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Research Report

A Randomized Controlled Trial of a Passive Accessory Joint Mobilization on Acute Ankle Inversion Sprains

Background and Purpose. Passive joint mobilization is commonly used by physical therapists as an intervention for acute ankle inversion sprains. A randomized controlled trial with blinded assessors was conducted to investigate the effect of a specific joint mobilization, the anteroposterior glide on the talus, on increasing pain-free dorsiflexion and 3 gait variables: stride speed (gait speed), step length, and single support time. **Subjects.** Forty-one subjects with acute ankle inversion sprains (<72 hours) and no other injury to the lower limb entered the trial. **Methods.** Subjects were randomly assigned to 1 of 2 treatment groups. The control group received a protocol of rest, ice, compression, and elevation (RICE). The experimental group received the anteroposterior mobilization, using a force that avoided incurring any increase in pain, in addition to the RICE protocol. Subjects in both groups were treated every second day for a maximum of 2 weeks or until the discharge criteria were met, and all subjects were given a home program of continued RICE application. Outcomes were measured before and after each treatment. **Results.** The results showed that the experimental group required fewer treatment sessions than the control group to achieve full pain-free dorsiflexion. The experimental group had greater improvement in range of movement before and after each of the first 3 treatment sessions. The experimental group also had greater increases in stride speed during the first and third treatment sessions. **Discussion and Conclusion.** Addition of a talocrural mobilization to the RICE protocol in the management of ankle inversion injuries necessitated fewer treatments to achieve pain-free dorsiflexion and to improve stride speed more than RICE alone. Improvement in step length symmetry and single support time was similar in both groups. [Green T, Refshauge K, Crosbie J, Adams R. A randomized controlled trial of a passive accessory joint mobilization on acute ankle inversion sprains. *Phys Ther.* 2001;81:984–994.]

Key Words: *Ankle sprain, Gait, Passive mobilization, Physical therapy.*

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Ankle inversion sprains occur frequently in sports,[1–3] predominantly in athletes participating in running and jumping sports.[4,5] The acute injury consists of damage to the lateral ligament[6,7] and results in pain, swelling, and limitation of movement. The inability to dorsiflex is thought to be indicative of a severe injury[8] and is often a complication of these injuries on follow-up.[9,10] Restriction of dorsiflexion would normally be expected to limit gait and other functional activities. At least 10 degrees of dorsiflexion is required for normal walking,[11] descending stairs, and kneeling, whereas running requires 20 to 30 degrees of dorsiflexion.[12] Gait limitations have been reported.[13,14] People with acute ankle sprains walk slowly and take smaller steps.[13] Furthermore, the available pain-free range of movement in dorsiflexion has been shown to determine walking speed, contralateral step length when the range of movement in dorsiflexion is less than 10 degrees, and single support time, with the relationships being nonlinear.[14] Subjects were less symmetrical for single support time when less than 4 degrees of dorsiflexion was available than when more than this range of movement was available.[14] Thus, it would be expected that a treatment resulting in reduced pain and improved dorsiflexion range of movement should also result in more rapid improvement of these gait variables. Walking speed has been shown to be a good predictor of recovery from injury or disease[15]; consequently, changes in walking speed between measurements made before and after treatment were considered to be functionally significant.

In the acute phase of an ankle injury, the treatment combination of rest, ice, compression, and elevation (RICE) is advocated for pain and swelling.[16–21] In addition, physical therapists commonly use passive joint mobilization to reduce pain by modulation of nervous tissue[22] and to increase range of movement,[23–26] despite the lack of evidence for the efficacy of this treatment.[27] A passive joint mobilization is a gentle oscillating movement of the articular surfaces that creates movement of mobile segments by a means other than by the muscles normally related to those particular segments' movement.[28] Some people[22,26,29–33] believe that joint mobilization can relieve pain and improve range of motion by neurophysiological and mechanical mechanisms or some combination of neurophysiological and mechanical mechanisms.

Because limited dorsiflexion can negatively influence gait, the mobilization we studied is aimed at moving the talus in an anteroposterior (AP) direction, a movement thought to improve dorsiflexion.[23,26] Selection of the AP mobilization is based on the opinions of MacConaill and Basmajian,[34] who hypothesized that the combination of spin, slide, and roll accessory movements that occur

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Ethical approval for the study was obtained from the human ethics committees of the University of Sydney and Calvary Hospital, Canberra.

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between joint surfaces is primarily determined by the shape of the surfaces. The concave/convex rule—which states that, when a convex surface moves on a concave one, the direction of the slide and roll should occur in opposite directions—was based on this view, although data are lacking to determine whether the rule actually describes what occurs. Some authors[35] have even provided evidence to dispute the rule. Thus, when the ankle is moved into dorsiflexion, the convex talus should roll upward and slide posteriorly on the concave surface of the crus. We believe, therefore, that mobilization of the talus in a posterior direction (an AP mobilization) restores dorsiflexion. Although the concave/convex rule has been disputed,[35] the AP mobilization continues to be widely used to restore dorsiflexion.

Our study was designed to determine whether an AP mobilization improved the outcome of therapy for acute ankle sprain compared with use of the conventional RICE protocol. We investigated whether the mobilization decreased pain during dorsiflexion, improved the range of movement in dorsiflexion, or improved the gait variables of speed, step length, and single support time.

Materials and Methods

A randomized controlled trial was conducted with assessors who were unaware of the subjects' group assignments to compare the effect of an AP glide on the talus in addition to the RICE protocol with the effect of the RICE protocol alone on the variables of pain on dorsiflexion motion, dorsiflexion range of movement, and gait.

Subjects were assigned to control and experimental groups by use of a random number system. Group assignment was concealed from the assessors. The control group received the RICE protocol alone. The experimental group received AP mobilization, using a force that avoided pain reproduction, in addition to the RICE protocol. Subjects consented to participate in the trial prior to being randomly assigned to groups.

Subjects were treated every second day, except over weekends or when subjects could not attend an appointment, for a maximum of 2 weeks. A maximum of 6 treatment sessions, therefore, was possible over the 14 days of the treatment period. The outcomes were measured by the assessors before and after each treatment session. One follow-up measurement was conducted one day after the final treatment session. One physical therapist (TG) with 15 years of experience in manual therapy and advanced training in manipulative physical therapy treated all subjects.

Subjects

From patients diagnosed with acute ankle sprain and referred by medical practitioners in the hospital's emergency department, 41 subjects volunteered to participate in the trial. A radiograph of each subject's ankle was obtained to screen for fractures and other abnormalities prior to entry into the trial. The control and experimental groups, in our opinion, were similar when they began the study in terms of age, time since onset of ankle injury, severity of ankle injury (Tab. 1) (t test, $P>.05$), and available range of movement in dorsiflexion (Tab. 2) (t test, $P>.05$). The groups appeared, in our view, to differ for history of a previous sprain, with more subjects in the experimental group reporting a previous sprain (Tab. 1).

Table 1.
Demographic Data and Injury Profiles of Subjects[a]

Characteristic	Experimental Group (n=19)	Control Group (n=19)
Age (y, $\bar{X}\pm$SEM)	26.1±2.0 (15–48)	24.9±1.6 (15–42)
Sex (N, % male)	14, 74%	12, 63%
First sprain (N, % of subjects)	7, 36.8%	12, 63.1%
Hours since injury (X±SEM)	68.2±0.8 (24–96)	67.0±0.8 (48–96)
Presence of obvious swelling (N, % of subjects)	17, 89.4%	17, 89.4%

[a] Ranges of values shown in parentheses.

Inclusion criteria. To be included in the study, subjects were required to enter the trial within 72 hours of injury. In addition, only subjects with a sprain of sufficient severity to require assisted ambulation were included. All subjects, however, could bear partial weight on entry to the trial. An initial examination was performed by the treating physical therapist to screen for inclusion and exclusion criteria. Bruising, swelling, and tenderness on palpation of the lateral ligament were noted. Tenderness on palpation of each portion of the lateral ligament was recorded as tenderness of the anterior talofibular ligament (ATFL) in isolation, of both the ATFL and the calcaneofibular ligament (CFL), or of all 3 portions of the lateral ligament. Only subjects with tenderness restricted to the lateral ligament were included to control for the presence of injury of other structures such as the deltoid ligament that may occur with severe sprains.

Exclusion criteria. Subjects were excluded if known factors were present that may have affected treatment outcome. Exclusion criteria included a history of previous injury (eg, fracture, talipes equinovarus), a sprain sustained in the previous 12 months, compensation claimed for this or any other condition, presence of severe vascular disease, or use of anticoagulant or anti-inflammatory medications.

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Table 2.
Dorsiflexion Range of Movement (in Degrees) Before and After Each Treatment Session

Treatment Session	Experimental Group							Control Group						
	Pretreatment			Posttreatment				Pretreatment			Posttreatment			
	$\bar{X}$	SEM	Range	$\bar{X}$	SEM	Range	n	$\bar{X}$	SEM	Range	$\bar{X}$	SEM	Range	n
1	8.9	2.2	−3 to 31	13.2	2.2	0 to 32	19	7.2	2.5	−10 to 16	8.1	1.9	−10 to 15	19
2	19.3	2.6	0 to 40	21.3	2.3	3 to 38	18	13.0	2.2	−8 to 23	15.0	2.2	−7 to 28	19
3	22.5	2.5	1 to 38	23.5	2.1	11 to 43	15	17.5	2.1	−3 to 35	16.4	1.9	−5 to 28	19
4	19.5	3.6	12 to 28	22.5	3.0	14 to 31	6	18.8	2.2	−5 to 28	17.5	1.7	2 to 26	16
5	25.0	5.2	15 to 34	26.0	6.1	18 to 38	4	21.3	1.7	14 to 29	22.9	1.9	14 to 30	11
6	24.0			24.0			1	23.3			24.0			4

Dropouts. Three experimental group subjects (7%) dropped out of the trial. One of these subjects failed to return for treatment (follow-up phone calls failed to identify the reason), one subject resprained the injured ankle, and one subject reported the use of anti-inflammatory medication after testing had commenced. No control group subject dropped out of the trial. Therefore, in this trial, 19 subjects were in each group.

Instrumentation

The Lidcombe template was used to measure dorsiflexion because measurements obtained with the template have been shown to have high interrater agreement of 77% and intrarater reliability (intraclass correlation coefficient [ICC]=.97) in subjects without health problems, subjects with cerebrovascular accidents, and subjects with head injuries.[36] The device was modified for our study in an effort to ensure that dorsiflexion occurred at the talocrural joint. The template consisted of 2 boards joined by an adjustable hinge; one board served as a footplate, and the other board was positioned under the subject's calf (Fig. 1). To accommodate individual foot size and center of ankle rotation, the template was adjustable in 2 ways. The hinge adjusted the axis of rotation of the template in the vertical plane, and wooden blocks inserted on the calf plate allowed for adjustment in the horizontal plane. A hydrogoniometer was attached to the footplate to measure the angle of dorsiflexion in degrees.

In an effort to standardize the measurement, both the force applied and the angle of dorsiflexion at which subjects first experienced onset of pain were recorded.[37] The force applied during measurement of dorsiflexion was standardized throughout the trial by use of a spring balance attached at the distal end of the footplate. The spring balance measured the applied force, and a spirit level attached to the spring balance ensured application of the force in a standardized direction. Both the applied force and the angle of dorsiflexion were recorded at the point when the subject first experienced onset of pain.[37]

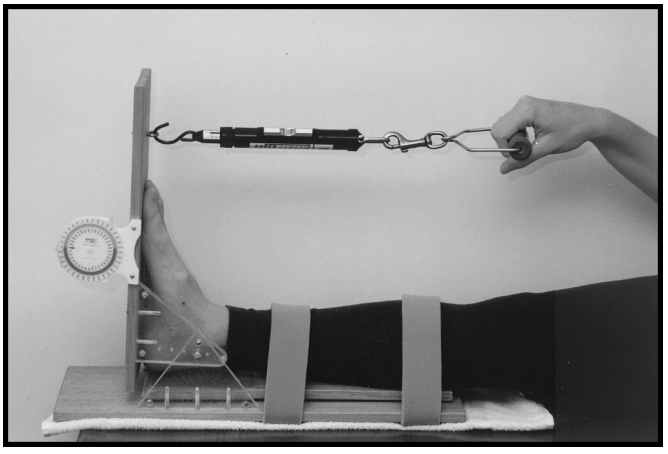

Figure 1.
The Lidcombe template. The template enabled standardized measurement of dorsiflexion range of movement. The axis of rotation of the ankle was aligned with the adjustable axis of rotation of the template. The spring balance attached to the footplate measured force, which was applied in a standardized direction.

The reliability of measurements obtained with the modified Lidcombe template by the assessors was tested prior to commencement of the trial. The range of dorsiflexion was measured in 30 subjects whose ankles had no impairment on 2 occasions 1 week apart. The measurements were made by 2 assessors on each occasion. The assessors were hospital staff physical therapists who were normally assigned to work in different departments on a rotating basis and, therefore, did not consistently work in the outpatient department for the 2-year duration of the trial. In addition, some assessors resigned from the hospital during this period. Therefore, 5 assessors were involved in the trial. Sixty-five measurements were made, of which 29% were in exact agreement and 84.5% were within 2 degrees. These results yielded an ICC (1,1) of .94, which is consistent with previous reports of reliability of measurements obtained with the Lidcombe template, with ICCs (2,1) ranging from .91[36] to .97.[38] Because the researchers in these previous studies[36,38] did not examine reliability on the type of subjects we studied (people with acute ankle injuries), we cannot be sure how reliable the measurements in our study were.

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Gait was analyzed with a National Panasonic video camera and recorder system,* using the procedure described previously by Crosbie et al.[14] The camera was located perpendicular to a level 7-m-long walkway. Subjects, who were dressed in shorts and wearing no shoes, were filmed at a shutter speed of 2 milliseconds as they walked along the walkway. The lateral and medial malleoli were located and marked with long-lasting dye during the initial visit, and subjects were instructed not to wash off these markings. Adhesive markers were attached over the dye markings to improve the clarity and, therefore, the location of markers.

The field of view of the camera was the central 2 m of the walkway, an arrangement that provided a resolution to approximately 1 mm and ensured that subjects were walking at "steady-state" speed when data were recorded. The camera image was calibrated against a rigid frame of known dimensions. Videotapes of the subjects' walking patterns were overdubbed with a time code with a resolution of 0.01 second. Thus, on field-by-field playback, sensitivity to 20 milliseconds was obtained. Initial videotape playback was used to derive temporal events.[39,40] The times of initial foot-ground contact and loss of foot contact on each side were recorded for each trial in turn. From these events, double and single support times for the affected and unaffected sides and the total stride time were calculated. *Double support time* was defined as the period between the commencement of foot contact on one side and the loss of foot contact on the other side. In the case of these subjects, *limitation of ankle motion* meant that, in the early trials particularly, the foot contact was not necessarily represented by a clear heel-strike. *Single support time* was defined as the period between loss of foot contact on the contralateral side and commencement of the next contralateral foot contact. *Stride time* was the time from one foot contact to the next initiation of foot contact on the same side.

The spatial coordinates of the foot markers were recorded using a manual digitizing tablet and the videotape playback unit in a configuration similar to that described by Abraham.[41] Images from the videotape recorder (National AG6200 freeze-frame recorder*) and from an overhead camera that captured the active area of a SummaSketch II Professional Plus digitizing tablet† were mixed (National WJ-SIN*) and displayed on a monitor. Prior to each test, a calibration frame of known dimensions (1 m^2) was filmed in the center of the target zone. The videotape was advanced or rewound until foot location during each stance phase of the cycle could be clearly identified. The digitizing tablet that we used has a stated resolution of less than 0.1 mm. The coordinates were stored using SigmaScan software‡ and subsequently analyzed with a customized program developed in-house. This program computed stride variables according to conventional definitions.[42] On completion of the process, data were derived for stride and left and right step lengths as well as the temporal variables described. In addition, stride speed (gait speed) was calculated using the formula:

$$\text{Stride speed} = \text{stride length} / \text{stride time} \quad (1)$$

Seven walks were filmed at each visit in an effort to ensure that each subject's typical gait was analyzed. Because the camera was positioned at the center of the walkway, approximately one gait cycle was in view of the camera. Therefore, it was necessary for subjects to repeat the walks to enable averaging of data to represent typical performance. This procedure has been shown to yield reliable measurements of gait variables.[43]

Interventions

All subjects received a standardized protocol of RICE.[23] During each treatment session, the subjects' affected foot was elevated above the heart for 20 minutes. Crushed ice was applied over the anterolateral aspect of the affected ankle during the period of elevation. In addition to an oral explanation of the protocol, all subjects were given written instructions on the application of RICE so that they could continue the treatment as a home program. *Rest* was defined as avoidance of pain-provoking activities. The ice application was recommended for a minimum of two 20-minute sessions each day. Subjects wore an elastic tubular bandage daily until completion of testing to apply compression to the ankle and calf. In addition, subjects were instructed to elevate the foot above the heart for at least 25% of the day.

During the third treatment session, all subjects were taught to tape their ankle and were told to do so on a daily basis in an effort to protect against exacerbation of current sprain and occurrence of a new sprain. They used a standard application of rigid sports tape.[44,45] Subjects were also given a written description of the taping procedure. Subjects continued to wear the elastic tubular bandage over the tape. During treatment session 4, subjects demonstrated how they applied the tape to ensure that the application was being done correctly.

The experimental group received passive joint mobilization during every treatment session before the application of the RICE. The mobilization was directed over the anterior surface of the talus to mobilize the talocrural joint with the subject lying supine (Fig. 2). The affected foot was positioned at the end of the available pain-free range of movement in dorsiflexion, and a gentle oscilla-

* Panasonic Inc, 1 Panasonic Way, Secaucus, NJ 07094.
† Summagraphics Inc, 60 Silvermine Rd, Seymour, CT 06483.
‡ Jandel Scientific Inc, 65 Koch Rd, Corte Madera, CA 94925.

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Figure 2.
Anteroposterior mobilization of the talus. The mobilization was performed with the subject lying supine and the ankle positioned over the edge of the plinth. The proximal hand of the therapist (left hand with the ring) stabilized the distal tibia and fibula while the distal (right) hand mobilized the talus with posteriorly directed oscillations.

tory technique as described by Maitland[30] was applied in an AP direction. In this trial, the gentle force used for the mobilization was a small-amplitude oscillation applied so that pain and spasm were not produced. Although the technique was performed as far as possible into range of the accessory glide movement without producing pain, the range actually used was the beginning of the range due to the presence of pain during the first few treatment sessions. Subjects were questioned frequently in an attempt to ensure that no pain was produced, and the magnitude of the force applied was based on this feedback. Throughout the trial, the technique was performed for 60 seconds and repeated 2 more times with a 10-second rest between repetitions. During this 60-second oscillatory period, approximately 60 oscillations were performed. When pain during dorsiflexion was reduced, treatment was progressed by increasing the amount of dorsiflexion in which the foot was positioned.

Adherence to Treatment

All subjects were given an activity diary to record daily adherence to the RICE protocol and to indicate their activity levels during the treatment period. The diary was a simple questionnaire designed to ascertain whether subjects had worn their bandage, applied ice, and elevated their foot each day. In addition, subjects responded to questions about when they returned to work and to their normal amount of walking. Because ankle inversion sprains are most commonly sustained during sporting activities, questions were also included about when subjects could run without pain and when they returned to sports.

Outcome Measures

Outcomes were measured before and after each treatment and one day after discharge from the trial. Subjects exited from the trial when they had attained full pain-free range of movement in dorsiflexion (ie, the available range of movement in dorsiflexion was the same in both ankles) with the application of 100 N of force (approximately 12 N·m of torque), because no further improvement in this variable was possible. The treatment period was limited to a maximum of 2 weeks.

The outcomes measured were dorsiflexion and the 3 gait variables of stride speed, step length, and single support time. The angle of pain-free dorsiflexion and the force applied to achieve this angle were recorded.

Subjects were all partial weight bearing using ambulation aids on entry to the trial, but walked without their aids for the gait analysis. The gait variables were measured before and after each treatment. Because it was likely that high intersubject variability with respect to the absolute step length and step time values would reduce the power of the analysis, the symmetry ratios for step length and single support time were used as indicators of functional status. Such ratios are largely independent of confounding variables such as walking speed and height and are most likely to be influenced by the pain on weight bearing and reduced ankle range of motion associated with the injury.[46]

Data Analysis

The number of treatments received by subjects was analyzed using the chi-square test.[47] Dorsiflexion range of movement was analyzed using planned contrasts within an analysis of variance for repeated measures.[47] Gait was analyzed in 2 ways. Walking speed was expressed as a percentage of the initial speed. For the variables of single support time and step length, a symmetry index was calculated using the following formula[48]:

$$(2) \qquad \textit{Symmetry Index} = \frac{\textit{Affected side}}{[\textit{Affected side} + \textit{Unaffected side}]}$$

Perfect symmetry is expressed by an index of 0.5. Single support time should be most affected on the injured side because it tends to be shorter in duration due to the pain associated with weight bearing on that side. In contrast, step length should be most affected on the side of the uninjured limb because a subject would be reluctant to take long steps due to pain and limited range of motion on the weight-bearing, injured side. We used statistical analysis to determine whether differences existed between the experimental and control groups and between treatment sessions. An analysis of variance for repeated measures was used to investigate these factors.

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Subjects were discharged from the trial when they had recovered dorsiflexion. We decided, therefore, to analyze our data when fewer than half of the subjects in either group remained in the trial. This occurred after 3 treatment sessions. By the fourth treatment session, fewer than half of the subjects in the experimental group (32%) remained in the trial. We believe that this method of analysis indicates rate of recovery in addition to differences in outcome measures.

Finally, diary entries relating to adherence to the home program and return to activity during the trial are described. At the end of the trial, not all subjects had returned to the activities listed in the diary. Therefore, for these subjects, return to the activity was assigned as 14 days (ie, the conclusion of the trial). Using this maximum is conservative and thereby underestimates the rate of return to these activities.

Results

This randomized controlled trial was designed to evaluate the effect of a common manual therapy technique for acute ankle inversion sprain on outcomes relevant to the patient, in particular, pain-free range of movement in dorsiflexion and gait.

Subjects were discharged from the trial when the application of a 100-N force led to full pain-free range of movement in dorsiflexion, that is, when no further improvement was possible for this variable. Therefore, the number of subjects continuing in the trial declined progressively over the 2 weeks of treatment. At completion of the trial, 1 subject remained in the experimental group and 4 subjects remained in the control group (Tab. 2). By the fourth treatment session, the majority of subjects in the experimental group (13/19 subjects [68%]) had been discharged from the trial because they had attained full range of movement in dorsiflexion, although only 3 subjects in the control group had been discharged by the same time (χ^2=10.80, P<.01). Because fewer than half of the subjects in the experimental group remained in the trial by the fourth treatment session, only data derived from the first 3 treatment sessions were analyzed further.

Dorsiflexion Range of Movement

Anteroposterior mobilization of the talus using a gentle force to avoid reproduction of pain in addition to the RICE protocol resulted in greater improvement in dorsiflexion range of movement than the application of RICE alone for measurements taken before (P<.02) and after (P<.01) each of the first 3 treatment sessions (Fig. 3). After the first treatment session, subjects in the experimental group improved 4.3 degrees, from a mean of 8.9 degrees (SEM=2.2°) to a mean of 13.2 degrees (SEM=2.2°), and subjects in the control group

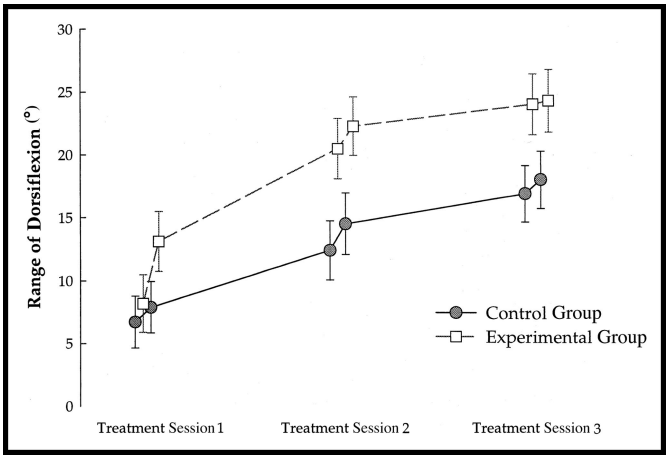

Figure 3.
Pain-free ankle dorsiflexion range of movement. The effect of anteroposterior mobilization on ankle dorsiflexion range of movement was greater than the control treatment in the first treatment session. Although the rate of recovery of the ankle was similar between treatment sessions for both groups, there was a continued gain in the experimental group as a result of the extra range of movement achieved in the first treatment session. Treatment 1 led to greater results than treatments 2 or 3 in the experimental group. No changes were observed in the control group.

improved 0.9 degree, from a mean of 7.2 degrees (SEM=2.5°) to a mean of 8.1 degrees (SEM=1.9°). From entry to the trial (baseline measurement before the first treatment session) until the start of the second treatment session, the experimental group improved 10.9 degrees (SEM=1.9°) compared with an improvement of 5.8 degrees (SEM=1.1°) for the control group.

Characteristics of Gait

Stride speed increased over the duration of the trial for both groups (Fig. 4). Greater increases were found within the first and third treatment sessions in the experimental group (P<.05). After the first treatment session, subjects in the experimental group improved from a mean of 0.41 $m{\cdot}s^{-1}$ to a mean of 0.50 $m{\cdot}s^{-1}$, and subjects in the control group improved from a mean of 0.43 $m{\cdot}s^{-1}$ to a mean of 0.47 $m{\cdot}s^{-1}$ (Tab. 3).

Step length symmetry improved in both groups, reaching values close to symmetrical (0.5) after 3 treatment sessions (Fig. 5). Measurements taken after the second treatment session showed greater gains in step length symmetry in the experimental group than in the control group (P<.05).

The symmetry of single support time (time spent on one leg alone) also improved with both treatments (Fig. 6). The distributions of these data, however, are skewed and demonstrate considerable intersubject variability. Consequently, there were no differences, based on our statistical analysis.

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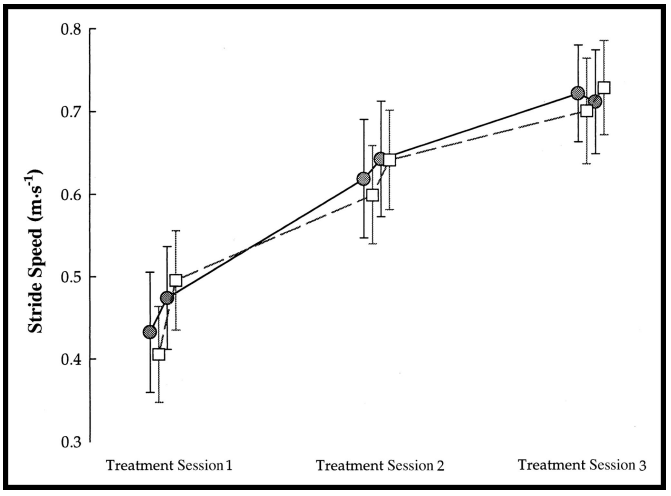

Figure 4.
Stride speed. Stride speed was measured before and after each of the first 3 treatments for the experimental and control groups. The control group is represented by the filled circles, and the experimental group is represented by the open squares. Improvement was greater in the experimental group than in the control group. Error bars represent SEM.

Return to Normal Activity

Return to normal activity was monitored using the activity diary. Because not all questions were applicable to all subjects, the mean was calculated only for those subjects for whom a particular activity was relevant, and the number of subjects is indicated in parentheses. The subjects in the experimental group (n=17) returned to work 6 days after injury, and the subjects in the control group (n=18) returned to work 5.3 days after injury. Subjects in the experimental group returned to a normal amount of walking (n=19) after 7.7 days, were able to run (n=16) after 12.6 days, and returned to sports (n=13) after 12.2 days. Subjects in the control group returned to a normal amount of walking (n=19) after 9.2 days, were able to run (n=19) after 13.3 days, and returned to sports (n=16) after 13.4 days.

Discussion

In our study, we showed that when acute ankle inversion sprains were treated with AP mobilization of the talocrural joint in addition to the conventional RICE protocol, fewer treatments were required for pain-free dorsiflexion range of movement and stride speed to improve than when RICE alone was administered. Although researchers in pilot studies have demonstrated that passive mobilization can improve pain-free ankle range of motion,[24,49] our trial is the first randomized controlled trial to demonstrate an effect of passive joint mobilization on sprained ankles.

We noted an apparent continued improvement in pain-free dorsiflexion range of movement for both groups between treatment sessions (Fig. 3). The measurements taken after one treatment and before the next treatment showed that dorsiflexion improved 5 to 6 degrees between treatment sessions for both groups. We believe that this improvement is likely to represent the rate of natural recovery from acute ankle sprain.

The improvement conferred by the AP mobilization is unlikely to be accounted for by differences in the groups that existed before the study. The 2 groups were similar at entry to the trial for most variables except that more subjects in the experimental group previously had sprains (Tab. 1). Although previous sprains might have worsened the prognosis, the experimental group improved more quickly than the control group. This finding suggests to us that passive mobilization is an effective additional treatment for improving pain-free range of movement and some gait variables.

Adherence

Both groups reported good adherence to the home program. All subjects in the control group returned their adherence diary, but 3 subjects in the experimental group failed to return the diary, resulting in a return rate of 93%. Adherence was calculated as the percentage of days enrolled in the trial in which subjects performed each aspect of the protocol as required, and not as a percentage of subjects. The 16 subjects in the experimental group who returned their diary reported adhering to the rest regimen 79% of the time, to the ice regimen 81% of the time, and to compression 64% of the time. The control group adhered to the rest regimen 81% of the time, to the ice regimen 67% of the time, and to compression 58% of the time. Different rates of adherence to the home program, therefore, are unlikely to explain the improvement with the passive mobilization treatment in the experimental group.

Pain-free Dorsiflexion Range of Movement

The reasons for the beneficial effects of mobilization are unclear, although several hypotheses have been advanced, including physiological modulation of pain and mechanical alteration of tissues.[33,50,51] Most authors agree that the mobilization should be performed at the end of the joint's range of motion, perhaps in the plastic deformation part of the tissue response to force, to effect these mechanical alterations. In our study, however, the mobilization was performed near the beginning of the joint's range of motion and not at the end of the range of motion. In addition, there was an immediate reduction in pain, as evidenced by the improvement in pain-free dorsiflexion range of movement, an unlikely response from a mechanical event.

Characteristics of Gait

The continued improvement of stride speed between treatment sessions indicates to us that the injury was resolving, and some benefits may or may not have been attributable to a treatment effect from the mobilization

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Table 3.
Gait Variables for the First Three Treatment Sessions

	Treatment Session 1				Treatment Session 2				Treatment Session 3			
	Pretreatment		Posttreatment		Pretreatment		Posttreatment		Pretreatment		Posttreatment	
Variable	$\bar{X}$	SEM	$\bar{X}$	SEM	$\bar{X}$	SEM	$\bar{X}$	SEM	$\bar{X}$	SEM	$\bar{X}$	SEM
Stride speed ($m \cdot s^{-1}$)												
Control group	0.43	0.30	0.47	0.26	0.62	0.29	0.64	0.29	0.72	0.24	0.71	0.26
Experimental group	0.41	0.24	0.50	0.25	0.60	0.24	0.64	0.25	0.70	0.26	0.73	0.23
Step length symmetry ratio												
Control group	0.29	0.15	0.30	0.14	0.39	0.09	0.39	0.10	0.44	0.07	0.44	0.06
Experimental group	0.35	0.01	0.36	0.10	0.43	0.07	0.44	0.07	0.46	0.06	0.47	0.04
Single support time symmetry ratio												
Control group	0.29	0.12	0.32	0.12	0.40	0.10	0.40	0.11	0.44	0.08	0.44	0.08
Experimental group	0.33	0.12	0.37	0.09	0.43	0.07	0.44	0.08	0.46	0.06	0.46	0.08

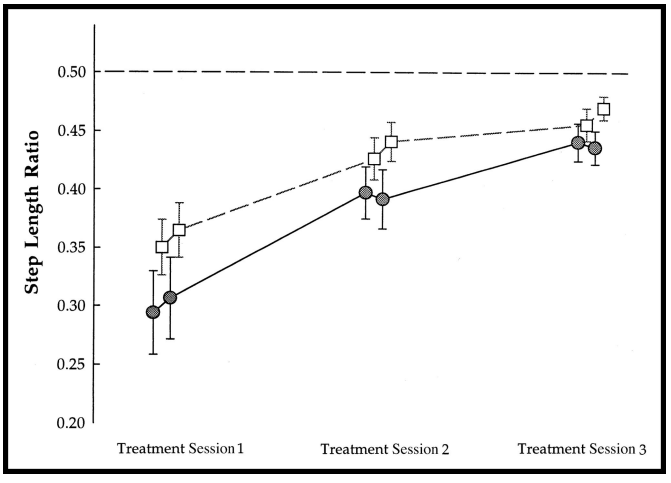

Figure 5.
Ratio of step length of uninjured limb to total stride length (symmetry ratio). The control group is represented by the filled circles, and the experimental group is represented by the open squares. There was no difference between groups in improvement in step length. Error bars represent SEM.

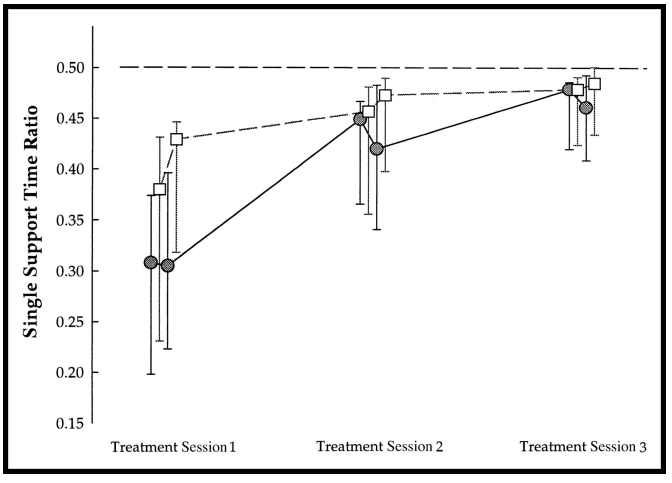

Figure 6.
Ratio of single support time on injured side to total time spent in single support. The median of the control group is represented by the filled circles, and the median of the experimental group is represented by the open squares. There was no difference between groups in improvement in step length. Error bars represent 25th and 75th percentiles.

in the experimental group. In both groups, there were measurable improvements in walking speed following each treatment. The magnitude of the improvement was relatively greater after the first treatment than subsequent treatments, irrespective of the intervention. This step speed gain is consistent with the finding of maximum effect on ankle dorsiflexion range of movement at the first treatment.

The use of a symmetry index to examine the effect of the treatments on step length and single support time, in our opinion, diminishes some of the problems of intersubject variability. It is clear that the symmetry index was not substantially influenced by the first treatment. The second experimental treatment, however, evoked an improvement in step length symmetry. Although there was a trend toward improvement in single support time symmetry in the experimental group, and an opposite trend in the control group, these data are not clearly distinct and no conclusion can be drawn concerning the effect of mobilization on the ability to spend a longer period bearing weight on the injured side.

Because the walking speed remained slow, the lack of a change in the first treatment may indicate that there was only a slight increase in the step length. Of more interest is the fact that, although walking speed changed only by about 10% after the second treatment session, the step length symmetry improved by 35%. This finding may reflect a pattern of improved range of movement and reduced pain on weight bearing, permitting a longer step on the uninjured side.

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Conclusions

Our research demonstrated that treatment (which included AP mobilization) improved pain-free ankle range of movement in dorsiflexion, as well as the functional outcome of stride speed. The improvement occurred with fewer AP mobilization treatments than were required for the control group. Subjects in both groups improved in all variables tested, although the improvement was greater for the experimental group than for the control group. Because a nontreatment group was not included in this trial for ethical reasons, it is unclear whether the improvements in the control group were achieved by the RICE protocol or by natural recovery.

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