The Foot 38 (2019) 12–18

Contents lists available at ScienceDirect

The Foot

journal homepage: www.elsevier.com/locate/foot

Original Article

Risk of chronic ankle instability: A reliability study on radiographic assessment of the ankle joint geometry

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ARTICLE INFO

Keywords:
Ankle instability
Joint geometry
Predisposing factors
Observer reliability
Conventional radiography

ABSTRACT

Background: Chronic ankle instability (CAI) is a multifactorial disabling condition. Ideally all factors contributing to CAI are identified and implemented in a risk assessment model. However, they need to meet strict reliability requirements. To assess usability of radiographic factors for this risk assessment model and future clinical practice, the objective of the current study was to assess the intra and inter observer reliability of three radiographic measurements.

Methods and methods: The radiographs of 39 consecutive patients, at least 16 years, who visited the Emergency Department after sustaining a lateral ankle sprain (LAS), were assessed by four observers. The radiographic measurements included absolute and relative ankle alignment, sagittal fibular position and ankle joint congruency (talar radius and height, and tibiotalar sector), performed twice by all observers independently. Reliability was assessed by calculating the Intraclass Correlation Coefficient (ICC) which was considered good when ICC > 0.70.

Results: The intra observer reliability of the absolute and relative fibular position, and talar height were good to excellent, (ICC 0.84–0.98, 0.85–0.98, and 0.79–0.93, respectively). The talar radius (ICC 0.69–0.89) was moderate to good. The overall inter observer reliability was good for the absolute and relative fibular position, and talar radius (ICC 0.84, 0.86, and 0.79, respectively). Other measurements had ICC values of < 0.70.

Conclusions: In an effort to identify the multifactorial nature of CAI, both the fibular position and the talar radius measurements showed good observer reliability, and will be implemented in a future risk assessment models. The other measurements are too prone for measurement errors, for future reference.

Level of evidence: IV Case Series.

1. Introduction

Ankle sprains are common injuries with an incidence rate of 12.8 per 1000 patients per year in the Netherlands.[27] The risk for recurrent sprains and, subsequently, chronic ankle instability (CAI), after an initial lateral ankle sprain (LAS) with persistent symptoms can be as high as 40%.[2,8] An acute rupture of the lateral ligaments is usually treated conservatively,[7] however, an estimated 20%[26] of conservatively treated patients will continue to experience complaints such as pain, swelling, and, a feeling of giving-way or recurrent ankle sprains. So, it

Abbreviations: Amsterdam UMC, Amsterdam University Medical Centers; AP, Anteroposterior mortise view; CAI, Chronic Ankle Instability; CT, Computed Tomography; EP, Emergency Physician; ER, Emergency Department; ICC, Intraclass Correlation Coefficient; LAS, Lateral Ankle Sprain; MCID, Minimal Clinical Important Difference; MDD, Minimal Detectable Difference; MDTA, Medial Distal Tibial Angle; MM, Millimeters; OA, Osteoarthritis; OAR, Ottawa Ankle Rules; Ortho, Orthopedic surgeon resident; Radio, Radiology resident; SD, Standard Deviation; SEM, Standard Error of the Mean

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https://doi.org/10.1016/j.foot.2018.11.001
Received 22 March 2018; Received in revised form 17 October 2018; Accepted 5 November 2018
0958-2592/

seems that a conservative treatment is insufficient for a specific group of patients that sustained a LAS. For this reason new treatment methods are increasingly being explored, especially for the high demanding athlete.[4]

CAI may negatively affect the performance of the athlete as 5% of those that sustained an ankle sprain will have to change their sport-activity, and another 4% has to stop playing sports.[28]

Several studies aimed to identify those patients that develop CAI by determining associated risk factors on different imaging modalities. Ankle bone and joint configuration such as hindfoot varus, the tibiotalar contact ratio and anterior/posterior fibular position were found to be significant predictors.[29,19,11,14,1,16,12,5,21,20,17,9] These associated risk factors could be used for creating a prognostic model that identifies the risk for CAI after a LAS.

Radiographic measurements are, generally, inaccurate, albeit accurate enough to be used in clinic.[22,18] However, before creating a prediction model that is based upon radiographic parameters, the reliability needs to be investigated first, ensuring negative correlations are not the result of unreliable measurements.

The primary objective of this study was to assess the usability of three radiographic factors for a risk assessment model and future clinical practice by assessing the intra and inter observer reliability. The null hypothesis of this study was that the radiographic measurements could be measured reliably.

2. Materials and methods

2.1. Study design and setting

This observational case series was conducted at the institutions' ER to evaluate the performance of three different specializations involved in the diagnostic and treatment process of LAS patients. The local Internal Review Board (IRB) approved this study being executed at the local ER.

Inclusion criteria were (1) a minimum age of 16 years old, (2) presentation at the ER within one week after sustaining an ankle inversion trauma, (3) anterolateral ankle pain, and (4) radiographic assessment to exclude a fracture. Patients were excluded if (1) a fracture or other joint pathology (e.g. osteochondral lesion, osteoarthritis) was present, (2) medial ankle instability was reported, (3) previous ankle surgery of the affected ankle or (4) if the radiograph was found unreliable due to insufficient quality, as determined by the radiologist. Eligible patients were identified retrospectively from the ER patient list (Fig. 1). After inclusion, the radiographs were assessed by two musculoskeletal specialized radiology residents, an orthopedic resident and an emergency physician. The measurements made by the radiology residents served as reference standard.

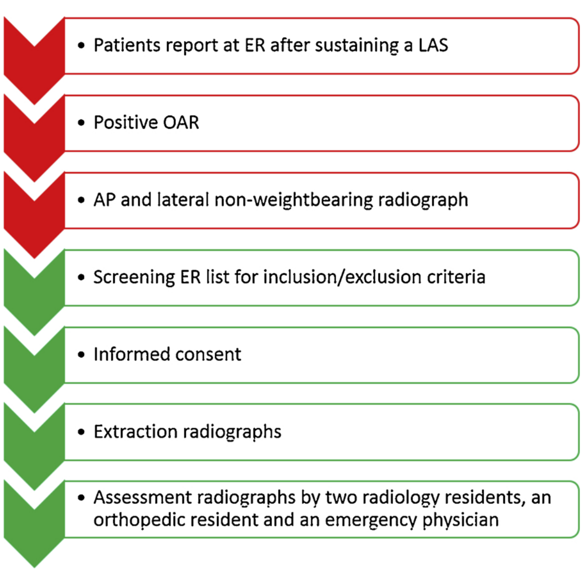

Fig. 1. Study design. Abbreviations: *ER: Emergency Department; OAR: Ottawa Ankle Rules, AP: Anteroposterior mortise view. Blue: Standard Dutch Protocol; Red: Study Protocol.*

To ensure adequate performance of the measurements and minimize the learning curve, each observer was required to assess 10 cases before scoring the official dataset, these 10 cases were not included in the analyses. For assessing the intra and inter observer reliability each observer then, individually, assessed all radiographic measurements twice for each case with a minimum time interval of two weeks. Radiographs were presented in random order at both assessments without identifying patient characteristics such as sex, age or injury mechanism.

2.2. Sample size

To reach a relative error of 20%, with an expected agreement of 80%, a sample size of 39 patients was required.[10] No extra patients were included to avoid statistical bias.

2.3. Radiographic measurement parameters

Three radiographic measurements, validated for non-weight bearing radiographs, were identified by means of a systematic search of literature, searching for potential prognostic factors for CAI after suffering from a LAS:

1. Ankle alignment on a non-weight bearing mortise view (Fig. 2). This measurement was based on the angle between the longitudinal axis of the tibia and the joint orientation line of the tibiotalar joint, defined as the Medial Distal Tibial Angle (MDTA). The MDTA was measured in two ways: (1) as the absolute angle and (2) categorized as varus (< 87°), normal (87–91°) or valgus (> 91°) position of the ankle.[24]
2. Position of the fibula in relation to the tibia on the lateral view (Fig. 3). For this measurement one vertical line was drawn at the anterior edge of the distal tibia. The absolute distance was measured as (3) the distance from the vertical line to the anterior edge of the fibula in (projected) millimeters (mm) and (4) the total tibial width in (projected) mm from the vertical line to the most dorsal tibial edge.[13] The relative fibular position was calculated by the distance to fibula divided by total tibial width multiplied by 100 expressed in percentages (%).
3. Tibiotalar contact ratio representing ankle joint congruency was assessed on the lateral view (Fig. 4). The measurement included (5) the radius of the talus (r) in (projected) mm, (6) height of the talus (h) in (projected) mm and (7) tibiotalar sector (α) in degrees.[6] A circle, that fit the talar joint surface best, was drawn. The height was measured by drawing a line perpendicular to the foot sole through the center of the circle to the distal intersection of the talocalcaneal joint line. The radius of this circle was measured. The tibiotalar sector was measured by drawing two lines from the center of the circle (intersection between (r) and (h); see Fig. 4) to the most dense anterior and posterior articulating margins of the distal tibia with the talus (over projection was ignored).

2.4. Statistical analysis

Statistical analysis was performed using SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). Demographics were analyzed using descriptive statistics to assess patients' sex, age and affected side. Data normality was assessed visually and using the Shapiro-Wilks test. In case of normally distributed data, a mean and standard deviation (SD) were provided, in case of skewed data the median and range were reported. A p-

Fig. 2. Measurement of the Medial Distal Tibial Angle: the ankle between the distal tibial joint line and the line through the middle of the tibia.

value of < 0.05 was considered as significant.

The intra-class correlation coefficient (ICC) was used to analyze both intra and inter observer reliability in case of normally distributed data. ICC was used because of interest in generalizing findings beyond the four specialists. An ICC of > 0.70 was considered good.[3] Interpretation of the ICC was as follows: ≤0.40 Poor reliability; 0.40–0.75 Moderate reliability; 0.75–0.90 Substantial reliability; and > 0.90 Excellent reliability.[25] For categorical data a Weighted Kappa was calculated. For future practice and implementation, measurements had to be performed with at least good reliability (ICC 0.70).

The intra and inter observer reliability scores were calculated for each measurement for all four specialists together and to compare measurement outcomes per two specialists. For the inter observer reliability the first set of measurements was used. To minimize the effect of a potential learning curve on our results, a calibration session and measurements on a training set of 10 cases were performed before collecting the 'real' data. The first 10 practice cases were not included in the analysis.

Bland–Altman plots were drawn to determine whether all measurements were within the limits of agreement. These plots were

Fig. 3. Measurement of the fibular position, distance a (distance fibula in relation to anterior edge tibia) and b (total tibial width) in millimeters.

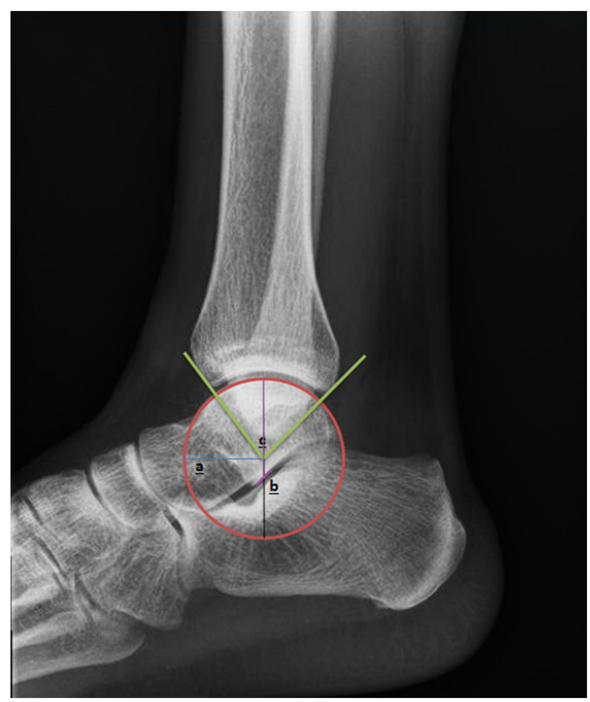

Fig. 4. Measurement of the tibiotalar contact ratio. A circle is drawn fitting the proximal talar dome. (a) (blue line) represents the radius of the talar dome and (b) (purple line) the height. The intersection between (a) and (b) represent the starting point of (c) (talar center) from where two lines are drawn to the most anterior and posterior edge (green lines e.a. sector α) of the distal tibial joint line representing the articulating surface and with that joint congruency. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

presented for the inter observer reliability and for the intra observer reliability in case of marked differences. Additionally, the Standard Error of Measurement (SEM; square root of the within-subject variance)

Table 1
Descriptives of measurements (first), mean (SD) unless stated otherwise.

	Observer Ortho	Observer Rad 1	Observer Rad 2	Observer SEH
MDTA (°)	89.8 (2.4)	90.1 (1.8)	90.2 (1.8)	90.5 (2.3)
MDTA, n (%)				
Under norm	4 (10)	1 (3)	0 (0)	3 (8)
Neutral	25 (64)	30 (77)	30 (77)	22 (56)
Above norm	10 (26)	8 (20)	9 (23)	14 (36)
Fibular position (mm)	8.0 (3.5)	7.8 (3.5)	8.5 (3.7)	7.9 (3.9)
Fibular position (%)	19.6 (8.0)	19.0 (8.1)	19.1 (7.7)	18.8 (9.0)
Talar radius (mm)	20.7 (3.3)	20.7 (2.9)	22.0 (3.5)	20.2 (3.2)
Talar height (mm)	29.1 (3.8)	29.3 (3.5)	34.8 (6.2)	30.0 (3.6)
Tibiotalar sector (°)	83.2 (5.6)	81.5 (5.5)	80.3 (4.9)	81.2 (6.2)

Abbreviations: MDTA: Medial Distal Tibial Angle; SD: Standard Deviation.

and Minimal Detectable Difference (MDD: 1.96 × √2 × SEM) were calculated to quantify the measurable difference in relation to the error.

2.5. Ethical approval

This study was approved by the local ethical committee.

3. Results

3.1. Demographics

Between October 2016 and February 2017, 39 patients visited the local ER after sustaining a LAS, meeting the inclusion criteria. Of all included patients a non-weight bearing mortise and lateral radiograph were available. No radiographs were excluded due to low quality.

The study group consisted of 18 male (46%) and 21 female patients. The median age was 25 years with a range from 18 to 59 years. Twenty-two sprains (56%) involved the left ankle and 17 the right ankle. Radiographic measurement outcomes are summarized in Table 1.

3.2. Intra observer reliability

Overall the intra observer reliability ranged from 0.43 to 0.91 for the absolute MDTA (Table 2). Expressing ankle alignment as varus/neutral/valgus did not improve the intra observer reliability (ICC 0.43–0.87). The absolute fibular position had an ICC ranging from 0.84 to 0.98 and no difference was seen in expression in either millimeters or percentage (ICC 0.85–0.98). Assessing the tibiotalar joint, the talar radius (ICC 0.69–0.89) and height (ICC 0.79–0.93) showed the greatest reliability. Individual assessment of the tibiotalar sector was found less reliable with ICC values ranging from 0.47 to 0.77.

3.3. Inter observer reliability

The overall inter observer reliability was moderate for the MDTA (ICC 0.51), varus/neutral/valgus alignment (ICC 0.45), talar height (ICC 0.43) and tibiotalar sector (ICC 0.46). A good overall reliability was found for the absolute and relative fibular position, and for the talar radius (ICC 0.84, ICC 0.86, and ICC 0.79, respectively) (Table 3).

For the inter observer reliability the greatest incongruence was found for the MDTA (ICC 0.25–0.75). The method of alignment expression (angle or varus/neutral/valgus position) did not improve the reliability (ICC 0.26–0.60). Both the absolute and relative fibular position show a moderate to good reliability (ICC 0.74–0.90 and ICC 0.76–0.91, respectively). The talar radius shows a good reliability (ICC 0.78–0.80). Despite the good intra observer reliability, talar height showed a poor to good reliability (ICC 0.29–81). Finally, the tibiotalar sector shows poor to moderate reliability (ICC 0.37–0.60).

Greatest agreement was found between radiology resident 1 and the ER physician, whereas the lowest agreement was found comparing radiology resident 2 and the orthopedic resident.

Relating these results to the Bland-Altman plots shows the majority of all measurements approximates 0, showing a small systemic measurement error. The size of the intended measurement did not affect the measurement error (Fig. 5).

4. Discussion

To assess usability of radiographic factors for a risk assessment model and future clinical practice, the intra and inter observer reliability of three radiographic measurements was assessed. The fibular position could be measured with good intra- and, inter observer

Table 2
Intra observer reliability; agreement (ICC, weighted kappa (K_w), Standard Error of Measurement (SEM) and Minimal Detectable Difference (MDD) for each observer.

		Observer Ortho	Observer Rad 1	Observer Rad 2	Observer ER
MDTA (°)	ICC (95%CI)	0.43 (0.13; 0.65)	0.50 (0.22; 0.70)	0.91 (0.83; 0.95)	0.87 (0.77; 0.93)
	SEM	1.77	1.19	0.61	0.76
	MDD	4.91	3.31	1.69	2.11
MDTA (valgus/neutral/varus)	K_w (95%CI)	0.43 (0.14; 0.72)	0.54 (0.23; 0.86)	0.87 (0.68; 1.00)	0.66 (0.44; 0.88)
Fibular position (mm)	ICC (95%CI)	0.88 (0.79; 0.94)	0.84 (0.61; 0.93)	0.97 (0.94; 0.98)	0.98 (0.97; 0.99)
	SEM	1.15	1.54	0.63	0.48
	MDD	3.20	4.28	1.75	1.33
Fibular position (%)	ICC (95%CI)	0.87 (0.77; 0.93)	0.85 (0.67; 0.93)	0.96 (0.92; 0.98)	0.98 (0.96; 0.99)
	SEM	2.69	3.41	1.56	1.18
	MDD	7.45	9.45	4.32	3.25
Talar radius (mm)	ICC (95%CI)	0.69 (0.49; 0.83)	0.89 (0.79; 0.94)	0.89 (0.79; 0.94)	0.89 (0.81; 0.94)
	SEM	2.09	1.00	1.13	1.09
	MDD	5.80	2.77	3.14	3.02
Talar height (mm)	ICC (95%CI)	0.81 (0.66; 0.90)	0.93 (0.87; 0.96)	0.79 (0.60; 0.89)	0.81 (0.65; 0.90)
	SEM	1.78	0.93	2.67	1.57
	MDD	4.92	2.59	7.40	4.36
Tibiotalar sector (°)	ICC (95%CI)	0.47 (0.19; 0.68)	0.62 (0.38; 0.79)	0.73 (0.49; 0.86)	0.77 (0.61; 0.87)
	SEM	4.52	3.23	2.71	3.31
	MDD	12.53	8.95	7.51	9.17

Abbreviations: ICC: intra-class correlation coefficient; SEM: Standard Error of Measurement; MDD: Minimal Detectable Change; K_w: Weighted Kappa; Radio: Radiology resident; Ortho: Orthopaedic Resident; ER: Emergency Physician.

Table 3
Inter observer reliability; agreement (ICC), weighted kappa (K_w), Standard Error of Measurement (SEM) and Minimal Detectable Difference (MDD) between the observers.

		Overall	Rad1 vs Rad2	Rad1 vs Ortho	Rad2 vs Ortho	Rad1 vs ER	Rad2 vs ER
MDTA (°)	ICC (95%CI)	0.51 (0.35; 0.67)	0.63 (039; 0.79)	0.43 (0.13; 0.65)	0.25 (−0.07; 0.52)	0.75 (0.56; 0.86)	0.57 (0.32; 0.75)
	SEM	1.47	1.10	1.60	1.85	1.04	1.36
	MDD	4.09	3.06	4.43	5.14	2.89	3.77
MDTA (valgus/neutral/varus)	K_w (95%CI)	0.45 (0.28; 0.61)	0.44 (0.12; 0.76)	0.26 (0; 0.54)	0.26 (0; 0.52)	0.60 (0.37; 0.83)	0.39 (0.13; 0.64)
Fibular position (mm)	ICC (95%CI)	0.84 (0.76; 0.90)	0.84 (0.71; 0.91)	0.90 (0.83; 0.95)	0.86 (0.75; 0.92)	0.87 (0.77; 0.93)	0.74 (0.55; 0.85)
	SEM	1.47	1.46	1.07	1.36	1.33	1.97
	MDD	4.07	4.06	2.98	3.78	3.70	5.47
Fibular position (%)	ICC (95%CI)	0.86 (0.78; 0.92)	0.86 (0.75; 0.92)	0.91 (0.84; 0.95)	0.88 (0.78; 0.93)	0.88 (0.78; 0.94)	0.76 (0.59; 0.87)
	SEM	3.10	2.98	2.39	2.78	2.97	4.12
	MDD	8.58	8.25	6.63	7.71	8.22	11.42
Talar radius (mm)	ICC (95%CI)	0.79 (0.66; 0.88)	0.79 (0.47; 0.91)	0.80 (0.65; 0.89)	0.77 (0.49; 0.89)	0.80 (0.66; 0.89)	0.78 (0.14; 0.92)
	SEM	1.51	1.51	1.40	1.67	1.37	1.66
	MDD	4.18	4.19	3.88	4.62	3.80	4.60
Talar height (mm)	ICC (95%CI)	0.43 (0.18; 0.63)	0.29 (−0.08; 0.59)	0.75 (0.57; 0.86)	0.29 (−0.08; 0.58)	0.81 (0.66; 0.90)	0.36 (−0.05; 0.64)
	SEM	3.90	5.34	1.81	5.49	1.55	4.85
	MDD	10.81	14.81	5.02	15.21	4.30	13.46
Tibiotalar sector (°)	ICC (95%CI)	0.46 (0.31; 0.63)	0.56 (0.31; 0.74)	0.43 (0.14; 0.65)	0.40 (0.10; 0.63)	0.37 (0.06; 0.62)	0.60 (0.36; 0.77)
	SEM	4.15	3.48	4.30	4.36	4.60	3.52
	MDD	11.50	9.65	11.91	12.08	12.76	9.74

Abbreviations: ICC: intra-correlation coefficient; SEM: Standard Error of Measurement; MDD: Minimal Detectable Change; K_w: Weighted Kappa; Radio: Radiology resident; Ortho: Orthopaedic Resident; ER: Emergency Physician.

reliability (ICC > 0.70). Other angles were measured with good intra and inter observer reliability between at least two observers, apart from the tibiotalar sector.

The fibular position was measured reliably both as a relative and as an absolute distance (ICC > 0.83). For the talar radius it could be argued that the talar radius, with good intra (ICC 0.69) and, inter observer reliability (ICC 0.79), should also be used for future reference to avoid missing a potential risk factor. These radiographic parameters will be implemented in the risk assessment model for their contributed risk of developing CAI. The fibular position and talar radius were measured reliably, decreasing the risk at observer bias in future studies. The SEM and MDD, calculated to assess relevancy of measurable differences, indicated no future limitation in differentiating between injured and non-injured patients. Therefore, it was decided that both the measurement of the fibular position, due to the good reliability, and the talar radius, may be used in the future. The other measurements, introduced in this paper should not be used, as low reliability will have implications for the assessment of potential risk and/or clinical value by allowing bias.

A calibration session was performed before assessment to make sure all observers measured consistently despite varying quality of radiographs. The quality of the radiographs was discussed and clear measurement rules were formulated as when to exclude radiographs or how to deal with over-projection. To avoid overestimation of reliability parameters residents were included instead of specialists, as they are also involved in patient care in daily practice and have to be able to adequately evaluate radiographs of patients with an ankle sprain. Especially as most sprains report at the ER late in the evening or weekends after sports when there might be no radiologist available and an orthopedic resident or ER physician should be able to adequately assess the need of follow-up.

This study was conducted in the larger perspective of developing a

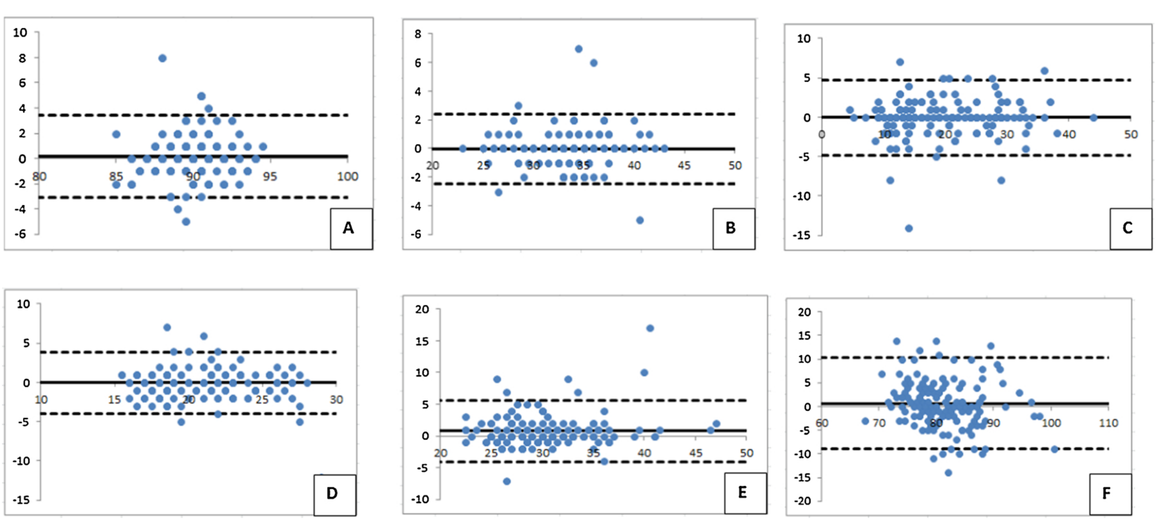

Fig. 5. Bland–Altman Plots of the overall reliability measurements (4 observers, 39 measurements each performed twice). X-axis: mean measurement; Y-axis: measurement error. **A**: MDTA (degrees); **B**: MDTA (varus/norm/valgus); **C**: fibular position (mm); D: fibular position (%); **E**: talar radius (mm); **F**: talar height (mm); **G**: tibiotalar sector (degrees).

risk assessment model for chronic ankle instability (trial registration no.: NCT02955485). To ensure clinical usability it required to fit the following criteria:

1. Include potential risk factors as identified in current literature[23]
2. Easily applicable (e.a. based on already collected or easily collectable data such as non-weight bearing AP and lateral radiographs of the ankle)
3. Include reliable measurements
4. Be cost-efficient (not require additional diagnostics increasing the risk of subjective application of the model by physicians)

The patients most at risk are the ones with a lateral ankle sprain in history.[15] Therefore ideally patients at risk of CAI are identified after sustaining such a sprain. It is hypothesized the most severe sprains, and therefore most at risk of CAI, report at the ER. There in addition to a physical examination often radiographic diagnostics are included to exclude a fracture. Based on the minimal information collected at first presentation (patient characteristics, physical examination and standard non-weight bearing radiographs) the risk assessment should be applied. For this reason measurements based on for example weight bearing radiographs and CT scans have been excluded as they may be of minimal additional value and exposure patients to an unnecessary load of extra diagnostics, radiation and additional costs. Therefore we came to the consensus to only use the radiographic measurements that have been described as potentially prognostic for CAI and can be applied on standard non-weight bearing radiographs as made at the ER.

A limitation of this study was the requirement was that these measurements need to be applicable on the standard non-weight bearing radiographs as made at the ER in patients who sustained a LAS. This ensures the risk assessment model will be easily applicable in current practice on all patients presented at the ER during their initial visit and avoids additional diagnostics and costs. Additionally the study was limited by the variety in quality of the radiographs including a short tibial length or rotation of the foot. Despite the ideal of strict imaging protocols these cannot always be followed due to a high workload. Although lower quality radiographs increases the risk of unreliable measurements, this will be the setting in which the future model will be implemented. An additional limitation was the low number of radiographic factors included in this assessment. However, other radiographic measurements, specifically designed to assess ankle joint geometry first require further assessment on their role in sustaining an ankle sprain before implementing them in a risk assessment model.

Chronic ankle instability has been reported as complicated and to be of a multifactorial origin. Despite some limitations, this was the first study to assess reliability of bone geometric factors that have been reported as potential risk factors of CAI, assessed by all specialists that are involved in the process in case of an ankle sprain. This study is a first step in the systematic assessment of multiple risk factors for CAI and define the size of their contributed risk. Simplified implementation in the clinical setting in the form of a risk assessment model will help defining which patients require active follow-up and potentially early (surgical) treatment.

5. Conclusion

Measurement of fibular position and talar radius can be reliably performed by orthopedic surgery residents, radiology and by emergency physicians. These radiographic parameters can therefore be implemented in a risk assessment model to identify the contributed risk per factor, so the model in turn function as a decision aid in defining the best treatment and whether active follow-up is required. Poor and moderate reliability was found for the other radiographic parameters based on non-weight bearing lateral and mortise radiographs of the ankle and should not be used in a risk assessment model or clinical practice as it will to greater heterogeneity of measurements and unreliable results.

5.1. Brief Summary

Already known:

1. Ankle alignment, fibular position and tibiotalar congruency have been described as potentially prognostic for chronic ankle instability;
2. A risk assessment model based on these prognostic factors may help decide upon the best treatment;
3. To develop a risk prediction model measurements need to meet strict requirements such as inter and intra observer reliability.

This study adds:

1. Before implementation of (radiographic) measurements, reliability has to be assessed;
2. To minimize measurement bias and unreliable conclusions only measurements with sufficient reliability should be implemented into clinical practice and future research;
3. Only the fibular position and the talar radius could be reliable measured and may be implanted in clinical practice and future research.

Author contributions

All authors payed significant contributions to each of the 4 criteria suggested by the ICMJE. Study coordination was done by GV. EB helped GV with the logistics implementation of this study at the Emergency Department. The group provided significant input for the study design (GV, LW, IS, SJ, RH, GK, MM), ethical approval (GV, LW), online registration (GV), calibration of the radiographical measurement (GV, LW, SJ, RH, MB, PB), data acquisition (SJ, RH, MB, PB), datamanagement (GV, LW), statistical analysis, data validation (GV, IS) and interpretation (GV, IS, SJ, RH, GK, MM). Figures (GV, LW) and tables (GV, IS) were created and adjusted and approved by the full team. For the final manuscript all authors contributed to the draft, (final) approval and revisions made up to date and are all accountable for this study's content.

Summarizing: This large team this was important for this study as we wish to implement these measurements in a multicentre study. For this a solid design, reliable statistics and experts of each participating field were required. This lead to a large team of which each member contributed equally and intensively to come to the results we present you by means of this manuscript.

Trial Registration PREDICT

Dutch Trial Registry: NTR6139.
ClinicalTrials: NCT02955485.

Funding

No funding was received for performing this study.

Conflicts of interest

The authors have no conflicts of interest to declare.

Informed Consent

Of all patients verbal informed consent was obtained to use their radiographs.

Acknowledgements

We acknowledge the help of Dr. J.J. Stunt[b,c,e], Clinical Epidemiologist, and N.C. Hagemeijer[a,h] for their help.

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