful to exclude complete discontinuity of the lateral ankle ligaments. When swelling over the lateral malleolus is absent in the first 2 days, complete discontinuity is unlikely. In the acute setting, clinical findings with high specificity (e.g., haematoma, anterior drawer test, and talar tilt test) can identify athletes with an increased probability of complete discontinuity. Within 2 days post-injury, the combination of lateral and medial swelling best identified acute ankle injuries at risk for complete discontinuity of the lateral ankle ligaments. In the delayed setting, the diagnostic value of common clinical findings is improved as pain and swelling subsides. After 5–8 days post-injury, the presence of haematoma and posterior swelling best-identified ankle injuries at risk for complete discontinuity of the lateral ankle ligaments. When in the acute or delayed setting, the physician's overall clinical suspicion is positive, and a high probability for complete discontinuity of the lateral ankle ligaments exists.

Diagnostic value of injury history

A history of injury recurrence had a positive predictive value of 78% for complete discontinuity of the lateral ankle ligaments. This is in contrast with previous studies which did not find a correlation between prior injury and complete discontinuity [8, 19]. The patient's perceived swelling had a negative predictive value of 100% in the acute setting. In the study by van Dijk et al., no negative predictive value for perceived swelling was provided. However, patients reported immediate swelling in

TABLE 4 Diagnostic accuracy of delayed physical examination for complete discontinuity of the lateral ankle ligaments in 43 athletes.

	Positive findings	Sensitivity%	*p* Value	Specificity%	*p* Value	LR+	LR-	PPV%	NPV%	AUC
Clinical findings										
Presence of haematoma	27/43 (63%)	91 (70–98)	<0.01	70 (46–87)	n.s.	3.04 (1.54–6.01)	0.12 (0.03–0.49)	78 (57–91)	88 (60–98)	0.81 (0.67–0.95)
Tenderness to palpation										
• Lateral	35/43 (81%)	100 (82–100)	n.s.	40 (20–64)	n.s.	1.67 (1.17–2.38)	-	66 (48–80)	100 (60–100)	0.70 (0.54–0.86)
• Medial	27/43 (63%)	78 (56–92)	n.s.	55 (32–76)	n.s.	1.74 (1.02–2.96)	0.40 (0.17–0.93)	67 (46–83)	69 (41–88)	0.67 (0.50–0.83)
• Anterior	19/43 (44%)	65 (43–83)	n.s.	80 (56–93)	n.s.	3.26 (1.29–8.23)	0.43 (0.24–0.78)	79 (54–93)	67 (45–84)	0.73 (0.57–0.88)
• Posterior	16/43 (37%)	61 (39–80)	0.04	90 (67–98)	n.s.	6.09 (1.57–23.60)	0.43 (0.26–0.73)	88 (60–98)	67 (46–83)	0.75 (0.61–0.90)
• Syndesmosis	28/43 (65%)	74 (51–89)	n.s.	45 (24–68)	n.s.	1.34 (0.84–2.14)	0.58 (0.26–1.30)	61 (41–78)	60 (33–83)	0.60 (0.42–0.77)
– Unable to walk normal	15/43 (35%)	52 (31–73)	0.02	85 (61–96)	0.04	3.48 (1.14–10.60)	0.56 (0.36–0.88)	80 (51–95)	61 (41–78)	0.69 (0.53–0.85)
– Unable to walk on toes	15/43 (35%)	39 (20–61)	<0.01	70 (46–87)	0.04	1.30 (0.56–3.03)	0.87 (0.60–1.26)	60 (33–83)	50 (31–69)	0.55 (0.37–0.72)
– Unable to walk on heels	15/43 (35%)	39 (20–61)	<0.01	70 (46–87)	n.s.	1.30 (0.56–3.03)	0.87 (0.60–1.26)	60 (33–83)	50 (31–69)	0.55 (0.37–0.72)
– Range of motion										
• Pain on dorsal flexion	29/43 (67%)	83 (60–94)	n.s.	50 (28–72)	n.s.	1.65 (1.03–2.66)	0.35 (0.13–0.93)	66 (46–81)	71 (42–90)	0.66 (0.50–0.83)
• Pain on plantar flexion	19/43 (44%)	57 (35–76)	n.s.	70 (46–87)	n.s.	1.88 (0.88–4.03)	0.62 (0.37–1.03)	68 (43–86)	58 (37–77)	0.63 (0.46–0.80)
• Pain on inversion	34/43 (79%)	83 (60–94)	n.s.	25 (10–49)	n.s.	1.10 (0.80–1.51)	0.70 (0.21–2.27)	56 (38–72)	56 (23–85)	0.54 (0.36–0.71)
• Pain on eversion	27/43 (63%)	70 (47–86)	n.s.	45 (24–68)	n.s.	1.26 (0.78–2.04)	0.68 (0.32–1.41)	59 (39–77)	56 (31–79)	0.57 (0.40–0.75)
Presence of swelling										
• Lateral	36/43 (84%)	100 (82–100)	n.s.	35 (16–59)	n.s.	1.54 (1.12–2.12)	-	64 (46–79)	100 (56–100)	0.68 (0.51–0.84)
• Medial	25/43 (58%)	78 (56–92)	n.s.	65 (41v84)	n.s.	2.24 (1.19–4.22)	0.33 (0.15–0.77)	72 (50–87)	72 (46–89)	0.72 (0.56–0.88)
• Anterior	26/43 (60%)	74 (51–89)	n.s.	55 (32–76)	0.02	1.64 (0.96–2.82)	0.47 (0.22–1.02)	65 (44–82)	65 (39–85)	0.65 (0.48–0.81)
• Posterior	22/43 (51%)	83 (60–94)	<0.01	85 (61–96)	n.s.	5.51 (1.91–15.90)	0.20 (0.08–0.51)	86 (64–96)	81 (57–94)	0.84 (0.71–0.97)

(Continues)

TABLE 4 (Continued)

	Positive findings	Sensitivity%	*p* Value	Specificity%	*p* Value	LR+	LR-	PPV%	NPV%	AUC
Laxity tests										
– Anterior drawer test	16/41 (39%)	61 (39–80)	0.02	89 (64–98)	n.s.	5.48 (1.42–21.07)	0.44 (0.26–0.74)	88 (60–98)	64 (43–81)	0.75 (0.60–0.90)
– Talar tilt test	13/41 (32%)	52 (31–73)	0.03	94 (71–100)	n.s.	9.39 (1.34–65.65)	0.51 (0.33–0.78)	92 (62–100)	61 (41–78)	0.73 (0.60–0.89)
Clinical suspicion										
– Complete discontinuity	16/43 (37%)	61 (39–80)	0.02	90 (67–98)	n.s.	6.09 (1.57–23.60)	0.43 (0.26–0.73)	88 (60–98)	67 (46–83)	0.75 (0.61–0.90)

Note: MR imaging was used as the reference standard. The prevalence of positive findings and diagnostic value of physical examination in the delayed setting are presented. Diagnostic values are presented with a 95% confidence interval (95% CI). Comparison of sensitivity and specificity between the acute and delayed settings is reported using *p* values. Positive likelihood ratio (LR+); negative likelihood ratio (LR−); positive predictive value (PPV%); negative predictive value (NPV); area under the curve (AUC); not statistically significant (n.s.).

Abbreviation: MR, magnetic resonance.

78% of patients with ligament lesions compared to 55% of those without lesions [5–7]. No previous study has investigated the diagnostic value of perceived instability. In our study, perceived instability had a specificity of 85% (61–96) and a positive LR of 2.35 (0.69–8.02) within 2 days post-injury. The observations in our study underwrite the importance of clinical history in the diagnosis of complete discontinuity of the lateral ankle ligaments.

Physical examination in the acute setting

In the acute setting, the presence of swelling or tenderness over the lateral malleolus had 100% sensitivity. The anterior drawer test and the talar tilt test, both demonstrated 100% specificity. The specificity for the presence of haematoma and tenderness over the posterior aspect of the ankle was 85% and 90%, respectively. The diagnostic values observed in the current study are in stark contrast with the findings in the study by van Dijk et al. [5–7]. In this study, the combination of lateral haematoma, tenderness over the ATFL and a positive anterior drawer test within 48 h post-injury only had 71% sensitivity and 33% specificity. The findings of our study demonstrate that physical examination in the acute setting can be used to exclude complete discontinuity of the lateral ankle ligaments and identify athletes with a high probability of complete discontinuity.

Physical examination in the delayed setting

In the delayed setting, sensitivity for the presence of haematoma improved significantly from 43% (0–2 days) to 91% (5–8 days). Sensitivity for swelling over the posterior aspect of the ankle improved significantly from 9% to 61%, making it the most discriminatory finding in the delayed setting. Similar observations were made in a previous study that noted that swelling and tenderness along the posterior border of the lateral malleolus were associated with complete rupture of the ATFL and CFL [19]. Finally, the sensitivity of both laxity tests improved in the delayed setting. The anterior drawer test demonstrated a positive LR of 5.48 and a negative LR of 0.44. This corresponds with a recent meta-analysis of six studies (885 observations), which reported a pooled positive LR of 3.97 and a negative LR of 0.54 [16]. In line with previous studies, the talar tilt test demonstrated a positive LR of 9.39 and a negative LR of 0.51 [16]. The findings of the current study confirm that the sensitivity of physical examination is improved when performed 5–8 days post-injury [5–7].

Overall clinical suspicion

This is the first study to investigate the physician's overall clinical suspicion for complete discontinuity of the lateral ankle ligaments. Clinical suspicion had a positive LR of 4.35 in the acute setting (post-test probability of 83%) and a positive LR of 6.09 in the delayed setting (post-test probability of 88%). The sensitivity of clinical suspicion improved significantly in the delayed setting.

This study is the first to validate the notion that the diagnostic value of physical examination improves when performed 5–8 days post-injury. The strength of this study lies in its prospective design and use of 3 T MR imaging as the reference standard. A limitation of this study is that only complete discontinuity of the lateral ankle ligaments was considered disease-positive. This might have influenced the reported diagnostic accuracy as partial discontinuity might mimic the clinical signs and symptoms of complete discontinuity. In addition, all athletes were examined by a senior Sports Medicine Physician or Orthopaedic Surgeon which might decrease the external validity of this study. Finally, by only including patients who underwent acute clinical evaluation within 2 days post-injury and delayed clinical evaluation 5–8 days post-injury, a selection bias may have occurred.

Clinical implications

This study demonstrates that physical examination in the acute setting (0–2 days post-injury) is useful to exclude complete discontinuity of the lateral ankle ligaments. (Figure 2) Patients with a high probability of complete discontinuity of the lateral ankle ligaments can be identified using clinical findings with high specificity (haematoma, anterior drawer test and talar tilt test). This is especially relevant in elite athletes where there are important time constraints on return to play and early and accurate diagnosis is essential. In the delayed setting, sensitivity of common clinical findings increases significantly as pain and swelling subsides. Therefore, the ability of physical examination to rule out complete discontinuity is enhanced when performed in the delayed setting (5–8 days post-injury). In clinical practice, these findings may expedite the diagnosis of lateral ligament injuries in athletes and may reduce the need for delayed follow-up clinical evaluation. As demonstrated by this study, physical examination is an accurate diagnostic method and MR imaging should therefore be reserved for selected cases, including elite athletes. When a concomitant injury is suspected (e.g., syndesmosis injury), alternative diagnostic strategies might be considered [2, 3, 11, 18].

Conclusion

In the acute setting (0–2 days post-injury), clinical evaluation can exclude complete discontinuity of the lateral ankle ligaments and identify athletes with a high probability of complete discontinuity. Complete discontinuity is unlikely when swelling over the lateral malleolus is absent. Clinical findings with high

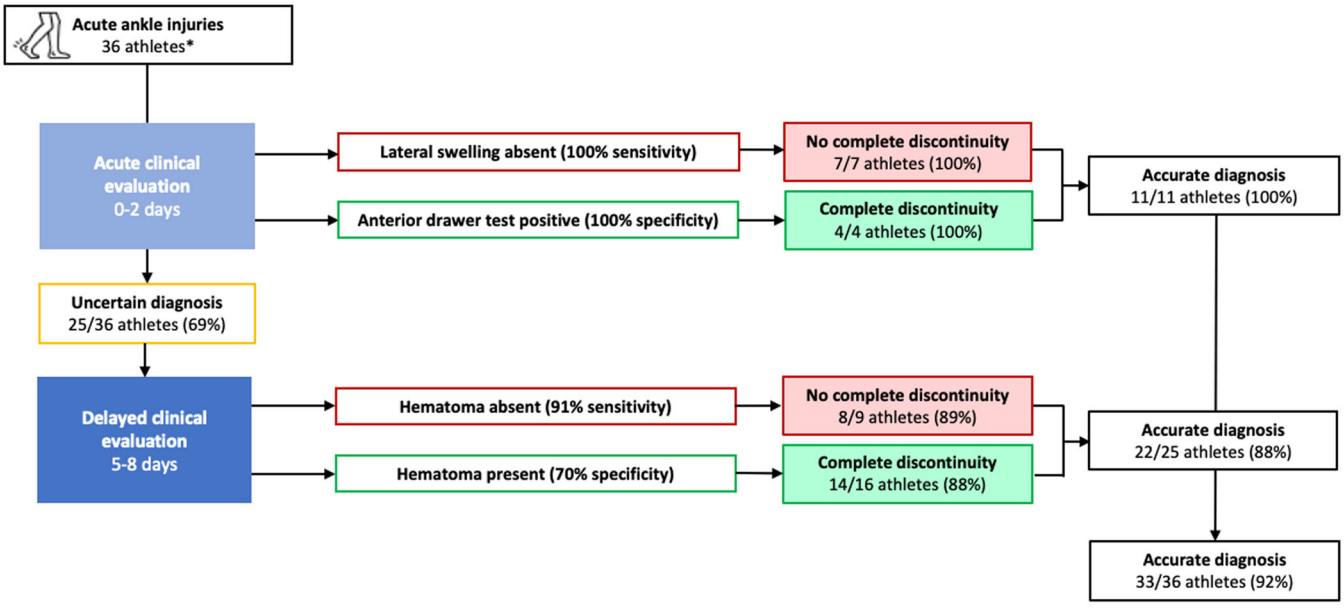

FIGURE 2 Proposed diagnostic work-up of acute lateral ligament injuries. * Data on the anterior drawer test in the acute setting was missing in six patients.

specificity (e.g., positive anterior drawer test) can be used to identify patients with a high probability of complete discontinuity. In the delayed setting (5–8 days post-injury), the diagnostic accuracy of common clinical findings (e.g., haematoma or the anterior drawer test) is improved due to increased sensitivity. When the physician's overall clinical suspicion is positive, a high probability of complete discontinuity of the lateral ankle ligaments exists.

AUTHOR CONTRIBUTIONS

Study concepts: Thomas P. A. Baltes, Gino M. M. J. Kerkhoffs and Johannes L. Tol; Study design: Thomas P. A. Baltes, Celeste Geertsema, Liesel Geertsema, Louis Holtzhausen, Javier Arnáiz, Maryam R. Al-Naimi, Omar Al-Sayrafi, Rod Whiteley, Monia Slim, Pieter D'Hooghe, Gino M. M. J. Kerkhoffs and Johannes L. Tol; Data acquisition: Thomas P. A. Baltes, Celeste Geertsema, Liesel Geertsema, Louis Holtzhausen, Javier Arnáiz, Maryam R. Al-Naimi, Omar Al-Sayrafi, Rod Whiteley, Monia Slim, Pieter D'Hooghe, Gino M. M. J. Kerkhoffs and Johannes L. Tol; Quality control of data and algorithms: Thomas P. A. Baltes and Johannes L. Tol; Data analysis and interpretation: Thomas P. A. Baltes, Johannes L. Tol and Gino M. M. J. Kerkhoffs; Statistical analysis: Thomas P. A. Baltes and Johannes L. Tol; Manuscript preparation: Thomas P. A. Baltes, Gino M. M. J. Kerkhoffs and Johannes L. Tol; Manuscript editing: Thomas P. A. Baltes, Gino M. M. J. Kerkhoffs and Johannes L. Tol; Manuscript review: Thomas P. A. Baltes, Celeste Geertsema, Liesel Geertsema, Louis Holtzhausen, Javier Arnáiz, Maryam R. Al-Naimi, Omar Al-Sayrafi, Rod Whiteley, Monia Slim, Pieter D'Hooghe, Gino M. M. J. Kerkhoffs and Johannes L. Tol.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS STATEMENT

Ethics approval was acquired from the Anti-Doping Lab Qatar Review Board (IRB No. F2016000153). Written informed consent was obtained from all athletes at the time of inclusion.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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