

Factors Associated to Return to Sport after Surgical Repair of Achilles Tendon Ruptures. A Clinical and Functional Retrospective Study

R. Tanaka¹, T. Imai¹, S. Katsuki¹, T. Sanada², A. Fukai^{2,3}, E. Honda², H. Yoshitomi²

¹ Central Department of Rehabilitation Medicine, Kanto Rosai Hospital, Kawasaki, Japan

² Sports Orthopedics Surgery, Kanto Rosai Hospital, Kawasaki, Japan

³ Faculty of Medical Technology, Teikyo University, Kanto Rosai Hospital, Kawasaki, Japan

CORRESPONDING AUTHOR:

Ryuta Tanaka
Central Department of Rehabilitation
Medicine
Kanto Rosai Hospital
1-1 Kizuki Sumiyoshi-cho
Nakahara-Ku
211-8510 Kawasaki, Japan
E-mail: ryuta-tanaka@kantoh.johas.go.jp

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SUMMARY

Background. The factors that influence a successful return sport following Achilles tendon rupture repair have not been identified. Furthermore, the extent of heel-rise height index (HRHI) and Achilles tendon resting angle (ATRA) as indicators of Achilles tendon function recovery are unclear.

Methods. We included 94 subjects who underwent a first unilateral Achilles tendon repair between 2017 and 2019, and returned to sports 9 months after surgery. Preoperative activity was set at 100 points, and subjects were classified into two groups with ≥ 80 points and < 80 points. Multiple logistic regression analysis was performed. The cutoff value of the extracted factors was also calculated. Dependent variables were patient background, extent of heel-rise height index (HRHI), and Achilles tendon resting angle (ATRA) for the unaffected side.

Results. HRHI was only extracted as an influencing factor (odds ratio, 1.104), with a cutoff value of 89.5%. The ATRA required for this HRHI was 72.4% as the cutoff value calculated.

Conclusions. After Achilles tendon repair, the HRHI required for good sports activity. The HRHI was about 90%, ATRA required was 70% or more. It is necessary to prevent Achilles tendon elongation after surgery.

KEY WORDS

Achilles tendon rupture repair; return to sports; Achilles tendon resting angle (ATRA); heel-rise height index (HRHI); rehabilitation; surgery; sports level classification.

INTRODUCTION

Various factors are involved in the recovery of function after an Achilles tendon rupture repair, and various evaluation tools have been used to assess the recovery. Factors that affect functional recovery after an Achilles tendon rupture repair include age, body mass index (BMI), and surgery (1, 2). The single-leg heel rise (HR) we incorporated into our functional evaluation is considered an important index for functional evaluation following surgery (3-5). We previously reported a correlation between achieving a single-leg HR and jogging and between performing 25 consecutive single-leg HR (continuous HR) and being able to return to

sport (5). Studies have also reported that single-leg HR is an indispensable factor in returning to competition (4, 5). In contrast, regarding the elevation-unaffected ratio of the single-leg HR, a residual dysfunction in the heel-rise height index (HRHI) has been reported after Achilles tendon rupture repair (6, 7). Moreover, it is unclear how HRHI affects sports activities (8). Another factor to consider is the elongation of the Achilles tendon (6, 9, 10). A useful method for assessing tendon elongation is measuring the Achilles tendon resting angle (ATRA), which is reported to reflect the length of the tendon (11). ATRA was reported to demonstrate a positive correlation with the HRHI (12).

Because minimized strength of the triceps surae is considered important, setting the angle of the tendon during surgery while suturing is essential, and also important when considering how to proceed with rehabilitation (13-15). However, it is unclear whether the ATRA meets the HRHI requirements for sports activities.

This study considered HRHI as one of the functional factors required for sports activities. It is important to demonstrate that ATRA is able to achieve the HRHI necessary for sporting activities. By doing so, it becomes possible to provide clear indicators of rehabilitation. Therefore, this study aimed to clearly define the HRHI and ATRA necessary for sports activities.

METHODS

This is a retrospective study. We extracted the necessary factors between the two groups and calculated the necessary cutoff value. All patients agreed to be included in research and ethics services. The study was approved by the Research Ethics Committee of our hospital (approval number: 2020-10). Research meets ethics Journal criteria (16).

Subjects

In this study, return to sports was defined as being able to participate in regular sports, matches, or match-style practice after undergoing surgery. The target populations were individuals who regularly engage in sports activities. In the past, when it comes to returning to sports, there is a wide range of topics, from interviewing patients, using sports participation scores, to objective sports performance indicators (17-20). However, much of the research is vague, “returning to preoperative sports levels (21, 22)”. It examines “quality and content when returning”. The definition of returning to sports needs to be clear and straightforward. Therefore, the definition of sports return used to include participants in this study is defined as “participating in a match or participating in a match-style practice.” Subjects excluded from this study were included in the “Level 0” category of sports level criteria (**table I**).

Table I. Sports level classification.

Level 0 (L0): non-sports
Level 1 (L1): recreation level
Level 2 (L2): district convention, municipality level
Level 3 (L3): prefectural level
Level 4 (L4): national level
Level 5 (L5): professional, olympic level

In the present study level 0 is excluded.

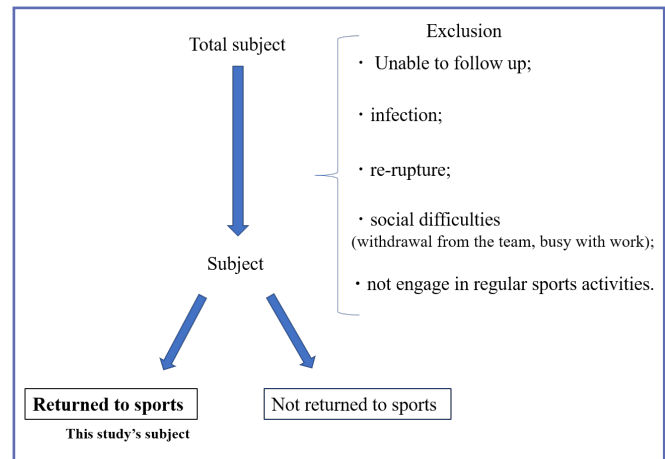


Figure 1. Patient recruitment flow chart.

From January 2017 to August 2019, 342 subjects underwent unilateral Achilles tendon rupture repair in our center within 3 weeks of injury. Of these, the 94 subjects who were able to participate in the 9-month follow-up and return to sports were included in this study (**figure 1**), which used a retrospective questionnaire.

Surgery

The half-mini-Bunnell method (Uchiyama method), where the nodule is sutured to the stump (4), was used in all cases. The knee joint was in the 90° flexion position, and the ankle plantar flexion angle on the unaffected side was adjusted further by 5°. A repair was sandwiched between the bundles, each sutured distally and proximally with the same degree of tension. The surgery is performed by 6 doctors belonging to our hospital, each with more than 10 years of experience as an orthopedic surgeon.

Rehabilitation

On postoperative day 5, the below-knee cast was changed to a walking cast and used for 2 weeks. Patients were discharged after receiving instructions on all possible full weight-bearing gaits. The range of motion and active movement were expanded with a focus on the removal of adhesions around the wound. HR in the sitting position was performed on week 3 after repair, and double-leg HR in the standing position was performed from week 5 to 6 after surgery. Subjects started with single-leg HRs from weeks 8 to 9 after surgery. The angle setting of the orthosis was gradually changed from - 20° to - 10°, 0°, and 10° according to the acquired angle. The brace was removed at week 10 after the

operation. If > 50% of the HRHI was possible, the subject was allowed to start jogging, and after acquiring continuous HR, the subject shifted to practicing sports activities such as jumping or stepping actions (jumping movement). We proceeded with rehabilitation with the target of returning to sports in 5 months (4, 5).

Outcome measurement

ATRA

The ATRA was measured in the prone position, with the knee joint in the 90° flexion position, with the ankle joint fully relaxed, and the ankle joint natural plantar flexion angle. The angle between the fibula head and the fifth metatarsal was measured in 1° increments using a standard 30 cm long arm goniometer (figure 2). The evaluation determined the ratio with the unaffected side.

HRHI

HR was performed on a single leg while the subject was standing, with the knees in the extended position and the upper limbs supporting the wall to the extent that the fingers were balanced. When the heel was raised, the distance of the heel bottom from the floor was measured with a standard tape. Measurement is performed in 0.5 cm units in consideration of measurement error, the ratio between the affected and unaffected sides was calculated (figure 3).



Figure 2. Achires tendon resting angle (ATRA) inspection and measurement method.

The angle between the fibula head and the fifth metatarsal bone is measured with an angle meter, and the ratio between the effected side and unaffected side is calculated.

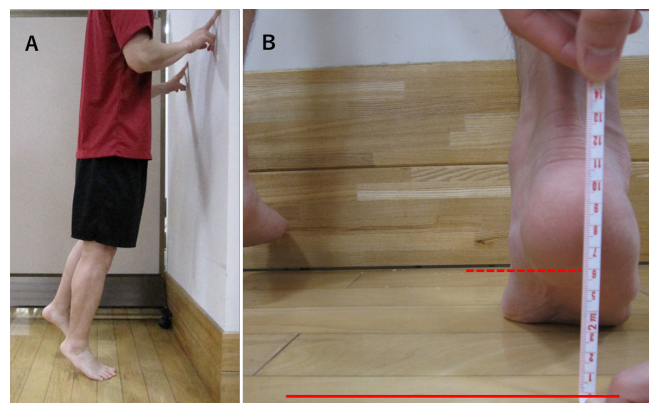


Figure 3. Heel rise height index (HRHI) inspection and measurement method.

(A) The upper limbs are balanced by putting fingers on the wall. Knees should be in the extended position. (B) Measure the bottom of the calcaneus from the floor and compare the laterality.

Study protocol and statistical analysis

At 9 months after surgery and return to sports, patients were asked for a subjective recovery score. As a result, the average was 80.2 ± 13.2 points. The subjects were divided into two groups, which were used as dependent variables. Those with a subjective recovery score of ≥ 80 points were classified in the good group (N = 68, average recovery rate, 86.9 ± 6.4 points), and those with a subjective recovery score of < 80 points were classified in the poor group (N = 26, average recovery rate, 62.7 ± 13.1 points).

Patient demographics

Between the two groups, Waiting period, Age, Sports Level, BMI, ATRA, HRHI, The Pain rate, and The items of The Anxiety rate were compared (figure 4 A).

Movement starting time and achieved time

Between the two groups, Full Dorsal flexion ROM achieved, Jogging start, HRHI 50% achieved, Continuous HR achieved, Jumping Movement achieved (Perform 5 consecutive single-legged jumps on the spot), and Return to sports achieved were compared at movement starting time and achieved time (figure 4 B).

Regarding the items of Patient demographic and Movement starting time and achieved time, the differences between the two groups were compared. The presence or absence of a normal distribution was evaluated. Variables that were normally distributed were analyzed using an unpaired t-test, and variables that were not normally distributed were evaluated using the Mann-Whitney U test. Pain and anxiety rates were compared using the chi-square test.

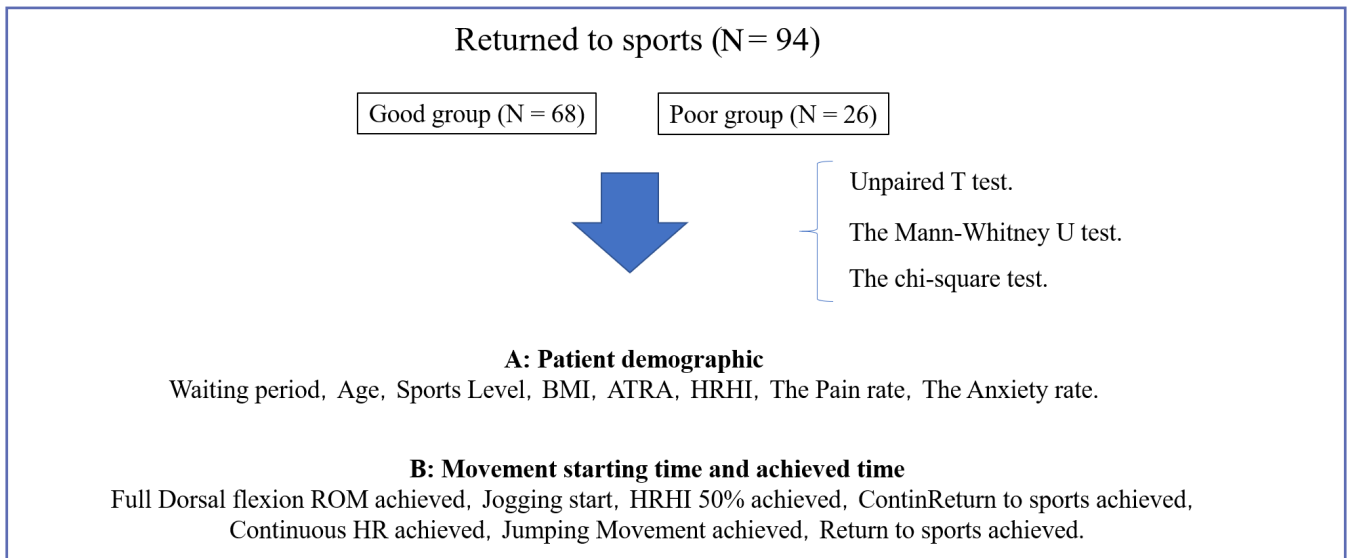


Figure 4. Study protocol flow chart (A) Patient demographic. (B) Movement starting time and achieved time.

Outcomes of interest

Age, sports level, BMI, ATRA, HRHI, pain rate, and anxiety rate were assessed (figure 5) and used as target variables for the multiple logistic regression analysis. We defined the good group as 1 and the poor group as 0, and these groups were the dependent variables. Then, each evaluation item was set as an independent variable, and the test was performed taking into

consideration the problem of multicollinearity between the variables.

The cutoff value was calculated using the receiver operating characteristic (ROC) curve of the extracted factors. In addition, the positive and negative predictive values were calculated based on the cutoff value.

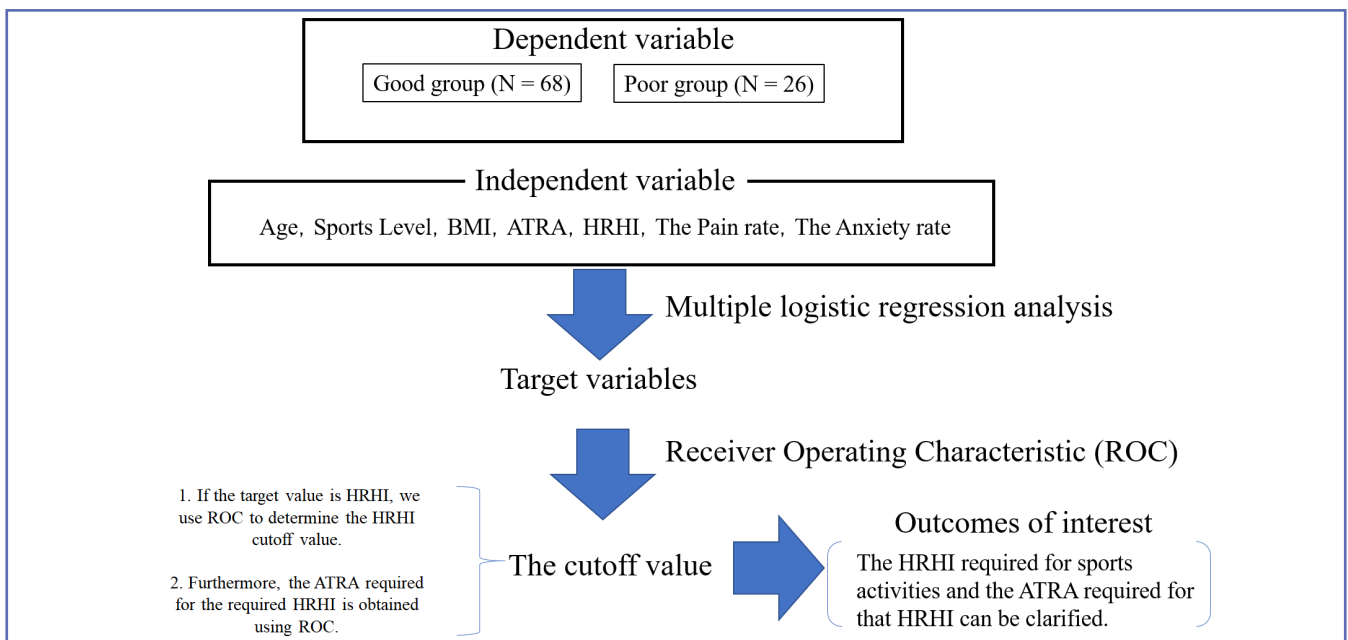


Figure 5. Study protocol flow chart (outcomes of interest).

When the HRHI was included in the factors extracted, the obtained points were classified into two groups: the first group satisfied the cutoff value of HRHI and the other group did not. The ATRA required for that HRHI was determined from the ROC curve.

For all the data analysis, SPSS version 25.0 for Windows (IBM Corp., Armonk, NY, USA) was used, and the significance level was set at < 5%.

RESULTS

Patient recruitment

Of the 342 patients who underwent surgery, those who were unable to follow up for 9 months (N = 127), were infected (N = 12), experienced a re-rupture (N = 5), did not engage in regular sports activities (N = 40), or did not participate in sports activities due to retirement or busyness (N = 40). Of the 118 patients who were able to re-engage in sports activities, 94 were the subjects of this study (figure 6). Table II shows the main sports.

Patient demographics

As regards to age, the subjects in the good group were 38.0 ± 11.6 years old and those in the poor group were 44.0 ± 11.5 years old (table III), and the difference was significant (table IV). A significant difference in the HRHI was found between the good group (95.9%; range, 60.0-105.0) and the poor group (82.6%; range, 60.9-100.0). The ATRA was 78.6 ± 16.2 in the good group and 67.3 ± 18.8 in the poor group, showing a significant difference.

Table II. Main sports events in the good group and poor group.

Good group	N
Soccer, Futsal	12
Badminton	11
Basketball	11
Tennis	6
Volleyball	4
Kendo	3
Martial arts	2
Baseball	1
Other	19

Poor group	N
Badminton	5
Soccer, Futsal	4
Basketball	4
Tennis	3
Baseball	1
Other	9

Movement starting time and achieved time

Full dorsal flexion was achieved at 12.0 (range, 6.0-24.0) weeks in the good group and at 10.0 (range, 6.0-25.0) weeks in the poor group (table IV), showing a significant difference in surgical outcomes and start time of returning to sports. Continuous HR was achieved at 4.0 (range, 2.3-6.5)

Table III. Patient demographic.

	Good group (N = 68)	Poor group (N = 26)	P value	Statics
Subjective recovery degree scores(point)	86.9 ± 6.4 85.0 (80.0-100)	62.7 ± 13.1 70.0 (22.0-80.0)	-	-
Sex	Male: 45 Female: 23	Male: 20 Female: 6	-	-
waiting period day)	5.0 (1.0-19.0)	6.0.(0.0-20.0)	0.882	U
Average Age (year)	38.0 ± 11.6	44.0 ± 11.5	< 0.025	T
Sports Level (N)	L1: 36 L2: 8 L3: 13 L4: 7 L5: 4	L1: 19 L2: 3 L3: 2 L4: 1 L5: 1	-	-
BMI	23.1 (18.6-29.4)	23.1 (18.0-30.8)	0.980	U
ATRA (%)	78.6 ± 16.2	67.3±18.8	< 0.005	T
HRHI (%)	95.9 (60.0-105.0)	82.6(60.9-100.0)	< 0.001	U
The Pain rate (%)	16.2	26.9	0.236	χ ²
The Anxiety rate (%)	58.8	61.5	0.810	χ ²
	Mean ± SD			
	Median (MIN-MAX)			

Table IV. Movement starting time and achieved time.

	Good group (N = 68)	Poor group (N = 26)	P value	Statics
Full Dorsal flexion ROM achieved (week)	12.0 (6.0-24.0)	10.0 (6.0-25.0)	< 0.036	U
Jogging start (week)	13.0 (9.0-20.0)	16.0 (10.0-25.0)	0.122	U
HRHI 50% achieved (week)	12.0 (4.0-20.0)	14.5 (9.0-25.0)	0.222	U
Continuous HR achieved (month)	4.0 (2.3-6.5)	4.5 (2.5-7.0)	< 0.000	U
Jumping Movement achieved (month)	5.0 (3.5-7.0)	6.0 (3.5-8.0)	< 0.001	U
Return to sports achieved (month)	5.5 (4.0-8.0)	6.5 (4.5-8.0)	< 0.001	U
	Median (MIN-MAX)			

months in the good group and at 4.5 (range, 2.5-7.0) months in the poor group, showing a significant difference. Jumping movement was achieved at 5.0 (range, 3.5-7.0) months in the good group and at 6.0 (range, 3.5-8.0) months in the poor group, showing a significant difference. Return to sports was achieved at 5.5 (range, 4.0-8.0) months in the good group and at 6.5 (range, 4.5-8.0) months in the poor group, and the difference was statistically significant. No significant difference was found in other items.

Outcomes of interest

Of the 94 subjects, 68 and 26 subjects belonged to the good and poor groups, respectively (**table V**). The extracted factor was only HRHI (odds ratio, 1.104, 95% confidence interval 1.051-1.160, discriminant intermediate rate, 73.4%). The cutoff HRHI value was 89.5% (sensitivity, 0.794; 1-specificity, 0.192; positive predictive value, 79.4%; negative predictive value, 80.8%; area under the curve (AUC), 78.6%). Other outcomes that were examined were not extracted. The cutoff ATRA value from the ROC curve based on this HRHI was 72.4% (sensitivity, 0.797; 1-specificity, 0.371; positive predictive value, 71.2%; negative predictive value, 68.6%; AUC, 74.6%).

DISCUSSION

It is important to know whether the subjects that returned to sports were able to carry out sports activities to a satisfac-

tory level and to clarify what kind of function was necessary. The biggest goal after surgery was the return to sports. The rate of return to sports after Achilles tendon repair in our hospital was 79.7%, which is considered to be as good as the return rate of 80% reported by Zellers *et al.* (23).

In this study, only the HRHI was extracted as a necessary factor for sufficient sports activities; it was not extracted as an influencing factor like age BMI, pain, and anxiety. The results of this study clearly present that an HRHI of approximately 90% is an indicator of good function at 9 months after surgery. Furthermore, the ATRA required for the HRHI was approximately 70% on the unaffected side. Single-leg HR is a method of evaluating the strength of the triceps surae muscle through the Achilles tendon, and HRHI evaluates functional recovery based on the laterality of the unaffected side (24). Therefore, single-leg HR was evaluated as an index of functional recovery after Achilles tendon repair. We have previously reported that acquisition of a single-leg HR and continuous HR are necessary for sports movement acquisition and, as a result, return to sports (4, 5). We also reported that a continuous single-leg HR is defined as more than half the capacity of the unaffected side, and acquiring this movement and the return to sports show a correlation ($r = 0.433$ $P < 0.001$) (5). However, it was necessary to clarify whether the maximum elevation of the single-leg HR should be the same as that of the unaffected side for sufficient functioning during sports activities. In addition, some studies have reported the relationship between the HRHI and ATRA, such as those by Zellers *et al.* (11), Silbernagel *et al.* (24), and Kangas *et al.* (25), Carmont

Table V. Multiple logistic regression analysis result (poor group and good group).

	B	Standard error	Wald	Degree of freedom	Significance	Odds rate	95% Confidence interval	
							minimum	maximum
HRHI	0.099	0.025	15.349	1	0.000	1.104	1.051	1.160

Poor group: 0, good group: 1; model χ^2 Test $p < 0.01$; Hosmer-Lemeshow Test $p = 0.080$; Discriminant intermediate rate: 73.4%.

MR *et al.* (26). However, it was unclear whether increased ATRA could lead to an increase in muscle strength.

In the rehabilitation course after Achilles tendon rupture repair, we actively prevent and remove adhesions around the Achilles tendon to “create an environment that does not inhibit the sliding of the Achilles tendon” (27). A study reported that exercise therapy from the early post-operative period had excellent mechanical effects on the ligaments and tendons and made adhesions less likely to occur (28, 29). The degree of adhesions around the Achilles tendon affects the patient’s subjective satisfaction level (30). However, adhesions around the Achilles tendon are inevitable after Achilles tendon rupture repair. Subsequent soft tissue, fat pad, and Kager’s fat pad hardening occur (31), and adhesions and loss of elasticity may be two factors that cause range of motion limitation and pain, which can interfere with tendon microcirculation and reduce tendon strength (32). The range of motion training in cases of adhesions may exert excessive stress on the tendon sutures and stretches the tendon.

Elongation of the Achilles tendon results from the weakness of the triceps surae muscle (7, 11, 12), which is reported to affect HRHI and performance. Brorsson *et al.* (33) compared two groups with single-leg HR-deficient rates on the unaffected side of $\geq 30\%$ and $< 15\%$ and reported that the group with $< 15\%$ had good clinical results. Carmont *et al.* (8), contrarily report that surgery needs to increase suture strength to eliminate the difference in ATRA. However, if the sutures are too strong, ATRA may be minimized, but range of motion is more likely to be restricted and more likely to cause pain. As a result, it lowers HRHI due to pain. Based on the results of this study, the flexion ATRA required to increase the HRHI to approximately 90% that enables sufficient sports activity is approximately 70%. Carmont *et al.* (8) reported that 12-month ATRS is 87%, HRHI is 82%, and ATRA is about -5° on the healthy side, concurring with the results of this study and are valid target values following Achilles tendon suture. To maintain this angle, good gliding of the Achilles tendon was ensured by preventing and removing adhesions above the tendon, paying attention to suturing to the plantar flexion angle during surgery. Based on the results of this study, it is important to aim for a dorsi-

flexion angle that does not differ between the left and right at 10-12 weeks following the surgery.

This study has some limitations. This study is not a quantitative assessment as it does not use a strength tester to assess strength. Therefore, the results here cannot be used to objectively assess the strength of the triceps surae. In addition, it is not possible to accurately evaluate the extension of the Achilles tendon because image evaluation by echo or MRI was not performed. Moreover, the presence and degree of adhesions and tendon gliding have not been accurately evaluated. In addition, the relationship with motor function is immature because no quantitative movement drill evaluation of steps and jumps was performed.

In this study, patients were classified into two groups by applying the Subjective Numerical Evaluation Scale (NRS). This method is an easy and effective way to quickly record the patient’s subjective activities opinion to be used the evaluation. However, in many studies, subjective evaluation after Achilles tendon surgery is often reported using ATRS, so we will discuss it with other papers by clarifying the relationship between this NRS evaluation and ATRS evaluation in the future. I think the consistency of can be made clearer Improving the follow-up rate and extending the long-term follow-up period of one to two years are additional future study aims. It is also necessary to clarify the relationship between the characteristics of each sport and physical characteristics-such as muscle strength evaluation, posture evaluation, and bone morphology evaluation of other joints-in other future studies.

CONCLUSIONS

After Achilles tendon rupture repair, the HRHI required for good sports activity was approximately 90% of the unaffected side and the ATRA required for the same HRHI was $> 70\%$. In addition to the resting angle, improving the gliding of the tendon perioperatively is necessary to prevent elongation of the Achilles tendon. Rehabilitation after Achilles tendon repair is essential for functional recovery.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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