

Original Article

Intra- and interobserver reliability of Achilles tendon resting angle: A simple and affordable clinical tool

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Abstract

Objective: To evaluate the intra- and interobserver reliability of the Achilles tendon resting angle (ARTA) measurement, using a standardized protocol.

Methods: Observational study with 50 volunteers (100 feet), evaluated by two independent observers. The ARTA was measured with an analog goniometer, with the patient prone and the knee flexed to 90°. Two measurements were performed by each evaluator, with a minimum interval of 10 minutes between them. Statistical analysis included Pearson's correlation coefficient and intraclass correlation coefficient (ICC).

Results: Mean ARTA was 39.64° (± 7.18), with a significant difference between the sexes ($p = 0.0004$), lower in men and equivalent between the right and left sides. Intraobserver reliability was excellent, with ICCs of 0.980 for evaluator A and 0.971 for evaluator B. Interobserver reliability was also excellent, with an ICC of 0.934 in the first measure and 0.936 in the second measure.

Conclusion: Clinical Achilles tendon resting angle measurement with an analog goniometer showed excellent intra- and interobserver reliability, making it a simple, accessible, and reproducible method.

Level of Evidence III; Retrospective Case Series.

Keywords: Achilles tendon; Reference values; Reproducibility of tests.

Introduction

Achilles tendon rupture (ATR) is a prevalent injury, especially in adults, with a significant impact on gait function, plantar flexion force, and quality of life⁽¹⁾. Despite advances in treatment, whether surgical or conservative, tendon stretching during healing is a common complication that can compromise long-term functional outcomes^(2,3).

Evaluating Achilles tendon length seems fundamental for treatment and postoperative clinical monitoring⁽⁴⁾. Imaging methods such as ultrasound (US) are considered the reference for this evaluation⁽⁵⁾. In this context, Achilles tendon resting angle (ARTA) has gained prominence as an alternative^(4,5). This angle is defined as the angle formed between the longitudinal

axis of the fibula and a line extending from the apex of the lateral malleolus to the head of the fifth metatarsal, with the patient prone and the knee flexed at 90°, reflecting residual tension in the musculotendinous complex⁽⁴⁾. It is a practical, affordable, low-cost measure that allows indirect inference about tendon length. In addition, it can be performed before, during, and after surgery, making it potentially useful at different stages of treatment⁽⁶⁾.

Recent studies have shown correlations between ARTA and tendon stretching measured by US, as well as with functional variables: Total Achilles tendon rupture score and muscle endurance tests, such as the heel-rise test^(5,6). Some authors have documented good reproducibility of this parameter in clinical practice, with ICCs between 0.91 and 0.92⁽⁴⁾.

Study performed at the Department of Foot and Ankle, Hospital Pompéia, Caxias do Sul, RS, Brazil.

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Despite the increasing use of ATRA as a clinical tool, few studies have systematically evaluated its intra- and interobserver reliability—a crucial factor in ensuring its usefulness^(4,5). In this scenario, the study aimed to evaluate the intra- and interobserver reliability of ATRA measurement in individuals with no history of musculoskeletal disease or dysfunction in the lower limbs and to describe normative values by sex and side evaluated.

Methods

This study was conducted in the Department of Orthopedics and Traumatology at our institution, with approval from the Institutional Review Board. All participants signed the Informed Consent Form (ICF) before inclusion in the study.

The sample consisted of 50 individuals consecutively recruited from the institution's outpatient population. Inclusion criteria were age ≤ 18 years and no pain or current lower-limb dysfunction. Individuals with joint changes in the hip or knee, restricted foot movement, amputations, or a history of lower-limb pathologies were excluded. The sample size was calculated using the method proposed by Walter et al.⁽⁷⁾, assuming a minimum acceptable ICC (ρ_o) of 0.80 and an expected ICC (ρ_e) of 0.90, a significance level of 5%, 80% power, and two evaluations per individual. The expected ICC was based on a previous study by Carmont et al.⁽⁴⁾, which reported values greater than 0.90 for ATRA measurement in healthy individuals. Using these parameters, a minimum sample size of 46 individuals was estimated. Fifty participants were included in the present study.

Two medical students, previously trained in the protocol, performed the ATRA measurement with an analog goniometer as independent evaluators and were blinded to each other. The patient was positioned prone, with the hip in neutral and the knee flexed at 90°. The goniometer axis was positioned over the apex of the fibula. The proximal arm was aligned to the longitudinal axis of the fibula, oriented toward its head, while the distal arm was oriented to the center of the head of the fifth metatarsal (Figure 1). Each observer took bilateral measurements at least 10 minutes apart to reduce memory bias.

Data were organized in a spreadsheet (Microsoft Excel[®]) and analyzed with IBM SPSS Statistics for Windows[®] software, version 20.0. Descriptive statistical analysis included means, standard deviations, medians, and interquartile ranges for quantitative variables.

The normality of continuous variables was evaluated using the Shapiro-Wilk test and the homogeneity of variances using the Levene test. To compare ATRA between the sexes, Student's t-test was used for independent samples, while the right and left sides were compared using Student's t-test for paired samples. Intraobserver reliability was assessed by ICC using a two-way mixed-effects model, single measure, and absolute agreement [ICC (A,1)]. For interobserver reliability, a two-way random-effects model, single measure, and absolute agreement [ICC (2,1)] was used. ICC values were presented

with their respective 95% confidence intervals. In addition, Pearson's correlation coefficients were calculated between repeated measures and between evaluators. The standard error of measurement (SEM) was calculated using the formula $SEM = SD \times \sqrt{1 - ICC}$, using the combined standard deviation of the compared measurements. The significance level was set at 5% ($p < 0.05$).

Results

Of the 50 individuals evaluated, 24 (48%) were male, and 26 (52%) were female, with a median age of 25 years (IQR: 21–41.5; total range: 20–64 years). Among the participants, 30% reported being smokers, and 2% were diabetic. Descriptive data on weight, height, and body mass index (BMI) are shown in Table 1.

The overall mean ATRA was 39.64° (± 7.18). A statistically significant difference was observed between the sexes, with a mean of 36.11° (± 7.06) in men and 42.90° (± 5.25) in women (Student's t-test = 3.83; $p = 0.0004$). No significant difference was observed between the right and left sides (39.53° ± 7.27 vs. 39.76° ± 6.92 , respectively; $t(49) = -0.762$;



Figure 1. Achilles tendon resting angle measurement with the goniometer positioned on the apex of the fibula, aligned with the longitudinal axis of the fibula to the center of the head of the fifth metatarsal.

$p = 0.449$). Measurement means were similar between evaluators. Evaluator A had a mean of $40.00^\circ (\pm 7.35)$ in the first measurement and $40.23^\circ (\pm 7.18)$ in the second; evaluator B, $39.10^\circ (\pm 7.33)$ and $39.25^\circ (\pm 6.89)$, respectively.

Intraobserver reliability

Intraobserver reliability was excellent for both raters. For evaluator A, an ICC of 0.980 (95% CI: 0.971-0.987) and a Pearson's correlation coefficient of 0.981 ($p < 0.001$) were observed. For evaluator B, the ICC was 0.971 (95% CI: 0.957-0.980), with a Pearson's correlation coefficient of 0.972 ($p < 0.001$) (Table 2).

Interobserver reliability

Interobserver reliability was also excellent. In the first measurement, the ICC was 0.934 (95% CI: 0.893-0.958), with a Pearson's correlation coefficient of 0.941 ($p < 0.001$). In the second measure, the ICC was 0.936 (95% CI: 0.888-0.961), with a Pearson's correlation coefficient of 0.945 ($p < 0.001$) (Table 3).

Table 1. Descriptive data

Sex	Male	24 (48%)
	Female	26 (52%)
Age		25 (IQR: 21-41.5)
Weight		68.5kg (IQR: 63-83)
Height*		1.69 m (± 0.11)
BMI		24.86 (IQR: 22.3-26.8)
Smoke	Yes	15 (30%)
	No	35 (70%)
Diabetes	Yes	1 (2%)
	No	49 (98%)

*Mean and standard deviation. Other numerical variables did not present a normal distribution; therefore, they are described with the median and interquartile range. BMI: Body mass index; IQR: Interquartile range.

Discussion

The main finding of this study was the high intra- and interobserver reliability of the clinical ATRA measurement using an analog goniometer and standardized measurements. ICC values ranged from 0.971 to 0.980 in intraobserver analyses and from 0.934 to 0.936 in interobserver analyses, demonstrating excellent measurement reliability^(8,9,10). These results reinforce ATRA reproducibility and support its potential as a simple, accessible clinical tool for indirect assessment of the Achilles musculotendinous complex.

The results found are consistent with those previously described by Carmont et al.⁽⁴⁾ who demonstrated high reliability of ATRA measurement in healthy individuals, with ICC values of 0.92 for the left limb and 0.91 for the right limb. In the present study, ICC values were similarly high, ranging from 0.934 to 0.980 in both intra- and interobserver analyses. In addition, the use of two independent evaluators and bilaterally repeated measures allowed to evaluate the reproducibility of the method under different measurement conditions. These findings provide additional support for the use of ATRA as a reliable and easy-to-apply clinical measure.

The clinical relevance of ATRA goes beyond its reproducibility. Previous studies have shown an association between ATRA, Achilles tendon length, and functional parameters after rupture, including performance in the heel-rise test^(1,5,6). Thus, measuring ATRA can provide an indirect clinical estimate of changes in the length of the musculotendinous complex during follow-up. However, ATRA should not be interpreted as a direct measurement of tendon length. Larsson et al.⁽⁵⁾ showed that although it can identify deficits after Achilles tendon rupture, ATRA does not replace direct methods for evaluating tendon stretching, such as US. Thus, its main applicability seems to be as a complementary, simple, and accessible clinical tool, especially when imaging assessments are unavailable or not feasible.

In the studied population, the mean ATRA was $39.64^\circ (\pm 7.18)$, close to values previously described in healthy individuals. The sexes differed significantly, with higher values in females

Table 2. Intraobserver reliability

Rater	1st measurement (mean $\pm$ SD)	2nd measurement (mean $\pm$ SD)	Pearson (r)	ICC (model)	95%CI	SEM (")	Interpretation
A	40.00 $\pm$ 7.35	40.23 $\pm$ 7.18	0.98	0.98 - ICC (A,1)	0.97 - 0.98	1.03	Excellent
B	39.10 $\pm$ 7.33	39.25 $\pm$ 6.89	0.97	0.97 - ICC (A,1)	0.95 - 0.98	1.21	Excellent

ICC (A,1): Two-way mixed effects model, single measure, absolute agreement. SEM: Standard error of measurement; SD: Standard deviation; CI: Confidence interval.

Table 3. Interobserver reliability

Measurement	Evaluator A (mean $\pm$ SD)	Evaluator B (mean $\pm$ SD)	Pearson (r)	ICC (model)	95%CI	SEM (")	Interpretation
1st	40.00 $\pm$ 7.35	39.10 $\pm$ 7.33	0.94	0.93 - ICC (2,1)	0.89 - 0.95	1.89	Excellent
2nd	40.23 $\pm$ 7.18	39.25 $\pm$ 6.89	0.94	0.93 - ICC (2,1)	0.88 - 0.96	1.78	Excellent

ICC (2,1): Two-way random effects model, single measure, absolute agreement. SEM: Standard error of measurement; SD: Standard deviation; CI: Confidence interval.

($42.90^{\circ} \pm 5.25$) than in males ($36.11^{\circ} \pm 7.06$). Although anatomical and biomechanical differences between the sexes may contribute to this finding, its clinical significance remains uncertain and warrants investigation in specific studies. In contrast, no significant difference was observed between the right and left sides, reinforcing the possibility of using the contralateral limb as an individual reference in the ATRA evaluation.

The high reproducibility observed also supports the potential of ATRA for use at different times in the treatment of Achilles tendon rupture. In the preoperative period, measuring the contralateral limb can provide an individual reference for the resting position of the musculotendinous complex. During surgical repair, comparing the limbs can help evaluate the tension conferred to the reconstructed tendon, a relevant consideration given the association between tendon stretching and functional deficits after rupture. In this context, objective intraoperative evaluation methods have been proposed to reduce the variability inherent in subjective estimation of tension and tendon length⁽¹⁾. However, the ATRA's ability to guide intraoperative adjustments and influence functional outcomes still needs prospective investigation in patients with acute Achilles tendon rupture.

This study has several limitations. The sample included individuals with no history of musculoskeletal disease or lower limb dysfunction, excluding patients with Achilles tendon rupture, who represent the population of greatest interest for the clinical ATRA application. Metabolic and systemic diseases were not specific exclusion criteria, which should be considered when interpreting the results. In addition, imaging methods such as US were not used to directly evaluate tendon length, and those results do not allow us to establish

ATRA as a valid indirect measure of this parameter. Finally, bilateral inclusion implies potential dependence between observations from the same participant, which should be considered when interpreting the results.

The main contribution of this study is to demonstrate, through standardized measures, the high intra- and inter-observer reliability of the clinical ATRA measurement. The technique's simplicity, along with its use of a widely available, low-cost instrument, supports its applicability in clinical practice. Future studies should evaluate its reliability in patients with acute Achilles tendon rupture and prospectively investigate its relationship with tendon stretching, functional parameters, and imaging methods, as well as its potential role in the intraoperative evaluation of tendon tension and length during surgical repair.

Conclusion

Clinical ATRA measurement using an analog goniometer demonstrated excellent intra- and interobserver reliability. As a simple, accessible, and low-cost method, ATRA has potential as a reproducible clinical tool for Achilles tendon evaluation.

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