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〔 Original Article 〕

Inter-examiner variability in three-dimensional kinematics of manual ankle anterior drawer test

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Abstract

【Purpose】To clarify three-dimensional ankle kinematics during manual anterior drawer test in cadaveric anterior talofibular ligament (ATFL) injury models.

【Methods】A total of eight certified orthopedic surgeons performed anterior drawer tests on intact and ATFL-resected cadaveric ankles in a blind fashion. Three-dimensional ankle kinematics, including the ATFL length change, talar anterior translation, and talar internal rotation, were measured during the test using infrared markers mounted on the tibia and talus. An independent certified orthopaedic surgeon visually evaluated the examiner's technique. Furthermore, the examiners also assessed ankle instability. The kinematic variables between the intact and ATFL-resected ankles were compared using Wilcoxon signed-rank tests.

【Results】The median (25th, 75th percentiles) ATFL length change during the maneuver was 3.1 (2.4, 6.8) mm in the intact and 6.2 (4.2, 7.3) mm in the ATFL-resected ankles, with no significant difference ($P = 0.31$). Moreover, three of eight examiners had smaller length changes in the ATFL-resected ankles than in the intact ankles. There were no significant differences in talar anterior translation or internal rotation between the ligament conditions. Five of the eight examiners assessed the intact ankle incorrectly as unstable, and two examiners assessed the ATFL-resected ankle incorrectly as stable.

【Conclusion】Ankle kinematics and examination techniques of manual anterior drawer tests varied greatly among certified orthopaedic surgeons. Moreover, the examiner's assessments of

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instability were inconsistent. This study highlighted the difficulty of the anterior drawer test and the need for further research to improve the technique and diagnostic accuracy.

***Key words*: ankle, ankle instability, anterior drawer test, anterior talofibular ligament, biomechanics**

Ⅰ. Introduction

Ankle sprains are the most common ankle injuries in daily life and sports activities. The anterior talofibular ligament (ATFL) is injured in 80% of sprains due to the inversion mechanism[1]. One-third of individuals experience residual symptoms one year after injury. Inadequate management may pose a risk of chronic ankle instability and ankle osteoarthritis[2]. Therefore, assessment of ankle instability is mandatory for satisfactory outcomes.

Manual anterior drawer test (ADT) is the most widely used technique for evaluating ankle instability due to lateral ankle ligament injury[3]. It is a simple physical examination, and no instrument is required. Therefore, ADT is recommended for assessing acute and chronic ATFL injury in clinical guidelines[4,5]. However, its implementation is not easy[6]. The reported diagnostic accuracy varies greatly among studies, with a specificity of 12%–80% and a sensitivity of 67%–100%[2]. While there are reports that ADT has higher diagnostic accuracy than stress X-rays, there are also reports that ADT alone does not have enough diagnostic accuracy to determine a treatment plan[7]. This variability suggests that disagreement in the test results could occur among examiners. For clinicians, whether their diagnosis agrees with the diagnosis made by colleagues is of interest[8]. This is a typical case in daily practice when patients are referred to different physicians with varying experience[8]. Therefore, identifying the differences among examiners provides essential information contributing to improved diagnostic accuracy.

Previous studies have reported various ADT techniques, which can cause insufficient test reliability [2,3]. The variations include ankle and knee positions and placement of the examiner's hands to hold the lower leg and foot. The direction of the stress to induce talar displacement is also variable, such as simple anterior drawer force, internal rotation, and their combination. Regardless of the techniques, a sufficient talar translation is mandatory for an accurate diagnosis. However, most reports on ADT used mechanical devices to apply controlled stress in a laboratory setting. The ankle position was also strictly fixed. The constrained environment does not recreate kinematic variations in clinical practice, in which the stress and ankle position may vary among examiners. Few studies have compared kinematics during manual ADT across examiners[6,9]. However, the number of examiners in their study was relatively small, with the test maneuver being standardized[6,9]. To clarify the variability in ADT techniques and kinematics in clinical practice, a study with a large number of examiners and without a limitation on the test maneuver is necessary.

This study aimed to measure ankle kinematics during ADT in a cadaveric lateral ankle ligament injury model and three-dimensional motion analysis system.

Ⅱ. Methods

Examiners

Inclusion criteria of the examiners were 1) board-certified orthopaedic surgeons and 2) those specializing in foot and ankle surgery. There was no specific exclusion criterion. The potential examiners were identified from hospitals in Chiba prefecture and were emailed for availability. A total of 8 male surgeons participated in the experiment. The mean ± standard deviation age was 43 ± 8 years, with a mean experience of 14 ± 8 years in foot and ankle surgery. The Research Ethics Committee of our institute approved this study, and informed consent was obtained from all examiners.

Cadaveric models

Two pairs of fresh-frozen, above-knee amputated limbs were used. They were 76-year-old male and 84-year-old female. The cadavers were thawed at room temperature 48 hours before the experiment. The absence of joint contracture, deformity, or osteoarthritic change was confirmed in both specimens. Intact and ATFL-resected models were created using the right ankle of each pair for kinematic analysis. A 3-cm skin incision was made along the anterior border of the lateral malleolus. After the subcutaneous tissue was dissected, the ATFL was exposed. In the intact model, no ligament resection was performed (sham surgery) and no instability was observed by direct inspection. In the ATFL-resected model, we cut the ligament in the mid-substance and instability was observed, followed by subcutaneous and skin closures. Left ankles were used as references for the examiner's assessment of ankle instability during ADT. We also performed sham surgeries on the left ankles. The femur of each limb was fixed on an operating table using an external fixator. The lower leg was hung over the edge of the table.

Manual anterior drawer test

The examiners performed the anterior drawer tests on the intact and ATFL-resected ankles, blinded to the stability of the ankles and other examiner's techniques. They were requested to conduct the test as they did in clinical practice. The evaluation items were 1) ankle kinematics, 2) assessment of ankle instability, and 3) examination technique.

Ankle kinematics

We measured the three-dimensional kinematics of the tibiotalar joint using a commercial motion capture system (VICON, Vicon Motion Systems Ltd, Oxfordshire, United Kingdom). A stainless steel pin of 4 mm diameter, mounted with five 14-mm reflective markers attached, was inserted into the anterior aspect of the tibial distal third and talar neck (Fig. 1A).

Anatomical coordinate systems of the tibia/fibula and talus were defined during surgery before transecting the ankle ligament. For the tibia/fibula, the origin was the center of the ATFL fibular footprint, depicted under a direct vision. Superoinferior, anteroposterior, and mediolateral axes were parallel to the International Society of Biomechanics recommendation in the ankle neutral position; the superoinferior axis was a line connecting the midpoint between the ankle medial and lateral malleolus and the midpoint between the medial and lateral tibial condyles[10]. The anteroposterior axis was a line perpendicular to a plane containing the medial and lateral malleolus and the superoinferior axis. The mediolateral axis was a line mutually perpendicular to the superoinferior and anteroposterior axes. For the talus, the origin was defined as the center of the ATFL fibular footprint. The coordinate axes were defined so that they were parallel to the tibia/fibular axes in a neutral ankle position. Six infrared cameras (Bonita 10, Vicon Motion Systems Ltd, Oxfordshire, United Kingdom) were placed to detect the motion of the reflective markers with a sampling frequency of 100 Hz (Fig. 1B). The tibiotalar kinematics were expressed as a motion of the talus relative to the tibia/fibula using

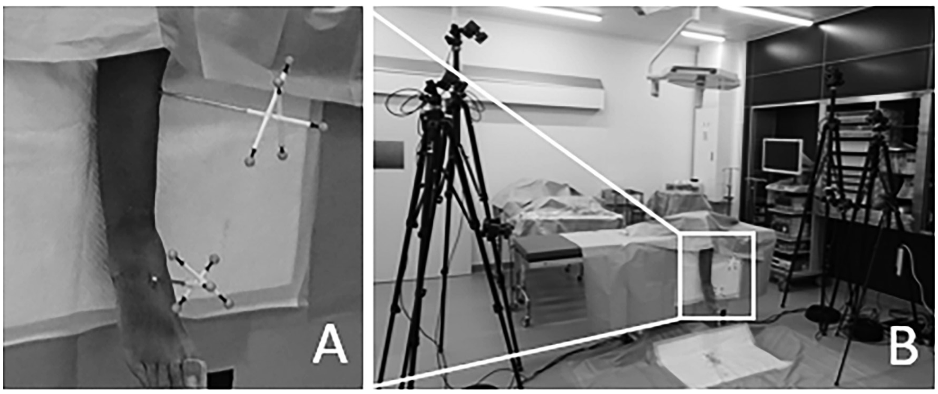

Fig. 1 Experimental setting of ankle kinematics measurement. Placement of infrared markers (**A**) and cameras (**B**).

Euler angles with a dorsi/plantarflexion-internal/external rotation-inversion/eversion sequence. Furthermore, we calculated the distance between the coordinate origins of the tibia/fibula and talus as the ATFL length. Raw kinematic data were smoothed using a Butterworth filter with a cutoff frequency of 6 Hz.

The primary kinematic outcome was the ATFL length change, defined as the difference between the maximum and minimum ATFL length during the test cycle[6]. The secondary outcomes were the change in talar anterior translation and internal rotation. After several trials to familiarize themselves with the experimental setting, the examiner performed five consecutive tests. We used the mean values of the second, third, and fourth trials for analysis.

Assessment of ankle instability

The examiners assessed the degree of ankle instability, with the contralateral left intact ankle as a reference. Instability was classified into three grades: - (stable), + (unstable), and ++ (very unstable with a sulcus sign)[5]. The assessments were further dichotomized into stable (-) and unstable (+ and ++).

Examination technique

The examiners answered a questionnaire on their preferred ADT technique. Question items included 1) hand placement to hold the foot (hold the patient's foot from the lateral side /hold the foot from the medial side /Hold the foot with the right hand regardless of the laterality of patient's ankle/the foot with the left hand), 2) stress direction (anterior drawer with no internal or external foot rotation/anterior drawer with unconstrained foot rotation/anterior drawer with intentional rotation), 3) instability assessment (two grades with negative and positive/three grades with negative, positive, and gross). Additionally, a 44-year-old certified orthopaedic surgeon with 12 years of experience in foot and ankle surgery visually evaluated the position of the cadaveric limb during the examination. The evaluations were 4) ankle position (plantarflexed/neutral) and 5) knee position (flexed/extended).

Statistical analysis

We used descriptive statistics to present the ankle kinematics, examination technique, and examiner's evaluation of ankle instability. Continuous variables were expressed using medians and interquartile values because they had non-normal distribution. Categorical variables were shown using numbers. The ATFL length changes and other kinematic variables between the intact and ATFL-resected ankles were compared using Wilcoxon signed-rank tests. Statistical significance was set at $P < 0.05$.

Ⅲ. Results

The ATFL length changes during ADT ranged between 2.0 mm and 9.3 mm in the intact ankle and between 2.2 mm and 7.4 mm in the ATFL-resected ankle. The median ATFL length change was larger in the ATFL-resected ankle than in the intact ankle; however, the difference did not reach statistical significance (Table 1). When assessing the individual data, three examiners had smaller length changes in the ATFL-resected ankles than in the intact ankles (Fig. 2A). Similar to the ATFL length change, there were no significant differences in the talar anterior translation or internal rotation between the intact and ATFL-resected ankles (Table 1, Fig. 2B, and C).

In the ligament intact ankle, three of eight examiners assessed it as stable, while the other five evaluated it incorrectly as unstable. (Fig. 2A). Furthermore, six examiners assessed the ATFL-resected ankle as unstable, and the other two evaluated it incorrectly as stable. The instability assessments were not associated with the kinematic parameters and examiner's age and years of experience, although statistical analysis was not performed (Fig. 2A-C). For example, the ATFL length changes for the ATFL-resected ankles by the incorrect examiners were above the median value at 6.5 mm and 6.9 mm (Fig. 2A).

The examination techniques were variable among examiners. The majority of examiners (n = 5) held the patient's foot with the right hand regardless of the laterality of the ankle examined (Fig. 3A, Table 2).

Table 1 Ankle kinematics during anterior drawer test in the intact and ATFL-resected ankles.

	Intact	ATFL-resected	*P* value
ATFL length change (mm)	3.1 (2.4, 6.8)	6.2 (4.2, 7.3)	0.31
Talar anterior translation (mm)	8.7 (5.9, 13.4)	10.2 (6.9, 12.7)	1.00
Talar internal rotation (degrees)	3.4 (1.5, 5.6)	2.5 (2.0, 4.1)	0.74

[a]Values indicate median (25th, 75th percentiles). ATFL, anterior talofibular ligament.

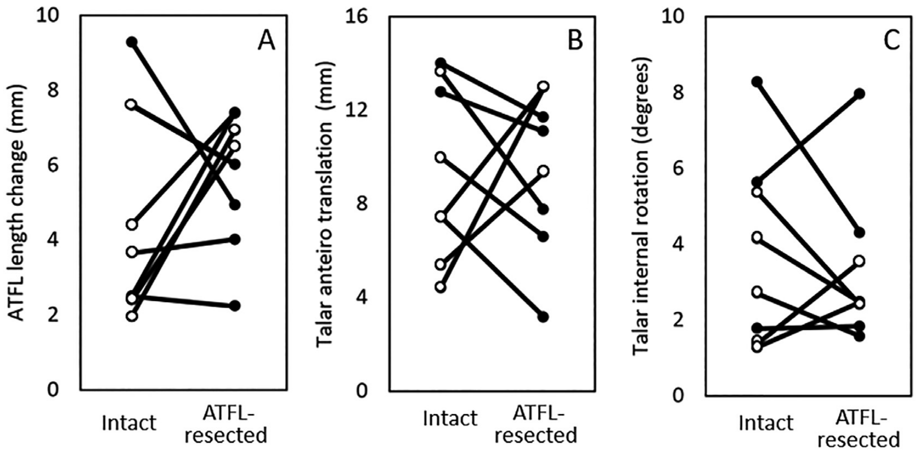

Fig. 2 Ankle kinematics during anterior drawer test. ATFL length change (**A**), talar anterior translation (**B**), and internal rotation (**C**). Black and white circles indicate examiners with correct and incorrect instability assessments, respectively. ATFL, anterior talofibular ligament.

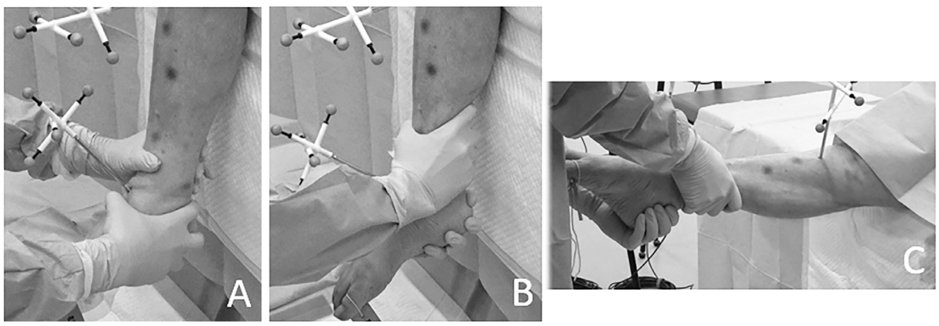

Fig. 3 Various anterior drawer test techniques. An examiner holds the lower leg from the inside and the foot from the outside with the knee flexed (**A**), and another examiner grasps the lower leg from the outside and the foot from the inside (**B**). An examiner holds the lower leg with the knee extended (**C**).

Table 2 Examination technique.

Items	Options			
Hand placement on the patient's foot	From the lateral side	From the medial side	With the right hand	With the left hand
	3	0	5	0
Stress direction	Fixed foot rotation	Unconstrained foot rotation	Intentional foot rotation	
	1	6	1	
Instability assessment	Two grades	Three grades		
	4	4		
Ankle position	Plantrarflexed	Neutral		
	8	0		
Knee position	Flexed	Extended		
	7	1		

The others grasped the foot from the lateral side (Fig. 3B). One examiner performed ADT with the knee extended (Fig. 3C), while others performed it with the knee flexed. The ankle position was consistent among examiners and plantarflexed (Table 2).

Ⅳ. Discussion

We found that the ankle kinematics during ADT varied across examiners, with no difference in the ATFL length changes between the intact and ATFL-resected ankles. Furthermore, some examiners misjudged instability. The examination techniques were also variable. Although orthopedic surgeons commonly evaluate ankle instability due to the prevalence of ankle sprains, our findings underscored the challenges in consistently conducting ADT and emphasized the imperative for technical standardization.

This study showed that the ATFL length changes were variable in intact and ATFL-resected ankles based on the examiner's individual ADT methods. Despite a median length change of 3 mm greater in ATFL-resected ankles than intact ankles, the difference lacked statistical significance. Our results are consistent with previous cadaveric research that found variability in anterior talar displacement during ADT among five clinicians, even though the ankle plantarflexion angle during the examination was standardized[9]. The authors found a wide overlap in displacement between the intact and ATFL-resected ankles[9]. Conversely, a separate study employing a standardized ADT technique after video instruction and one-hour hands-on training showed relatively small inter-examiner variance[6]. However, the difference in ATFL length change between the intact and ATFL-resected ankles was only about 2 mm[6]. Our study and existing literature suggest the necessity for standardizing techniques and training to ensure consistent kinematics across examiners.

Some examiners inaccurately assessed the intact ankle as unstable in our study. Our results contradict a recent meta-analysis that reported a high specificity of ADT[2]. A possible explanation is that we used cadaveric ankles. The talar displacement in cadaveric ankles may be larger than in vivo ankles due to the absence of muscle guarding, leading to false positive instability assessment on the ligament intact ankle [11]. As a result, the specificity is lower in cadaveric studies than in vivo studies[12]. We also found that two examiners misdiagnosed the ATFL-resected ankle as stable, aligning with a meta-analysis reporting a low sensitivity of 54%[2]. ADT diagnosis requires a proper maneuver execution to induce sufficient talar translation and accurate interpretation of the talar translation. Difficulty in satisfying the two elements in knee and shoulder physical examination has been reported[13]. No gold standard exists for assessing ankle instability. Stress radiography has a large inter-patient variability and low test-retest reliability[14]. The sonographic ADT has recently gained attention. However, it also resulted in measurement variability among examiners[15]. Furthermore, these methods are not easily available because they need instruments. Our study highlighted a need for a more sophisticated ADT method.

We found that the examiner's hand positions were inconsistent between examiners. Our results agree with a recent systematic review that addressed various ADT techniques. Further different methods have been proposed for improved diagnostic accuracy[16,17], highlighting the absence of a standard ADT technique. However, subtle differences in stress direction may influence ankle kinematics and detection of talar displacement[6,16,17]. The knee position also plays a role because the tension of the gastrocnemius prevents the talar anterior translation with extended knees[10]. Similar to ADT, large inter-examiner differences have been reported for the pivot shift test of the knee[18]. Moreover, standardization of the pivot shift maneuver leads to diagnostic consistency among examiners [19]. We did not assess the relationship between the ADT technique and kinematics because the number of examiners was limited. Further research is required to determine whether standardizing the technique produces consistent kinematics and sufficient diagnostic accuracy.

This study has several limitations. First, we used cadaveric ankles, which lack muscle contraction.

However, measuring detailed kinematics using in vivo ankles is difficult. Second, the infrared markers for the kinematic measurement may have interfered with the examiners' natural grasp of the ankle, although we carefully selected the marker positions to minimize the effect. Third, we did not measure the amount and direction of anterior drawer stress, which influences ankle kinematics. Fourth, we recruited examiners with a mean experience of 13 years. The measurements may be consistent if more experienced examiners performed ADT. Lastly, the number of examiners was determined based on availability. More examiners with formal power analysis may be necessary to determine the measurement differences between intact and unstable ankles.

In conclusion, the ankle kinematics and the examination techniques during ADT varied across examiners. The ankle instability assessments were also inconsistent. Our results highlighted the difficulty in performing the ADT correctly and emphasized the need for further research to establish a standardized technique and uniform evaluation.

Contributors

Guarantor of integrity of the entire study: SY, SO, TS. Study concepts and design: All authors. Clinical studies: SK, HN. Manuscript preparations: SK. Manuscript editing: SY.

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Conflict of interest

The authors declare that they have no conflicts of interest, either financial or non financial, with the contents of this article.

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Ethical approval

Ethical approval for this study was obtained from Chiba University Graduate School of Medicine Ethics Review Committee（APPROVAL NUMBER/ 3801）.

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