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Review paper

Anterior lateral ankle ligament damage and anterior talocrural-joint laxity: an overview of the in vitro reports in literature

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Abstract

Objective. To provide a clear overview of the literature on the relationship between increased lateral ankle ligament damage and anterior talocrural-joint laxity.

Design. A systematic review of the literature.

Background. Diagnostic methods for inversion injuries of the ankle have remained controversial throughout the years. An instrumented test for anterior talocrural-joint laxity could be a diagnostic tool for evaluation of anterior lateral ankle ligament function.

Methods. An advanced electronic database search using MEDLINE and EMBASE was performed to find studies describing the correlation between lateral ankle ligament damage and talocrural-joint laxity. Two reviewers assessed the methodological quality for each study and agreement was noted. Two reviewers extracted all relevant data with respect to methodology, motion constraints and laxity measurement.

Results. The quality assessment resulted in 5 studies being scored as high quality and 5 as low quality. Different test devices were used to apply the load and measure the displacement. All in vitro tests applied a load to the calcaneus and subsequently measured the translation of the talus and/or calcaneus relative to the tibial dome. Rotation in the transversal and frontal plane was restricted in 8 tests. After analysis of the results presented by nine different studies, the mean value of anterior talocrural-joint laxity with intact ligaments is 4.2 mm. After sectioning of the anterior talofibular ligament, the mean anterior laxity value is 6.5 mm. The mean anterior laxity value after sectioning of the calcaneofibular ligament increases to 8.4 mm. The mean anterior laxity value with the foot in dorsal flexion (3.1 mm) is less than the mean value with the foot in neutral position (4.5 mm) or in plantar flexion (4.7 mm). The applied load and the anterior laxity values between the different studies vary greatly.

Conclusions. Each ligament section results in significantly increased talocrural-joint laxity. Talocrural-joint laxity can be used as a measure for damage to the anterior talofibular ligament and/or the calcaneofibular ligament. From this review, it is neither possible to give universal recommendations about the optimal flexion angle for testing talocrural-joint laxity as a measure for lateral ankle ligament function, nor to recommend the ideal load for performing the test.

Relevance

The development of an instrumented test as a diagnostic tool for anterior talocrural-joint laxity in the clinical setting is near at hand and practicable.

Keywords: Ankle; Sprain; Ligament; Anterior drawer; Laxity-test and review

1. Introduction

Inversion injuries of the ankle are common problems in medical care. It is estimated that one occurs per 10 000 population per day [1]. In the emergency room it is the most frequently observed injury [2]. The diagnostic methods for these injuries have remained controversial throughout the years, because there is no standard clinical assessment technique to quantify an inversion injury.

The anterior talofibular ligament (ATFL) is the most frequently involved ligament in an inversion injury of the ankle and the most important stabilizer of the

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Table 1
Inclusion criteria

1.	A sequential cutting experiment was performed, evaluating the effect of damage of the lateral ankle ligaments on talocrural-joint laxity
2.	An instrumented test device was used to objectively measure talocrural-joint laxity
3.	A quantified load was applied and the displacement was measured, or the displacement was prescribed and the load measured
4.	The test-protocol was described in the methods section
5.	Talocrural-joint laxity was tested in the sagittal plane

talocrural-joint [3]. Laxity of the talocrural-joint is examined by mechanical stress testing [4–9]. These tests are all painful and have the disadvantage of the use of radiography. The most common clinical test for testing talocrural-joint laxity is the anterior drawer test (ADT) [5,7–11]. This is a manual examination, which depends on the clinician's sensitivity and experience [9]. Consequently, a reliable instrumented test is desirable for objective and reproducible examination of talocrural-joint laxity. In order to develop such a reliable mechanical test device, it is important to understand the relationship between increased ligament damage and clinically relevant talocrural-joint laxity. This relationship can only be evaluated by analysis in an in vitro setting, because in such a setting the sequential cutting of the ligaments can objectively be correlated to (clinical) talocrural-joint laxity. A variety of in vitro test devices, evaluating the relationship between damage to the anterior lateral ankle ligaments and increasing talocrural-joint laxity has been described [7,8,11–21].

The primary aim of this study was to systematically search the literature, in order to provide an exhaustive overview of the reported effects of sequential cutting of the anterior lateral ankle ligaments on anterior talocrural-joint laxity. The secondary aim was to evaluate the methodology used in the different test devices.

2. Methods

2.1. Search strategy

In order to identify studies describing tests that evaluate the relationship between anterior lateral ankle ligament damage and anterior talocrural-joint laxity, an electronic database search was performed using MEDLINE (from 1980 to 2000) and EMBASE (from 1980 to 1999). If acquired, unpublished trial reports retrieved from authors were also used and no restrictions were made concerning the language of publication. The reference lists of all incoming papers were reviewed for potentially missed studies. The following keywords were used: ankle, talocrural-joint, mechanical test, ankle joint, ankle injury, ankle stability, ligaments, anterior talofibular ligament, sequential cutting, calcaneofibular ligament, posterior talofibular ligament, lateral ligament complex, ankle biomechanics, biomechanics, talar tilt and anterior drawer.

From the title and abstract two reviewers selected relevant studies for full review. For inclusion in the analysis two reviewers independently analyzed the full text, using a predefined set of criteria defined (Table 1). The reviewers were not blinded to study author, place of publication or results [22]. Disagreement was resolved by consensus.

2.2. Methodological quality assessment

Two reviewers independently and without masking assessed methodological quality for each study [23,24], using an adapted form of a piloted, quantitative scoring method used (but never published) by the International Society of the Knee (ISK) and the European Society of Sports traumatology Knee surgery and Arthroscopy (ESSKA) (Table 4). Era-bound quality assessments, as for example the novelty of results, were performed in the light of current relevance. The mean score for each article was used as the final score. The ESSKA uses 50 as an acceptable score for acceptation of an abstract for congress-presentation. Our aim was to assess quality of published manuscripts. Therefore, it was decided that articles scoring 65 or higher were considered high quality articles.

2.3. Data-extraction

Two review authors independently extracted the data with respect to methodology, motion constraints and laxity measurement. After consensus, there was no disagreement and therefore no third party adjudication was required. If a study or trial was excluded because of a lack of data, then an attempt was made to contact the investigators. Where appropriate, results of comparable studies were pooled using fixed effects.

3. Results

3.1. Search results

Nineteen studies met the search criteria and were subsequently evaluated concerning the inclusion criteria. A total of 10 studies met the inclusion criteria outlined in the protocol (Tables 2 and 3). Nine of these were published in English and one was published in Japanese. A Japanese translator performed the translation to English.

Table 2
Descriptive characteristics of included studies. All studies aimed at the effect of sequential cutting on talocrural-joint laxity

Author	Publication year	Secondary aim(s) of the study	Test device	Motion restrictions when measuring AP displacement	Measurement technique
Rasmussen [21]	1981	Determination of optimal test angle	Support frame	No motion restrictions	Radiographic measurement, Lindstrand [34] technique
Johnson [26]	1983	Determination of optimal test angle	MTS (Minneapolis, Minnesota)	No motion restrictions described	Continuous measurement load-cell force and actuator displacement of anterior tip of talus to tibial dome
Grace [15]	1984	Determination of optimal test angle	Support frame	No motion in transversal plane allowed	Radiographic measurement, Lindstrand [34] technique
Kaneko [20]	1985	–	Support frame	No motion in transversal plane allowed	Measurement of displacement of anterior tip of talus to tibial dome with use of transducers and jig sets
Bulucu [19]	1991	Determination of optimal test angle	MTS	No motion in transversal or frontal allowed	Continuous measurement load-cell force and actuator displacement of anterior tip of talus to tibial dome
Kjaersgaard-Andersen [18]	1991	Determination of optimal test angle	Support frame	No motion in transversal or frontal plane allowed	Measurement of the displacement between the middle of the talocalcaneal joint complex and the tibia by a lever arm fitted with strain gauges and potentiometers
Hollis [17]	1995	Determination of optimal test angle	MTS	No motion in frontal plane allowed	Continuous measurement load-cell force and actuator displacement of anterior tip of talus to tibial dome
Tohyama [11]	1995	Determination of optimal test angle	MTS	No motion in frontal plane allowed	Continuous measurement load-cell force and actuator displacement of anterior tip of talus to tibial dome
Bahr [16]	1997	Determination of optimal test angle	MTS	No motion in frontal plane allowed	Continuous measurement load-cell force and actuator displacement of anterior tip of talus to tibial dome
Lapointe [4]	1997	–	Ankle Flexibility Tester [18]	No motion restrictions	Measurement of motion between calcaneus and tibia/fibula with help of motion sensors equipped with potentiometers

Table 3
Quantitative characteristics of included studies

Author	Mean anterior laxity values						
	Number of specimens	Load (N)	Flexion angle (°)	Intact ligaments (mm)	ATFL cut (mm)	ATFL and CFL cut (mm)	ATFL, CFL and PTFL cut (mm)
Rasmussen	7	69	20 dorsal	3.2	4.8	7.9	11
			Neutral	5.2	7.0	9.0	13
			20 plantar	5.0	7.3	8.6	8.6
Johnson	30	150	20 dorsal	5.8	8.3		
			Neutral	6.6	10.3		
			20 plantar	5.5	9.8		
Grace	14	67	Neutral	5.0	9.0	9.5	10
			25 plantar	3.5	8.5	8.0	
			Full plantar	3.0	4.5	3.5	5.5
Kaneko	20	100	Neutral	2.4	5.0	9.2	
Bulucu	8	150	15 dorsal	4.5	6.1	8.1	12
			Neutral	6.4	8.9	10	12
			15 plantar	6.0	9.0	11	12
Kjaersgaard-Andersen	22	150	10 dorsal	1.6	4.3	6.3	
			Neutral	3.1	6.2	7.0	
			15 plantar	3.0	4.8	5.2	
Hollis	36	50	15 dorsal	4.0	3.5	6.0	
			Neutral	7.0	8.0	7.5	
			15 plantar	8.0	9.0	7.5	
Tohyama	12	60	10 dorsal	1.1	2.1		
			Neutral	2.2	3.7		
			10 plantar	3.1	5.4		
			20 plantar	2.8	5.3		
Bahr	8	80	10 dorsal	2.2	3.4	8.0	
			Neutral	2.8	4.8	9.5	
			10 plantar	2.8	5.0	9.0	
			20 plantar	3.0	5.3	7.0	
Lapointe	6	–[a]	Neutral		60[b]	74[b]	

[a] At each extreme of the ranges of motion, loading was increased until no further motion was observed. Exact load was not described neither could it be retrieved from the authors.
[b] These values represent the relative increase of anterior talocrural-joint laxity values.

Table 4
Quality assessment

1.	*Problem description*	
	Important	+5
	Clear	0
	Vague	−5
2.	*Material (samples, specimens)*	
	Unique	+10
	Adequate	0
	Insufficient	−10
3.	*Methods*	
	Objective and valid	+15
	Well described (accuracy and technique)	+5
	Described	0
	Not described	−10
4.	*Results*	
	Unique	+10
	New and important	+5
	Existing knowledge	0
	Not important or incoherent	−5
	Not presented	−10
5.	*Conclusions*	
	Unique	+10
	New and important	+5
	Valid	0
	Not supported by results	−5
	Not described	

The base score is 50 points. Points are subtracted or added based on the item scores. The lowest possible score is 5 points; the highest score is 100 points.

Table 5
Characteristics of excluded studies

Study	Publication year	Reason of exclusion
Castaing [30]	1972	No Sequential cutting experiment (SCE)
Glasgow [31]	1980	Outcomes not quantifiable
Rijke [12]	1986	Anterior laxity not tested in anterior–posterior direction
Ahuovo [8]	1988	No SCE
Rijke [5]	1990	No SCE
Siegler [14]	1990	Anterior laxity not tested in anterior–posterior direction
Nyska [7]	1992	No SCE
Bennett [32]	1994	Outcomes not quantifiable
Siegler [33]	1995	No SCE

Nine studies were excluded (Table 5). The main reason for exclusion was the lack of a separate analysis of talocrural-joint laxity as a function of ligament damage.

3.2. Methodological quality-score

The quality-score after initial assessment of included trials ranged from 50 to 90 points. This assessment resulted in 5 studies being scored as high quality (65 points or more), 5 studies as low quality (Table 6). After retrieving additional information from the authors, the mean validity score did not increase.

Table 6
Quality assessment included studies

Author	Points
Lapointe [4]	90
Kjaersgaard-Andersen [18]	80
Bahr [16]	75
Tohyama [11]	75
Hollis [17]	65
Bulucu [19]	60
Johnson [26]	60
Rasmussen [21]	55
Kaneko [20]	50
Grace [15]	50

The initial agreement of the two reviewers on the quality assessment of the included trials was 76% (38 out of 50 items). The median kappa value (K) [25] for measurement of agreement beyond change of the separate items between these two reviewers was 0.65 (range 0.34–0.85).

3.3. Data

For load application and displacement measurement, different devices were used (Table 2). Five studies used the MTS testing machine (MTS, Minneapolis, MN, USA) [11,16,17,19,26] (Fig. 1). Five studies used different, specifically designed electro-mechanic devices for

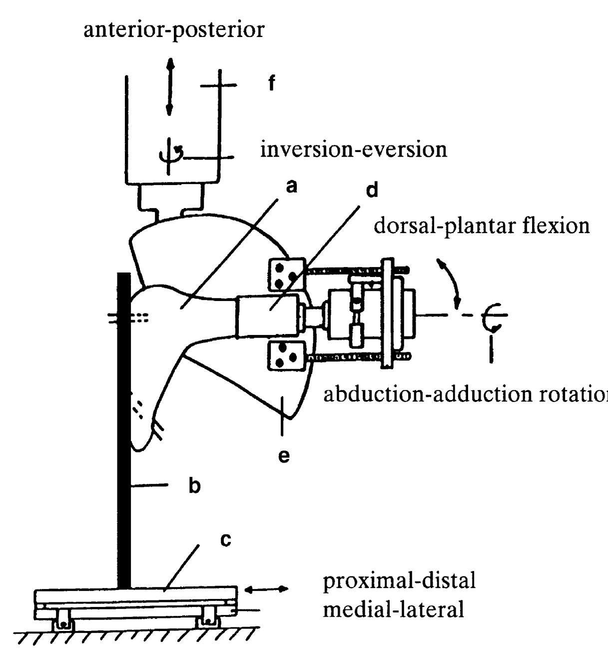

Fig. 1. MTS (Minneapolis, Minnesota) as used by Tohyama et al. [11]. (Reproduced with permission from *Journal of Orthopaedic Research,* vol. 13, p. 610.)

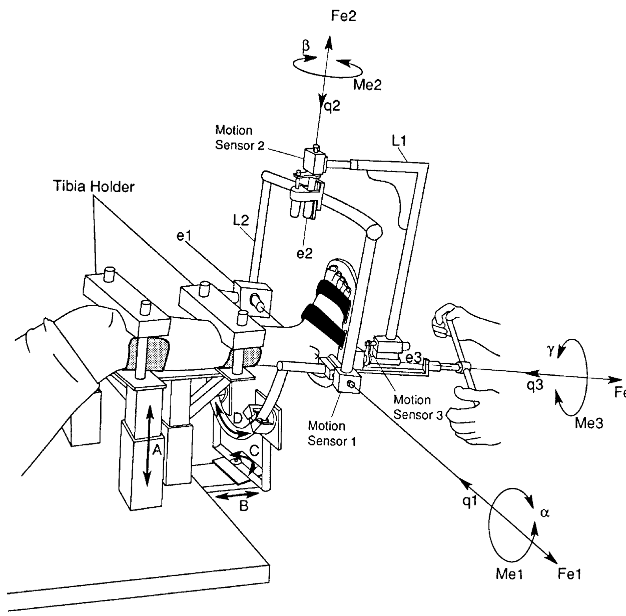

Fig. 2. The Ankle Flexibility Tester [18], as used by Lapointe et al. (Reproduced with permission from *Journal of Biomechanics,* vol. 29, p. 945 [33]).

applying load and direct measurement of the bone motions [4,15,18,20,21]. Loads applied varied from 50 N up to 150 N. The test fixtures and methods of Kjaersgaard-Andersen [18] and Kaneko [20] allowed accurate flexion–extension positioning of the ankle, as well as maintaining a constraint on rotation (internal–external and inversion–eversion). Lapointe et al. [4] described an experimental procedure that imposed no constraints to the motion of the ankle (Fig. 2). As was the case for [15,16,21]. Only Rasmussen [21] and Grace [15] used support frames applying the load by hanging weights from the distal tibia. Thereby they allowed freedom of rotation in the transverse and frontal plane. They conducted the only studies that measured the displacement on radiographs.

3.4. Laxity measurements

The anterior laxity values with intact ligaments vary greatly in the literature. After analysis of the results presented by nine different studies the mean value of anterior talocrural-joint laxity with intact ligaments is 4.2 mm (Fig. 3(a)). Lapointe [4] did not present absolute values for anterior talocrural-joint laxity (Table 3). After sectioning of the ATFL, as described in all nine studies [11,15–21,26], the mean anterior laxity value is 6.5 mm (Fig. 3(a)). So there is a mean increase of 2.3 mm that resembles a mean relative increase in anterior talocrural-joint laxity after sectioning of the ATFL of 55%. In addition, seven studies presented the anterior laxity values after sectioning of the calcaneofibular ligament (CFL) [15–21]. The mean anterior laxity value increases to 8.4 mm (Fig. 3(b)). The increase from 4.2 to 8.4 mm resembles a mean relative increase of 100%. As mentioned above, anterior talocrural-joint laxity values vary in literature. In order to gain insight in the variation of anterior laxity values in different test-positions of the foot, the results of tests with the foot in dorsal flexion, neutral position or plantar flexion were pooled and evaluated. The mean anterior laxity value with the foot in dorsal flexion (3.1 mm) is less than the mean value with the foot in neutral position (4.5 mm) or in plantar flexion (4.7 mm) (Figs. 4(a)–(c)). None of

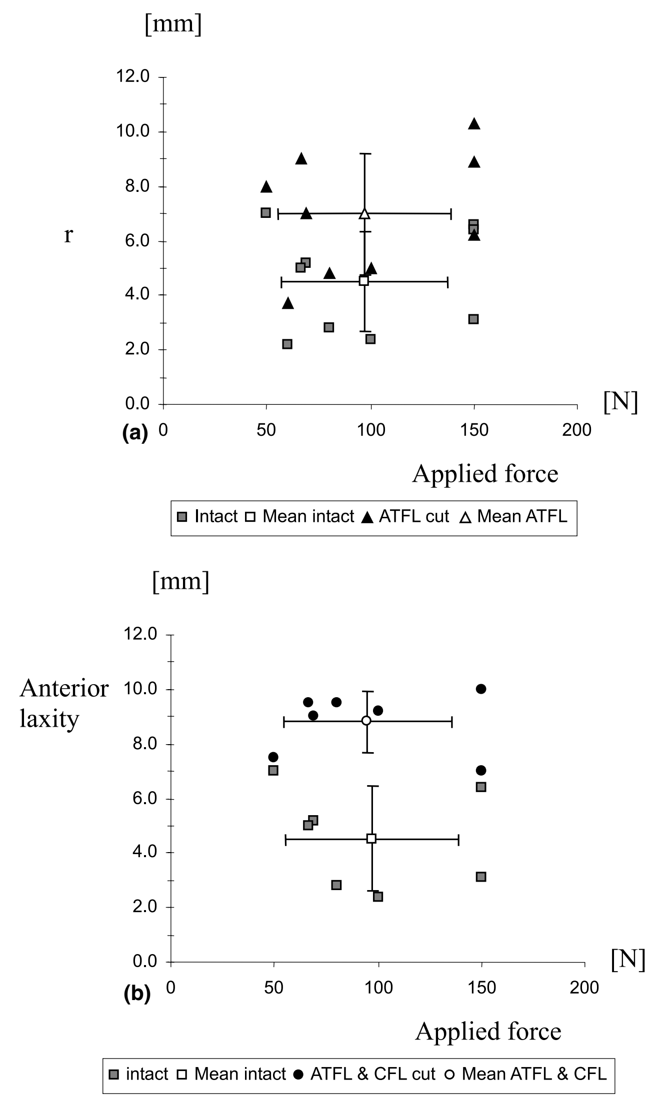

Fig. 3. Scatter diagrams showing anterior laxity and applied force for intact and ligament deficient ankles from the different studies. The values represent tests with the foot in neutral flexion: (a) represents all 9 studies, (b) represents 7 studies that described the anterior laxity values after cutting of the CFL as well.

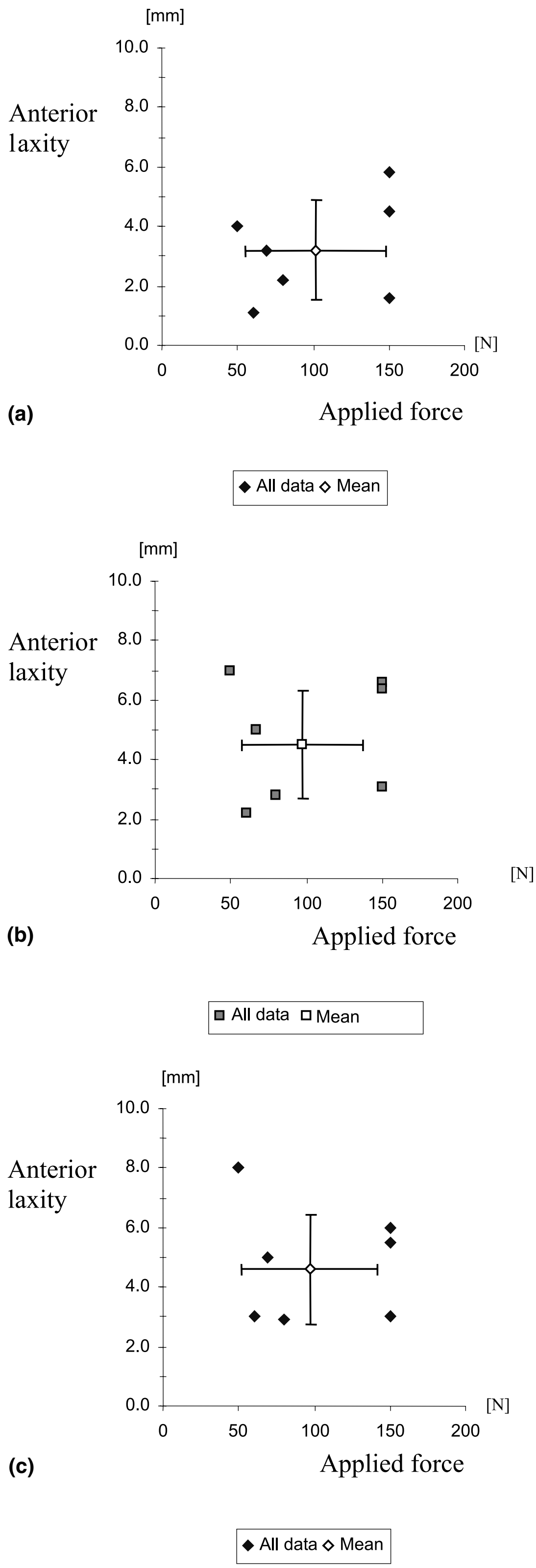

Fig. 4. Scatter diagrams showing anterior laxity and applied force for the intact ankle from the different studies. The values represent tests with the foot in dorsal flexion (a), neutral flexion (b) and plantar flexion (c).

these values are statistically significant. Each ligament section results in significantly increased anterior talocrural-joint laxity in each flexion angle. No optimal test position of the foot can be defined based on the results described in the literature, a test procedure with the foot in dorsal flexion seems not advisable because of the low absolute anterior laxity values. Although the most important parameter is the increase in anterior talocrural-joint laxity after cutting of the ligament(s). Standard Deviations of the separate studies are not listed, since these values were not presented in most studies, neither could these be calculated nor retrieved from the authors.

4. Discussion

General consensus in the literature is that the talocrural-joint laxity in anterior–posterior direction is best tested by analyzing the motion of the talus relative to the tibia. A significant increase in talocrural-joint laxity is described after sequentially cutting ATFL, CFL, both or in combination with PTFL. Hence, each ligament sectioning results in significantly increased talocrural-joint laxity. In order to be able to develop a clinical test device for evaluating the damage to the ligaments based on quantitative talocrural-joint laxity values, it is important to know the expected range of the increase in talocrural-joint laxity after damage to the anterior lateral ankle ligaments. Ranges differ widely in literature [4,11,15–21,26]. However, the expected range when regarding the mean values of the different studies that tested the ankle in neutral position is an increase of about 2.5 mm in talocrural-joint laxity with damage to the anterior talofibular ligament and an additional increase of about 2 mm with damage to both the ATFL and calcaneofibular ligament.

A point of discussion remains the optimal flexion angle for testing the anterior talocrural-joint laxity. Burks and Morgan [27] showed that, when the foot is in dorsal flexion, the CFL assumes a course parallel to the axis of the fibula, thereby functioning as a collateral ligament. On the other hand, with the foot in plantar flexion, the ATFL is expected to function as the main collateral ligament. These results indicate that the largest increase in laxity after sectioning of the ATFL is observed with the foot in plantar flexion and that the additional CFL lesion is best diagnosed in dorsal flexion. However, some studies [17,26] have concluded that the laxity increase resulting from ATFL injury is greater in dorsal flexion than in plantar flexion; whereas others advocate plantar flexion as the best testing position to detect isolated ATFL lesions [11]. Kjaersgaard-Andersen et al. [18] concluded that the laxity increase after an isolated ATFL injury is similar throughout the entire flexion angle. The analysis of the pooled results from the literature showed that sectioning of each of the ligaments results in a significant increase in talocrural-joint laxity in *each* flexion angle. So the recommendation about the optimal flexion angle at which specific ligament injuries should be tested varies greatly between the different studies.

For the variation in findings of the different authors, different explanatory theories are exclaimed. Apart from differences in experimental setup, which could, in part, explain the different conclusions reached, the fact remains that individual variations in ligament orientation [27] may cause different laxity patterns in different patients [16]. However in a randomly selected patient population that sufficiently resembles the general population, these individual variations should be averaged out. The examination of the natural variation between the different specimens was not described in any of the studies. Another theory comprises the measure of freedom of rotation allowed to the foot. Some devices did not allow freedom of rotation of the foot [11,17,18,20], which occurs during the anterior–posterior testing of the talocrural-joint laxity [28]. This may in part explain that some of these investigators [11,17,18] found the greatest relative increase with the foot in dorsal flexion after sectioning of both the ATFL and CFL. As mentioned by Renstrom and Kannus [29], a large increase in internal rotation (7–8°) was observed after combined injury during anterior drawer testing. Presumably, a test limiting internal rotation of the foot will reduce the sensitivity of testing talocrural-joint laxity. Therefore, a technique, where the foot is pulled forward with internal rotation, using the deltoid ligament as a center of rotation, is probably preferable to a technique where the foot is pulled straight forward [9].

In conclusion, each ligament section results in significantly increased talocrural-joint laxity in each flexion angle. It is not possible to give a universal recommendation for the optimal flexion angle for testing talocrural-joint laxity. Test devices should not restrict internal rotation of the foot in order to allow the full talocrural-joint laxity to be monitored when performing the test.

In order to be able to clearly indicate damage to the anterior lateral ankle ligaments in the clinical practice it is important to have insight into the absolute values of the right–left differences in anterior talocrural-joint laxity in general population. This way the measured values can best be interpret. Regarding the reported results in literature, no thorough conclusion can be drawn with regard to the expected absolute range of the right–left difference in an individual patient. This is an important issue to bear in mind and to investigate during the development of an objective test for anterior talocrural-joint laxity for use in the clinical practice.

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