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No difference in Achilles Tendon Resting Angle, Patient-reported outcome or Heel-rise height Index between Non- and Early-weightbearing the First Year after an Achilles Tendon Rupture

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SUMMARY

Background. Patient-reported outcome scores and comparable re-rupture rates in randomized controlled trials have not shown a definitive benefit for operative treatment after acute Achilles tendon rupture. This, together with the increasing rupture rates in the older age group has led to non-operative treatment being increasingly used.

Objective. This study aimed to determine the variation in Achilles Tendon Resting Angle (ATRA) together with patient reported and functional outcome, with non-operative management of the ruptured Achilles tendon using two different regimes, which have been shown to offer low re-rupture rates.

Methods. This is a non-randomised cohort comparison of Achilles tendon rupture patients managed with Non-Weight-Bearing (NWB) for 6 weeks *vs*. Early Weight-Bearing (EWB). The NWB-group received a cast in plantar flexion for 2 weeks followed by 6 weeks in a controlled ankle motion boot with incremental diminishing plantar flexion. The EWB-group received an initial anterior protective plaster slab in plantar flexion followed by 6 weeks of weight-bearing on the meta-tarsal heads, with an anterior shell restricting dorsiflexion.

Results. At 12 months after the injury there were no differences in any of the variables between the two treatment groups. The NWB-group compared to the EWB-group reported at mean (SD) for ATRA -9.8° (4.6°) *versus* -11.4° (5°), p=0.32, for Achilles tendon Total Rupture Score (ATRS) 87 (10) *versus* 79 (19), p=0.43 and for Heel-Rise Height Index (HRHI) 71% (19%) *versus* 59% (13%), p=0.13.

Conclusions. The two methods of non-operative treatment studied lead to increased relative ATRA following injury, however, patients report only minor limitation in terms of outcome. Patients had almost a third less heel-rise height compared with the non-injured ankle.

KEY WORDS

Achilles tendon rupture; non-operative management; patient choice; Achilles tendon resting angle; heel-rise height; weight bearing.

BACKGROUND

Following an Achilles tendon rupture, patients suffer up to 10-30% of calf weakness (1-3). This is manifest as reduced heel-rise height (3), decreased ankle plantar flexion strength 3 and push off during gait (4).

Despite the reports about operative treatment is leading to less strength deficits (5-8) and tendon elongation (8), non-operative treatment after an Achilles tendon rupture has increased (9). A reason for this may be the lack of superiority in terms of Patient Reported Outcome Measures (PROMS) for operative treatment in randomized controlled

trials. Non-operative treatment may be considered to be the current evidence-based guideline following acute Achilles tendon rupture (9) although in mainland Europe there is a trend towards individualized patient treatment as per the ISMuLT Achilles tendon guidelines (10).

A wide variety of non-operative treatments have been used, with different duration, cast or bracing techniques, weight-bearing and early functional movement (10, 11). Weight-bearing compared with non-weight-bearing during rehabilitation leads to higher health-related quality of life without reduction in Achilles specific outcome scores (12).

Low re-rupture rates of 1.1%-2.9% have in some studies been reported for Achilles tendon rupture managed non-operatively (13, 14) with protected weight-bearing in a brace for up to 4 months. Using a full below knee weight-bearing plantar flexion cast for 6 weeks followed by 6 weeks in a boot with reducing wedges showed satisfactory functional outcomes and low re-rupture rate (15). As early functional rehabilitation is adopted more commonly, it is important to avoid tendon elongation to optimize functional outcome (3). However, the 12-month functional outcome of commonly adopted non-operative rehabilitation regimes is not known (13, 14).

Recent, biomechanical studies of ankle position and tendon end apposition using casts and functional braces have shown that the frequently used walker boot with wedges does not provide plantar flexion at the ankle but at the mid-foot instead (16). The use of a cast in maximal *equinus* has been recommended to appose tendon ends of a simulated ruptured tendon (16). Post-operative regimes have used an anterior shell to restrict dorsiflexion together with heel wedges have been extended to non-operative regimes giving excellent or good outcome. Nevertheless, patients were noted to have increased passive dorsiflexion, which correlated with reduced vertical force output during gait analysis.

The Achilles Tendon Resting Angle (ATRA) has been shown to be a valid measure of ankle position (17, 18); it correlates with Achilles tendon length (19) and independently found to have excellent reliability (ICC ≥ 0.75) (20). The ATRA is increased following rupture, is decreased by operative repair and then increases again to approximately that of the non-injured side at 6 weeks after weight-bearing using a functional brace to prevent dorsiflexion. After the brace is removed the ATRA increases into dorsiflexion (17).

This study aimed to determine the variation in ATRA together with patient reported and functional outcomes between two different non-operative regimes for patients at different time points during the first 12 months after their Achilles tendon rupture. It was hypothesised there would be no difference in any variable between the two treatment groups.

MATERIALS AND METHODS

This is a non-randomized cohort comparison study between two non-operative rehabilitation regimes. Observational analysis of the outcome of patients who declined enrolment has also been performed. All patients consented for inclusion in the study and National Research Ethics Service The study received Research and Ethical Committee Approval (IRAS Number 15-WA-0058). The study meets the ethical standards of the journal (21).

Non-Weight Bearing (NWB) group

Between 2013 and 2018, 29 patients were approached for inclusion in the study (**figure 1**). All patients demonstrated the triad of a palpable gap, the absence of plantar flexion with the calf squeeze test and increased dorsiflexion of the ankle on resting.

This left a study group of 24 patients who were managed similarly to a non-operative protocol described by Wallace *et al*. (13) (**figure 2**). Following diagnosis in the Emergency department, the patient was immobilised in a plaster back slab in full plantar flexion. The diagnosis was confirmed by clinical examination in fracture clinic, within 1-2 days, and the back slab was changed to a full cast in full plantar flexion and the patient was referred to a Specialist Achilles tendon clinic. At 2-4 weeks following rupture the cast was changed to a functional brace, with a Controlled Ankle Motion (CAM) hinge brace (**figure 3 a**).

The CAM brace application was performed using a standard method as per the user instructions. The liner was applied around the calf so that the heel pad was directly beneath the heel. The lateral and medial malleoli were palpated through the liner to determine the axis of the ankle joint. The graduated hinge of the CAM brace was centred at the tip of the lateral malleolus. The leg arm of the brace was placed along the shaft of the fibula aiming for the head of the fibula proximally. The liner was then wrapped and secured around the ankle and the two straps tightened and secured to plantar flex the ankle to the pre-determined hinge angle.

The brace, worn 24 hours a day, was initially positioned at 30° of plantar flexion for 2 weeks, then adjusted to 15° plantar flexion for 2 weeks and finally at plantigrade/neutral for a final two weeks. The patient was non-weight-bearing for 6 weeks. At the 6-week time-point, when the ankle was plantigrade in the brace weight-bearing was permitted. Low molecular heparin thromboprophylaxis was prescribed for the first 6 weeks. The brace was discontinued after 8 weeks and the patient referred to the physical therapist.

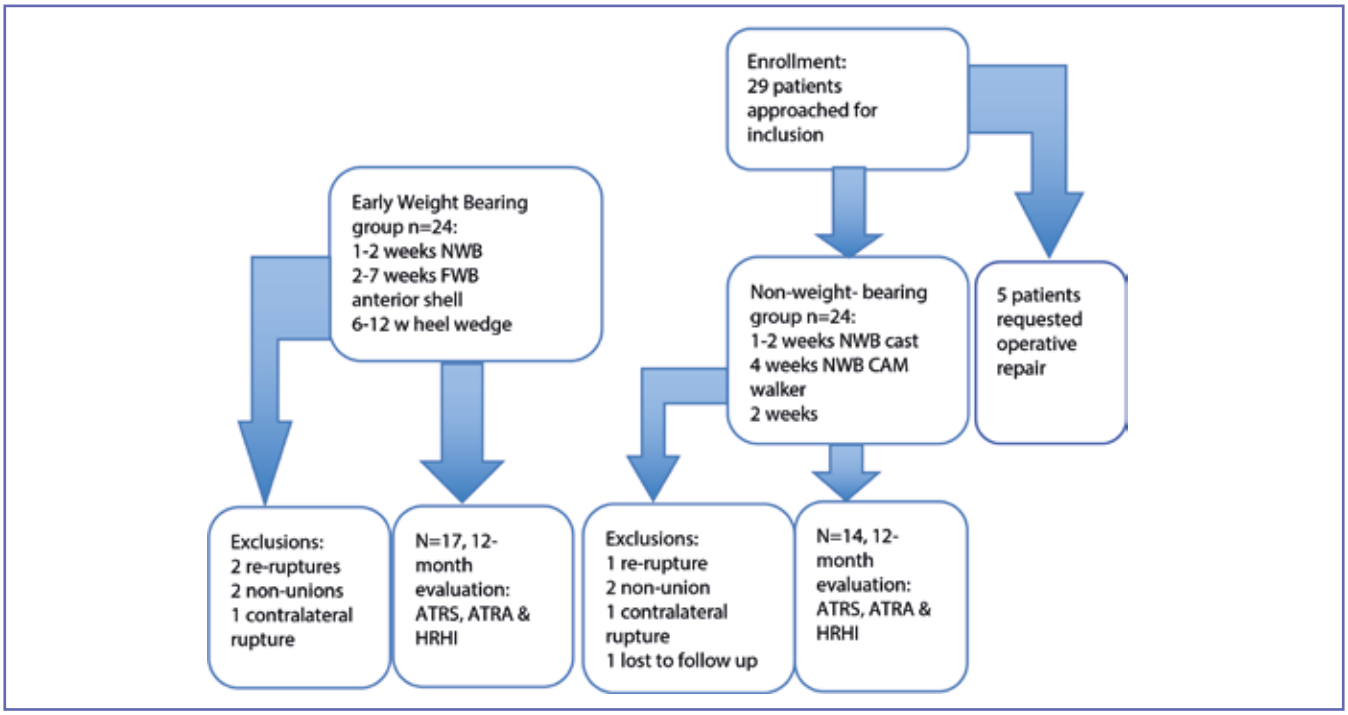

Figure 1. Flow chart for the study.

Early Weight-Bearing (EWB) Regime

0-2 weeks- Emergency Department-placed NWB & below knee anterior plaster slab in full plantar flexion applied.
Fracture clinic-NWB and below knee anterior plaster slab in maximal plantar flexion, referral to Specialist Achilles clinic

2 weeks- diagnosis confirmed and full synthetic reinforced below knee cast, applied, split & supported with velcro straps, WB as tolerated using crutches on meta-tarsal heads only

4 weeks- back shell removed, continue FWB with crutches protected by anterior shell & velcro straps

7 weeks- anterior shell removed, physio referral and 1.5cm in shoe heel wedge to be worn for all WB until 3 months

Non-Weight-Bearing (NWB) Regime

0-2 weeks- Emergency Department-placed NWB & below knee anterior plaster slab in full plantar flexion applied, Fracture clinic- full NWB maximal plantar flexion cast

2 weeks- Controlled Ankle Motion (CAM) walker blocked at 30˚, NWB

4 weeks- CAM walker blocked at 15˚, NWB

6 weeks- CAM walker adjusted to neutral & WB

8 weeks- CAM walker removed and physio referral

Figure 2. The rehabilitation protocols used in the NWB and EWB groups.

Figure 3. Figure 3 a (left) and 3 b (right) showing the Non-Weight-Bearing and Early-Weight-Bearing regimes.

Early weight-bearing (EWB) group

Twenty patients, who were included in the EWB group after discussion of the benefits and risk of operative treatment, chose non-operative treatment with accelerated rehabilitation (**figures 1, 2**). Following diagnosis at the Emergency Department, the lower leg was placed into a back slab in full plantar flexion and referred to fracture clinic. In the fracture clinic the ankle placed into a synthetic cast in full plantar flexion. The cast was split and secured with 4 circumferential elasticated velcro straps. Weight-bearing was permitted as tolerated on the meta-tarsal heads only and the patients advised to use crutches for all mobilisation. After 2 weeks, the posterior half of the cast was removed and the plantar flexed anterior shell held in position using the straps (**figure 3 b**). Early active movement exercises consisting of plantar flexion, inversion and eversion contractions of 10 s duration performed for 10 repetitions, 3 times per day were commenced. This regime was similar to the post-operative rehabilitation following percutaneous and minimally-invasive repair (17).

The anterior shell was discontinued after 7 weeks of management and patients were permitted to load on the heel whilst using a 1.5 cm in-shoe heel wedge until 3 months. Referral for formal physiotherapy occurred at the 7-8-week time point consisting of gait retraining and strengthening with double heel rises progressing to single heel rises. Stretching and plyometric exercises were avoided until the 3-month time-point.

Outcome evaluation

Patients were reviewed at 6 weeks, 8 weeks and 3, 6, 9 and 12 months after the injury. Symptoms and function were evaluated using the Achilles tendon Total Rupture Score (ATRS) (17).

Patients were examined for palpable tendon gaps and tendon continuity using a calf squeeze test. For calculations the relative ATRA was used. This is the difference between the ATRA of the injured and the non-injured sides. A relative dorsiflexed angle is expressed as being negative and plantar flexion as positive. A maximal single-leg Heel Rise Height (HRH), (17) was compared with the non-affected side at 6, 9, and 12 months respectively. Fingertip contact with the wall was permitted for balance. Limb Symmetry producing a Heel Rise Height Index (HRHI) was calculated as the maximal height of a single heel rise on the injured side/the maximal height of a single heel rise on the uninjured side x 100, presented as percent.

Statistical analysis

All data were analysed using IBM SPSS Statistics Version 26 (IBM Corp, Armonk NY). All patients who met the inclusion criteria at the two different hospitals between 2013 and 2018 were offered to participate in the study. Therefore, no sample size calculation was performed. Descriptive statistics for ATRS were reported using mean ± Standard Devia-

tion (SD) and median (range). A patient-reported outcome of > 80 points using the ATRS was considered to be good. Normality was tested by Shapiro Wilks test. For comparison between groups, Mann Whitney-U test was used. A level of significance was set at $p < 0.05$.

Patients who suffered a major complication, which may influence the ATRS, ATRA and HRHI evaluations, *e.g.* those sustaining a re-rupture and/or required reconstruction surgery for non-union or healing with gaping were excluded from 3- to 12-month evaluation. Patients were also excluded if they had previously sustained a contra-lateral Achilles tendon rupture.

RESULTS

Patients were enrolled between 2013 and 2018 from Princess Royal Hospital and Royal Shrewsbury Hospital, illustrated in flow chart (**figure 1**). The overall number of patients studied was 44, with 20 in the NWB and 19 in the EWB groups. The demographic details of these patients are shown in **table I**.

Complications of management sustained by the patients are shown in **table II**. Two patients sustained neuropraxia of the deep peroneal nerve relating to cast and brace compression. Both recovered with time. One patient sustained soft tissue infection consisting of cellulitis following a cast sore requiring oral antibiotic treatment. Elongation was considered to be a relative ATRA of more than ≥ 12° at 12-month evaluation, an angle considered to be consistent with an acutely ruptured Achilles tendon (17).

There were no differences in the relative ATRA at 12 months between the groups (mean (SD)) ATRA NWB -9.8° (4.6°) and EWB -11.4° (5°) (p=0.3). There was a difference in relative ATRA at the 6-week time-point (p=0.03) between the NWB and EWB groups although no difference in any other outcome measures between the non-operatively managed groups (**figure 4-6** and **table III**).

At 12 months following rupture, NWB and EWB patients reported an ATRS of mean (SD) 87.4 (10) and 79.2 (19), (p=0.43) (**figure 5**) and the HRHI was at mean (SD) 71 (19.4)% and 59 (13)% (p=0.13) for the groups respectively (**figure 6**).

Table I. Group Demographics.

	NWB (n=20)	EWB (n=19)
Age Mean (SD) Min-max	 55 (15) (29-77)	 55(14) (29-81)
Left:Right	9:11	6:13
Male:Female	3:1	2.1:1
Tegner	6 (6-8)	7 (3-7)

Table II. Complications of management.

Complication N (%)	NWB (n=20)	EWB (n=19)
Re-rupture	1 (5%)	2 (11%)
Non-union	2 (10%)	1 (5%)
Nerve injury	1 (5%)	1 (5%)
DVT	1 (5%)	1 (5%)
Infection	0 (0%)	1 (5%)
Elongation	4 (20%)	4 (21%)

NWB = Non-Weight-Bearing, EWB = Early-Weight-Bearing, DVT = Deep Venous Thrombosis.

Table III. Differences in ATRA, ATRS and HRHI 6 and 12 months after the injury between the NWB- and EWB-groups.

	NWB mean (SD)	EWB Mean (SD)	Mean difference	95% CI	P value
ATRA 6 m (°) (n=16/19)	-12.5 (6.1)	-10.7 (8)	1.8	-2-7	0.30
ATRA 12 m (°) (n=12/14)	-9.8 (4.6)	-11.4 (5.0)	-1.6	-5-1	0.32
ATRS 6 m (points) (n=16/19)	70.3 (17)	64.6 (23)	-5.7	-22-12	0.43
ATRS 12 m (points) (n=17/14)	87.4 (10)	79.2 (19)	-8.2	-21-5	0.43
HRHI 6 m (%) (n=11/17)	54 (21)	51 (27)	-3	-22-17	0.80
HRHI 12 m (%) (n=11/13)	71 (19)	59 (13)	-12	-27-2	0.13

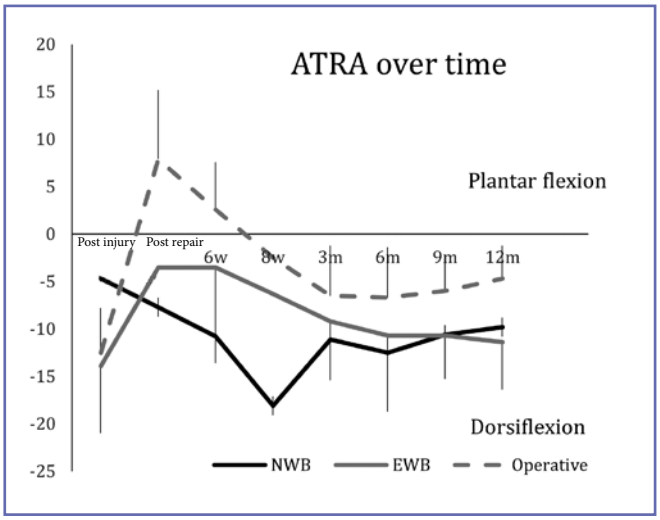

Figure 4. The change in Relative Achilles Tendon Resting Angle over time for NWB and EWB groups with negative error bars. The operative data in this figure is included for visual comparison and shows the post-operative variation in ATRA from a historical cohort of patients managed using minimally-invasive repair and a post-operative regime identical to the EWB cohort (17).

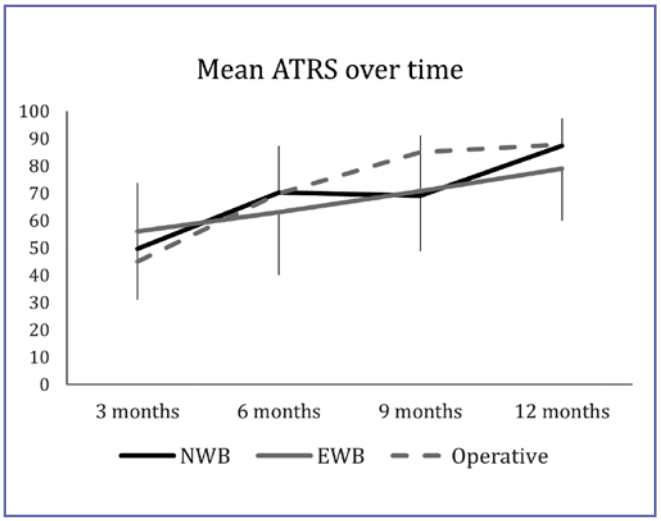

Figure 5. The Achilles tendon Total Rupture Score increasing (ATRS) over time in the patients evaluated. The Operative data in this figure is included for visual comparison (17). Positive error bars are shown for NWB and a comparison operative regime, negative error bars for the EWB regime.

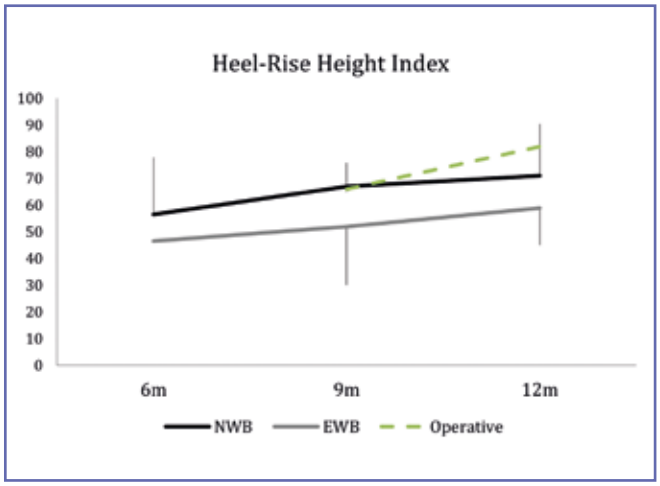

Figure 6. HRHI over time over time in the patients evaluated. The Operative data in this figure is included for visual comparison (17). Positive error bars are shown for NWB and a comparison operative regime, negative error bars for the EWB regime.

DISCUSSION

The most important finding of this study of non-operative management of Achilles tendon rupture was that there was no difference in NWB and EWB for any of the outcome measures studied. In these cohorts managed non-operatively, there was considerable reduction in heel-rise height compared with the non-injured leg although both groups reported an ATRS of ≥ 79 points at 12 months following injury.

At 3 months following rupture in patients managed using both non-operative regimes the relative ATRA had increased to approximately -12°, a value similar to the relative ATRA immediately after the injury. In the NWB group, the ATRA in the injured limb decreased over the period of non-weight bearing, and increased when the plantar flexion angle of the controlled ankle motion brace was changed in the brace and increased further during the subsequent two weeks when weight-bearing was permitted. In the EWB group, the ATRA increased despite restriction of dorsiflexion with the anterior shell, and increased further during heel weight-bearing in the 1.5 cm heel wedge. In the 6 weeks of non-operative management, neither brace nor rehabilitation program prevented a subsequent increase in ATRA with weight-bearing and patients had a considerable reduction in heel-rise height at the 12-month time-point.

The observed changes in ATRA in patients managed non-operatively with the EWB regime were different compared with the historical cohort receiving minimally-invasive repair with similar rehabilitation (17). This historical group had a similar elongation pattern as previous series of patients following percutaneous and minimally invasive repair using the same rehabilitation regime (17). Following

the tightening of the tendon during surgical repair, elongation occurred with immediate weight-bearing in the functional brace, but to only that of the non-injured side. During this time the ATRA increased, but not to the extent of the ATRA following injury.

In the NWB- EWB- and historical, surgically treated, cohort groups, once initial elongation had occurred, the relative ATRA tended to decrease over time, however, this was not significant, similar to other studies on tendon length (22). The elongation findings are similar to Eliasson *et al.*'s study (22) with changes in tendon length with elongation occurring during the period of strengthening during the first 6 months following rupture. In their study there was no effect of weight-bearing nor movement during the first 7 weeks following operative repair (22).

Recent series of patients with Achilles tendon rupture managed non-operatively have used periods of brace protection for much longer than those used in this series (13, 14). In Hutchison *et al.*'s study, patients were immobilised in a cast for 2 weeks followed by an additional 7 weeks using a Vacoped boot. At 9 months, 43 out of 273 patients were evaluated and had a mean (SD) ATRS of 72.4 (14) together with an Achilles tendon repair score of mean (SD) 72.3 (13) indicating that heel-rise height was less than the non-injured side at this time point (13). In Ecker *et al.*'s non weight-bearing protocol using full weight-bearing and cast immobilization over a 3-month time period, 76% of patients performed ≥ 75% repetitive single heel rises compared with the uninjured side after 27 months of follow up (15). Ninety-five percent of patients had ≤ 10° difference in resting plantar flexor angle. The Leicester Achilles rupture Management Protocol (24) involves immediate weight-bearing with graduated dynamic plantar flexion using a Vacoped boot for 8 weeks, and a mean ATRS of 75.5 with a functional outcome in terms of HRHI of 77.2% (Heel-Rise Height (HRH) of 8.5 *vs.* 10.1 cm) at 12 months or more follow-up 50. Taken together, there is still no consensus neither for the optimal time being immobilized after an Achilles tendon rupture nor when it is the best time to start to weight bear in order to receive the best possible functional outcome.

Maffulli *et al.* (25) placed patients in a synthetic plantar flexed cast or brace with wedges for a combined duration of 11 weeks following the minimally-invasive repair of acute (< 14 days) and delayed Achilles tendon rupture (14-30 days) (n=21 per group). The repair consisted of a modified Bunnell and Kessler suture using an absorbable suture, with immediate post-operative weight bearing on the metatarsal heads similar to the method previously described by Carmont *et al.* (17) represented in **figure 4-6**. Despite the longer period of immobilization in the brace, the ATRA at 12 months following repair was similar in both acute (-3.9°(2)) and delayed (-3.7 (1.9)) groups to the historical group (-4.7° (6.5)) and re-rupture did not occur in either group (25). This may indicate the importance of brace protection to reduce the re-rupture rate.

Strengths of the present study were that all patients were assessed by the same observer leading to no inter-assessor bias. Limitations of this study include the small number of patients per group although the number is similar to other studies looking at ATRA over time. In common with other studies of regimes including non-weight-bearing without weight sensors it can never be known how compliant patients have been. Additionally, there was a loss to follow-up over time for patients in both groups. Other limitations include the inability to determine ATRA within the first two weeks of injury in the NWB patients, which was due to the time limitations of referrals. The ATRA at initial referral was negative indicating that the patients had ankles that were in relative dorsiflexion (-5.4°) at this time point. This was, however, within ≤ 10° of the non-injured side, the criteria used for non-operative treatment in the study by Ecker *et al.* (15). Another limitation of this study is that ultrasonography was not available to determine the location of tendon tears or to assess tendon continuity or tendon length during follow-up.

Beyond the 8-week time-point patients received departmental physiotherapy with advice to restore gait, and strengthening exercises to the calf in the form of double heel rises to single heel rises. Stretching and plyometric exercises were to be avoided until beyond the 3-month time point. The physiotherapy received by each individual patient was not standardized and will be gauged upon individual progress. In the literature, a number of rehabilitation programs have been presented, but there is no consensus.

Taken together, this study has shown that these two methods of non-operative treatment lead to increased ATRA compared with that of the un-injured ankle. However, patients report little limitation on outcome but there was more calf weakness compared with other studies (17, 22). One possible explanation can be that functional braces that restrict dorsiflexion and maintain the resting angle of the ankle more effectively were used in these studies.

The two methods of non-operative treatment studied lead to increased ATRA following injury. However, patients report little limitation in terms of outcome. Patients had almost a third less calf muscle performance compared with the non-injured ankle one year after the injury. This considerable reduced calf muscle performance should be discussed with patients when counseling between non-operative and operative treatment options.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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