Single-leg loading test performed after acute lateral ankle sprain in competitive athletes

大阪府立大学大学院

総合リハビリテーション学研究科

博　士　論　文

Single-leg loading test performed after acute lateral ankle sprain in competitive athletes

2022 年 3 月

野田　優希

Table of contents

Abstract

Lateral ankle sprain (LAS) is one of the most common injuries during sports activities. Due to its high incidence rate, LAS tends to be neglected, with more than half of the patients who injured their ankle joints do not take a medical treatment, and a previous study reported that approximately 90% of the patients with (LAS) have returned within 1 week. Another report also showed that many athletes still had symptoms such as pain and joint instability 1 year after the injury, and most of athletes were re-injured as a result of inadequate treatment and premature return to sports.

For early return to sports after a LAS and recurrence prevention, effective rehabilitation and gradual return to sports should be initiated while predicting the return time based on the appropriate severity evaluation immediately after injury. However, since severity evaluations performed in previous studies required large space and stairs and involved high-revel activity, their use as a test and index to evaluate severity after LAS was not appropriate considering convenience and risk of re-injury. Therefore, a quick and simple test was developed to evaluate the severity of acute LAS.

In the experiment 1, we aimed to verify the association between ankle function for severity evaluation and anterior talofibular ligament (ATFL) injury type by ultrasonography and to clarify the usefulness for acute LAS severity evaluation of the single-leg loading (SLL) test. A total of 50 patients (34 men, 16 women) who visited our sports clinic within 3 days after sustaining acute LAS and who conformed to the study criteria were included. The SLL test and objective/subjective ankle joint evaluation were performed at the first visit to our clinic. The SLL test consists of difficulty in standing, standing, heel raising, and step-by-step hopping. The test was terminated when the patient felt pain or fear. Then patients were classified into four levels (Levels 1–4) based on the evaluation results. In addition, ultrasonographic evaluation was performed within 1 week after the first visit to evaluate the type of ATFL injury. Type I was defined as intact ATFL, Type II as swollen ATFL with an almost intact fibrillar pattern and Type III as ATFL appearing swollen with a disrupted fibrillar pattern. The relationship between the SLL test and each evaluation item was investigated using Spearman's correlation coefficient. As per the correlation coefficients of the SLL test, Japanese Society for Surgery of the Foot ankle/hindfoot scale and sports activity were $r_s = 0.71$ ($p < 0.001$) and $r_s = 0.66$ ($p < 0.001$), respectively, showing a significant positive correlation. SLL test and the type of ATFL injury also showed a significant negative correlation ($r_s = -0.58$, $p < 0.001$). These results suggested that the SLL test was a simple and useful test that can be used as an index to evaluate the severity of acute LAS.

Although we elucidated the utility of SLL test in the experiment 1, it is unclear whether the severity level of the SLL test is associated with the time to jog and return to sports (RTS). Therefore, we aimed to examine whether the time to jog and RTS differ depending on the severity level assessed by the SLL test in competitive athletes with LAS in experiment 2. A total of 240 ankles with a Tegner activity level scale of ≥7 who visited our sports clinic within 3 days after sustaining acute LAS were included in this experiment. The SLL test was performed at the first visit, and the patients were classified into four levels. The Steel–Dwass multiple comparison method was used to examine whether a difference between the time to jog and RTS could be observed depending on the severity level assessed by the SLL test. Furthermore, multiple regression analysis was performed to verify whether the test affected the time to jog and RTS. As a result of Steel–Dwass multiple comparison method, significant differences were found among almost all the levels of the SLL test. Moreover, as a result of multiple regression analysis, only the SLL test was selected as a significant variable for both the time to jog and RTS. These results suggested that the time to jog and RTS can be predicted by the level of the SLL test.

In conclusion, the SLL test which we devised as a screening test for acute LAS was thought to be useful evaluation and could predict the time to jog and RTS in competitive athletes.

Key words: Acute lateral ankle sprain, Severity evaluation, Single-leg loading test, Time to jog, Time to return to sports

Chapter 1: Quick and simple test to evaluate severity of acute lateral ankle sprain

I. Introduction

According to a survey conducted in the United States,[1] approximately half of ankle sprains occur during sports activities and can be said as one of the most frequent musculoskeletal disorders in sports.[2] However, more than half of patients who injured their ankle joint do not take a medical treatment,[3] accurate diagnosis and appropriate severity evaluation have not been made, and a previous study reported that approximately 90% of patients with lateral ankle sprain (LAS) have returned within 1 week.[4] Another report also showed that many athletes still had symptoms such as pain and joint instability 1 year after the injury,[5] and >70% of athletes were re-injured in basketball as a result of inadequate treatment and premature return to sports.[6] To prevent re-injury and achieve the earliest possible return to sports, effective rehabilitation and gradual return to sports should be initiated, while predicting the return time based on an appropriate severity evaluation immediately after the injury. Some studies have investigated the relationship between the prognosis after LAS and physical status, such as load capacity, self-reported motor function and injured ligament evaluation, using ultrasonography at the first visit.[7–9] Wilson *et al*.[8] reported a significant correlation between the scores of six functional evaluations performed on patients after LAS and residual dysfunction duration. Docherty *et al*.[10] performed four hopping tests and reported a significant correlation between the score of ankle function and some hopping test. Cross *et al*.[9] demonstrated a significant correlation between the time to return to sports and subjective functional evaluation in collegiate athletes with LAS. However, many issues have been encountered when using the functional evaluation of previous studies as a test and index to evaluate severity after LAS. In fact, these functional evaluations needed a large space or stairs and involved high-revel activity if performed immediately after injury, without considering the severity of the injured ligament. Therefore, a test for evaluating the severity of acute LAS that can be performed easily and anywhere, such as in clinical or sports settings, is required.

A single-leg loading (SLL) test was developed as a screening test and used as an index of severity for acute LAS. This study aimed to examine the relationship between SLL test and ankle functional evaluation and anterior talofibular ligament (ATFL) injury type using an ultrasonography examination.

II. Materials and Methods

1. Participants

A total of 58 patients who visited our sports clinic within 3 days after acute LAS from October 2018 to March 2019 and were diagnosed with lateral ligament injury. Radiographic assessment was performed at the first visit to determine the presence of fractures.

We defined our criteria as the following: (1) cases wherein ATFL damage was the main injury and (2) cases with grade I or II lateral ligament injury were included; (3) cases with a history of LAS within 3 months of injury and (4) cases with fractures (including avulsion fractures) were excluded. Of the 58 patients, 8 patients were not analysed because they did not meet the inclusion criteria: 1 patient had grade III lateral ligament injury, 1 had avulsion fracture, 2 had other complex ligament injuries, 2 had a history of LAS within 3 months of injury and 2 were excluded due to a mistake in filling out the questionnaire. Finally, 50 patients (34 men, 16 women) were included in this study. The average age of the 50 patients was 15.6 ± 3.0 years, ranging from 9 to 28 years, and the average number of days from injury to the first visit was 1.5 ± 1.0 days. The injury was right-sided in 30 ankles and left-sided in 20 ankles.

For these cases, SLL test was performed and an objective and subjective evaluation questionnaire was administered at the first visit; ATFL ultrasonography was performed within 1 week after the first visit. All ultrasound examinations were performed by one physical therapist using SONIMAGE HS1 (KONICA MINORUTA, Japan) with linear-array probes at 18–4 MHz in B-mode. Physiotherapy was started at the first visit, and most patients were given taping or ankle brace.

This study was a case-series study approved by the institutional ethics review board of Graduate School of Comprehensive Rehabilitation, Osaka Prefecture University (approval number: 2019-110). All patients provided written informed consent after receiving an explanation of the study protocol, and the study was conducted according to the principles of the Declaration of Helsinki.

2. SLL test

SLL test was conducted in four steps with two fingers on the evaluator's hand to control posture (Fig 1). First, patients were instructed to stand on a single leg. If they could not stand for 3 seconds, the test was terminated. Otherwise, i.e. if they could stand for 3 seconds, they proceeded to the next step. Then the patients were instructed to raise their heel while standing on a single leg while keeping a distance of >3 cm between the floor and heel. If they could perform this three times, they proceeded to the next step.

Finally, patients were instructed to hop on a single leg such that their toes were off the floor. If they could perform this activity three times, the test was complete. The test was considered successful when the patient could complete the task with or without pain. The test was terminated if the patients were not able to continue the test owing to pain or fear. Based on the results of this test, patients were classified into four levels as follows: Level 1, difficulty in single-leg standing; Level 2, single-leg standing; Level 3, single-leg heel raising and Level 4, single-leg hopping.

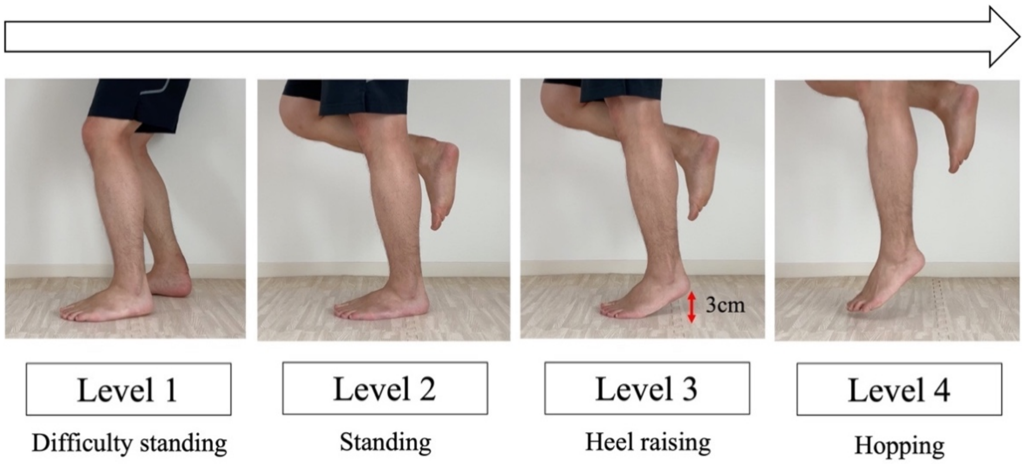


Figure 1. Flow chart indicating the method of classification using the SLL test.

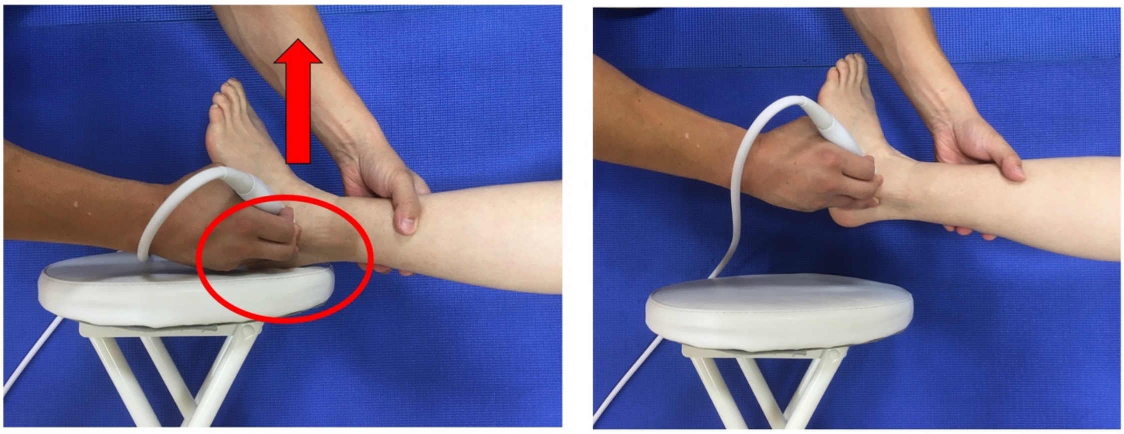
Patients were classified into four levels, depending on SLL test results as follows: Level 1, difficulty in standing with a single leg; Level 2, standing with a single leg; Level 3, heel raising with a single leg and Level 4, hopping with a single leg.

3. Objective/subjective ankle joint evaluation

As an objective functional evaluation, Japanese Society for Surgery of the Foot (JSSF) ankle/hindfoot scale[11,12] was used, which consists of three items: '*pain*', '*function*' and '*alignment*', and has a maximum score of 100 points. As a subjective evaluation, a self-administered foot evaluation questionnaire (SAFE-Q) created by the Japanese Orthopaedic Association and Japanese Society for Surgery of the Foot[13] was used. SAFE-Q includes six subscales: pain and pain related, physical functioning and daily living, social functioning, shoe related, general health and well-being and sports activity subscales. Each subscale has a maximum score of 100 points.

4. Ultrasonographic evaluation of ATFL injury

During the examination, the patient was seated on the treatment bed with the heel of the affected ankle on the edge of the chair. The ankle joint was held in the neutral position and instructed to relax. The probe was placed at the lower end of the lateral malleolus in order to be parallel to the sole of the foot, and from that state, the ATFL was visualised by slowly rotating the probe toward the sole of the foot by 45°. ATFL was evaluated with or without anterior drawer force to the ankle joint. The anterior drawer test was performed by placing the heel to a chair as it took anterior drawer force by the weight of the lower leg (Fig 2-a). The evaluation without anterior drawer force was performed by grasping the distal lower leg with the hand opposite to the one holding the probe and lifting the heel from the chair (Fig 2-b).



a b

Figure 2. Patient's ankle position during ultrasonography.

ATFL was evaluated with or without anterior drawer force to the ankle joint. (a) The evaluation with anterior drawer force was performed by attaching the heel to a chair as it took anterior drawer force by the gravity of the lower leg. (b) The evaluation without anterior drawer force was performed by grasping the distal lower leg with the hand opposite to the one holding the probe and lifting the heel from the chair.

Ultrasonographic evaluation of the ATFL injury was performed within 1 week after the first visit. The severity of the ATFL injury was classified using the method reported by Kemmochi et al.[14] Type I is defined as intact ATFL (Fig 3-a), Type II as swollen ATFL but almost intact fibrillar pattern(Fig 3-b) and Type III as ATFL that appears to be swollen and disrupted fibrillar pattern(Fig 3-c). Type IV is defined as a completely torn ATFL, and Type V is defined as an avulsion fracture of the talar end or with distal lateral malleolus of the ankle. In this study, Types I to III injuries were included.

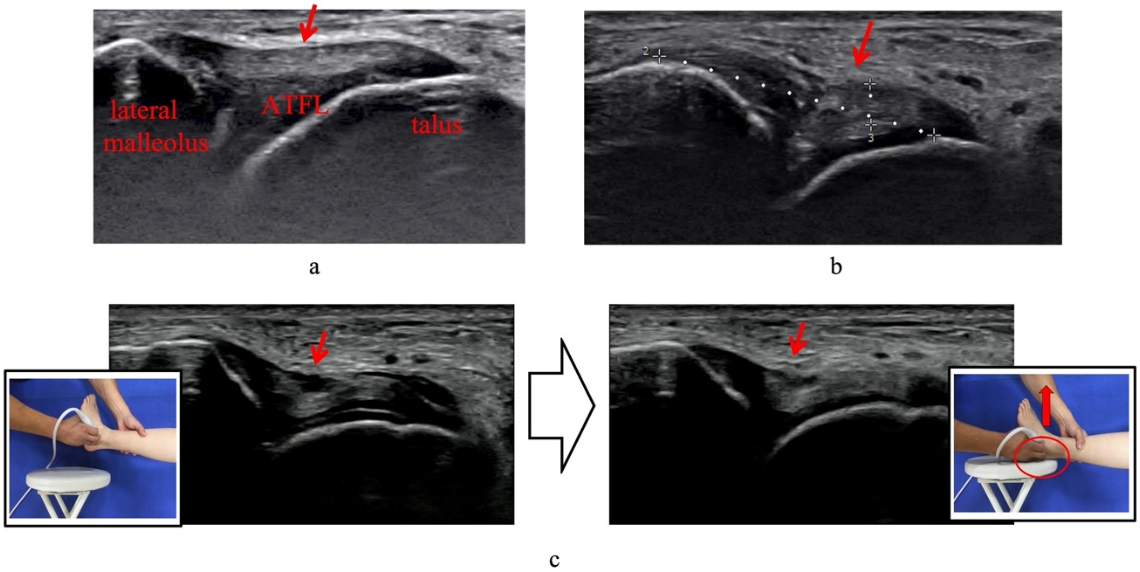


Figure 3. Ultrasonographic classification of ATFL injury

(a) Type I : ATFL is intact. Fibrillar pattern is intact. (b) Type II : Swelling of the ATFL. Fibrillar pattern is nearly intact. (c) Type III : ATFL is elongated. Fibrillar pattern is disrrupted. ATFL, anterior talofibular ligament.

5. Statistical analysis

The normality of each SLL test subscale, JSSF ankle/hindfoot scale, SAFE-Q and ATFL injury type was confirmed using the Shapiro–Wilk test. The association between SLL test and JSSF ankle/hindfoot scale, SAFE-Q subscales and ATFL injury type was examined using Spearman's correlation coefficient. All statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan),[15] a graphical user interface for R (the R Foundation for Statistical Computing, Vienna, Austria). More precisely, a modified version of R commander was designed to add statistical functions frequently used in biostatistics. p-values of ≤ 0.05 were considered statistically significant. For the inter-examiner reliability of SLL test, the κ coefficient of Cohen was calculated in 31 patients who can successfully perform SLL test with two examiners. The κ coefficient of the SLL test was 0.78, and the inter-examiner reliability was substantial according to the Landis *et al.*'s criteria.[16]

III. Results

Based on the SLL test, 15 patients were classified as Level 1 (30%), 19 as Level 2 (38%), 5 as Level 3 (10%) and 11 as Level 4 (22%). In addition, based on the ultrasonographic classification of the ATFL injury, 1 patient was classified as Type I

(2%), 16 as Type II (32%) and 33 as Type III (66%). The JSSF ankle/hind foot scale and SAFE-Q subscale scores are shown in Table 1.

Table 1. Scores of the JSSF ankle/hindfoot scale and SAFE-Q subscales.

Evaluation items	Median	Quartile
JSSF ankle / hindfoot scale	36.5	27.5-54.8
SAFE-Q		
Pain and Pain Related	45.8	32.3-60.0
Physical Functioning and Daily Living	52.3	39.2-67.6
Social Functioning	50.0	20.8-75.0
Shoe Related	75.0	52.1-91.7
General Health and Well Being	65.0	46.3-85.0
Sports Activity	14.3	3.0-33.8

All values are presented as the median and 1st–3rd quantile. JSSF ankle/hindfoot scale, Japanese Society for Surgery of the foot ankle/hindfoot scale; SAFE-Q, self-administered foot evaluation questionnaire.

A highly significant positive correlation was observed between the SLL test and the JSSF ankle/hindfoot scale ($r_s = 0.71$, $p < 0.001$). In addition, a significant positive correlation was found between the SLL test and all SAFE-Q subscales, especially the correlation of sports activity was high ($r_s = 0.66$, $p < 0.001$) (Table 2). A statistically significant negative correlation was also observed between the SLL test and ultrasonographic classification of ATFL injury ($r_s = -0.58$, $p < 0.001$).

Table 2. Correlations between the SLL test and evaluation items.

Evaluation items	r_s	95%CI		p value
		lower	upper	
JSSF ankle / hindfoot scale	0.71	0.54	0.83	<0.001
SAFE-Q				
Pain and Pain Related	0.51	0.27	0.69	<0.001
Physical Functioning and Daily Living	0.67	0.48	0.80	<0.001
Social Functioning	0.44	0.19	0.64	0.001
Shoe Related	0.56	0.34	0.73	<0.001
General Health and Well Being	0.41	0.15	0.62	0.003
Sports Activity	0.66	0.47	0.79	<0.001
Ultrasonographic classification of ATFL injury	-0.58	-0.74	-0.36	<0.001

SLL test, single-leg loading test; 95%CI, 95% confidence interval; JSSF ankle/hindfoot scale, Japanese Society for Surgery of the foot ankle/hindfoot scale; SAFE-Q, self-administered foot evaluation questionnaire, ATFL, anterior talofibular ligament. P-values were determined using the Spearman's correlation coefficient.

IV. Discussion

This study aimed to clarify the relationship between the SLL test and objective/subjective ankle evaluation and the severity of the injured ligament and to show the usefulness of SLL test as an evaluation index for acute LAS. In this study, SLL test showed a significantly high positive correlation with the JSSF ankle/hindfoot scale. In addition, SLL test showed a significant positive correlation with all SAFE-Q subscales, especially the correlation coefficient of sports activity was higher than that of other subscales. Furthermore, a significant negative correlation was observed between the SLL test and the severity of the ATFL injury using ultrasonography. Therefore, the SLL test was confirmed to be associated with the objective/subjective evaluation of acute LAS and also with the severity of ligament injury.

Wilson et al.[8] conducted a functional test consisting of various items, such as figure-8 hop and cross-over hop in the acute lateral ankle ligament I and II injuries. A significant correlation between the test and the subjective motor ability assessment was reported. Functional evaluation for chronic ankle instability requires physical examinations, including varus/valgus and internal/external rotational motion examinations[9]. However, these examinations may be difficult to perform because of the risk of re-injury or aggravation in cases with acute LAS. Conversely, SLL test comprises four levels, difficulty in standing, standing, heel raising and hopping, and can be evaluated in a step-by-step manner depending on the severity of the ATFL injury. Therefore, SLL test can be safely used as a test for examining acute LAS. In addition, as SLL test takes only approximately 1 minute to be performed, it can be performed easily, with minimal discomfort to the patient. Furthermore, this study demonstrated that SLL test was significantly correlated with the JSSF ankle/hindfoot scale and sports activity. Hence, SLL test was considered useful in terms of safety and convenience for evaluating the severity of acute LAS.

Several studies have reported the usefulness of ultrasonography for lateral ankle ligament injuries.[17–19] Ultrasonography for ATFL injury has been found to be equally sensitive and specific as MRI[20] and had a good correlation with intraoperative findings.[21] In addition, Kemmoch et al.[14] reported a positive outcome of ATFL injury using only ultrasonography and by deciding the treatment method based on these results. These results indicate that ultrasonographic evaluation of ATFL injury may be useful as an index of severity. In this study, a significant negative correlation was found between the SLL test and the severity classification of the ATFL injury, using ultrasonography. So, SLL test is useful for severity assessment of acute LAS because the severity level of the SLL test reflected the severity of the ATFL injury. Therefore, the SLL test can be an alternative in clinical and sports settings, where expensive procedures such as ultrasonography cannot be performed. However, since the correlation coefficient between the SLL test and ligament evaluation by ultrasonography was moderate ($r = -058$), using the SLL test in combination with ultrasonography, rather than using the SLL test alone, may provide a more accurate evaluation.

To predict the prognosis of ankle sprains, it is important to determine the exact time of return to sports. Previous studies have suggested that prognosis can be predicted more accurately by assessing not only objective evaluation but also subjective evaluation, such as walking and athletic abilities.[8,9,22,23] Choi et al. evaluated the severity of lateral ankle ligament injury using ultrasonography after LAS and then examined the relationship between the severity and foot and ankle outcome score at 12 months after the injury. They concluded that the severity immediately after injury might predict the long-term results.[24] In this study, we used the JSSF ankle/hindfoot scale for objective evaluation, SAFE-Q for subjective evaluation and ultrasonography for ligament injury classification. Questionnaires, such as the JSSF ankle/hindfoot scale and SAFE-Q are cost-effective, but are time-consuming and require approximately ≥20 minutes to complete (for each). Ultrasonography accurately evaluates injured ligaments, but this procedure is expensive and can be used in only few clinical or sports settings. On the contrary, the SLL test can be used easily, requires ≤1 minute for completion and does not require any special techniques or equipment. Furthermore, a significant positive correlation was found between the SLL test and the JSSF ankle/hindfoot scale and SAFE-Q. Also, a significant negative correlation was found between the SLL test and the severity of ATFL injury evaluated using ultrasonography. Therefore, performing the SLL test in cases of acute LAS and observing the subsequent course might clarify the most adequate time of return to sports.

This study has some limitations. First, this study only targeted ATFL grade I and grade II injuries and did not includ grade III injuries. In fact, SLL test results may differ depending on the severity of ligament injury. However, SLL test for patients with grade III injury may pose a high risk of re-injury. Therefore, a screening method should be used to determine whether the test can be safely performed in such cases. Second, in this study only ATFL, not calcaneofibular ligament (CFL), was evaluated. As lateral ankle instability and subtalar joint instability involve CFL injury,[25] the presence or absence of CFL injury may affect load capacity and long-term performance after an injury. However, as researchers have varied opinions regarding the measurement position of the ankle during an ultrasonographic examination for CFL[26,27], the examination method has not been established yet. Therefore, this study only focused on ATFL, which has an established test method and can be easily visualised and examined using the SLL test.

Ⅴ. Conclusion

In this study, we devised a simple SLL test as a screening test for acute LAS. The SLL test was thought to be a useful test of the severity evaluation of acute LAS because a significant correlation was found between the objective and subjective ankle joint evaluation and the severity classification of the ATFL injury using ultrasonography.

Chapter 2: Single-leg loading test to predict time to jog and return to sports after acute lateral ankle sprain in competitive athletes

I. Introduction

Lateral ankle sprain (LAS) is one of the most common injuries encountered in sports settings[1,2] and its incidence rate was reported to be 0.70/1000 h for professional soccer players[28] and 0.83/1000 h for professional basketball players.[29] Its incidence is 5–6 times higher than that of anterior cruciate ligament injury (0.15/1000 h).[30] Due to the high incidence rate of LAS, it tends to be neglected, with more than half of the affected individuals not visiting a doctor[3]; thus, approximately 90% of people return to sports (RTS) within a week after injury.[4] In addition, a survey of basketball players at a wide range of levels, from recreational to national, reported that >70% of people had a recurrence and 60% had some residual symptoms.[6] Thus, inadequate rehabilitation and premature RTS result in high LAS recurrence rates,[31] leading to chronic symptoms. To prevent recurrence and achieve a safe and early RTS, a treatment program should be developed after predicting the time to RTS, and the treatment process should be initiated at an early stage based on an appropriate severity assessment. Therefore, RTS predicted through severity assessment at an early stage after injury is considered as useful information for medical staff. Furthermore, in clinical settings, the most frequently asked questions by injured athletes are “when can I move?” and “when can I return to sports?” Therefore, information on the prospect of RTS is important for both the players and medical staff.[32]

With regard to factors related to prognosis after LAS and RTS, performing objective (range of motion and swelling) as well as subjective evaluations (weight-bearing status and functional test) has been reported to be important.[8,9,21,22] However, previously reported functional tests for LAS evaluate motion including varus/valgus and internal/external rotational motions[8,9]; therefore, it is difficult to use them in clinical settings due to the high risk of reinjury and pain exacerbation. For the abovementioned reasons, the single-leg loading (SLL) test was developed as an index to evaluate the severity of acute LAS.[33] This test consists of four evaluation items—difficulty in standing, heel raising, and hopping step-by-step. Because in this test, the load is gradually increased, it can be safely performed for individuals with acute LAS. Furthermore, a significant correlation was found between ultrasonographic evaluation of the injured ligament properties and objective and subjective evaluation questionnaires,[33] and even with a relatively low load setting, the SLL test can be used sufficiently as a screening test for acute LAS. However, whether the severity level evaluated by the SLL test is associated with the RTS of competitive athletes remains unclear.

Therefore, this study aimed to investigate whether the severity level assessed by the SLL test is related to the time to jog and RTS in competitive athletes with acute LAS. This study hypothesized that the higher the severity level assessed by the SLL test, the shorter will be the time to jog and RTS.

II. Material and methods

1. Participants

We included 465 athletes with a Tegner activity level scale of ≥7[34], who visited our sports clinic within 3 days after acute LAS between January 2011 and March 2019 and were diagnosed with anterior talofibular ligament (ATFL) injury. The diagnostic criteria for ATFL injury were as follows: ankle varus injury mechanism, ATFL tenderness, swelling, and fracture absence confirmed by radiography. All patients were diagnosed by the same orthopedic surgeon.

We defined our inclusion criteria as follows: patients (1) who visited our sports clinic within 3 days after sustaining acute LAS, (2) wherein ATFL damage was the main injury and (3) fractures (including avulsion fractures) were absent. Furthermore, patients using steroid injections as of the first visit were excluded. Of the 465 athletes, 57 athletes had steroid injections and 168 athletes were excluded because follow-up until RTS was not performed for them. Finally, a total of 240 athletes (149 men, 91 women) were included in this study (Fig 4). The mean age of 240 athletes was 15.3 ± 2.5 years, and the mean number of days from injury to the first visit was 1.4 ± 1.0 days. The injury was right- and left-sided in 122 and 118 ankles, respectively. For these cases, the SLL test was performed at the first visit, and we investigated the relationship between the severity level assessed by the SLL test and time to jog and RTS. The time to jog and RTS were investigated from the electronic medical record.

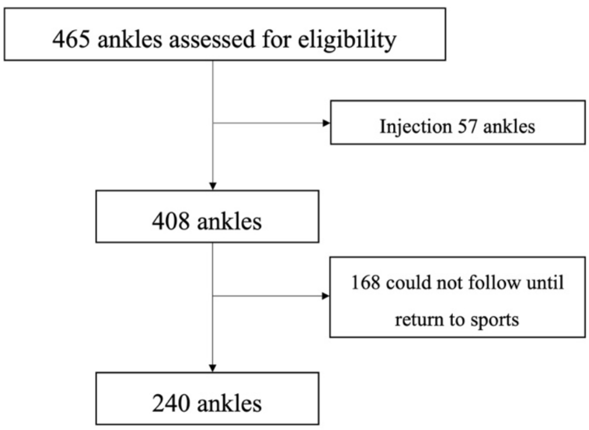


Figure 4. Enrolment of participants who had acute LAS

The criteria for the time to jog were defined as follows: when swelling had subsided and continuous single-leg hopping and jogging could be performed without pain. The criteria for the time to RTS were defined as follows: when deep squats, single-legged side hops, and competition-specific movements could be performed. Moreover, we defined RTS based on a previous study[35]—the athlete has returned to their previous sports but may not be performing at their desired performance level.

This case-series study was approved by the institutional ethics review board of Graduate School of Comprehensive Rehabilitation, Osaka Prefecture University (approval number: 2019-109). The option to opt-out of the study was available on the website of our sports clinic for the participants, and the study was conducted following the principles of the Declaration of Helsinki.

2. SLL test

See Figure 1 of Chapter 1.[33]

3. Statistical analysis

The normality of each SLL test subscale score, time to jog, and time to RTS was confirmed using the Shapiro–Wilk test. The Steel–Dwass multiple comparison method was used to examine whether a difference between the time to jog and RTS could be observed depending on the severity level assessed by the SLL test. The effect size was calculated to examine the magnitude of the differences between each severity level using the following formula[36]:

$$r = Z/\sqrt{n}$$

As a guideline for the effect size (r), the small effect size was 0.10, medium effect size was 0.30, and large effect size was 0.50.[37]

Multiple regression analysis was performed to examine whether the SLL test affects the time to jog and RTS even when the effect of the confounding factors is considered and the extent of the effect. The objective variables were the time to jog and RTS, and the SLL test was input as explanatory variables for each. Because age and gender have been reported to affect RTS,[38] they were used as adjustment variables. Gender was considered a dummy variable and set as male (0) and female (1).

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan),[15] a gr user interface for R (the R Foundation for Statistical Computing, Vienna, Austria). More precisely, a modified version of R commander was designed to add statistical functions frequently used in biostatistics. P-values ≤ 0.05 were considered statistically significant.

III. Results

The median Tegner activity level scale (1st–3rd quartile) of the patients was 9 (7–9). Basketball was the sport accounted for the largest percentage, followed by soccer, accounting for approximately 50% of these two sports (Fig. 5). As per the SLL test results, 66 patients (28%) belonged to Level 1, 81 (34%) to Level 2, 37 (15%) to Level 3, and 56 (23%) to Level 4.

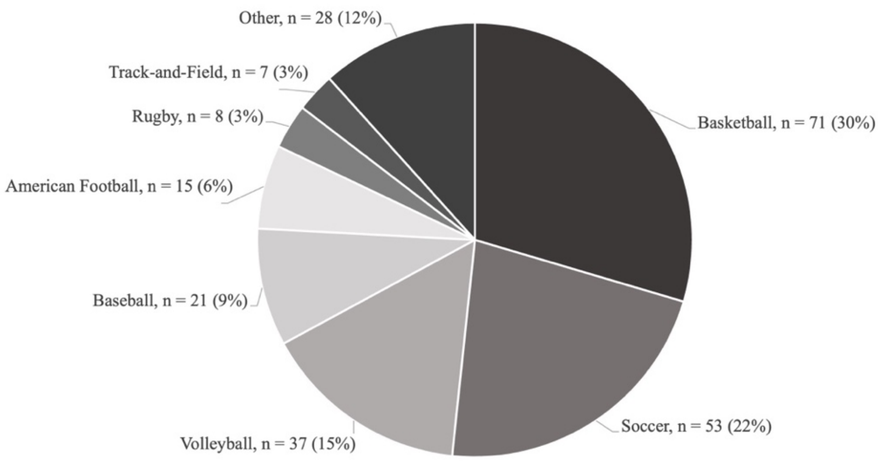


Figure 5. Sports type of participants

1. The time to jog and RTS

The median time to jog for each severity level assessed by the SLL test was as follows: 14 days for Level 1, 8 days for Level 2, 7 days for Level 3, and 2 days for Level 4 (Table 3). The time to jog shortened as the severity level assessed by the SLL test increased, and significant differences were observed among all the severity levels assessed by the SLL test ($p < 0.05$) (Table 4) (Fig. 6).

The median time to RTS for each severity level assessed by the SLL test was as follows: 26 days for Level 1, 20 days for Level 2, 15 days for Level 3, and 10 days for Level 4 (Table 3). Moreover, the time to RTS shortened as the level of the SLL test increased, and significant differences were observed between all the severity levels, except between Levels 2 and 3 and Levels 3 and 4 ($p < 0.05$) (Table 4) (Fig. 7).

Table 3. The time to jog and RTS at each level of the SLL test

SLL test level	Time to jog	Time to RTS
	median (1st–3rd quantile)	Median (1st–3rd quantil
Level 1	14 (7–18)	26 (17–35)
Level 2	8 (7–13)	20 (14–26)
Level 3	7 (4–8)	15 (7–27)
Level 4	2 (0–4)	10 (7–15)
Overall	8 (5–13.9)	19 (12–29)

All values are presented as the median.
RTS, return to sports; SLL test, single-leg loading test

Table 4. Effect size between each level of the SLL test

SLL test level	Time to jog		Time to RTS	
	p value	Effect size	p value	Effect size
1 vs. 2	0.018	r = −0.24	0.016	r = −0.24
1 vs. 3	<0.001	r = −0.52	<0.001	r = −0.35
1 vs. 4	<0.001	r = −0.70	<0.001	r = −0.63
2 vs. 3	0.005	r = −0.31	0.399	r = −0.14
2 vs. 4	<0.001	r = −0.59	<0.001	r = −0.41
3 vs. 4	0.001	r = −0.38	0.246	r = −0.19

RTS, return to sports; SLL test, single-leg loading test

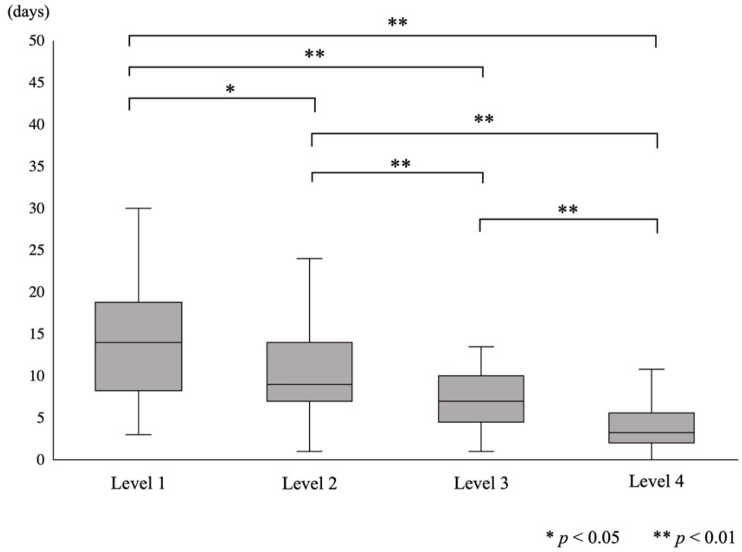


Figure 6. The relationship between the SLL test and time to jog
Boxplots indicate the median; error bars indicate the quantile.
SLL test, single-leg loading test
P-values were determined using the Steel–Dwass multiple comparison method.

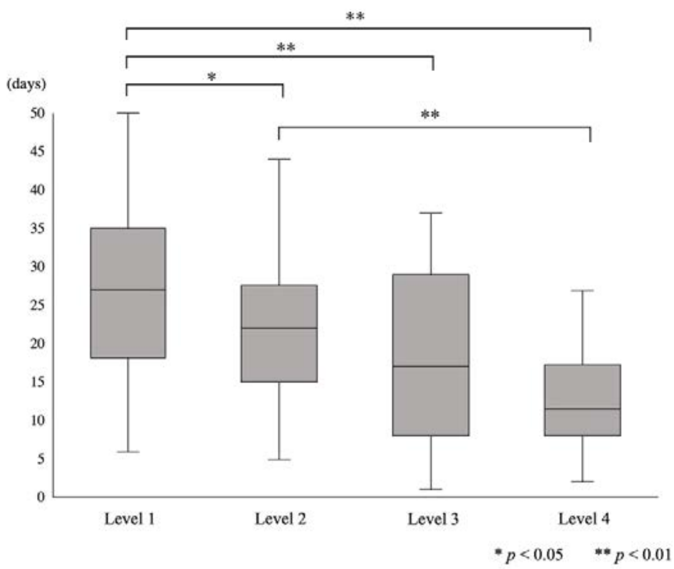


Figure 7. The relationship between the SLL test and time to RTS
Boxplots indicate the median; error bars indicate the quantile.
SLL test, single-leg loading test; RTS, return to sport
P-values were determined using the Steel–Dwass multiple comparison method.

2. Results of multiple regression analysis

Multiple regression analysis was performed by inputting the time to jog and RTS as objective variables, the severity levels assessed by the SLL test as explanatory variables for each objective variable, and age and gender as adjustment variables. Consequently, only the SLL test was found to a variable that significantly affected the time to jog and RTS ($\beta = -0.52$, $p < 0.001$) (Table 5). Furthermore, similar results were obtained for the multiple regression analysis performed by inputting the time to RTS as the objective variable ($\beta = -0.42$, $p < 0.001$) (Table 6).

Table 5. Multiple regression analysis at the time to jog

	Estimate	β	t value	p value
Intercept	16.41			
SLL test	−3.29	−0.52	−9.15	<0.001
Age	0.10	0.03	0.60	0.547
Sex (female)	−0.56	−0.04	−0.68	0.496

ANOVA; p < 0.001

ANOVA, analysis of variance

Table 6. Multiple regression analysis at the time to RTS

	Estimate	β	t value	p value
Intercept	30.59			
SLL test	−4.64	−0.42	−7.05	<0.001
Age	0.10	0.02	0.34	0.736
Sex (female)	−0.09	−0.004	−0.06	0.951

ANOVA; p < 0.001

ANOVA, analysis of variance; RTS, return to sport

IV. Discussion

In this study, we investigated the relationship between the severity levels assessed by the SLL test, which was originally developed by us,[33] and time to jog and RTS. Significant differences were observed among almost all the severity levels assessed by the SLL test, and only the SLL test was found to significantly affect the time to jog and RTS.

The time to acquire normal stair climbing and walking functions was reported as an index of gradual functional recovery.[39] However, in clinical practice, "when can I move?" is the most frequently asked question by athletes, and it cannot be said that the time to acquire normal stair climbing and walking functions is the information that satisfies the needs of competitive athletes. Furthermore, although the weight-bearing capacity at an acute phase after an injury is an important factor that affects short-term functional recovery,[22] no study has reported the time to jog as a functional recovery index. The time to RTS consists of three elements—return to participation, RTS, and return to performance,[35] and jogging is the first step toward a gradual return. Since the time to jog is an index for the consideration of subsequent rehabilitation programs, predicting the time to jog through the severity levels assessed by the SLL test may be useful for competitive athletes.

A systematic review investigating factors that affect RTS in patients with acute LAS reported that weight-bearing capacity was a predictor of RTS.[40] However, in previous studies on loading capacity, the evaluation items consisted of a 40-m walk or run and cross-over hop tests,[8] which are associated with several problems such as 1) the places where they can be carried out are limited or 2) they involve a risk of reinjury because of high loading if they are carried out early after an injury. Conversely, the SLL test can be performed anywhere and the stress experienced in the varus/valgus and internal/external rotational directions is less. In addition, the task is set when considering the stepwise acquisition of the ankle joint function and loading capacity. In previous studies investigating functional recovery after ankle trauma,[41] evaluation items same as those used in this study were used, suggesting that they were appropriate for evaluating ankle function. The time to RTS is determined comprehensively considering not only physical factors, such as muscle strength and range of motion, but also psychological and social factors and performance[35]; therefore, the time to RTS cannot be determined by the SLL test alone. However, it may enable a safe RTS using the severity level evaluated by the SLL test as an index while considering the functional recovery and schedule of each athlete.

Hence, our results suggest that the time to RTS can be predicted by the severity level evaluated by the SLL test and support our hypothesis that “the higher the severity level assessed by the SLL test, the shorter will be the time to jog and RTS.”

We recognize that this study has some limitations. First, we examined the relationship between the severity level assessed by the SLL test at baseline and time to jog and RTS but did not consider factors other than age and gender. Particularly, the time to RTS is expected to differ depending on the sport; however, this point was not considered. Second, common criteria for RTS after LAS have not been established,[42] the criteria for RTS used in this study are unique to our sports clinic, and the generalizability of our results is limited. Therefore, in the future, the utility of the SLL test should be investigated by conducting the SLL test for each sport and among multicenter institutions based on unified criteria for RTS.

Ⅴ. Conclusion

The severity level assessed by the SLL test showed a good correlation to the time to jog and RTS in competitive athletes with acute LAS. This study suggested that the time to jog and RTS can be predicted using the severity levels assessed by the SLL test.

Ⅵ. Reference

1) Waterman BR, Owens BD, Daveyet S et al. (2010) The epidemiology of ankle sprains in the United States. J Bone Jt Surg, 92:2279–84.
2) Doherty C, Delahunt E, Caulfiel B, et al. (2014) The incidence and prevalence of ankle sprain injury: A systematic review and meta-analysis of prospective epidemiological studies. Sport Med, 44:123–40.
3) McKay GD, Goldie PA, Payne WR, et al. (2001) Ankle injuries in basketball: injury rate and risk factors. Br J Sports Med, 35:103–8.
4) Medina McKeon JM, Bush HM, Reed A, et al. (2014) Return-to-play probabilities following new versus recurrent ankle sprains in high school athletes. J Sci Med Sport, 17:23–8.
5) van Rijn RM, van Os AG, Bernsen RMD, et al. (2008) What Is the Clinical Course of Acute Ankle Sprains? A Systematic Literature Review. Am J Med, 121:324–31.
6) Yeung MS, Chan KM, So CH, et al. (1994) An epidemiological survey on ankle sprain. Br J Sports Med, 28:112–6.
7) Thompson JY, Byrne C, Williams MA, et al. (2017) Prognostic factors for recovery following acute lateral ankle ligament sprain: A systematic review. BMC Musculoskelet. Disord. BioMed :421–35.
8) Wilson RW, Gansneder BM (2000) Measures of functional limitation as predictors of disablement in athletes with acute ankle sprains. J Orthop Sport Phys Ther, 30:528–35.
9) Docherty CL, Arnold BL, Gansneder BM, et al. (2005) Functional-performance deficits in volunteers with functional ankle instability. J Athl Train, 40:30–4.
10) Cross KM, Worrell TW, Leslie JE, et al. (2002) The relationship between self-reported and clinical measures and the number of days to return to sport following acute lateral ankle sprains. J. Orthop. Sports Phys. Ther :16–23.
11) Niki H, Aoki H, Inokuchi S, et al. (2005) Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders I: Development of standard rating system. J Orthop Sci, 10:457–65.
12) Niki H, Aoki H, Inokuchi S, et al. (2005) Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders II: Interclinician and intraclinician reliability and validity of the newly established standard rating scales and Japanese Orthopaedic Association. J Orthop Sci, 10:466–74.
13) Niki H, Tatsunami S, Haraguchi N, et al. (2013) Validity and reliability of a

self-administered foot evaluation questionnaire (SAFE-Q). J Orthop Sci, 18:298–320.

14) Kemmochi M, Sasaki S, Fujisaki K, et al. (2016) A new classification of anterior talofibular ligament injuries based on ultrasonography findings. J Orthop Sci, 21:770–8.

15) Kanda Y (2013) Investigation of the freely available easy-to-use software "EZR" for medical statistics. Bone Marrow Transplant, 48:452–8.

16) Landis JR, Koch GG (1977) The Measurement of Observer Agreement for Categorical Data. Biometrics, 33:159.

17) Park JW, Lee SJ, Choo HJ, et al. (2017) Ultrasonography of the ankle joint. Ultrasonography, 36:321–35.

18) Lee SH, Yun SJ (2017) The feasibility of point-of-care ankle ultrasound examination in patients with recurrent ankle sprain and chronic ankle instability: Comparison with magnetic resonance imaging. Injury, 48:2323–8.

19) Alves T, Dong Q, Jacobson J, et al. (2019) Normal and Injured Ankle Ligaments on Ultrasonography With Magnetic Resonance Imaging Correlation. J Ultrasound Med, 38:513–28.

20) Gün C, Ünlüer EE, Vandenberk N, et al. (2013) Bedside ultrasonography by emergency physicians for anterior talofibular ligament injury. J Emergencies, Trauma Shock J Emerg Trauma Shock, 6:195–8.

21) Lee SH, Yun SJ (2020) Ankle ultrasound for detecting anterior talofibular ligament tear using operative finding as reference standard: a systematic review and meta-analysis. Eur J Trauma Emerg Surg, 46:73–81.

22) O'Connor SR, Bleakley CM, Tully MA, et al. (2013) Predicting Functional Recovery after Acute Ankle Sprain. PLoS One, 8.

23) De Bie RA, De Vet HCW, van den Wildenberg FAJM, et al. (1997) The prognosis of ankle sprains. Int J Sports Med, 18:285–9.

24) Choi WS, Cho JH, Lee DH, et al. (2020) Prognostic factors of acute ankle sprain: Need for ultrasonography to predict prognosis. J Orthop Sci, 25:303–9.

25) Yoon DY, Moon SG, Jung HG, et al. (2018) Differences between subtalar instability and lateral ankle instability focusing on subtalar ligaments based on three dimensional isotropic magnetic resonance imaging. J Comput Assist Tomogr, 42:566–73.

26) Precerutti M, Bonardi M, Ferrozzi G, et al. (2014) Sonographic anatomy of the ankle. J Ultrasound, 17:79–87.

27) Cheng Y, Cai Y, Wang Y (2014) Value of ultrasonography for detecting chronic

injury of the lateral ligaments of the ankle joint compared with ultrasonography findings. Br J Radiol, 87.

28) Waldén M, Hägglund M, Ekstrand J (2013) Time-trends and circumstances surrounding ankle injuries in men's professional football: An 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med, 47:748–53.

29) Kofotolis N, Kellis E (2007) Ankle sprain injuries: A 2-year prospective cohort study in female Greek professional basketball players. J Athl Train, 42:388–94.

30) Hootman JM, Dick R, Agel J (2007) Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. J. Athl. Train, 42:311–9.

31) Delahunt E, Bleakley CM, Bossard DS, et al. (2018) Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. Br J Sports Med, 0:1–7.

32) White WJ, McCollum GA, Calder JDF (2016) Return to sport following acute lateral ligament repair of the ankle in professional athletes. Knee Surgery, Sport Traumatol Arthrosc, 24:1124–9.

33) Noda Y, Horibe S, Hiramatsu K, et al. (2021) Quick and simple test to evaluate severity of acute lateral ankle sprain. Asia-Pacific J Sport Med Arthrosc Rehabil Technol, 25:30–4.

34) Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res, 198:43–9.

35) Ardern CL, Glasgow P, Schneiders A, et al. (2016) 2016 Consensus statement on return to sport from the First World Congress in Sports Physical. Br J Sports Med, 50:853–64.

36) Mizumoto A, Takeuchi O (2008) Basics and Considerations for Reporting Effect Sizes in Research Papers. Bull Kansai English Lang Educ Soc, 31:57–66.

37) Field A (2009) Discovering statistics using IBM SPSS statistics. 2nd ed. Statistics (Ber). SAGE Publications Ltd.

38) Akacha M, Hutton JL, Lamb SE (2010) Modelling treatment, age- and gender-specific recovery in acute injury studies. Univ Warwick :1–12.

39) Beynnon BD, Renström PA, Haugh L, et al. (2006) A prospective, randomized clinical investigation of the treatment of first-time ankle sprains. Am J Sports Med, 34:1401–12.

40) Al Bimani SA, Gates LS, Warner M, et al. (2019) Factors influencing return to play following conservatively treated ankle sprain: a systematic review. Phys Sportsmed, 47:31–46.

41) Bullock SA, Allen GM, Watson MS, et al. (2018) Predicting poor outcome from simple ankle injuries: A prospective cohort study. Br J Radiol, 91.
42) Tassignon B, Verschueren J, Delahunt E, et al. (2019) Criteria-Based Return to Sport Decision-Making Following Lateral Ankle Sprain Injury: a Systematic Review and Narrative Synthesis [Internet]. Sport. Med. Sports Med, 49:601–19.

VII. Acknowledgement

I would like to express my sincere gratitude to Professor Shuji Horibe and Dr. Kunihiko Hiramatsu for their guidance and encouragement. I am also very grateful to Associate Professor Rikio Takao for his advice on the statistical analysis. Finally, I would like to express my sincere gratitude to Dr. Kenji Fujita for providing me with a place for clinical research.