Is Early Controlled Motion and Weightbearing Recommended for Nonoperatively Treated Acute Achilles Tendon Rupture? A Systematic Review and Meta-analysis

Yi-jun Zhang,*† MD, Xiao Long,† MD, Jing-yu Du,† MD, Quan Wang,† MD, and Xiang-jin Lin,† MD
Investigation performed at The First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, PR China

Background: There is disagreement as to whether early controlled motion and weightbearing confer a beneficial effect for nonoperatively treated acute Achilles tendon rupture (ATR) compared with immobilization and late weightbearing.

Purpose: To conduct a meta-analysis of randomized controlled trials (RCTs) to determine whether early controlled motion and weightbearing results in different outcomes compared with immobilization and late weightbearing for nonoperatively treated patients with acute ATR.

Study Design: Systematic review; Level of evidence, 1.

Methods: We conducted a search in the PubMed, Web of Science, and EMBASE databases for relevant RCTs in humans from January 1981 to August 2020. The primary outcome was the Achilles Tendon Total Rupture Score (ATRS) at 1-year follow-up. The secondary outcomes were the rerupture rate, return to sports activity and work, and the heel-rise work (limb symmetry index [LSI]). Study quality was assessed using the Cochrane Collaboration risk of bias tool.

Results: Included were 7 RCTs involving 424 participants (n = 215 treated with early controlled motion and weightbearing [early group], n = 209 treated with immobilization and late weightbearing [late group]). The quality assessment indicated a low risk of bias in all included RCTs. There was no difference between the early and late groups regarding the ATRS (mean difference [MD], -0.220; 95% CI, -4.489 to 4.049; $P = .920$). Likewise, we found no difference between the 2 groups in terms of the rerupture rate (odds ratio [OR], 1.107; 95% CI, 0.552 to 2.219; $P = .775$), the number of patients who returned to sports (OR, 0.766; 95% CI, 0.438 to 1.341; $P = .351$) and returned to work (OR, 0.706; 95% CI, 0.397 to 1.253; $P = .234$), the time to return to work (MD, -2.802 days; 95% CI, -6.525 to 0.921 days; $P = .140$), or the heel-rise work LSI (MD, -0.135; 95% CI, -6.243 to 5.973; $P = .965$).

Conclusion: No significant differences were found between early controlled motion and weightbearing compared with immobilization and late weightbearing regarding the ATRS, the rerupture rate, return to sports activity and work, and the heel-rise work in nonoperatively treated patients with acute ATR.

Keywords: achilles tendon rupture; conservative treatment; rehabilitation; weightbearing

Acute Achilles tendon rupture (ATR) is a common problem in foot and ankle surgery. The treatment is still controversial, and the main alternatives are either nonoperative or surgical.[4,5,17,18] During the past decade, surgical treatment has been regarded as the first choice in many hospitals. In addition, it has become common to add early functional controlled motion and weightbearing, such as using an adjustable brace, after surgical treatment.[6,22,23,26] Studies on treatment with only early functional controlled motion and weightbearing, using a mobile cast without any preceding surgery, also show

promising results.[25,37] Animal studies in an unrepaired Achilles tendon model have shown faster and stronger tendon healing because of the release of growth factors with early controlled motion and weightbearing.[1,24] Clinical studies in surgically and nonsurgically treated Achilles tendon tears have also shown that early controlled motion could promote faster and better healing of the tendons.[11,35,39] Despite there being no statistically significant differences in functional outcomes, a trend toward better treatment outcome was found in studies both operatively and nonoperatively using early controlled motion and weightbearing.[33,40] This has led to the controversy that the early controlled motion of the ankle might be the key to the best treatment for both operatively and nonoperatively treated patients with acute ATR.[33,38,40]

Early controlled motion might have beneficial effects. However, it has also been shown in an animal laboratory study on nonoperatively treated Achilles tears that early controlled motion can cause tendon elongation,[20] which leads to a decrease in humans' push off strength, and thus a poor functional outcome.[14,32] However, 3 randomized controlled trials (RCTs)[15,27,30] found a tendency toward better push off strength and shorter rehabilitation in both operatively and nonoperatively treated patients with early controlled motion and weightbearing.

To our knowledge, no one has pooled the trials data in a meta-analysis to reconcile those differences. Therefore, we performed a systematic review and meta-analysis of RCTs to determine whether early controlled motion and weightbearing results in different outcomes compared with immobilization and late weightbearing in nonoperatively treated patients with acute ATR. The hypothesis was that there would be no significant differences between the treatment strategies.

METHODS

Search Strategy and Criteria

Our study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and the PRISMA-IPD (individual patient data) statement.[21,34] We conducted a thorough search of peer-reviewed articles in the PubMed, Web of Science, and EMBASE databases to identify all RCTs comparing early controlled motion and weightbearing versus immobilization and late weightbearing for nonoperatively treated acute ATRs from January 1981 to August 2020. The keywords "Achilles tendon" and "rupture" were chosen, and the following terms were applied to the search in the 3 chosen databases: (Achilles AND (rupture OR ruptures OR tearing OR tears OR tear OR damage OR damages OR injury OR injuries)) OR (gilles AND (rupture OR ruptures OR tearing OR tears OR tear OR damage OR damages OR injury OR injuries)) OR (akilli AND (rupture OR ruptures OR tearing OR tears OR tear OR damage OR damages OR injury OR injuries). The results were limited to human RCTs and were published in all languages.

Initially, the retrieved articles were screened for relevance by the title and abstract. Articles that met the following criteria were included: (1) RCTs; (2) trials enrolling adults diagnosed with acute ATR; (3) trials that compared early controlled motion and weightbearing with immobilization and late weightbearing for nonoperatively treated acute ATRs; (4) trials that reported the Achilles Tendon Total Rupture Score (ATRS), the rerupture rate, return to sports activity and work, times to return to work, the heel-

rise work, or other functional measures. Exclusion criteria were case-control studies, case reports, studies without abstracts, patient age <18 years, chronic Achilles tendinopathy, a history of previous injury or surgery to the same Achilles tendon and surgical treatment, and known inflammatory diseases (eg, rheumatoid arthritis, psoriatic arthritis, or inflammatory bowel). We also hand searched the bibliographies of the included trials as well as the conference proceedings and meeting abstracts. Only full-length published articles were included in this study.

Summary of Included Studies

Of the 8120 studies identified by our search, 7 studies[2,3,9,16,19,30,41] were included in the qualitative synthesis. Full-text articles that were excluded were those that related to tendinopathy rather than tendon tears, assessed muscle injuries, were duplicates, related to ligament injuries, or had surgical interventions (Figure 1). Studies were analyzed for control type as well as treatment type and technique. All included studies were RCTs that compared early controlled motion and weightbearing with immobilization and late weightbearing for nonoperatively treated acute ATRs. No included study performed early motion, but they performed delayed weightbearing.

Quality Assessment and Data Collection

The full-text articles were extracted by 1 reviewer (Y.-j.Z.) and checked by a second reviewer (J-y.D.). We assessed the risk of bias for all the included studies using the Cochrane risk of bias tool.[12,21] An additional quantification of the degree of possible bias was performed by the modified Coleman Methodology Score,[7] consisting of 10 criteria each scored from 0 to 10. A perfect score of 100 represents a study design that largely avoids the influence of chance, different biases, and confounding factors.[8] The level of evidence for all included studies was determined according to the Cochrane Handbook for Systematic Reviews of Interventions.[13]

Data that were collected in this study included the number of patients, the mean age, the treatment procedure, and clinical outcomes. We defined early motion and weightbearing as that occurring within the first 4 weeks of treatment. The intervention group in 3 studies[9,19,41] was instructed to perform early controlled ankle motion and weightbearing immediately, 2 studies[2,16] from the first day, and another 2 studies[3,30] after 2 weeks. The control group in all 7 studies was instructed to perform immobilization and nonweightbearing at least for 4 weeks.

*Address correspondence to Yi-jun Zhang, MD, Department of Orthopedics, The First Affiliated Hospital, Zhejiang University School of Medicine, No.79 Qingchun Road, Hangzhou, Zhejiang Province, PR China 310003 (email: zhangyijun87@zju.edu.cn).
†Department of Orthopedics, The First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, PR China.
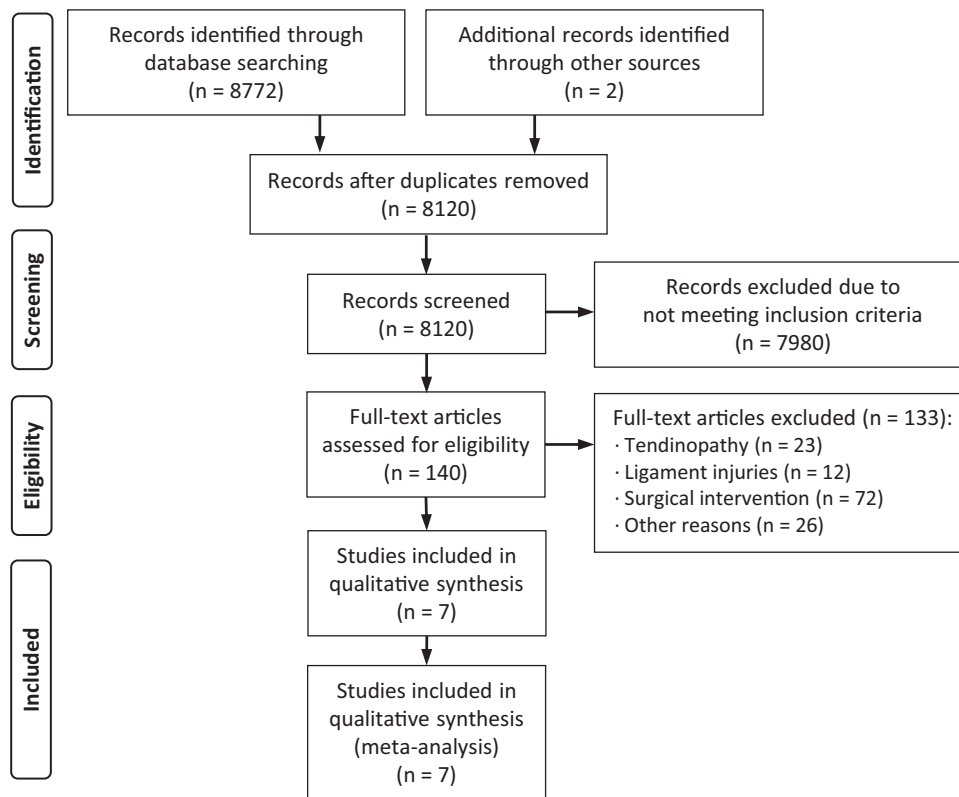Y.-j.Z. and X.L. contributed equally to this study.

Figure 1. The flow of information is shown through a systematic review for early controlled motion and weightbearing versus immobilization and late weightbearing in nonoperatively treated acute Achilles tendon ruptures.

Study Outcomes

The primary outcome assessed was the ATRS at 1-year follow-up visit. The ATRS is the only patient-reported outcome measure developed and the validated patient-reported instrument with high reliability, validity, and sensitivity for measuring the outcome related to symptoms and physical activity after treatment in patients with a total ATR.[29] This 100-point scale was scored using identical questionnaires and in an identical setting as at 1-year follow-up.[2] The initial study was designed with a sample size with sufficient power to detect a difference in the ATRS of 10 points and a power of 0.9 (2-sided).[2]

The secondary outcomes were the rerupture rate, the number of patients who returned to sports activity and work, and heel-rise work (reported as limb symmetry index [LSI]). The mean time to return to work was also calculated. The heel-rise work was measured as described by Silbernagel et al[31] and Nilsson-Helander et al[28] and reported as an LSI ([injured limb/healthy limb] × 100%). A muscle lab test unit (Ergotest Technology) was used for the data acquisition. Standardized instructions were given to patients, including a 5-minute warm-up on a low-load stationary bicycle, followed by 3 sets of ten 2-legged toe raises. The uninjured side was tested first.

It was possible to conduct a meta-analysis of the ATRS, the rerupture rate, return to sports activity and work, and the heel-rise work. Other functional measures that were used by different studies included tendon strength, quality of life during treatment, and ankle range of motion; we have presented the results of these outcomes separately. The results of the last follow-up examination included in the RCTs were used when possible.

Statistical Analysis

A statistical analysis was performed using STATA Version 12 (Stata Corp). Continuous variables were analyzed using the weighted mean difference (MD), and categorical variables were assessed using relative risks. In this study, $P < .05$ was statistically significant and 95% CIs were reported. A funnel plot and the Egger test were performed for any publication bias of the pooled results of the ATRS in the meta-analysis. The results of the funnel plot suggested that no publication bias was present (Figure 2), which was also statistically supported by the Egger test ($P = .920$). Heterogeneity among trials was assessed using the I^2 test statistic (0.50% is considered having substantial heterogeneity). A random-effects model was used if the I^2 value was statistically significant; otherwise, a fixed-effects model was used. In this meta-analysis, there was no heterogeneity in the ATRS (chi-square = 0.27; $P = .966$; $I^2 = 0\%$), the rerupture rate (chi-square = 1.26; $P = .974$; $I^2 = 0\%$), return to sports activity (chi-square = 1.06; $P = .901$; $I^2 = 0\%$), return to work (chi square = 1.78; $P = .776$, $I^2 = 0\%$), the time to return to work (chi-square = 1.58; $P = .664$;

$I^2 = 0\%$), and the heel-rise work (chi-square = 0.94; $P = .626$; $I^2 = 0\%$); and a fixed-effects model was used.

RESULTS

All 7 included studies were RCT studies with low risk of bias and high modified Coleman Methodology scores (>80) (Table 1). A total number of 424 patients were enrolled in the meta-analysis, including 215 patients who underwent early controlled motion and weightbearing (early group) and 209 patients who underwent immobilization and late weightbearing (late group). The mean age between these 2 groups was similar; however, overall there were fewer women than men. The length of follow-up ranged from 3 months to 4.5 years. The detailed demographic characteristics of the included studies are presented in Table 2.

Study Outcomes

There was no difference between the early and late groups regarding the primary outcome in the 4 studies[2,3,16,19] that
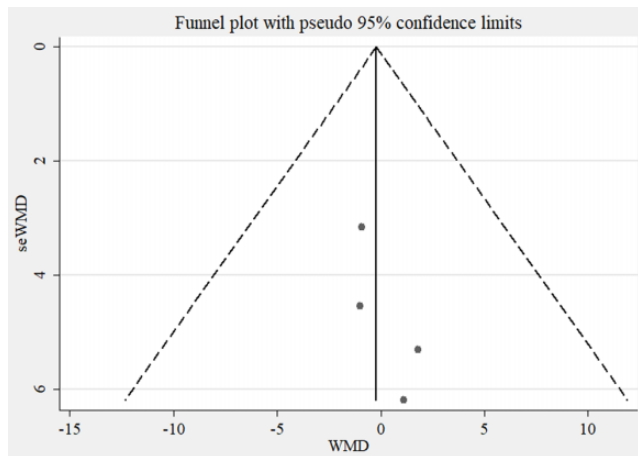

Figure 2. The funnel plot with pseudo 95% confidence limits of the Achilles Tendon Total Rupture Score suggested that there was no publication bias, which was also statistically supported by the Egger test ($P = .920$). WMD, weighted mean difference.

reported the ATRS (76.2 ± 18.3 [early group] vs 76.6 ± 18.6 [late group]; MD, -0.220; 95% CI, -4.489 to 4.049; $P = .920$) (Figure 3). There was also no difference between the early and late groups in terms of tendon rerupture rate (7 studies[2,3,9,16,19,30,41]; odds ratio [OR], 1.107; 95% CI, 0.552 to 2.219; $P = .775$) (Figure 4), the number of patients who returned to sports activity (5 studies[2,3,9,16,30]; OR, 0.766; 95% CI, 0.438 to 1.341; $P = .351$) (Figure 5), or the number of patients who returned to work (5 studies[2,3,16,19,41]; OR, 0.706; 95% CI, 0.397 to 1.253; $P = .234$) (Figure 6). In 4 studies[2,3,19,41] that reported the time to return to work, the MD between the early and late groups was -2.802 days, which was not significantly different (56.6 ± 70.9 days [early group] vs 52.3 ± 45.1 days [late group]; 95% CI, -6.525 to 0.921; $P = .140$) (Figure 7). Finally, we found no difference between the early and late groups in terms of the heel-rise work in 3 studies[2,3,16] (58% ± 22.1% [early group] vs 58.0% ± 24.5% [late group]; MD, -0.135; 95% CI, -6.243 to 5.973; $P = .965$) (Figure 8).

Other Outcomes

Two studies[2,16] evaluated the heel-rise height and found no significant difference between the early and late groups. One study[41] reported no significant difference in tendon isokinetic strength between the 2 groups. Two studies[19,41] reported the subjective outcomes of the Leppilahti questionnaire, Tegner ankle scores, the self-rated Achilles tendon score, the American Orthopaedic Foot & Ankle Society ankle-hindfoot score, and the Physical Activity Scale. Fewer patients in the early group reported pain, stiffness, or weakness at 1 year.[41] However, apart from the subjective stiffness rating, none of these differences were statistically significant. One study[30] reported the results of ankle plantarflexion increasing not significantly between the 2 groups, with dorsiflexion increasing significantly in the early controlled motion and weightbearing group ($P < .001$). In the early controlled motion and weightbearing group, almost normal dorsiflexion was achieved by 6 months. Other complications were pulmonary embolism, no signs of tendon healing and tendon elongation.[3,9,41]

TABLE 1
Quality Assessment of Included Studies[a]

Lead Author (year)	Study Design	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Coleman Methodlogy Score[7]	LOE[b]
Saleh[30] (1992)	RCT	+	+	+	+	+	85	1
Costa[9] (2006)	RCT	+	+	+	−	+	87	1
Young[41] (2014)	RCT	+	+	+	−	+	89	1
Barfod[2] (2014)	RCT	+	+	+	−	+	90	1
Korkmaz[19] (2015)	RCT	+	+	+	+	+	88	1
Kastoft[16] (2019)	RCT	+	+	+	−	+	86	2
Barfod[3] (2020)	RCT	+	+	+	−	+	91	1

[a]LOE, level of evidence; RCT, randomized controlled trial; +, the article does not contain bias; −, bias exists.
[b]According to the Cochrane Handbook for Systematic Reviews of Interventions.[13]

TABLE 2
Demographic Characteristics of the Included Studies[a]

Lead Author (Year)	No. of Patients		Mean Age		Men/Women		Time to Begin Early Motion/ Weightbearing	Outcomes	Follow-up
	Early	Late	Early	Late	Early	Late			
Saleh[30] (1992)	20	20	39	41	15/5	16/4	2 wk	rerupture rate, return to sports activity, and ankle ROM	3-12 mo
Costa[9] (2006)	19	21	53	53	12/7	13/8	Immediately	rerupture rate, return to sports activity, return to work, the EuroQol, and health status questionnaires	3-12 mo
Young[41] (2014)	32	35	NA	NA	NA	NA	Immediately	rerupture rate, return to sports activity, return to work, and the Leppilahti questionnaire score, Tegner ankle scores, and self-rated Achilles tendon scores	6-24 mo
Barfod[2] (2014)	29	27	41.2 ± 6.4	39.1 ± 7.5	24/5	24/4	Day 1	ATRS, rerupture rate, heel-rise work and height, return to sports activity, sick leave, and quality of life	6-12 mo
Korkmaz (2015)[19]	23	24	37.4 ± 4.5	36.8 ± 5.2	19/4	20/4	Immediately	ATRS, rerupture rate, time to return to work, the AOFAS, and the PAS	6-12 mo
Kastoft[16] (2019)	19	18	45.3 ± 5.8	44.7 ± 7.7	15/4	16/2	Day 1	ATRS, rerupture rate, heel-rise work and height, return to work, and return to sports activity	6 mo to 4.5 y
Barfod[3] (2020)	68	62	41 ± 9.3	42.7 ± 11.7	56/12	51/11	2 wk	ATRS, rerupture rate, heel-rise work, return to work, return to sports activity, and Achilles tendon elongation	4-12 mo

[a]All studies were randomized controlled trials comparing early controlled motion and weightbearing (early group) with immobilization and late weightbearing (late group). AOFAS, American Orthopaedic Foot & Ankle Society; ATRS, Achilles Tendon Total Rupture Score; EuroQol, European Quality of Life; NA, not available; PAS, Physical Activity Scale; ROM, range of motion.
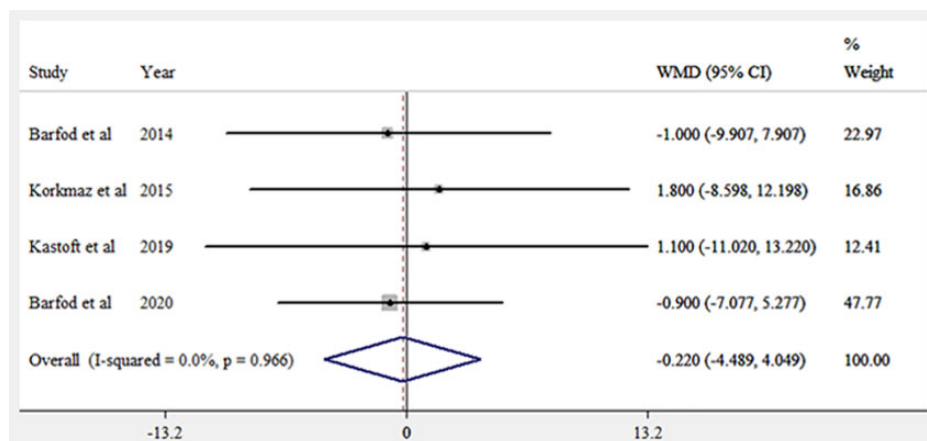

Figure 3. Forest plot of the ATRS in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. There was no heterogeneity in the ATRS (chi square = 0.27; P = .966; I^2 = 0%) and a fixed-effects model was used. ATRS, Achilles Tendon Total Rupture Score; WMD, weighted mean difference.

DISCUSSION

In this meta-analysis, the most important result was that no statistically significant difference was found between early controlled motion and weightbearing and immobilization and late weightbearing in nonoperatively treated patients regarding the ATRS, the rerupture rate, return to sports activity and work, and the and heel-rise work with the numbers available.
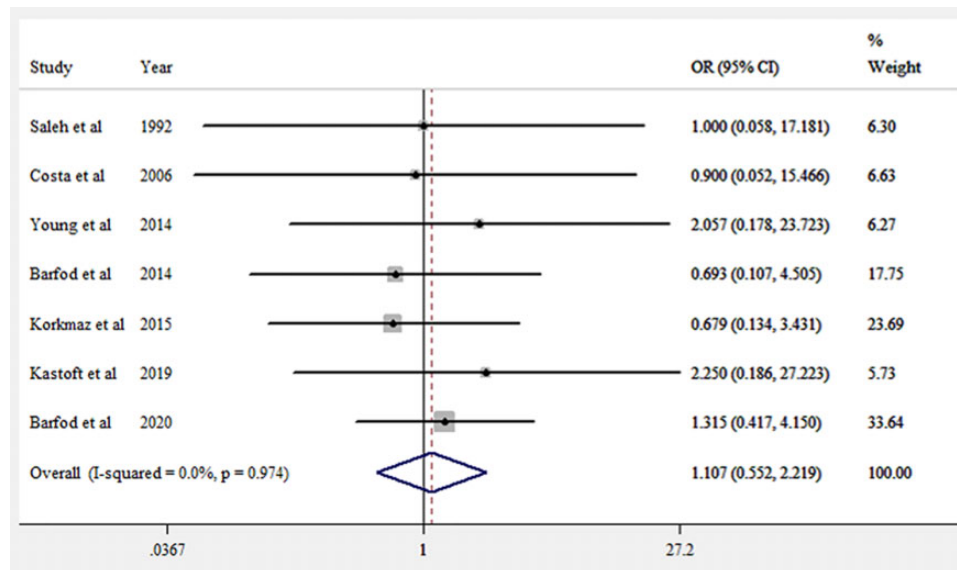
Figure 4. Forest plot of tendon rerupture rate in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. No significant heterogeneity was found in the tendon rerupture rate (chi square = 1.26; P = .974; I^2 = 0%), and a fixed-effects model was used. OR, odds ratio.
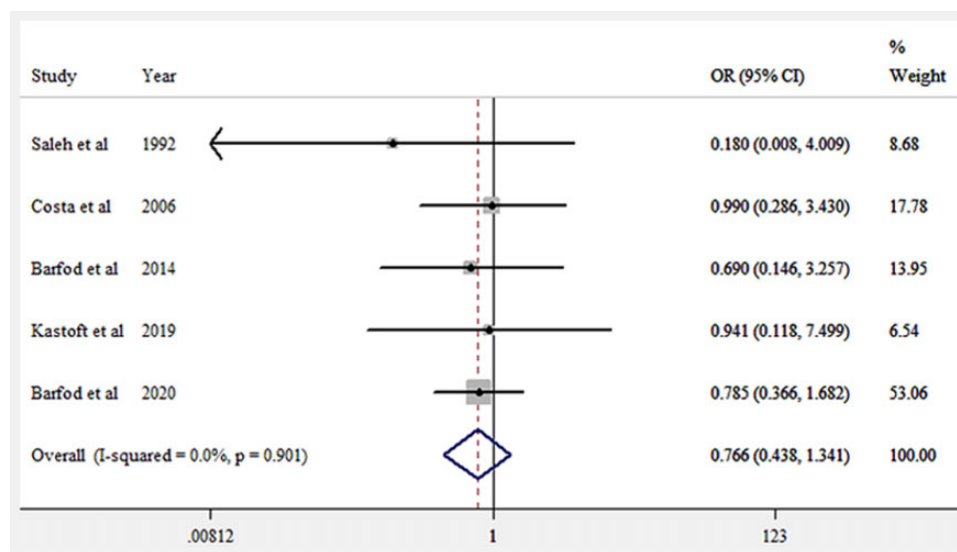

Figure 5. Forest plot of return to sports activity in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. No significant heterogeneity was found in the number of return to sports activity (chi square = 1.06; P = .901; I^2 = 0%), and a fixed-effects model was used. OR, odds ratio.

Four of the included studies[2,3,16,19] had reported that the ATRS increased significantly from 6 to 12 months in both groups. However, in this meta-analysis, we found no significant differences between early controlled motion and weightbearing over immobilization and late weightbearing with respect to ATRS, despite having adequate statistical power to detect a clinically important difference in the ATRS.

The rate of rerupture has been the commonly used outcome in research regarding treatment of Achilles tendon rupture. A previous study reported that early weightbearing increased the force on the Achilles tendon, which could potentially lead to elongation or rerupture of the healing tendon. Use of the orthotic heel lift reduces the Achilles tendon force and the resulting strain while allowing for isometric contraction.[10] In this meta-analysis, the pooled rerupture rate was 7.9% in the early group and 8.6% in the late group. However, there was no significant difference in these 2 groups, indicating that early controlled motion and weightbearing may not increase the risk of rerupture rate during the treatment period of acute ATR.
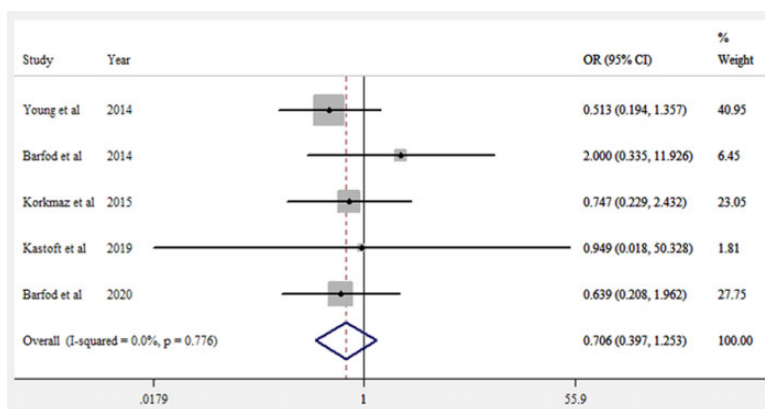
Figure 6. Forest plot of return to work in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. No significant heterogeneity was found in the number of return to work (chi square = 1.78; P = .776; I^2 = 0%), and a fixed-effects model was used. OR, odds ratio.
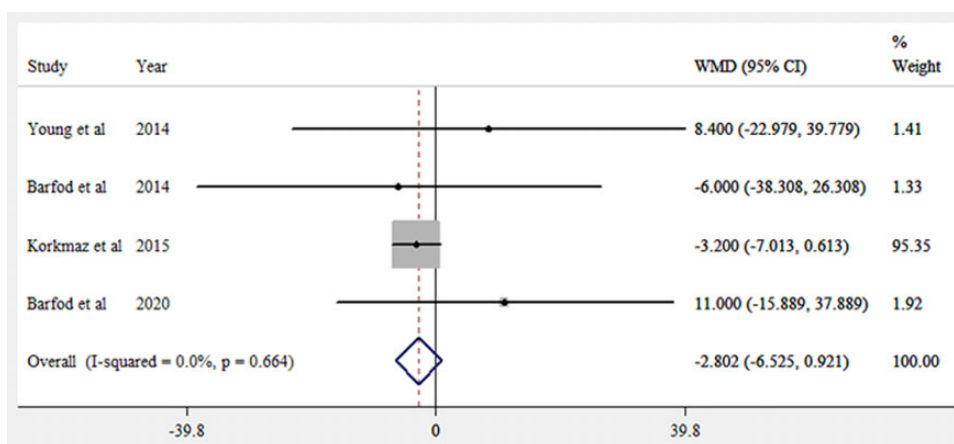

Figure 7. Forest plot of time to return to work in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. No significant heterogeneity was found in the number of return to work (chi square = 1.58; P = .664; I^2 = 0%), and a fixed-effects model was used. WMD, weighted mean difference.
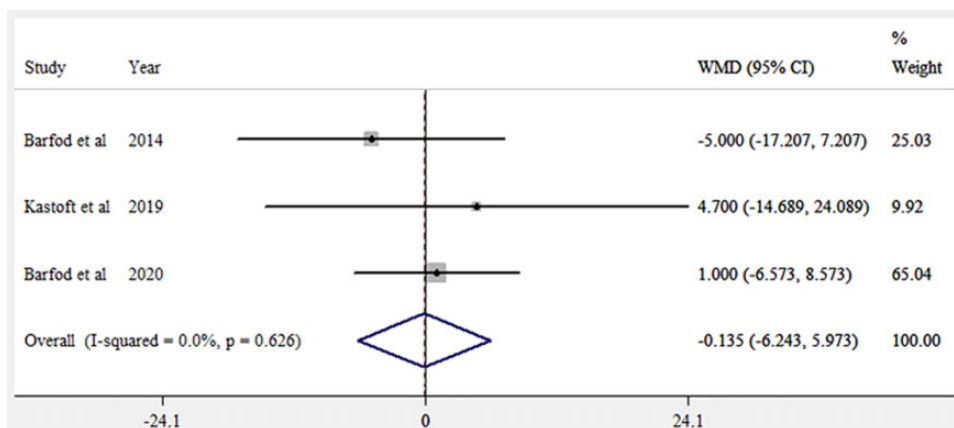

Figure 8. Forest plot of the heel-rise work in patients treated with early controlled motion and weightbearing versus immobilization and late weightbearing. No significant heterogeneity was found in the heel-rise work (chi square = 0.94; P = .626; I^2 = 0%), and a fixed-effects model was used. WMD, weighted mean difference.

Regarding the return to sports activity and work as a secondary outcome, we found no statistically significant difference between the 2 groups based on 5 studies[2,3,16,19,41] and confirmed that the individual result from each study showed no significant difference. In addition, great variation existed in the individual incidence of return to sports in each study, which depends on how to define a return to sports. For example, Barfod et al[2] reported 18% of patients, and Costa et al[9] 56% of patients, as having returned to sports in the early controlled motion and weightbearing group at 1-year follow-up. Previous studies have shown 30% to 60% return to the same level of sports activity in both operatively and nonoperatively treated patients.[5,26] Two studies[3,19] reported on the times required to return to work and showed no statistically significant difference. However, they did not report the type of work. Young et al[41] reported that the type of work was similar in both groups, and Barfod et al[2] divided work into 3 types, including heavy, light, and sedentary. It seemed that the early weightbearing group included more heavy and light types of employment when compared with the late weightbearing group.[2,41] Three studies[2,3,16] had reported that the heel-rise work and height had no significant differences between early controlled motion and weightbearing and immobilization and late weightbearing groups, although Kastoft et al[16] found that the heel-rise height was significantly higher in the early controlled motion and weightbearing group at 6 months, but it was equalized at 1 year.

One study[2] noted that health-related quality of life during the first 8 weeks of treatment appeared to be better in the early controlled motion and weightbearing group. This is in line with the conclusion of Suchak et al[36] that early weightbearing provides enhanced quality of life.[36] However, the authors indicated that the result should be interpreted with caution, as health-related quality of life was measured with use of a custom-designed measure with unknown validity and reliability. One study[30] reported that the increased range of plantarflexion in the early controlled motion and weightbearing group at 3 and 6 months was not statistically significant, but the increased range of dorsiflexion in the early controlled motion and weightbearing group at 3, 6, and 12 months was highly significant ($P < .001$). They concluded that ankle dorsiflexion rehabilitation is faster without overstretching, and return to sports activities is more rapid with early controlled motion and weightbearing. One study[41] reported the subjective outcomes, including the scores for the subjective section of the Leppilahti questionnaire, Tegner ankle scores, and self-rated Achilles tendon scores were slightly more favorable in the early controlled motion and weightbearing group, but not significantly so. Therefore, we would recommend to allow early motion and weightbearing because that early motion may minimize problems with stiffness without increasing the rerupture rate or affecting outcomes.

This study has several limitations. First, the sample size was small. Seven RCTs involving only 424 participants were eligible for inclusion, with 215 participants in the early controlled motion and weightbearing group and 209 in the immobilization and late weightbearing group. The power calculation in the present study was based on a standard deviation of 10 points in the ATRS, as reported by Nilsson-Helander et al.[28] However, the actual standard deviation in the meta-analysis study was 16, which should be taken into consideration when utilizing the ATRS as the primary outcome. There might be small but still clinically important treatment benefits, and the size of the meta-analysis we conducted may not have sufficient power to detect this benefit. Second, the studies in this meta-analysis included few competitive elite athlete patients from the general population, and there were fewer women in the study groups. Moreover, physicians often choose surgical repair in higher demand patients. Therefore, there is likely some selection bias. Third, we chose not to focus on different types of orthoses used in individual studies but rather on the time interval until full weightbearing. Fourth, the included studies also used different definitions of early motion and different types of casts. Therefore, we could not rule out the existence of confounding factors stratified by mobilization period and cast type, but we did not believe that they exist.

In conclusion, no significant differences were found between early controlled motion and weightbearing and immobilization and late weightbearing regarding the ATRS, the rerupture rate, return to sports activity and work, and the heel-rise work in nonoperatively treated patients with acute ATR. Larger randomized controlled studies are needed to confirm these outcomes.

ACKNOWLEDGMENT

REFERENCES

1. Aspenberg P. Stimulation of tendon repair: mechanical loading, GDFs and platelets. A mini-review. *Int Orthop.* 2007;31:783-789.
2. Barfod KW, Bencke J, Lauridsen HB, Ban I, Ebskov L, Troelsen A. Nonoperative dynamic treatment of acute Achilles tendon rupture: the influence of early weight-bearing on clinical outcome: a blinded, randomized controlled trial. *J Bone Joint Surg Am.* 2014;96:1497-503.
3. Barfod KW, Hansen MS, Hölmich P, Kristensen MT, Troelsen A. Efficacy of early controlled motion of the ankle compared with immobilisation in non-operative treatment of patients with an acute Achilles tendon rupture: an assessor-blinded, randomised controlled trial. *Br J Sports Med.* 2020;54:719-724.
4. Bhandari M, Guyatt GH, Siddiqui F, et al. Treatment of acute Achilles tendon ruptures: a systematic overview and meta-analysis. *Clin Orthop Relat Res.* 2002;400:190-200.
5. 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;21:791-799.
6. Cetti R, Henriksen LO, Jacobsen KS. A new treatment of ruptured Achilles tendons: a prospective randomized study. *Clin Orthop Relat Res.* 1994;308:155-165.
7. Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. *Scand J Med Sci Sports.* 2000;10:2-11.
8. Coombes BK, Bisset L, Vincenzo B. Efficacy and safety of corticosteroid injections and other injections for management of tendinopathy: a

systematic review of randomised controlled trials. *Lancet*. 2010;376: 1751-1767.

9. Costa ML, MacMillan K, Halliday D, et al. Randomised controlled trials of immediate weight-bearing mobilisation for rupture of the tendo Achillis. *J Bone Joint Surg Br*. 2006;88(1):69-77.

10. Farris DJ, Buckeridge E, Trewartha G, McGuigan MP. The effects of orthotic heel lifts on Achilles tendon force and strain during running. *J Appl Biomech*. 2012;28(5):511-519.

11. Gelberman RH, Woo SL-Y. The physiological basis for application of controlled stress in the rehabilitation of flexor tendon injuries. *J Hand Ther*. 1989;2:66-70.

12. Higgins JP, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011; 343:D5928.

13. Higgins JP, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. The Cochrane Collaboration. Updated September 2011. Accessed July 5, 2020. http://handbook. cochrane.org/

14. 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.

15. 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;54:1171-1180.

16. Kastoft R, Bencke J, Speedtsberg MB, Penny J, Barfod K. Early weight-bearing in nonoperative treatment of acute Achilles tendon rupture did not influence mid-term outcome: a blinded, randomised controlled trial. *Knee Surg Sports Traumatol Arthrosc*. 2019;27: 2781-2788.

17. Khan RJ, Fick D, Brammar T, Crawford J, Parker M. Interventions for treating acute Achilles tendon ruptures. *Cochrane Database Syst Rev*. 2004;3:CD003674.

18. 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;87:2202-2210.

19. Korkmaz M, Erkoc MF, Yolcu S, Balbaloglu O, Öztemur Z, Karaaslan F. Weight bearing the same day versus non-weight bearing for 4 weeks in Achilles tendon rupture. *J Orthop Sci*. 2015;(20):513-516.

20. Krapf D, Kaipel M, Majewski M. Structural and biomechanical characteristics after early mobilization in an Achilles tendon rupture model: operative versus nonoperative treatment. *Orthopedics*. 2012;35: e1383-e1388.

21. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med*. 2009;6:e1000100.

22. 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;7:207-211.

23. 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.

24. Matsumoto F, Trudel G, Uhthoff HK, Backman DS. Mechanical effects of immobilization on the Achilles' tendon. *Arch Phys Med Rehabil*. 2003;84:662-667.

25. 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;79:1799-1808.

26. Möller M, Movin T, Granhed H, Link K, Faxen E, Karlsson J. Acute rupture of tendon Achilles: a prospective randomised study of comparison between surgical and non-surgical treatment. *J Bone Joint Surg Br*. 2001;83:843-848.

27. 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;81:983-990.

28. Nilsson-Helander K, Silbernagel KG, Thomeé R, et al. Acute Achilles tendon rupture: a randomized, controlled study comparing surgical and nonsurgical treatments using validated outcome measures. *Am J Sports Med*. 2010;38(11):2186-2193.

29. Nilsson-Helander K, Thomeé R, Silbernagel KG, et al. The Achilles Tendon Total Rupture Score (ATRS): development and validation. *Am J Sports Med*. 2007;35:421-426.

30. 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-B:206-209.

31. Silbernagel KG, Nilsson-Helander K, Thomeé R, Eriksson BI, Karlsson J. A new measurement of heel-rise endurance with the ability to detect functional deficits in patients with Achilles tendon rupture. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(2):258-264.

32. Silbernagel KG, Steele R, Manal K. Deficits in heel-rise height and Achilles tendon elongation occur in patients recovering from an Achilles tendon rupture. *Am J Sports Med*. 2012;40:1564-1571.

33. Soroceanu A, Sidhwa F, Aarabi S, Kaufman A, Glazebrookl M. Surgical versus nonsurgical treatment of acute Achilles tendon rupture: a meta-analysis of randomized trials. *J Bone Joint Surg Am*. 2012;94: 2136-2143.

34. Stewart LA, Clarke M, Rovers M, et al. Preferred Reporting Items for Systematic Review and Meta-Analyses of individual participant data: the PRISMA-IPD Statement. *JAMA*. 2015;313:1657-1665.

35. Strickland JW. The scientific basis for advances in flexor tendon surgery. *J Hand Ther*. 2005;18:94-110.

36. Suchak AA, Bostick GP, Beaupre 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(9):1876-1883.

37. Thermann H, Hufner T, Tscherne H. Achilles tendon rupture. *Orthopäde*. 2000;29:235-250.

38. Twaddle BC, Poon P. Early motion for Achilles tendon ruptures: is surgery important? A randomized, prospective study. *Am J Sports Med*. 2007;35:2033-2038.

39. Valkering KP, Aufwerber S, Ranuccio F, Lunini E, Edman G, Ackermann PW. Functional weight-bearing mobilization after Achilles tendon rupture enhances early healing response: a single-blinded randomized controlled trial. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:1807-1816.

40. Wu Y, Lin L, Li H, et al. Is surgical intervention more effective than nonsurgical treatment for acute Achilles tendon rupture? A systematic review of overlapping meta-analyses. *Int J Surg*. 2016;36:305-311.

41. Young SW, Patel A, Zhu M, et al. Weight-bearing in the nonoperative treatment of acute Achilles tendon ruptures: a randomized controlled trial. *J Bone Joint Surg Am*. 2014;96(13):1073-1079.