ORIGINAL ARTICLE

Passive Stretching Does Not Enhance Outcomes in Patients With Plantarflexion Contracture After Cast Immobilization for Ankle Fracture: A Randomized Controlled Trial

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ABSTRACT. Moseley AM, Herbert RD, Nightingale EJ, Taylor DA, Evans TM, Robertson GJ, Gupta SK, Penn J. Passive stretching does not enhance outcomes in patients with plantarflexion contracture after cast immobilization for ankle fracture: a randomized controlled trial. Arch Phys Med Rehabil 2005;86:1118-26.

Objective: To compare the efficacy of short- and long-duration passive stretches with a control treatment for the management of plantarflexion contracture after cast immobilization for ankle fracture.

Design: Assessor-blinded, randomized controlled trial.

Setting: Hospital physical therapy outpatient departments.

Participants: Adults with plantarflexion contracture (N=150) after cast immobilization for ankle fracture. All subjects were weight bearing or partial weight bearing.

Interventions: Exercise only, exercise plus short-duration passive stretch, and exercise plus long-duration passive stretch. All subjects had a 4-week course of exercises. In addition, subjects in the short-duration stretch plus exercise group completed 6 minutes of stretching per day, and subjects in the long-duration stretch plus exercise group completed 30 minutes of stretching per day.

Main Outcome Measures: Lower Extremity Functional Scale and passive dorsiflexion range of motion with the knee bent and straight at baseline, and at 4 weeks and 3 months postintervention.

Results: One hundred thirty-nine (93%) subjects completed the 4-week assessment and 134 (89%) subjects completed the 3-month assessment. There were no statistically significant or clinically important between-group differences for the primary outcomes.

Conclusions: The addition of passive stretching confers no benefit over exercise alone for the treatment of plantarflexion contracture after cast immobilization for ankle fracture.

Key Words: Ankle injuries; Fractures; Physical therapy techniques; Randomized controlled trials; Rehabilitation.

ANKLE FRACTURES (ie, fractures of the distal tibia or fibula) are common. People at highest risk of ankle fracture are young men and, to a lesser extent, older women.[1,2] The incidence of ankle fractures in the United Kingdom per 10,000 population per annum is estimated to be 13 to 28 for young men and 16 to 20 for older women.[1,2] Orthopedic management depends on the severity of the fracture but generally involves immobilization of the ankle in a cast, in many cases after surgical fixation.[3] Cast immobilization usually lasts from 3 to 6 weeks.[3] When the cast is removed, many patients have plantarflexion contracture (ie, loss of dorsiflexion, increased stiffness).[4,5] The prevalence of plantarflexion contracture has been estimated at 77% immediately after cast removal[4] and at 22% 2 years after removal.[5]

Contracture is not caused directly by fracture but develops as an adaptive response to immobilization. Studies with animals indicate that when joints are immobilized, muscles become short[6] and lose sarcomeres in series,[7] intramuscular connective tissue undergoes morphologic changes,[8] tendons shorten,[9] and periarticular connective tissues become inextensible.[10] It is likely that similar adaptations produce contracture after cast immobilization for ankle fracture in humans. After injury, tissue repair processes may also influence the mechanical properties of soft tissues.[11]

When tissues are stretched, they become more extensible as the result of both short-term mechanical mechanisms[12] and longer-term adaptations of tissue structure.[7] Adaptations of tissue structure are required to make lasting differences to joint flexibility.[13] It is not clear how much stretching is required to induce clinically worthwhile adaptations. In physical therapy (PT) practice, passive stretches are usually applied for less than 15 minutes.[14] Sometimes longer duration stretches are used (eg, standing on a wedge for 30min to stretch calf muscles).[15] In the case of extreme contracture, a continuous stretch can be applied by using a cast.[16]

The effects of stretching have been investigated in 1 systematic review[17] and a modest number of randomized controlled trials (RCTs), but the results of these trials are not conclusive. The systematic review[17] concluded that passive stretching produced a lasting increase in range of motion (ROM) in able-bodied subjects with less than normal joint range. We identified 19 randomized or pseudorandomized controlled trials that evaluated stretching for people with a pathologic condition with contracture (eg, ankle fracture).[16,18-35] These studies provide inconsistent evidence of clinically worthwhile effects of some interventions. Eight trials performed head-to-head comparisons of different stretching protocols in subjects with pathologic conditions with contracture.[22,26,28,29,32,34,35] These provide

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conflicting evidence of the superiority of long-duration stretches over short-duration stretches for treatment of contracture.[28,32,34] The quality of the trials was generally poor: the median PEDro score (a score of methodologic quality)[36] for the randomized trials was 4 out of 10.

Physical therapists are currently basing decisions about treatment of contracture on limited, poor quality, and inconsistent experimental evidence. The purpose of this RCT was to compare the efficacy of 2 stretching treatments (short- and long-duration stretches) and a control treatment (exercise only) for the management of plantarflexion contracture after ankle fracture. The experimental hypotheses were that the addition of stretching would produce better outcomes than would exercise only and that long-duration stretches would be superior to stretches of short duration. A secondary purpose was to determine if any effects of treatment are influenced by fracture severity.

METHODS

Participants

Subjects were recruited from the plaster clinics of 2 large teaching hospitals (Royal North Shore Hospital and Royal Prince Alfred Hospital, Sydney, Australia). All patients referred to the outpatient PT service who met the following criteria were invited to participate: (1) ankle fracture treated with cast immobilization (with or without surgical fixation), (2) cast removed in preceding 5 days, (3) approval received from orthopedic specialist to weight-bear as tolerated or partial weight-bear, (4) reduced passive dorsiflexion motion (at least 5° less than the contralateral ankle),[37] (5) completed skeletal growth (no evidence of tibial epiphyseal cartilage in radiographs taken for fracture management), and (6) no concurrent pathologies (eg, symptomatic osteoarthritis, stroke, other fractures) that affect the ability to perform everyday tasks or the measurement procedures used in this study.

Subjects were randomly allocated into 1 of 3 groups—exercise only, exercise plus short-duration passive stretches, and exercise plus long-duration passive stretches—using a procedure that was stratified and blocked by site. The randomization sequence was concealed by using consecutively numbered, sealed, opaque envelopes.

Subjects provided informed consent to participate. The trial adhered to principles of the Declaration of Helsinki. The study was approved by the relevant institutional ethics committees (University of Sydney Human Research Ethics Committee, the Northern Sydney Health Human Research Ethics Committee, and the Central Sydney Area Health Service ethics review committee).

Interventions

Subjects attended up to 5 treatment sessions with a registered physical therapist and completed a 4-week home exercise program. Treatment involved prescription, instruction, monitoring, and progression of an exercise program and (for the stretch groups) monitoring and progression of a stretching program. Subjects were encouraged to perform carefully structured programs of exercise and to stretch at home between PT appointments.

Three types of exercises were prescribed for all groups: ankle mobility and strengthening exercises, stepping exercises, and exercises involving weight bearing and balancing on the affected leg. Subjects were instructed to complete 30 repetitions of each exercise every day. Subjects in the exercise plus short-duration stretch group were also instructed to stretch for 6 minutes every day (twelve 30-second stretches; initially these could be applied in a non–weight-bearing position, with progression to standing as tolerated). This stretch duration was selected because it reflected typical current practice.[14] Subjects in the exercise plus long-duration stretch group were instructed to stretch for 30 minutes every day. Initially, the long-duration stretch could be subdivided into shorter periods totaling 30 minutes but then progressed to 30 continuous minutes, as tolerated. The long-duration stretches were applied by standing with the affected foot on a wedge with the back against a wall[15] or, if weight bearing was not tolerated, in the sitting position. The slope of the wedge and the weight borne through the leg were adjusted so that the subject felt a comfortable stretch in the ankle or calf muscles. Both the slope and the weight were progressed throughout the course of treatment. A 30-minute stretch duration was selected because it was considered the longest duration of weight-bearing stretch that subjects with contracture after ankle fracture would tolerate. Exercise cards were used to standardize the exercises and stretches. Subjects completed exercise diaries that were analyzed to ascertain compliance.

All subjects received gait training and advice. If necessary, subjects could use ice for pain relief and compression and elevation for management of swelling. No other PT treatments were administered during the 4-week experimental period. Because this was a pragmatic trial, treatment during the follow-up period was not controlled.

Outcomes

Baseline data obtained before randomization included subject characteristics and injury details (cause of injury, ankle fractured, need for surgical fixation, angle and duration of cast immobilization, other concurrent injuries). Fracture severity was measured by using the Weber ankle fracture classification[38] and the Arbetsgemeinschaft für Osteosythgesefragen Association for the Study of Internal Fixation (AOSIF)[39] scales. In the spirit of intention-to-treat (ITT) analysis, outcomes of all randomized subjects were reassessed at 4 weeks and 3 months, insofar as that was possible, regardless of subjects' compliance with the experimental protocols.

Primary outcomes. The 3 primary outcomes were: (1) perceived disability, (2) passive dorsiflexion ROM with the knee bent, and (3) passive dorsiflexion ROM with the knee straight. Perceived disability was assessed by using the Lower Extremity Functional Scale (LEFS),[40] with subjects rating the degree of difficulty in performing 20 different functional activities on a 5-point scale ranging from 0 (extreme difficulty or unable to perform activity) to 4 (no difficulty). This scale has excellent test-retest reliability (intraclass correlation coefficient [ICC]=.94) and construct validity and is more sensitive to change than other scales such as the Medical Outcomes Study 36-Item Short-Form Health Survey.[40]

Passive dorsiflexion ROM was determined by using an instrumented footplate that quantified the relation between passive torque and ankle angle as the ankle was manually rotated through range with the knee bent and straight.[41] Peak dorsiflexion varied between subjects and was defined as the angle where either the heel just commenced to lift off the footplate, or the subject reported a stretching sensation. An exponential equation was fitted to the torque-displacement relationship.[41] The equation took the form $\tau = e^{k\theta + b}$, with τ, the passive torque in newton meters, and θ, the ankle angle in degrees, being the measured variables, k being a stiffness coefficient that reflects the slope of the log passive torque-displacement curve, and b the preload coefficient equal to the log of the passive torque at 0° dorsiflexion. The fit between the raw data and the model was

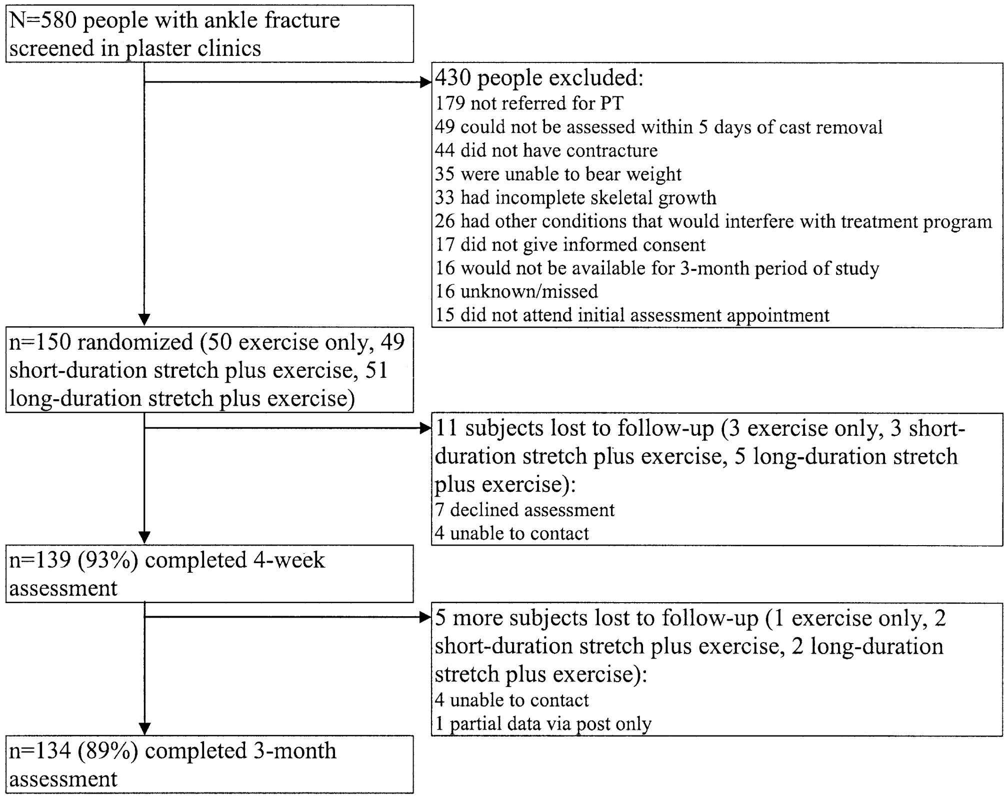

Fig 1. Recruitment and flow of subjects.

excellent (mean r^2=.95; standard deviation [SD], .04). The passive dorsiflexion ROM produced by the peak torque at baseline with the knee bent and straight was calculated by using the coefficients from curve fitting. Measures of passive dorsiflexion range obtained in this way have high test-retest reliability (ICC range, .85–.91).[4]

Secondary outcomes. The secondary outcomes were (1) measures of ankle stiffness (*k*); (2) preload coefficients (*b*); (3) peak ankle dorsiflexion ROM; (4) ankle torque at the peak baseline dorsiflexion angle with the knee bent; (5–8) outcomes (1) to (4) with the knee straight; (9) pain in standing with equal weight distribution; (10) pain during stair descent; (11) return to usual work; (12) return to sport and leisure activities; (13) speed, and (14) step length asymmetry when walking; (15) stepping rate when stair climbing; (16) global perception of effect of treatment; (17) perceived adverse effects of treatment; (18) satisfaction with treatment; and (19) duration of PT treatment.

Pain was measured by using a 10-cm horizontal visual analog scale (VAS) labeled "no pain" and "worst pain I have ever had" at its extremes.[42] Subjects estimated their return to usual work and sport and leisure activities by using a 10-cm VAS labeled "not participating at all" and "returned to full level" at its extremes. Unaided walking speed was measured with a stopwatch on a 10-m walkway, with step length asymmetry measured from video recordings of the feet over the center of the walkway.[43] The standardized stair climbing task for assessing stepping rate was ascending and descending 4 steps 3 times as fast as possible without using the handrails. The global perceived effect of treatment was measured with a 5-point scale that ranges from 1 (completely recovered) to 5 (worsened).[44] Subjects were asked if treatment had any negative effects and, if so, the nature of the effects. At the 4-week assessment only, subjects were asked to rate their satisfaction with treatment using a 10-cm horizontal VAS labeled "physical therapy was completely unsatisfactory" and "physical therapy was best possible" at its extremes.

All measurements were made by assessors who were blind to group allocation. The adequacy of assessor blinding was evaluated by asking the assessor if he/she had been unblinded after each assessment and, for the assessments reported as blinded, guessing the group allocation for the subject.

Sample Size

It was estimated that a sample of 150 subjects (50 in each group) would provide an 80% probability of detecting differences between pairs of group means of 10 points on the LEFS (assuming an SD of 16 points[40]) and 5° in passive dorsiflexion ROM (assuming an SD of 7°). We judged that effects smaller than these were unlikely to be clinically worthwhile. In our calculations we assumed, probably conservatively, a correlation of 0.6 between pre- and posttest measures, an α of .05, a loss to follow-up of 10%, and 20% noncompliance.

Statistical Analyses

Data were coded so that the statistical analysis and interpretation of the results could be conducted blind to allocation. All analyses were by ITT.[45] To test the effects of treatment, between-group differences were examined with analysis of covariance by using a linear regression approach. Separate analyses were performed on 4-week and 3-month follow-up data.

Pretest scores and site of recruitment were entered into the model as covariates. The Kruskal-Wallis test was used for variables with highly skewed distributions. Odds ratios (ORs) were calculated for categoric data.

In a secondary analysis designed to test the influence of fracture severity on treatment response, additional terms (fracture severity, group by fracture severity interaction) were entered into the multiple linear regression model. Two levels of fracture severity were used: less severe (ie, not requiring surgical fixation) and more severe (ie, requiring surgical fixation). The effect of fracture severity on treatment response was determined by examining the interactions between group membership and fracture severity.

RESULTS

Participants

The subject flow is illustrated in figure 1. One hundred thirty-nine subjects (139/150; 93%) completed the 4-week assessment and 134 (134/150; 89%) completed the 3-month assessment.

Subject characteristics and baseline values of primary variables are listed in table 1. There were no clinically important differences between the groups at baseline for any of the variables listed in table 1, although there were more right-sided fractures in the short duration stretch group than in the exercise only group.

Compliance With the Trial Protocol

Compliance with the 4-week exercise and stretching programs was excellent. Attendance by the 139 subjects who completed the 4-week outcome assessment was between 91% and 94%, on average, for the 3 groups. Subjects from all groups reported completing an average of more than two thirds of the prescribed exercises. The short-duration and long-duration stretch groups reported completing 69.5% and 72.7% of the prescribed stretches, respectively.

Blinding of assessors to group allocation was largely successful. Assessors reported being unblinded in only 12 of the 139 four-week assessments and 6 of the 134 three-month assessments. For the remaining assessments, assessors' guesses at group allocation were no better than chance.

Outcomes

Baseline, end treatment (4-wk), and follow-up (3-mo) data for each treatment group for the 3 primary outcome variables are plotted in figure 2. There were no statistically significant or clinically relevant between-group differences at 4 weeks or 3 months for any of the primary variables (table 2).

Outcomes for secondary outcome variables are listed in table 3, with between-group comparisons listed in table 4. In general, all 3 groups experienced substantial but incomplete recovery over the 3-month follow-up period. With the exception of 3 outcomes, differences between groups were small and not statistically significant. The short-duration stretch group had slightly lower values for the preload coefficient b than the long-duration stretch group with the knee straight only, at 3 months only (P=.017). The long-duration stretch group felt more ready to return to usual sport and leisure activities at 4 weeks than did the short-duration stretch and exercise only groups (P=.03), but not at 3 months; the difference appears to be attributable to a

Table 1: Subject Characteristics and Primary Outcome Variables at Baseline

Characteristics and Variables	Exercise Only (n=50)	Short-Duration Stretch Plus Exercise (n=49)	Long-Duration Stretch Plus Exercise (n=51)
Sex (male/female)	24/26	23/26	24/27
Age (y)	49±15	43±15	47±15
Height (cm)	169±9	168±9	167±9
Mass (kg)	75±14	74±14	78±15
Cause of injury (fall/sport/other)	38/9/3	31/11/7	37/8/6
Ankle fractured (left/right)	36/14	19/30	28/23
Surgical fixation required (yes/no)	33/17	26/23	24/27
Weber rating (A/B/C/missing)	9/30/7/4	11/30/5/3	9/31/3/8
AOSIF rating			
44A1/44A2	8/1	9/2	9/0
44B1/44B2/44B3	16/9/5	12/11/6	20/5/9
44C1/44C2/44C3	2/5/0	1/3/1	2/1/0
43B1/missing	3/1	3/1	1/4
Sustained other injuries (yes/no)	19/31	22/27	21/30
Angle of cast immobilization (deg)	86±7	85±8	86±6
Cast duration (d)	47±17	46±9	42±10
Plantarflexion contracture (deg)	13±9	12±10	13±8
Sedentary work prefracture (yes/no)*	22/28	24/25	24/27
Sedentary sport/leisure activities prefracture (yes/no)*	10/40	12/37	17/34
LEFS score	28±11	29±11	30±13
Dorsiflexion angle at peak baseline torque			
Knee straight (deg)	8.4±5.5	9.9±5.7	9.8±7.2
Knee bent (deg)	12.7±8.2	11.1±6.9	12.1±9.5

NOTE. Counts are given for categoric data and means ± SDs are listed for interval data.
*Subjects were asked to classify their prefracture work and sport and leisure as "sedentary" or "not sedentary" based on the proportion of time that they spent "on their feet."

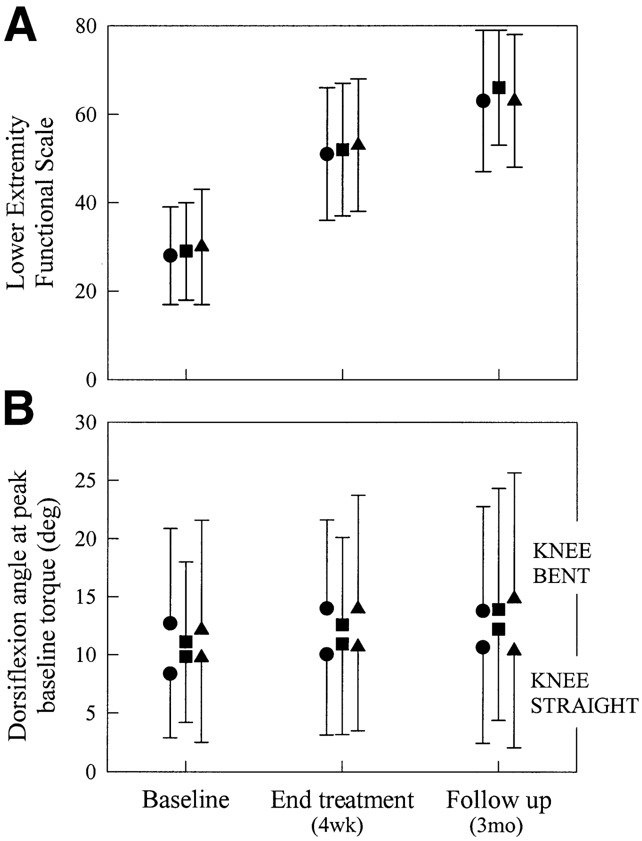

Fig 2. Primary outcomes. Data are means and SDs of (A) LEFS scores (maximal score, 80) and (B) passive dorsiflexion ROM with the knee bent and knee straight at the end of the treatment phase (4wk) and at follow-up (3mo). Legend: ●, exercise only; ■, short-duration stretch plus exercise; ▲, long-duration stretch plus exercise.

baseline imbalance in this variable (P=.02). A greater percentage of subjects in the long-duration stretch plus exercise group (20/44, 45%) were discharged at or by the end of the 4-week experimental treatment period than in the exercise only group (7/46, 15%; OR=1.71; 95% confidence interval [CI], 1.71–12.62; P<.05), but there were no differences for the short-duration stretch group (13/44, 30%). The treating physical therapist determined the timing of discharge based on a subject's plateau in ankle function or a return to prefracture level of function, and some subjects chose to discontinue treatment. Because these are modest effects on a small proportion of secondary variables and the timing of discharge was not assessor-blinded, we do not believe they represent substantial evidence of differential effects of therapy.

Only 4 subjects reported negative effects of PT treatment: 3 reported discomfort with exercise and one with daily activities. Because there were no differences between groups in satisfaction with treatment, the 3 treatment programs were deemed to be of equal credibility.

There were no significant group by fracture severity interactions for any primary variable at 4 weeks or 3 months. For example, the effect for the interaction between the long-duration stretch/exercise only contrast and fracture severity was 1.9 points on the 80-point LEFS (95% CI, −9.8 to 13.6). That is, there was no evidence that fracture severity was associated with the effects of stretch.

DISCUSSION

The principal finding of this trial was that the addition of a program of passive stretches confers no benefit over exercise alone in treating plantarflexion contracture after cast immobilization for ankle fracture. There were no statistically significant or clinically worthwhile differences between the exercise only, short-duration stretch plus exercise, and long-duration stretch plus exercise groups for perceived disability or passive dorsiflexion ROM. This result is consistent with those of previous research, including studies that compared long-duration stretch to no stretch after spinal cord injury,[24,25] or short- and long-duration stretch in nonambulant nursing home residents.[34]

One explanation for this result could be that the prescribed amount of passive stretching was insufficient to produce long-term adaptations of tissue structure.[7] Although that may be true, the long-duration stretch (30min) was sustained as long as could be practically administered on a daily basis. Subject adherence with the exercise and stretching protocols was excellent. A relatively high stretching intensity was used for both stretch groups as subjects were quickly progressed to weight-

Table 2: Effects of Stretch on Primary Outcomes

Variable	Between-Group Differences Mean (95% CI)	
	End Treatment (4wk)	Follow-Up (3mo)
LEFS score		
Exercise only vs short stretch	0.0 (−5.2 to 5.2)	−2.0 (−7.7 to 3.7)
Exercise only vs long stretch	−1.3 (−6.4 to 3.8)	0.9 (−4.7 to 6.6)
Short stretch vs long stretch	−1.3 (−6.4 to 3.8)	3.0 (−2.7 to 8.7)
Dorsiflexion angle at peak baseline torque (knee bent; deg)		
Exercise only vs short stretch	−0.1 (−2.1 to 2.0)	−0.9 (−3.9 to 2.2)
Exercise only vs long stretch	−1.6 (−3.6 to 0.5)	−1.4 (−4.4 to 1.6)
Short stretch vs long stretch	−1.6 (−3.7 to 0.4)	−0.6 (−3.6 to 2.5)
Dorsiflexion angle at peak baseline torque (knee straight; deg)		
Exercise only vs short stretch	0.1 (−2.2 to 2.3)	−0.7 (−3.3 to 1.9)
Exercise only vs long stretch	0.3 (−1.9 to 2.5)	1.3 (−1.3 to 3.9)
Short stretch vs long stretch	0.2 (−2.0 to 2.4)	2.0 (−0.6 to 4.6)

Table 3: Baseline, End of Treatment (4wk), and Follow-Up (3mo) Data for Each Group for the Secondary Outcome Variables

	Baseline			End Treatment			Follow-Up		
Variable	Exercise Only	Short Stretch	Long Stretch	Exercise Only	Short Stretch	Long Stretch	Exercise Only	Short Stretch	Long Stretch
Ankle stiffness coefficient $k \times 10^{-2}$ (knee straight)	8.58±1.94	9.95±2.67	8.57±2.11	7.54±2.15	7.61±2.12	6.94±1.63	6.60±1.85	6.79±1.79	5.99±1.59
Ankle stiffness coefficient $k \times 10^{-2}$ (knee bent)	8.57±2.51	9.01±3.02	9.10±3.20	7.16±2.23	7.72±2.29	7.19±2.41	6.47±2.04	6.93±2.14	6.22±1.95
Ankle preload coefficient *b* (knee straight)	1.55±0.51	1.38±0.54	1.51±0.50	1.45±0.51	1.38±0.57	1.52±0.37	1.46±0.46	1.44±0.39	1.64±0.41
Ankle preload coefficient *b* (knee bent)	1.12±0.63	1.16±0.51	1.20±0.62	1.12±0.46	1.10±0.50	1.11±0.44	1.19±0.40	1.17±0.43	1.21±0.53
Peak dorsiflexion ROM (knee straight; deg)	97.1±5.4	98.1±6.0	98.4±7.6	103.5±6.8	103.2±6.5	103.4±6.0	105.0±6.5	105.9±5.6	104.6±6.3
Peak dorsiflexion ROM (knee bent; deg)	100.4±7.5	98.5±6.5	99.8±9.0	107.5±7.8	105.7±7.2	106.5±7.6	108.1±6.7	108.3±6.5	108.6±7.3
Ankle torque at peak baseline dorsiflexion (knee straight; Nm)	9.23±3.60	8.90±3.20	9.54±3.57	3.52±1.53	3.83±2.14	4.05±2.50	1.79±1.54	1.99±2.39	2.46±2.79
Ankle torque at peak baseline dorsiflexion (knee bent; Nm)	7.46±2.98	7.09±2.75	7.74±3.14	7.38±6.88	6.53±3.56	6.46±2.93	7.66±6.66	6.38±3.56	6.99±3.78
Pain in standing with equal weight distribution (mm)*	6 (0–35)	4 (0–17)	4 (0–37)	0 (0–9)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Pain during stair descent (mm)*	†	†	†	15 (5–39)	8 (0–27)	9 (0–23)	0 (0–19)	0 (0–5)	1 (0–9)
Return to usual work activities (mm)*	39 (14–87)	32 (2–70)	50 (0–82)	95 (58–100)	83 (68–100)	86 (72–100)	100 (93–100)	99 (88–100)	100 (88–100)
Return to usual leisure activities (mm)*	0 (0–4)	1 (0–17)	4 (0–35)	34 (3–63)	32 (7–63)	63 (17–80)	84 (46–94)	78 (56–94)	82 (63–100)
Walking speed (m/s)	0.37±0.31	0.42±0.41	0.38±0.36	1.03±0.39	1.07±0.42	1.01±0.44	1.31±0.41	1.35±0.41	1.25±0.44
Step length asymmetry (cm)	18.22±10.24	17.97±9.91	17.51±8.58	8.94±6.78	7.65±7.19	8.13±7.73	3.81±4.83	3.48±4.03	4.06±5.81
Stepping rate when stair climbing (steps/min)	18.32±20.86	22.66±25.26	17.70±20.74	64.04±32.69	67.94±39.44	60.34±33.56	87.09±35.45	93.62±42.29	81.19±39.51
Global perceived effect of treatment‡	ND	ND	ND						
Completely recovered				1/47	0/46	0/46	10/46	12/44	11/44
Improved a lot				41/47	42/46	44/46	34/46	30/44	32/44
Improved a little				5/47	4/46	2/46	2/46	1/44	1/44
Stayed the same				0/47	0/46	0/46	0/46	0/44	0/44
Worsened				0/47	0/46	0/46	0/46	1/44	0/44
Satisfaction with treatment (mm)	ND	ND	ND	84±20	85±17	87±14	ND	ND	ND

Abbreviation: ND, no data.
NOTE. Means ± SDs are listed for interval data, median (interquartile range) are provided for:
*skewed interval data, and
†Not reported because many subjects required walking aids to descend stairs and therefore experienced little or no pain.
‡counts are given for categoric data.

Table 4: Effects of Stretch on Secondary Outcomes

Variable	Between-Group Differences Mean (95% CI)	
	End Treatment (4wk)	Follow-Up (3mo)
Ankle stiffness coefficient $k \times 10^{-2}$ (knee straight)		
Exercise only vs short stretch	0.08 (−0.6 to 0.7)	−0.05 (−0.6 to 0.5)
Exercise only vs long stretch	0.49 (−0.2 to 1.1)	0.46 (−0.1 to 1.1)
Short stretch vs long stretch	0.41 (−0.2 to 1.1)	0.51 (−0.1 to 1.1)
Ankle stiffness coefficient $k \times 10^{-2}$ (knee bent)		
Exercise only vs short stretch	−0.20 (−0.9 to 0.5)	0.35 (−1.0 to 0.3)
Exercise only vs long stretch	0.44 (−0.2 to 1.1)	0.36 (−0.3 to 1.0)
Short stretch vs long stretch	0.64 (0.0 to 1.3)	0.71 (0.0 to 1.4)
Ankle preload coefficient *b* (knee straight)		
Exercise only vs short stretch	0.04 (−0.15 to 0.24)	0.05 (−0.11 to 0.21)
Exercise only vs long stretch	−0.05 (−0.25 to 0.15)	−0.15 (−0.31 to 0.01)
Short stretch vs long stretch	−0.09 (−0.29 to 0.10)	−0.20 (−0.36 to −0.04)
Ankle preload coefficient *b* (knee bent)		
Exercise only vs short stretch	0.04 (−0.11 to 0.20)	0.07 (−0.10 to 0.23)
Exercise only vs long stretch	0.10 (−0.05 to 0.26)	0.04 (−0.12 to 0.21)
Short stretch vs long stretch	0.06 (−0.10 to 0.22)	−0.02 (−0.19 to 0.14)
Peak dorsiflexion ROM (knee straight; deg)		
Exercise only vs short stretch	0.6 (−1.7 to 2.9)	−1.0 (−3.4 to 1.5)
Exercise only vs long stretch	0.6 (−1.7 to 2.9)	0.4 (−2.1 to 2.9)
Short stretch vs long stretch	−0.1 (−2.3 to 2.2)	1.4 (−1.2 to 3.9)
Peak dorsiflexion ROM (knee bent; deg)		
Exercise only vs short stretch	0.5 (−1.9 to 2.8)	−1.2 (−3.8 to 1.4)
Exercise only vs long stretch	0.2 (−2.1 to 2.5)	−0.9 (−3.5 to 1.7)
Short stretch vs long stretch	−0.3 (−2.6 to 2.0)	0.3 (−2.3 to 2.9)
Ankle torque at peak baseline dorsiflexion (knee straight; Nm)		
Exercise only vs short stretch	−0.07 (−0.21 to 0.07)	0.01 (−0.21 to 0.23)
Exercise only vs long stretch	−0.07 (−0.21 to 0.07)	−0.19 (−0.40 to 0.03)
Short stretch vs long stretch	−0.02 (−0.16 to 0.12)	−0.20 (−0.42 to 0.02)
Ankle torque at peak baseline dorsiflexion (knee bent; Nm)		
Exercise only vs short stretch	0.04 (−0.12 to 0.20)	0.08 (−0.10 to 0.26)
Exercise only vs long stretch	0.13 (−0.03 to 0.29)	0.08 (−0.10 to 0.26)
Short stretch vs long stretch	0.09 (−0.07 to 0.25)	0.00 (−0.18 to 0.18)
Walking speed (m/s)		
Exercise only vs short stretch	−0.03 (−0.20 to 0.13)	−0.04 (−0.21 to 0.12)
Exercise only vs long stretch	0.03 (−0.14 to 0.19)	0.06 (−0.11 to 0.22)
Short stretch vs long stretch	0.06 (−0.10 to 0.23)	0.10 (−0.07 to 0.27)
Step length asymmetry (cm)		
Exercise only vs short stretch	1.29 (−1.63 to 4.22)	0.33 (−1.66 to 2.33)
Exercise only vs long stretch	0.81 (−2.11 to 3.74)	−0.25 (−2.24 to 1.74)
Short stretch vs long stretch	−0.48 (−3.40 to 2.44)	−0.58 (−2.57 to 1.41)
Stepping rate when stair climbing (steps/min)		
Exercise only vs short stretch	−3.9 (−17.9 to 10.1)	−6.5 (−22.1 to 9.0)
Exercise only vs long stretch	3.7 (−10.2 to 17.6)	5.9 (−9.5 to 21.3)
Short stretch vs long stretch	7.6 (−6.4 to 21.6)	12.4 (−3.1 to 27.9)
Satisfaction with treatment (mm)		
Exercise only vs short stretch	−1.2 (−8.3 to 5.9)	ND
Exercise only vs long stretch	−3.2 (−10.4 to 3.9)	
Short stretch vs long stretch	−2.1 (−9.2 to 5.1)	

bearing stretches with their ankle dorsiflexed to the point that they experienced a stretch sensation in their ankle or calf muscle. The weight-bearing exercise prescribed for all groups, along with return to usual daily activities, may therefore have provided the critical stimulus to reduce perceived disability and improve ankle flexibility.

We designed the trial to minimize bias by using random allocation to groups, concealment of the allocation schedule, and blinded outcome assessment. Importantly, the sample size of 150 subjects was sufficient to detect clinically important effects and minimize the possibility of a type II error. CIs for most estimates of effect ruled out clinically significant effects.

Now that we have shown that a clinical stretching protocol does not increase joint ROM or reduce disability in people with contracture after cast immobilization for ankle fracture, a question arises whether exercise programs produce clinically important effects. This requires empirical testing through an adequately powered and well-designed randomized trial. Such a trial may be very difficult to conduct from an ethical perspective. Other PT interventions commonly used after removal of cast immobilization for ankle fracture (eg, joint mobilization treatment) also require empirical validation.

CONCLUSIONS

The addition of a program of passive stretches confers no benefit over exercise alone for the treatment of plantarflexion contracture after cast immobilization for ankle fracture.

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