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Operative versus Nonoperative Treatment of Acute Achilles Tendon Ruptures

A Multicenter Randomized Trial Using Accelerated Functional Rehabilitation

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Background: To date, studies directly comparing the rerupture rate in patients with an Achilles tendon rupture who are treated with surgical repair with the rate in patients treated nonoperatively have been inconclusive but the pooled relative risk of rerupture favored surgical repair. In all but one study, the limb was immobilized for six to eight weeks. Published studies of animals and humans have shown a benefit of early functional stimulus to healing tendons. The purpose of the present study was to compare the outcomes of patients with an acute Achilles tendon rupture treated with operative repair and accelerated functional rehabilitation with the outcomes of similar patients treated with accelerated functional rehabilitation alone.

Methods: Patients were randomized to operative or nonoperative treatment for acute Achilles tendon rupture. All patients underwent an accelerated rehabilitation protocol that featured early weight-bearing and early range of motion. The primary outcome was the rerupture rate as demonstrated by a positive Thompson squeeze test, the presence of a palpable gap, and loss of plantar flexion strength. Secondary outcomes included isokinetic strength, the Leppilahti score, range of motion, and calf circumference measured at three, six, twelve, and twenty-four months after injury.

Results: A total of 144 patients (seventy-two treated operatively and seventy-two treated nonoperatively) were randomized. There were 118 males and twenty-six females, and the mean age (and standard deviation) was 40.4 ± 8.8 years. Rerupture occurred in two patients in the operative group and in three patients in the nonoperative group. There was no clinically important difference between groups with regard to strength, range of motion, calf circumference, or Leppilahti score. There were thirteen complications in the operative group and six in the nonoperative group, with the main difference being the greater number of soft-tissue-related complications in the operative group.

Conclusions: This study supports accelerated functional rehabilitation and nonoperative treatment for acute Achilles tendon ruptures. All measured outcomes of nonoperative treatment were acceptable and were clinically similar to those for operative treatment. In addition, this study suggests that the application of an accelerated-rehabilitation nonoperative protocol avoids serious complications related to surgical management.

Level of Evidence: Level I. See Instructions to Authors for a complete description of levels of evidence.

Rupture of the Achilles tendon is one of the most common tendon injuries in the adult population. The incidence of this injury is increasing as aging adults

continue their participation in high-demand sports¹⁻³. Although the impact of an Achilles tendon rupture is substantial, often resulting in prolonged disability and rehabilitation,

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the treatment of acute Achilles tendon ruptures remains controversial.

To date, studies directly comparing the rerupture rate in patients with an Achilles tendon rupture who are treated with surgical repair with the rerupture rate with nonoperative treatment have been inconclusive⁴⁻¹¹. In 2002, in a systematic review and meta-analysis, Bhandari et al.¹² pooled the results of 448 patients randomized to either operative or nonoperative treatment following Achilles tendon rupture and reported a relative risk of rerupture of 0.32 (95% confidence interval [CI], 0.14 to 0.71) in favor of surgical repair.

In all but one study that was included in the review by Bhandari et al.¹², patients wore a cast for six to eight weeks. Published studies of animals and humans, however, have demonstrated spontaneous healing of tendons without immobilization¹³⁻²⁴. Furthermore, there are several reports of the benefit of functional stimulus to healing tendons^{8,18,25-28}. In studies specific to the Achilles tendon, early weight-bearing with protected range of motion has been shown to achieve favorable outcomes in terms of range of motion, strength, and return to activities^{13,14,16,17,21,29} while minimizing the possibility of healing in a lengthened position or of rerupture^{14,23,24}.

To date, there have been two small randomized trials comparing the outcomes of patients with acute Achilles tendon rupture who were treated operatively with the outcomes of those treated nonoperatively in which early weight-bearing and mobilization was the focus of rehabilitation in both groups^{8,11}. In the first study, reported in 1995 by Thermann and colleagues⁸ and involving fifty patients, functional exercises (walking, isometrics, and stationary cycling) began two to three days after injury, followed by range-of-motion exercises at six weeks, strengthening at eight weeks, and running and jumping by twelve weeks. In the second study, reported in 2008 by Metz et al.^{11,30}, in which eighty-three patients were randomized to conservative treatment or minimally invasive surgical repair, patients wore a cast for seven days with no weight-bearing and then wore a functional brace with weight-bearing as tolerated; sports were permitted at twelve weeks. In both studies, there was no significant difference between groups with regard to the rerupture rate. There was also no significant difference between

groups with regard to range of motion, strength, calf circumference, or functional assessment^{8,11}.

The purpose of the current study was to compare the outcomes of patients with acute Achilles tendon ruptures who had been treated with operative repair and accelerated functional rehabilitation with the outcomes of similar patients who had been treated with accelerated functional rehabilitation alone.

Materials and Methods

This randomized controlled trial with a minimum two-year follow-up was conducted at two Canadian centers, the Fowler Kennedy Sport Medicine Clinic in London, Ontario, and the University of Calgary Sport Medicine Centre in Calgary, Alberta. Eligibility criteria are provided in Table I. To be eligible for participation, individuals had to meet all of the eligibility criteria. The study protocol was approved by the Human Research Ethics Board at both institutions.

As part of the recruitment process, all patients were informed of the current literature concerning the treatment of Achilles tendon injuries and were asked to read the information letter outlining the details of study participation and issues regarding randomization to operative or nonoperative treatment. Randomization was computer-generated and stratified by surgeon. Group allocation was revealed to patients only after the surgeon determined patient eligibility and the patient signed the consent document. With the exception of the presence or absence of surgical repair, all patients in this study underwent identical treatment.

Operative Treatment

Surgical treatment included a vertical posteromedial incision that was extended directly to the level of the paratenon. Care was taken to avoid damage to the soft-tissue envelope by utilizing only gentle traction of the skin edges for exposure. Two number-2 nonabsorbable sutures were placed across the tear in a Krackow-type stitch pattern, with the foot placed in plantar flexion to appose the tear ends. The contralateral extremity was used as a guide for the restoration of proper tendon length. Additional absorbable sutures were placed at the tear site to reappose any remaining tendon ends as needed. The paratenon was carefully repaired with nonabsorbable sutures. Interrupted

TABLE I Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
Complete primary Achilles tendon rupture demonstrated by a positive Thompson squeeze test and the presence of a palpable gap	Additional ipsilateral injury
Presenting within 14 days after injury	Open injury
Between 18 and 70 years of age	Fluoroquinolone-associated rupture (i.e., rupture within 2 weeks after taking this medication)
Willing and able to comply with and carry out the prescribed rehabilitation protocol	Insulin-dependent diabetes
Providing informed consent	Achilles avulsion from the calcaneus
Able to speak English	Surgical contraindications
	Neurological or vascular disease requiring medications recognized to impair tendon healing

Prolene sutures (Ethicon, Somerville, New Jersey) were placed in the skin layer to ensure meticulous closure. A posterior back slab splint was then applied with the foot in approximately 20° of plantar flexion.

Two weeks after surgery, a wound check was performed, the posterior back slab was removed, and the accelerated functional rehabilitation program commenced. Skin sutures were removed when complete skin healing was apparent.

Accelerated Functional Rehabilitation Program

All patients received a removable below-the-knee orthosis (pneumatic walking brace; Aircast, Summit, New Jersey) with a 2-cm heel lift to provide approximately 20° of plantar flexion. The rehabilitation program is outlined in the Appendix. Modalities to reduce pain and swelling were initiated during physiotherapy.

Outcome Measures

The primary outcome was the rerupture rate. Rerupture was diagnosed by the investigating surgeon on the basis of a positive Thompson squeeze test³¹, the presence of a palpable gap³², and loss of plantar flexion strength.

Secondary outcomes included isokinetic strength, the Leppilahti score³³, ankle range of motion, and calf circumference. The isokinetic plantar flexion strength and dorsiflexion strength of both limbs were assessed with use of a Biodex Multi-Joint System 3 dynamometer (Biodex Medical, Shirley, New York). Participants lay supine on the dynamometer with the knee supported and secured in approximately 20° of flexion. The lateral malleolus was aligned with the axis of rotation of the dynamometer, and the foot was fixed to the dynamometer footplate with use of two Velcro straps. In order to familiarize them with the protocol, the participants first performed submaximal contractions at each test velocity. They then performed five reciprocal concentric isokinetic contractions of plantar flexion and dorsiflexion with maximum effort at 30°/s and 60°/s, and ten reciprocal concentric isokinetic contractions at 240°/s, with a one-minute rest period between test velocities. Finally, testing was repeated for the contralateral limb.

Peak plantar flexion and dorsiflexion torques (in Nm) at each velocity were calculated by averaging the peak torque values of the individual contractions. To calculate a score for the Leppilahti scale, we calculated the percent difference between the injured and the noninjured limb for plantar flexion and for dorsiflexion at each velocity and assigned points according to scoring instructions for the Leppilahti scale³³.

The Leppilahti score³³ is a disease-specific functional outcome measure that includes patient ratings of pain, stiffness, calf muscle weakness, footwear restrictions, range of motion, and satisfaction as well as objective measures of strength to arrive at an overall score. A score of 100 represents the best possible score, and a score of 0 represents the worst possible score.

Range of motion was measured with use of a standard goniometer. Plantar flexion of the ankle was measured with the patient in the supine sitting position with the knee flexed to 30° and the gastrocnemius relaxed. The axis arm of the goniometer

was placed just inferior to the lateral malleolus and the stabilizing arm was placed parallel to the long axis of the fibula. The movable arm was positioned on the lateral border of the foot. Beginning at the neutral position (goniometer reading, 90°), the ankle was plantar flexed to its limit.

Calf circumference was measured with the patient seated with the knee flexed 90° and hanging over the edge of the table, with the gastrocnemius relaxed. A standard tape measure was used to measure calf circumference (in cm) at a position 15 cm distal to the inferior pole of the patella.

The presence or absence of rerupture, the Leppilahti score, range of motion, and calf circumference were measured at three, six, twelve, and twenty-four months after injury. Isokinetic strength was measured at twelve and twenty-four months. All complications including rerupture, superficial and deep infection, venous thrombosis, pulmonary embolus, and numbness were assessed at all follow-up visits.

Statistical Analysis

A meta-analysis showed the rate of rerupture to be approximately 2.5% following operative repair of an Achilles tendon rupture and 13% following nonoperative treatment³⁴. Thus, seventy-seven patients per group would be required to detect a difference of 11% in the rerupture rate (one-sided type-I error rate = 5%; power = 80%).

Independent-group t tests were used to make between-group comparisons, in which the independent variable was the treatment group and the dependent variable was the continuous outcome measure (i.e., strength, Leppilahti score, ankle range of motion, or calf circumference) at either one or two years after treatment. A p value of 0.05 was considered significant. An identical analysis was also performed with use of a nonparametric test (the Mann-Whitney U test), which gave similar results. Therefore, outcome data for each group are presented as the mean and standard deviation, and the mean difference between groups and the 95% confidence interval (CI) are provided.

Patients who withdrew from the study because they had moved or were unhappy with their group assignment, or who had been lost to follow-up, were excluded from the analysis as there were no data to carry forward or impute. It was believed that patients who had moved represented data that were missing completely at random and therefore would not threaten the validity of the estimate of the treatment effect. Those patients who withdrew because they were unhappy with their group assignment represented a small proportion of the patients in each group and were balanced between groups, and therefore also unlikely to influence the validity of the results. The seven patients who were lost to follow-up were also evenly distributed between groups and thus assumed to be randomly distributed.

Source of Funding

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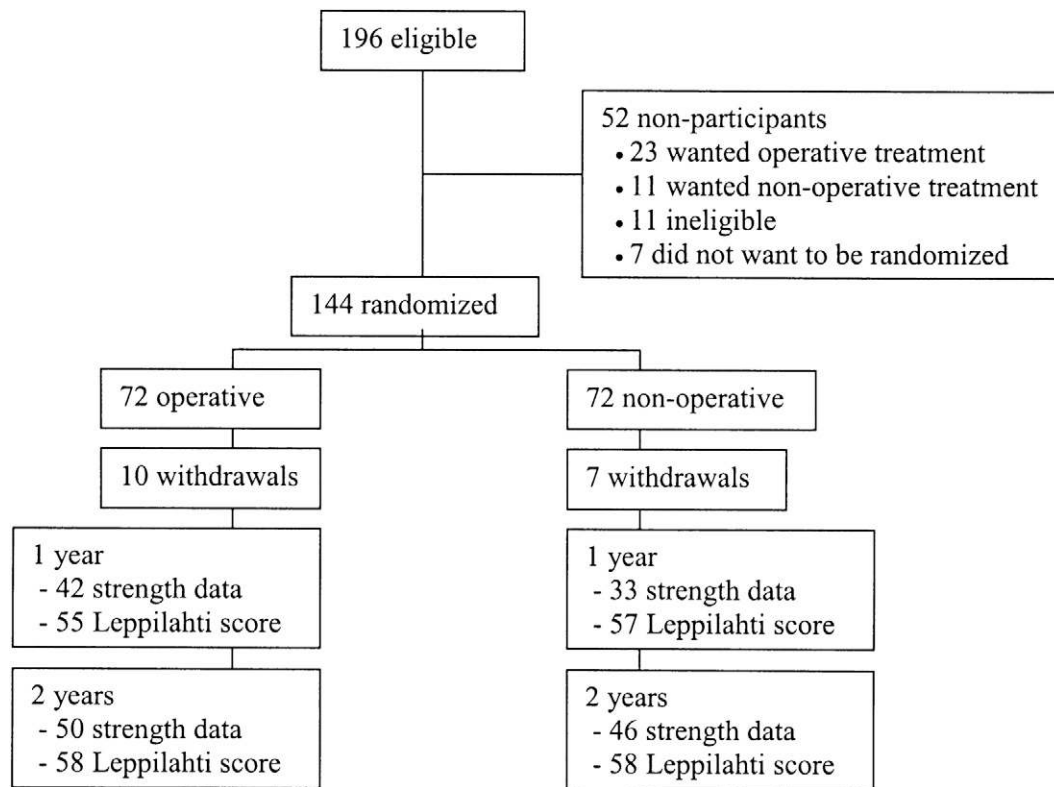


Fig. 1
Flow diagram for the study.

Results

Between 2000 and 2005, a total of 196 patients presented to the two study centers and were diagnosed with an Achilles tendon rupture. Fifty-two of these patients did not participate in the study (twenty-three patients elected to undergo surgical treatment, eleven elected to undergo nonsurgical treatment, seven were not comfortable with the randomization process, and eleven were ineligible). One hundred and forty-four patients gave their consent and were randomized; seventy-two patients were allocated to the operative group and seventy-two, to the nonoperative group (Fig. 1). There were 118 males and twenty-six females. The mean age (and standard deviation) was 40.4 ± 8.8 years, with a range of 22.5 to 67.2 years (Table II). The majority of primary ruptures were sustained during recreational sporting activities, and a small proportion occurred during activities of daily living (see Appendix).

Seventeen patients, ten in the operative group and seven in the nonoperative group, discontinued participation in the study. Of these, seven moved to areas where distance made attendance at follow-up visits difficult, three (two in the nonoperative group and one in the operative group) were unhappy with their group allocation, and the remaining seven patients were lost to follow-up.

Rerupture

Rerupture occurred in two patients in the operative group at one and three months after injury and in three patients in the nonoperative group at one, two, and three months after injury. Four of the patients

who experienced a rerupture were treated with surgical repair; one of these patients subsequently developed a deep wound infection requiring a prolonged course of antibiotic therapy and repeated debridements, and the remaining three patients had healing with no additional complications. One patient who experienced a rerupture was treated nonoperatively at her own request, and the rerupture went on to heal with no additional complications.

One Year Post-Injury

On average, at all three test velocities (30°/s, 60°/s, and 240°/s), the affected limb in both groups was able to achieve at least 80%

TABLE II Demographics

Characteristics	Operative (N = 72)	Nonoperative (N = 72)
Males:females	59:13	59:13
Mean age* (yr)	39.7 ± 11.0	41.1 ± 8.0
Height* (cm)	177.8 ± 13.6	177.3 ± 10.3
Weight* (kg)	88.4 ± 14.2	88.2 ± 17.6
Activity at injury† (no. of patients)	ADL 6, sports 64	ADL 15, sports 59

*Data are given as the mean and standard deviation. †ADL = activities of daily living.

of the plantar flexion strength and 100% of the dorsiflexion strength of the unaffected limb. There was a small but significant difference in the plantar flexion strength ratio (affected to unaffected limb) at 240°/s at one year (mean difference, 20.25%; 95% CI, 0.07% to 40.4%; $p = 0.05$) in favor of the operative group. This difference could not be explained by differences between groups related to the unaffected limb (Figs. 2-A and 2-B).

There was no significant difference between groups in the dorsiflexion strength ratio at any test velocity.

The mean range of dorsiflexion (and standard deviation) was $16.4^\circ \pm 6.5^\circ$ in the operative group and $17.2^\circ \pm 7.8^\circ$ in the nonoperative group. The mean range of plantar flexion was $44.4^\circ \pm 9.3^\circ$ in the operative group and $45.1^\circ \pm 9.2^\circ$ in the nonoperative group. The unaffected side in both groups

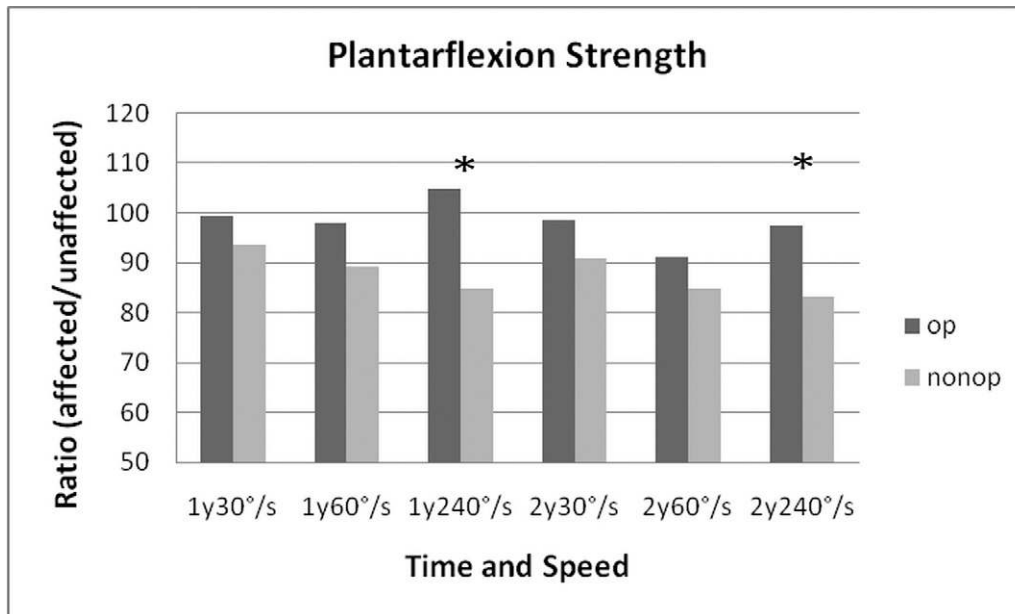


Fig. 2-A

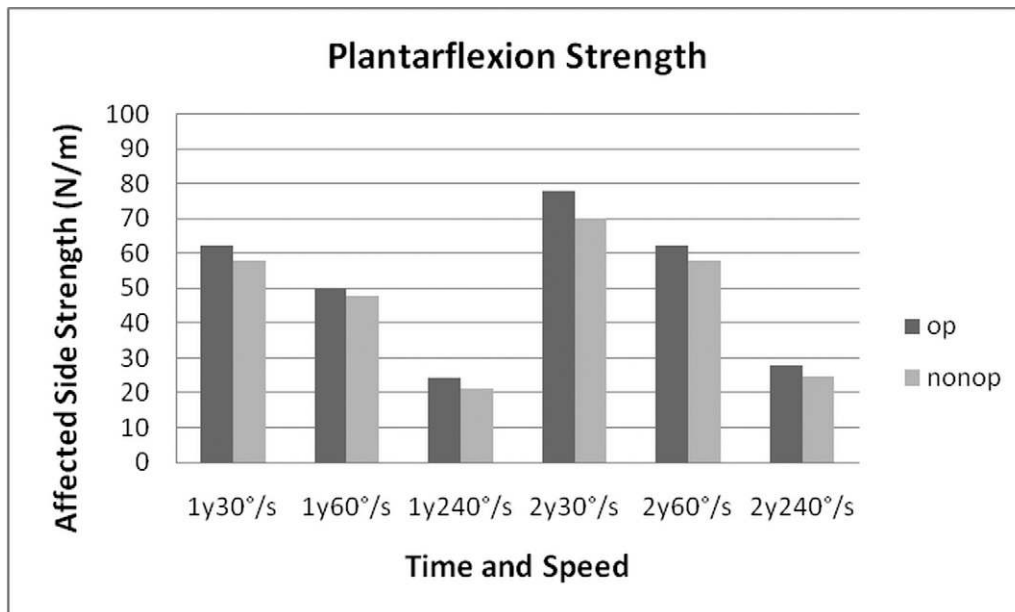


Fig. 2-B

Fig. 2-A Bar graph showing the ratio of plantar flexion strength of the affected limb to that of the unaffected limb at one year and two years at each of the three test velocities. An asterisk denotes a significant difference ($p \leq 0.05$) between the operative and the nonoperative group. **Fig. 2-B** Bar graph showing the plantar flexion strength of the affected limb in the operative and the nonoperative group at one year and two years at each of the three test velocities.

maintained a greater range of motion than the affected side at each of the study follow-up visits. The two groups did not differ significantly with respect to the side-to-side difference in either plantar flexion or dorsiflexion.

At one year, the mean side-to-side difference in calf circumference was -1.3 ± 1.4 cm in the operative group and -1.3 ± 4.4 cm in the nonoperative group; the difference between groups was not significant (mean difference, 0.0 cm; 95% CI, -1.2 to 1.2 cm; $p = 0.99$). The mean Leppilahti score was 78.5 ± 10.9 points in the operative group and 76.3 ± 15.8 points in the nonoperative group; this difference was also not significant (mean difference, -2.2 points; 95% CI, -9.1 to 4.7 points; $p = 0.53$).

Two Years Post-Injury

On average, at all three test velocities, the affected limb in both groups was able to achieve at least 80% of the plantar flexion strength and 100% of the dorsiflexion strength of the unaffected limb. There was a small but significant difference in the plantar flexion strength ratio (affected to unaffected limb) at $240^\circ/s$ at two years (mean difference, 14.15%; 95% CI, 1.12% to 27.19%; $p = 0.03$) in favor of the operative group, which could not be explained by differences between groups with regard to the unaffected limb (Figs. 2-A and 2-B). There was no significant difference between groups in the dorsiflexion strength ratio at any test velocity. There was no significant change in strength at any test velocity in either group between the one-year and the two-year time point.

The mean range of dorsiflexion was $20.3^\circ \pm 12.6^\circ$ in the operative group and $17.9^\circ \pm 6.0^\circ$ in the nonoperative group. The mean range of plantar flexion was $44.5^\circ \pm 8.4^\circ$ in the operative group and $46.8^\circ \pm 8.5^\circ$ in the nonoperative group. The unaffected side in both groups maintained a greater range of motion than the affected side at each of the study follow-up visits. The side-to-side difference in plantar flexion range of motion was greater in the nonoperative group than in the operative group (mean difference between groups, -2.21° ; 95% CI,

-3.9° to -0.5° ; $p = 0.01$). There was no significant difference between groups with regard to dorsiflexion.

At two years, the mean side-to-side difference in calf circumference was -1.7 ± 2.0 cm in the operative group and -1.5 ± 5.6 cm in the nonoperative group; these values were not significantly different (mean difference between groups, -0.2 cm; 95% CI, -1.8 to 1.3 cm; $p = 0.75$). The mean Leppilahti score was 82.6 ± 11.1 points in the operative group and 82.2 ± 12.3 points in the nonoperative group; these values were not significantly different (mean difference, -0.4 point; 95% CI, -5.4 to 5.0 points; $p = 0.89$).

There were thirteen complications (18%) in the operative group and six (8%) in the nonoperative group, with the primary difference being in the greater number of soft-tissue-related complications in the operative group (Table III).

Discussion

In this study, in which both groups participated in accelerated functional rehabilitation, we found no clinically important differences between operative and nonoperative treatment for any of the measured parameters. There was a significant difference in plantar flexion strength at the $240^\circ/s$ test velocity at one year and at two years, but these differences were small and their clinical importance remains uncertain, especially given the lack of significant differences in plantar flexion strength at $30^\circ/s$ and $60^\circ/s$ and in any other outcome. We found no difference in the rate of rerupture, a finding that is similar to that in other trials in which the authors recommended early mobilization^{8,11} but that differs from the rerupture rates reported in studies in which immobilization was the primary rehabilitation approach^{5,7,10,35,36} (Figs. 3-A and 3-B).

In particular, the rehabilitation plan for patients who participated in the study conducted by Thermann et al.⁸ was the most aggressive of all studies including ours, with full weight-bearing permitted three to five days after injury in the nonoperative group and eight to ten days postoperatively in the surgically treated group. Patients in both groups wore a functional boot for eight weeks. In the study by Metz et al.¹¹, full weight-bearing was permitted at one week after initial injury in the nonoperatively treated group and one week after operative repair in the surgically treated group. Patients in the nonoperative group wore a functional brace for six weeks, and patients in the operative group wore a tape bandage for six weeks. Our protocol permitted protected weight-bearing at two weeks that progressed to weight-bearing as tolerated at four weeks. Patients wore a functional boot for eight weeks.

Early range of motion and controlled loading of healing tendons has been shown to result in improved healing and outcomes in animal models and some human studies^{14,15,17,21-25,29}. For example, in 2003 Maffulli et al.²⁹ randomized fifty-six patients who had undergone surgical Achilles tendon repair to either casting with immediate weight-bearing or casting with no weight-bearing for the first four weeks postoperatively. For both groups, mobilization began at six weeks after surgery. Patients in the early weight-bearing group used less physiotherapy, and discontinued use of crutches an average of 2.5 weeks earlier. In addition, ul-

TABLE III Complications

Complication	Operative Group	Nonoperative Group
Rerupture	2	3
Deep venous thrombosis	1	1
Pain (substantial)		1
Failure to heal (palpable gap)		1
Achilles tendon tethered to skin	1	
Hypertrophic scar	1	
Superficial infection	4	
Deep infection	1	
Pulmonary embolus	1	
Wound complication (small opening in skin)	2	

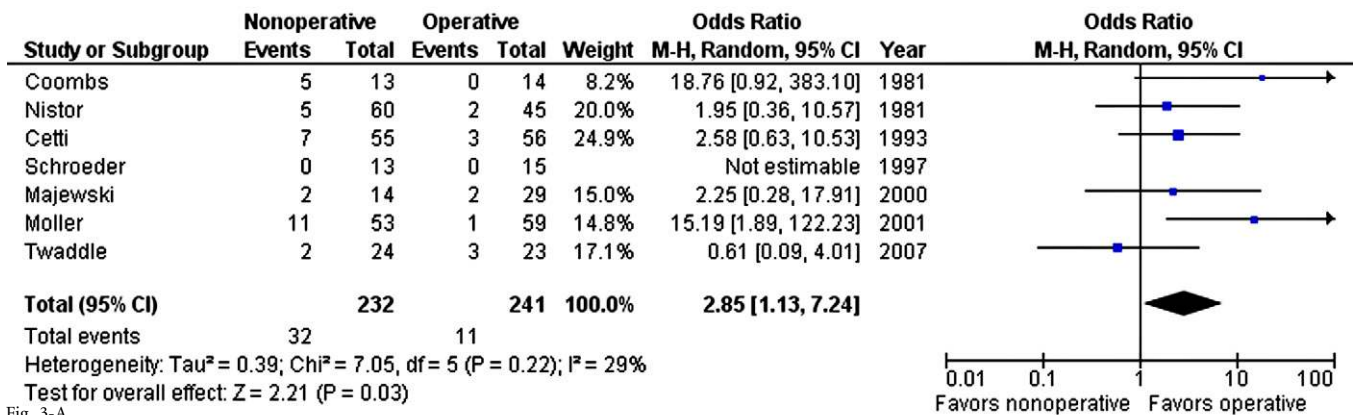


Fig. 3-A

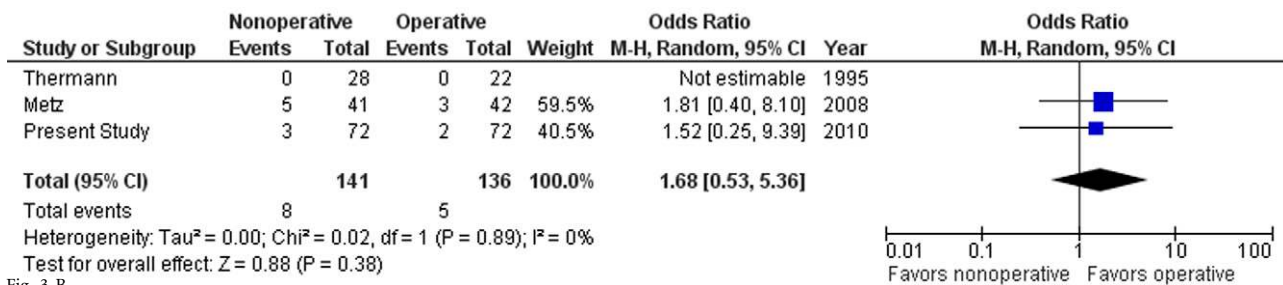


Fig. 3-B

Figs. 3-A and 3-B Forest plots presenting pooled rerupture data from randomized clinical trials comparing operative with nonoperative treatment for Achilles tendon rupture. CI = confidence interval, df = degrees of freedom, and M-H = Mantel-Haenszel. **Fig. 3-A** Studies in which rehabilitation involved immobilization and limited weight-bearing^{5,7,9,10,35,36,38}. **Fig. 3-B** Studies that involved early mobilization and weight-bearing^{8,11}.

trasonography showed no difference in tendon thickness between groups, and there was no difference between groups in isometric strength.

In two similar, randomized studies published in 2006, Costa et al.²¹ compared the outcome following immediate mobilization and weight-bearing in a carbon-fiber orthosis with that following traditional plaster cast immobilization and non-weight-bearing. The first study compared patients who had been treated with operative repair of the tendon, and the second study compared patients who had been treated nonoperatively. In the study of patients treated operatively, those randomized to mobilization and early weight-bearing showed significantly improved early functional outcomes compared with the other group. For patients treated nonoperatively, the outcomes in the early and late-weight-bearing groups were similar. There was no evidence of tendon lengthening or a higher rerupture rate in the early weight-bearing group. In addition, the number of complications was greater in the operatively treated group than in the nonoperatively treated group. Other studies, including a systematic review of randomized trials published in 2005³⁷, that have compared the outcomes for patients treated with weight-bearing at two weeks after surgical repair with the outcomes after the traditional four to six weeks with no weight-bearing have shown similar advantages for early mobilization^{14,17,23,24}.

As with other investigations^{12,34,37}, our study has shown a substantial rate of moderate and severe complications associ-

ated with operative treatment of acute Achilles tendon injury. Although precautions to avoid wound complications were instituted, such complications still occurred and led to prolonged recovery and inferior overall results.

The limitations of this study include its small sample size. Although the current study is the largest study to date comparing the outcomes of patients with an Achilles tendon rupture who were treated either nonoperatively or operatively and whose rehabilitation included early weight-bearing and mobilization, it is underpowered to provide definitive conclusions about rerupture rates. Our original sample size was calculated by assuming that the rerupture rate would be similar to those in other studies in which patients were treated conservatively (13%)^{12,34,37}. It appears, however, that the addition of early weight-bearing and mobilization may have resulted in a substantially reduced rate of rerupture (~4.6%). Proving that such a reduction is indeed real would require a sample size of 1275 per group, based on the absolute risk difference of 1.7% (relative risk difference, 40%) estimated from the pooled results of the current study and previous studies.

In conclusion, this study supports accelerated functional rehabilitation and nonoperative treatment for acute Achilles tendon ruptures. All measured outcomes of nonoperative treatment were acceptable and were clinically similar to those of operative treatment. In addition, this study suggests that the application of a nonoperative protocol involving

accelerated rehabilitation will avoid serious complications related to surgical management.

Appendix

eA Tables describing the rehabilitation protocol and listing mechanisms of injury are available with the electronic version of this article on our web site at jbjs.org (go to the article citation and click on "Supporting Data"). ■

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References

- Möller A, Astron M, Westlin N. Increasing incidence of Achilles tendon rupture. *Acta Orthop Scand*. 1996;67:479-81.
- Józsa L, Kvist M, Bálint BJ, Reffy A, Järvinen M, Lehto M, Barzo M. The role of recreational sport activity in Achilles tendon rupture. A clinical, pathoanatomical, and sociological study of 292 cases. *Am J Sports Med*. 1989;17:338-43.
- Leppilahti J, Puranen J, Orava S. Incidence of Achilles tendon rupture. *Acta Orthop Scand*. 1996;67:277-9.
- Cetti R, Henriksen LO, Jacobsen KS. A new treatment of ruptured Achilles tendons. A prospective randomized study. *Clin Orthop Relat Res*. 1994;308:155-65.
- Coombs RH. Prospective trial of conservative and surgical treatment of Achilles tendon rupture. *J Bone Joint Surg Br*. 1981;63:288.
- Möller M, Lind K, Movin T, Karlsson J. Calf muscle function after Achilles tendon rupture. A prospective, randomised study comparing surgical and non-surgical treatment. *Scand J Med Sci Sports*. 2002;12:9-16.
- Majewski M, Rickert M, Steinbrück K. [Achilles tendon rupture. A prospective study assessing various treatment possibilities]. *Orthopade*. 2000;29:670-6. German.
- Thermann H, Zwipp H, Tscherne H. [Functional treatment concept of acute rupture of the Achilles tendon. 2 years results of a prospective randomized study]. *Unfallchirurg*. 1995;98:21-32. German.
- Twaddle BC, Poon P. Early motion for Achilles tendon ruptures: is surgery important? A randomized, prospective study. *Am J Sports Med*. 2007;35:2033-8.
- Nistor L. Surgical and non-surgical treatment of Achilles tendon rupture. A prospective randomized study. *J Bone Joint Surg Am*. 1981;63:394-9.
- Metz R, Verleisdonk EJ, van der Heijden GJ, Clevers GJ, Hammacher ER, Verhofstad MH, van der Werken C. Acute Achilles tendon rupture: minimally invasive surgery versus nonoperative treatment with immediate full weightbearing—a randomized controlled trial. *Am J Sports Med*. 2008;36:1688-94.
- Bhandari M, Guyatt GH, Siddiqui F, Morrow F, Busse J, Leighton RK, Sprague S, Schemitsch EH. Treatment of acute Achilles tendon ruptures: a systematic overview and metaanalysis. *Clin Orthop Relat Res*. 2002;400:190-200.
- Lea RB, Smith L. Rupture of the Achilles tendon. Nonsurgical treatment. *Clin Orthop Relat Res*. 1968;60:115-8.
- Saleh M, Marshall PD, Senior R, MacFarlane A. The Sheffield splint for controlled early mobilisation after rupture of the calcaneal tendon. A prospective, randomised comparison with plaster treatment. *J Bone Joint Surg Br*. 1992;74:206-9.
- Gelberman RH, Woo SL, Amiel D, Horibe S, Lee D. Influences of flexor sheath continuity and early motion on tendon healing in dogs. *J Hand Surg Am*. 1990;15:69-77.
- McComis GP, Nawoczenski DA, DeHaven KE. Functional bracing for rupture of the Achilles tendon. Clinical results and analysis of ground-reaction forces and temporal data. *J Bone Joint Surg Am*. 1997;79:1799-808.
- Mortensen HM, Skov O, Jensen PE. Early motion of the ankle after operative treatment of a rupture of the Achilles tendon. A prospective, randomized clinical and radiographic study. *J Bone Joint Surg Am*. 1999;81:983-90.
- Bruns J, Kampen J, Kahrs J, Plitz W. Achilles tendon rupture: experimental results on spontaneous repair in a sheep-model. *Knee Surg Sports Traumatol Arthrosc*. 2000;8:364-9.
- Maffulli N, Tallon C, Wong J, Peng Lim K, Bleakney R. No adverse effect of early weight bearing following open repair of acute tears of the Achilles tendon. *J Sports Med Phys Fitness*. 2003;43:367-79.
- Costa ML, Shepstone L, Darrah C, Marshall T, Donell ST. Immediate full-weight-bearing mobilisation for repaired Achilles tendon ruptures: a pilot study. *Injury*. 2003;34:874-6.
- Costa ML, MacMillan K, Halliday D, Chester R, Shepstone L, Robinson AH, Donell ST. Randomised controlled trials of immediate weight-bearing mobilisation for rupture of the tendo Achillis. *J Bone Joint Surg Br*. 2006;88:69-77.
- Kangas J, Pajala A, Siira P, Hämäläinen M, Leppilahti J. Early functional treatment versus early immobilization in tension of the musculotendinous unit after Achilles rupture repair: a prospective, randomized, clinical study. *J Trauma*. 2003;54:1171-81.
- Kangas J, Pajala A, Ohtonen P, Leppilahti J. Achilles tendon elongation after rupture repair: a randomized comparison of 2 postoperative regimens. *Am J Sports Med*. 2007;35:59-64.
- Suchak AA, Bostick GP, Beaupré LA, Durand DC, Jomha NM. The influence of early weight-bearing compared with non-weight-bearing after surgical repair of the Achilles tendon. *J Bone Joint Surg Am*. 2008;90:1876-83.
- Lipscomb PR, Wakim KG. Regeneration of severed tendons: an experimental study. *Proc Staff Meet Mayo Clin*. 1961;36:271-6.
- Michna H, Hartmann G. Adaptation of tendon collagen to exercise. *Int Orthop*. 1989;13:161-5.
- Mosler E, Folkhard W, Knörzer E, Nemetschek-Gansler H, Nemetschek T, Koch MH. Stress-induced molecular rearrangement in tendon collagen. *J Mol Biol*. 1985;182:589-96.

- 28.** Woo SL, Gelberman RH, Cobb NG, Amiel D, Lothringer K, Akeson WH. The importance of controlled passive mobilization on flexor tendon healing. A biomechanical study. *Acta Orthop Scand.* 1981;52:615-22.
- 29.** Maffulli N, Tallon C, Wong J, Lim KP, Bleakney R. Early weightbearing and ankle mobilization after open repair of acute midsubstance tears of the Achilles tendon. *Am J Sports Med.* 2003;31:692-700.
- 30.** Metz R, Kerkhoffs GM, Verleisdonk EJ, van der Heijden GJ. Acute Achilles tendon rupture: minimally invasive surgery versus non operative treatment, with immediate full weight bearing. Design of a randomized controlled trial. *BMC Musculoskelet Disord.* 2007;8:108.
- 31.** Thompson TC, Doherty JH. Spontaneous rupture of tendon of Achilles: a new clinical diagnostic test. *J Trauma.* 1962;2:126-9.
- 32.** Cretnik A, Kosanovic M, Smrkolj V. Percutaneous versus open repair of the ruptured Achilles tendon: a comparative study. *Am J Sports Med.* 2005;33:1369-79.
- 33.** Leppilahti J, Forsman K, Puranen J, Orava S. Outcome and prognostic factors of Achilles rupture repair using a new scoring method. *Clin Orthop Relat Res.* 1998;346:152-61.
- 34.** Lo IK, Kirkley A, Nonweiler B, Kumbhare DA. Operative versus nonoperative treatment of acute Achilles tendon ruptures: a quantitative review. *Clin J Sport Med.* 1997;7:207-11.
- 35.** Cetti R, Christensen SE, Ejsted R, Jensen NM, Jorgensen U. Operative versus nonoperative treatment of Achilles tendon rupture. A prospective randomized study and review of the literature. *Am J Sports Med.* 1993;21:791-9.
- 36.** Möller M, Movin T, Granhed H, Lind K, Faxén E, Karlsson J. Acute rupture of tendon Achillis. A prospective randomised study of comparison between surgical and non-surgical treatment. *J Bone Joint Surg Br.* 2001;83:843-8.
- 37.** Khan RJ, Fick D, Keogh A, Crawford J, Brammar T, Parker M. Treatment of acute Achilles tendon ruptures. A meta-analysis of randomized, controlled trials. *J Bone Joint Surg Am.* 2005;87:2202-10.
- 38.** Schroeder D, Lehmann M, Steinbrueck K. Treatment of acute Achilles tendon ruptures: open vs. percutaneous repair vs conservative treatment. A prospective randomized study. *Orthop Trans.* 1997;21:1228.