Original Research

Serial Within-Session Improvements in Ankle Dorsiflexion During Clinical Interventions Including Mobilization-With-Movement and A Novel Manipulation Intervention – A Case Series

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Background

Persisting reductions in ankle dorsiflexion range of motion are commonly encountered clinically and seen to be associated with adverse outcomes after ankle and other lower extremity injuries. Accordingly improving identified deficits is a common goal for rehabilitation; however, little data exists documenting any improvement related to interventions in these patients.

Purpose

To document the change in dorsiflexion range of motion after stretching and mobilization-with-movement and exercise and a novel manipulation intervention in a population of injured athletes.

Design

Case series in 38 consecutive injured athletes with persisting reductions in ankle dorsiflexion range of motion (42 "stiff" ankles, 34 uninjured) in an outpatient sports physiotherapy clinic.

Method

During a single treatment session, two baseline measurements of weight-bearing dorsiflexion were taken at the start of the session to establish reliability and minimum detectable change, and then the same measures were performed after stretching and a mobilization-with-movement intervention, and again after clinical exercise and a novel manipulation which was applied on both ankles.

Results

Excellent reliability was demonstrated ($ICC_{2,1}$>0.93, MDC=3.5°) for the dorsiflexion measure. Statistically significant (p<0.01), but clinically meaningless improvements were seen after stretching and the mobilization-with-movement intervention on the injured and uninjured legs (1.9° and 1.4° respectively) with greater improvements seen after exercise and the subsequent manipulation (6.9° and 4.7°).

Conclusions

The relatively simple clinical exercise and manipulation intervention program was associated improvement in dorsiflexion range of motion in this cohort with persisting ankle stiffness. The interventions described largely restored range of motion consistent with baseline levels of the uninjured ankles. Improvements were also seen in the

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uninjured ankles following intervention.

INTRODUCTION

Despite recent international consortium[1] and clinical practice guideline[2] recommendations that ankle dorsiflexion range of motion be targeted during rehabilitation after ankle injury, evidence to guide the clinician regarding the effects of specific interventions remains unclear.[3,4] Dorsiflexion range of motion limitation has been identified as a prospective risk factor for a number of lower-limb injuries including ankle injury,[5,6] Achilles tendinopathy,[7] patellofemoral pain,[8] plantar fasciopathy,[9] and hamstring injury.[10] Additionally, limited ankle dorsiflexion range of motion is associated with impaired dynamic balance[11] and increased chronicity[1] and recurrence[12] in those recovered from lateral ankle sprain. Those with chronic lateral ankle instability display lower dorsiflexion range of motion during gait[13,14] as well as drop jumps,[15] and presumed compensatory movements in other parts of the kinetic chain.[15–18] During rehabilitation from ankle injury, restoration of this range of motion is often identified as an important treatment goal to address impairment.[11,19–22]

Weight-bearing dorsiflexion range of motion is typically measured as a "knee to wall" distance, or as an angle of inclination of the tibia.[23] Previously we have documented normal dorsiflexion range of motion as approximately 35° in an athletic population[24] using this measure. Many physiotherapy interventions have been described to improve ankle dorsiflexion range of motion including electrotherapy, ice application, relaxation and imagery programs, passive mobilization, psychological interventions, stretching, and mobilization with movement techniques.[4] Manual therapy interventions (joint mobilization, mobilization with movement, and high velocity low amplitude techniques) used on patients with reduced dorsiflexion after ankle injury have shown short-term improvements of 6 to 22mm[25–30] and 3.0° to 5.5°[31] depending on the intervention and measurement method employed. Stretching interventions have shown short-term improvements in range of 2° to 5.3°[32,33] depending on the technique and duration with larger effects seen for two- to six-week home programs.[3]

Research in this area typically examines single interventions in a pre- post- treatment design considering only the immediate effects of intervention. Multiple applications of joint mobilizations appear to show no further benefit beyond the second application[34] although this research is sparse[35]especially in professional athletes. Clinically, therapists will often employ a number of interventions on any single patient during a single session. It is not known if the addition of further interventions provides greater improvement in range of motion, and it is unusual to have any published information regarding anything other than the immediate effects of such interventions. It is possible that some improvement in range of motion is simply due to either test-retest variability independent of any real gain in flexibility, or test-retest improvement.[36] Clinically, therapists will often aim to improve range of motion and then capitalize on this by performing other exercises in this newly acquired range of motion in an effort to provide a more lasting benefit. It is not known if these gains persist

throughout the duration of any clinical encounter.

Accordingly, the purpose of this case series was to document the change in dorsiflexion range of motion after stretching and mobilization-with-movement and exercise and a novel manipulation intervention in a population of injured athletes. It was hypothesized that each of the interventions would be associated with an increase in dorsiflexion range of motion.

METHODS

Patients attending an outpatient sports physiotherapy clinic were targeted for inclusion after clinical identification of a relative reduction (compared to the uninjured side) in dorsiflexion range of motion along with one of several features during rehabilitation which suggested the athlete required more ankle joint dorsiflexion to reestablish normal movement under load. These features included observation of excessive pronation on the injured side during a bilateral squat, weight-shift toward the uninjured leg during a heavy squat, off-loading of the injured leg during bilateral jump-landing, reduced distance toward the posterior targets during star excursion balance testing on the injured leg. Four broad categories of patients were examined who had a reduction of ankle dorsiflexion identified as a therapeutic limitation. The first group were athletes at end-phase rehabilitation following knee injury with painless difficulty achieving full range during full squats or unable to land properly from a jump (6 patients with 7 stiff ankles). The second through fourth groups were all pain-free patients being treated for foot (second group), ankle (third group), or posterior lower leg (fourth group) injuries with similarly interfering ankle stiffness whose rehabilitation had persisted for more than 6 weeks (32 patients with 35 "stiff" ankles, Figure 1).

Contraindications for inclusion were medical diagnosis of acute anterior or posterior impingement, imaging-identified cartilage damage, or history of cartilage repair in either the tibiotalar or subtalar joints. Additionally, any patient from either group complaining of an ankle pain during active dorsiflexion, plantarflexion, one leg squat, one leg jump, or one leg hop were excluded.

Pilot investigation suggested that an improvement of approximately 5° (0.5° SD) was possible for this intervention. Thirty-three subjects would give a power of 0.8 to detect such an effect with a Type I error rate of 0.05, therefore we planned to enroll 36 subjects (allowing for data loss). Ultimately 38 consecutive patients met the inclusion criteria in this pragmatic clinical outcome trial. The study was conducted in accordance to the STROBE guidelines for cohort studies,[37] informed consent was sought and obtained for the use of these clinical data from the patients, and the study was approved by the local ethics committee (application number: E202009010).

INTER-RATER RELIABILITY AND BASELINE MEASUREMENT

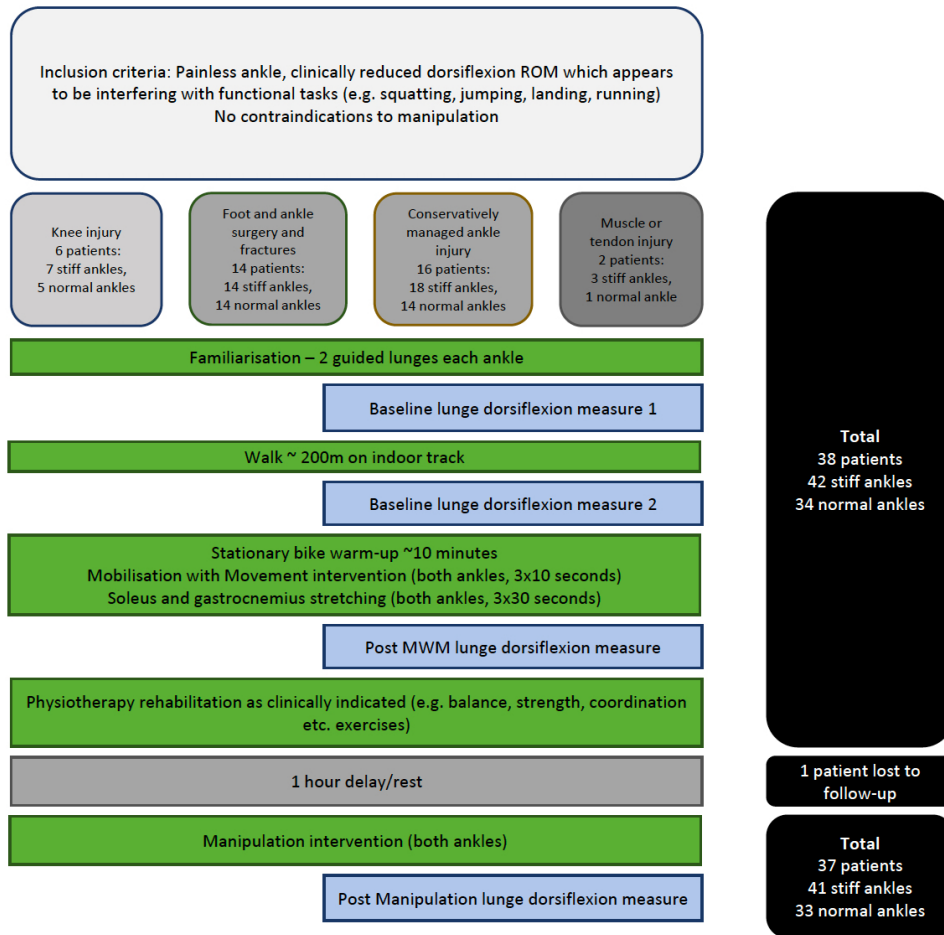The baseline dorsiflexion range of motion was measured be-

Figure 1. Flowchart of inclusion, intervention, and measurements.

fore any treatment or exercise was given at the beginning of the session. The patient started in a lunging position facing a wall, "knee over middle toe" where the pelvis remains parallel to the wall (figure 1). An initial familiarization of two lunges to the limit of dorsiflexion were performed. Subjects were instructed and manually guided, if required, to maintain neutral tibial rotation during these lunges. Two physiotherapists who were blinded to the intervention, injured side(s), and to each other's measurements recorded the subsequent clinical measurement on each ankle. For the measurement, an inclinometer (Magnetic *Polycast Protractor, Empire, USA*) was placed 4 fingers width proximal to the ankle joint line on the tibia avoiding the antero-lateral muscular compartment (Figure 2). Two baseline measurements were taken to determine within session inter-rater reliability, with the subject walking approximately 200m between these tests on an indoor track (Figure 2). Inter-rater reliability was assessed using $ICC_{(2,1)}$ (absolute agreement) and the minimum detectable change (MDC) through calculation of the Standard Error of the Measurement from the ICC ANOVA table.[38] Statistical analyses were performed using SPSS (v23, IBM Amarok, USA) and R[39,40] with the dabest 0.2.2 package.[41]

INTERVENTIONS

After a self-paced warm-up on a stationary bike for approximately 10 minutes, the patient had a series of three, 10-second mobilization with movement techniques performed on each ankle (Figure 3) at a rate of 1Hz followed by soleus and gastrocnemius self-stretching for 3 repetitions of 30 seconds each with 10 seconds rest between repetitions (Figure 4). Immediately after this, dorsiflexion measurement was taken by the experimental physiotherapist, blinded to the baseline measurements. The only difference in measurement technique described above is that no familiarization trials were conducted. The patient then continued with their scheduled rehabilitation treatment session. Typically, this session would include a variety of balance, strength, and coordination exercises relevant to the athlete's sport and their rehabilitation stage. After one hour of rest that followed the end of this session, the athlete was then recalled for a manipulative intervention technique which was applied to both ankles. After this intervention, the dorsiflexion range of motion was again assessed by an independent physiotherapist, blinded to the previous findings in a similar manner to the previous measurements (with no warm-up trials).

MOBILIZATION WITH MOVEMENT

The technique utilized incorporated Mulligan principles of applying subtle pain-free overpressure to an end-range movement, or specifically a "*sustained passive accessory force / glide to a joint while the patient actively performs a task that was previously identified as being problematic.*"[42] The patient was supine, foot off the edge of the treatment plinth so that the joint line is about 1 cm away from its edge (Figure 3). A rigid mobilization strap was placed at the level of the joint line its length is then adjusted to be 5 cm from the floor. The belt was folded at its upper part to cover the anterior surface of the talus only (i.e., avoiding coverage of the other tarsals and/or the tibia). The clinician inserted his foot in its lower part to create a downward pressure on the talus. While controlling the stability of the tibia with one hand ensuring full knee extension along the maneuver, the other hand grasping the heel and passively mobilizing the foot from plantarflexion to dorsiflexion. Three sets of 10 consecutive mobilizations with movement are applied with 10 seconds rest between sets.

STRETCHING

Soleus and gastrocnemius stretching were performed standing on a small (6.5 cm) platform for 3 repetitions of 30-seconds each with 10 seconds rest after each stretch (Figure 4).

MANIPULATIVE TECHNIQUE INTERVENTION

The manipulation technique (Figure 5) was performed on both ankles without any additional warm-up.

RESULTS

SUBJECT CHARACTERISTICS

Subject characteristics are presented in Table 1. One subject was unable to be measured for the final (post-manipulation) measurement. Sensitivity analysis (imputing these missing data from linear regression) showed no meaningful differences therefore these data were omitted from the final analysis.

RELIABILITY AND MINIMUM DETECTABLE CHANGE

Given the differences in range of motion for the uninjured and injured legs, inter-rater reliability was calculated initially for the injured ($ICC_{2,1}$ (absolute error) = 0.96, 95% confidence interval: 0.93 to 0.98, p<0.01) and uninjured (0.98, 0.98 to 0.99, p<0.01) legs separately, and then for all legs combined (0.98, 0.97 to 0.99, p<0.01). As these results were essentially the same the pooled (all legs) results are used for calculation of the minimum detectable change which was 3.5°. These measurements and the between group differences are depicted using bootstrap confidence intervals in Figure 6.

Figure 2. Positioning for dorsiflexion range of motion measurement.

Patient was facing the wall, knee over second toe, pelvis parallel to the wall. The magnetic inclinometer was placed four fingers width proximal to ankle joint.

Figure 3. Mobilization with movement technique.

The mobilization strap is placed slightly distal to the tibia over the athlete's talus and midfoot, and then while passively moving the ankle towards dorsiflexion, pressure is applied through the therapist's foot while stabilizing the proximal tibia. This mobilization was performed in an oscillatory manner at approximately 1Hz for the 10 repetitions. The degree of force applied by the therapist was adjusted to be progressively increased until reaching end range dorsiflexion where the end feel of the posterior glide is accomplished, the force was released slowly until returning to the starting position.

TREATMENT EFFECTS

A one-way repeated measures ANOVA was conducted to see if there were statistically significant differences in dorsi-

flexion range of motion at the three time points (Baseline measurement 1, post-MWM, and post-manipulation) for each of the injured and uninjured legs separately. There were no outliers and the data were normally distributed (visual inspection, Q-Q plots, and Shapiro-Wilk tests). The assumption of sphericity was met for both analyses (injured legs: χ^2 = 8.59, p = 0.014; uninjured legs: χ^2 = 9.97, p = 0.007). After post-hoc adjustment for multiple comparisons (Sidak) statistically significant differences were seen for dorsiflexion at all time points (p<0.01) except for the two baseline measures. It should be noted however that only the differences between baseline and manipulation for the injured and uninjured legs (6.9° and 4.7° improvement respectively), and injured leg mobilization with movement to manipulation (5.1°) exceeded the dorsiflexion minimum detectable change of 3.5°. These differences are depicted using bootstrap confidence intervals in Figure 7 and Table 2.

Between group comparisons for the baseline (reliability) measures, and the first baseline measure compared to the post-mobilization with movement, and post-manipulation conditions for both the injured and uninjured legs. Note that the MDC for this measurement is 3.5° therefore the only measurements to be considered clinically significant are: the injured leg from baseline to post-Manipulation and from post-MWM to post manipulation, while for the uninjured leg only baseline to post-manipulation reached this hurdle ("MWM": mobilization with movement).

DISCUSSION

The approach described here documents, for the first time, baseline dorsiflexion range of motion, and test-retest reliability for this measure along with in-session measurements after both a mobilization-with-movement and stretching, and exercise and a novel manipulation intervention. The stretching and mobilization with movement was associated with a likely clinically insignificant improvement of approximately 1-2°, and a further improvement of about 4-5° after the exercise treatment and the novel manipulation technique. The combination intervention appears to largely restore the injured ankle dorsiflexion range of motion compared to the baseline range of the healthy ankle (from 28° to 35° and 37° respectively). Previously we had documented healthy athletes' weight-bearing dorsiflexion range of motion to be approximately 35° which suggests this combination of interventions is restoring "normal" range of motion in athletes.[24] It should be noted however that the uninjured ankle demonstrated an improvement of a similar magnitude compared to the injured ankle. It is not clear if the therapeutic target value of the baseline uninvolved ankle's range of motion is appropriate, or if clinicians should aim for the "best possible" range available on the uninjured ankle.

The effects of the clinical intervention demonstrated here reflect usual clinical (multimodal) practice. Typically, clinical research will consider only a single intervention performed in isolation which allows for a clearer depiction of such an isolated intervention. This does not reflect usual clinical practice however where multimodal interventions are commonplace during an encounter. The authors' suggest that this approach may be useful to further tease out

Figure 4. Positioning during soleus and gastrocnemius stretching.

The patient uses the wall for balance and drops the heel toward the floor as low as possible while having the knee bent and extended respectively for 3 repetitions of 30 seconds each, with 10 seconds rest between repetitions.
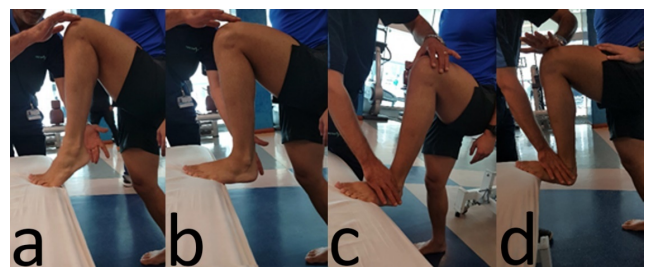

Figure 5. Description of the dorsiflexion manipulation technique

The patient stood facing a treatment table or a step-box, on the uninvolved leg, and placed the involved foot on the edge of the table so that the mid-tarsal (Chopart) joint is was aligned with edge of the table and the femur is was roughly parallel to the floor when the ankle is was in full dorsiflexion. The patient was asked to "drop" their heel towards the ground for several repetitions until they felt confident and relaxed about this movement with touch guidance from the therapist (Figure 5a,b). After this the clinician stood on the medial aspect of the side being manipulated and faced the patient, placed one hand on the distal part of the femur (so that both condyles are palpated with their thumb and fingers) and the other hand at the dorsum of the forefoot, sliding it toward the ankle joint line so that the line between the thumb and the first finger fit into the talocrural joint without contacting the tibial side, and the hypothenar eminence is resting over the tarsals and the thumb and the second finger pointing to the distal tip of the medial and lateral malleolus accordingly. Both of the clinician's hands followed and synchronized with the drops for few repetitions until the patient was comfortable with the movement (Figure 5c), and then the clinician suddenly over presses the drop process applying a postero-inferior pressure on the anterior part of the talus coupled with an internal rotation moment with the lower hand, along with an antero-inferior force on the distal part of the femur with the upper hand (Figure 5d). This maneuver forces the knee to move slightly anterior and the tibia inferiorly. The manual pressure was timed to coincide with the patient reaching their end-range of dorsiflexion.

aspects of a clinical encounter which contribute to improvements as well as their relative contributions, although future research will need to consider the order of application, more frequent measurements, the longer-term maintenance of these ranges of motion, and whether these improvements in flexibility transfer to daily activities.

The actual anatomic effects of the interventions cannot

Table 1. Summary subject characteristics

Age	Height	Weight	BMI	Professional sport (n)	Recreational sport (n)
Mean: 29.1 (SD: 6.4, Range: 18 to 54)	179.3 (SD: 8.7, Range: 161 to 202)	79.4 (SD: 15.6, Range: 58 to 127)	24.6 (SD: 4.0, Range: 19 to 37)	Football: 25 Basketball: 3 Volleyball: 3 Rugby: 3 Handball: 2 Track & field: 1	Ice hockey: 1 Football: 1

be inferred from this research. While some researchers ascribe treatment benefits to changing joint mechanics others suggest combinations of soft tissue relaxation and/or stretch tolerance are more important factors.[6,43–50] The data presented here suggests that stretch tolerance is less likely to be a major contributor to the improvements seen given the two baseline measures remained essentially unchanged however beyond this we are unable to speculate as to exactly how these ranges of motion are improving. Future work might consider muscle tone, tissue compliance, and arthrokinematics as potential sources of the improvements seen.

To the authors' knowledge, there is little research describing within-session changes in populations of ankle injured athletes with reduced dorsiflexion undertaking typical multimodal rehabilitation. Serial changes after repeated application of the same (mobilization) intervention[34] or the results of complete heterogenous treatment approaches are more commonly reported.[3,51] These approaches do not allow understanding of the different components of usual multimodal interventions and require different research methods.[52]

Importantly, the changes seen here are only documented within the session, in a static measurement, not during gait or other athletic tasks. Future research should examine the time course of these changes, specifically how long changes persist in the absence of further intervention, and whether these static improvements in flexibility are associated with altered kinematics and kinetics during functional tasks such as running, jumping, and direction change. These limitations notwithstanding, the previously documented association of reductions in dorsiflexion range of motion with adverse outcomes make the current findings likely of interest to clinicians and researchers alike.

CLINICAL IMPLICATIONS

The multi-modal intervention presented here resulted in potentially clinically important improvements in ankle dorsiflexion range of motion in a population that had failed to show sufficient improvement in this rehabilitation goal. Incremental improvements were seen with both the mobilization with movement and stretching, and subsequent exercise and manipulation interventions. Clinically, the authors have noticed this combination of treatment interventions

to show larger effects than any single intervention in the management of ankle dorsiflexion range of motion deficit. While we might attribute short-term improvements in flexibility to the application of manual therapy techniques, clinicians should consider the possibility that the exercise interventions may have contributed to these improvements when applied in combination with these techniques. The order of applications as well as the dose and the grade of the manual therapy techniques (repetitions and force applied) and exercises should be investigated in future research.

LIMITATIONS

Due to the nature of the clinical setting, this research was conducted only on adult male professional athletes; extrapolation to adolescents, females, and non-athletes should be done with care. As we only measured dorsiflexion range of motion four times during each session, we are unable to describe the independent effects of the exercise and manipulation interventions performed, nor the possible effects of a sham intervention. Future research could address this limitation but would need to control for differences in exercise prescription and baseline characteristics of the patients. The longer-term effects of these interventions were not documented need to be investigated in future research.

CONCLUSION

A combination of a mobilization with movement, exercise and stretching, and a novel manipulation induced changes in weight-bearing ankle dorsiflexion which were likely clinically meaningful. These represent relatively simple interventions which can be safely applied clinically for patients with persisting restrictions in ankle dorsiflexion. Future research needs to describe how long these changes are maintained, and if these changes are associated with other functional improvements such as performance and re-injury risk.

CONFLICTS OF INTEREST

The authors state no conflict of interest perceived or actual in the creation of this research.

Table 2. Between group comparisons for the baseline (reliability) measures, and the first baseline measure compared to the post-mobilization with movement, and post-manipulation conditions for both the injured and uninjured legs

Comparison	Mean Difference (95% confidence interval)	t	df	P-value
Injured Baseline 2 – Injured Baseline 1	0.18° (-0.34° to 0.71°)	0.70	41	0.49
Uninjured Baseline 2 – Uninjured Baseline 1	-0.09° (-0.52° to 0.35°)	-0.40	33	0.69
Injured Post-MWM – Injured Baseline 1	1.92° (1.30° to 2.53°)	6.28	41	<0.01
Uninjured Post-MWM – Uninjured Baseline 1	1.36° (0.72° to 2.01°)	4.30	33	<0.01
Injured Post-Manipulation – Injured Baseline 1	6.89° (6.09° to 7.69°)	17.42	40	<0.01
Uninjured Post-Manipulation – Uninjured Baseline 1	4.74° (3.71° to 5.78°)	9.34	32	<0.01
Injured Post-Manipulation – Injured Post-MWM	5.10° (4.50° to 5.69°)	17.29	40	<0.01
Uninjured Post-Manipulation – Uninjured Post-MWM	3.49° (2.60° to 4.38°)	8.01	32	<0.01

Note that the MDC for this measurement is 3.5° therefore the only measurements to be considered clinically significant are: the injured leg from baseline to post-Manipulation and from post-MWM to post manipulation, while for the uninjured leg only baseline to post-manipulation reached this hurdle ("MWM": mobilization with movement).
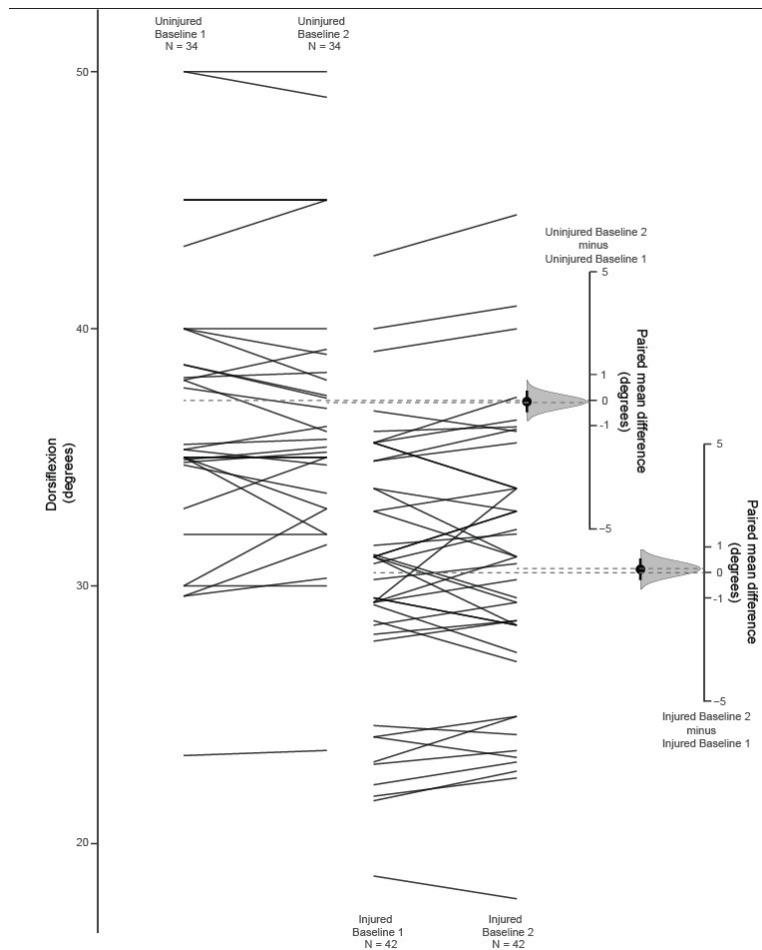

Figure 6. Baseline dorsiflexion measures for both the injured and uninjured groups along with bootstrap estimated paired mean differences.

The two slopegraphs on the left are the two measures each for the uninjured and injured legs. To the right is the bootstrap estimated group mean difference for the injured and uninjured legs along with its distribution.
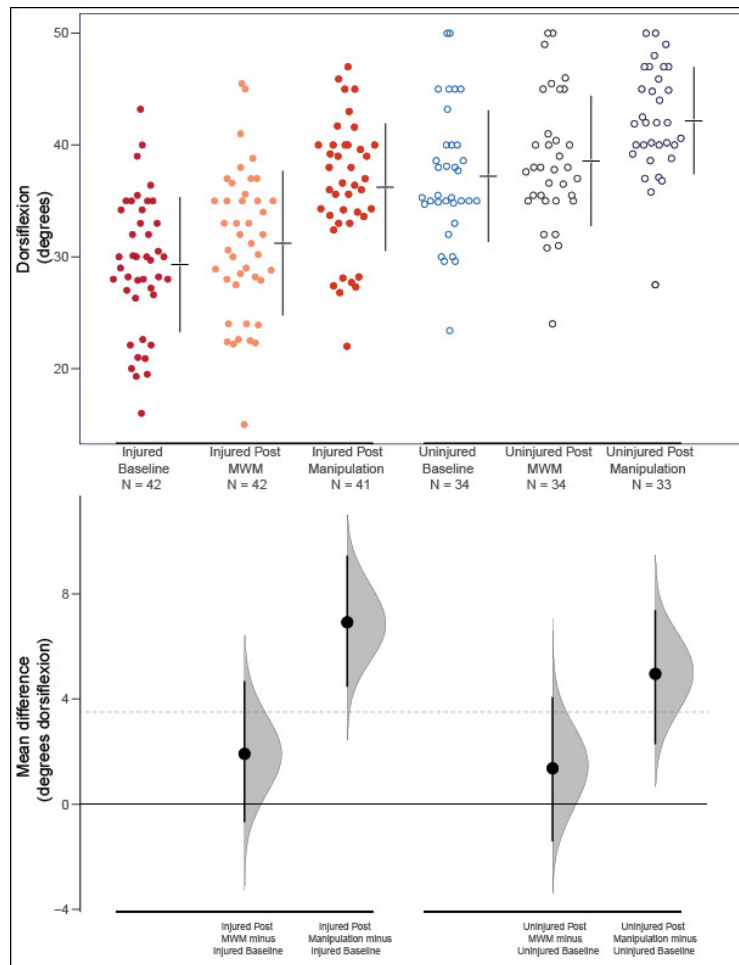
Figure 7. Estimation plot of dorsiflexion range of motion at: baseline (first measurement), post-stretching and mobilization-with-movement, and post-clinical exercise and then manipulation (upper panel - injured ankles filled circles on the left, uninjured on the right). Lower panel shows the bootstrap estimated mean differences for both the injured and uninjured legs (with the associated 95% confidence intervals) along with standard and confidence interval for these estimates.

Dashed horizontal line in the mean difference panel is placed at 3.5° representing the MDC for the dorsiflexion measure.

REFERENCES

1. Delahunt E, Bleakley CM, Bossard DS, et al. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. *Br J Sports Med*. 2018;52(20):1304-1310. doi:10.1136/bjsports-2017-098885

2. Martin RL, Davenport TE, Fraser JJ, et al. Ankle stability and movement coordination impairments: Lateral ankle ligament sprains revision 2021. *J Orthop Sports Phys Ther*. 2021;51(4):CPG1-CPG80. doi:10.2519/jospt.2021.0302

3. Terada M, Pietrosimone BG, Gribble PA. Therapeutic interventions for increasing ankle dorsiflexion after ankle sprain: a systematic review. *J Athl Train*. 2013;48(5):696-709. doi:10.4085/1062-6050-48.4.11

4. Doherty C, Bleakley C, Delahunt E, Holden S. Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. *Br J Sports Med*. 2017;51(2):113-125. doi:10.1136/bjsports-2016-096178

5. Tabrizi P, McIntyre WM, Quesnel MB, Howard AW. Limited dorsiflexion predisposes to injuries of the ankle in children. *J Bone Joint Surg Br*. 2000;82(8):1103-1106. doi:10.1302/0301-620x.82b8.10134

6. Hertel J. Functional Anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *J Athl Train*. 2002;37(4):364-375.

7. Kaufman KR, Brodine SK, Shaffer RA, Johnson CW, Cullison TR. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med*. 1999;27(5):585-593. doi:10.1177/03635465990270050701

8. Lun V, Meeuwisse WH, Stergiou P, Stefanyshyn D. Relation between running injury and static lower limb alignment in recreational runners. *Br J Sports Med*. 2004;38(5):576-580. doi:10.1136/bjsm.2003.005488

9. Riddle DL, Pulisic M, Pidcoe P, Johnson RE. Risk factors for Plantar fasciitis: a matched case-control study. *J Bone Joint Surg Am*. 2003;85(5):872-877. doi:10.2106/00004623-200305000-00015

10. van Dyk N, Farooq A, Bahr R, Witvrouw E. Hamstring and ankle flexibility deficits are weak risk factors for hamstring injury in professional soccer players: A prospective cohort study of 438 players including 78 injuries. *Am J Sports Med*. 2018;46(9):2203-2210. doi:10.1177/0363546518773057

11. Hoch MC, Staton GS, McKeon PO. Dorsiflexion range of motion significantly influences dynamic balance. *J Sci Med Sport*. 2011;14(1):90-92. doi:10.1016/j.jsams.2010.08.001

12. Kobayashi T, Yoshida M, Yoshida M, Gamada K. Intrinsic predictive factors of noncontact lateral ankle sprain in collegiate athletes: A case-control study. *Orthop J Sports Med*. 2013;1(7):2325967113518163. doi:10.1177/2325967113518163

13. Chinn L, Dicharry J, Hertel J. Ankle kinematics of individuals with chronic ankle instability while walking and jogging on a treadmill in shoes. *Phys Ther Sport*. 2013;14(4):232-239. doi:10.1016/j.ptsp.2012.10.001

14. Drewes LK, McKeon PO, Kerrigan DC, Hertel J. Dorsiflexion deficit during jogging with chronic ankle instability. *J Sci Med Sport*. 2009;12(6):685-687. doi:10.1016/j.jsams.2008.07.003

15. Delahunt E, Monaghan K, Caulfield B. Changes in lower limb kinematics, kinetics, and muscle activity in subjects with functional instability of the ankle joint during a single leg drop jump. *J Orthop Res*. 2006;24(10):1991-2000. doi:10.1002/jor.20235

16. Herb CC, Grossman K, Feger MA, Donovan L, Hertel J. Lower extremity biomechanics during a drop-vertical jump in participants with or without chronic ankle instability. *J Athl Train*. 2018;53(4):364-371. doi:10.4085/1062-6050-481-15

17. Doherty C, Bleakley C, Hertel J, et al. Coordination and symmetry patterns during the drop vertical jump in people with chronic ankle instability and lateral ankle sprain copers. *Phys Ther*. 2016;96(8):1152-1161. doi:10.2522/ptj.20150160

18. Doherty C, Bleakley C, Hertel J, et al. Coordination and symmetry patterns during the drop vertical jump, 6-months after first-time lateral ankle sprain. *J Orthop Res*. 2015;33(10):1537-1544. doi:10.1002/jor.22915

19. Lavery LA, Armstrong DG, Boulton AJ, Diabetex Research G. Ankle equinus deformity and its relationship to high plantar pressure in a large population with diabetes mellitus. *J Am Podiatr Med Assoc*. 2002;92(9):479-482. doi:10.7547/87507315-92-9-479

20. Wilken J, Rao S, Estin M, Saltzman CL, Yack HJ. A new device for assessing ankle dorsiflexion motion: reliability and validity. *J Orthop Sports Phys Ther*. 2011;41(4):274-280. doi:10.2519/jospt.2011.3397

21. DiGiovanni CW, Kuo R, Tejwani N, et al. Isolated gastrocnemius tightness. *J Bone Joint Surg Am*. 2002;84(6):962-970. doi:10.2106/00004623-200206000-00010

22. Elveru RA, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting. Subtalar and ankle joint measurements. *Phys Ther*. 1988;68(5):672-677. doi:10.1093/ptj/68.5.672

23. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother*. 1998;44(3):175-180. doi:10.1016/s0004-9514(14)60377-9

24. Abassi M, Bleakley C, Whiteley R. Athletes at late stage rehabilitation have persisting deficits in plantar- and dorsiflexion, and inversion (but not eversion) after ankle sprain. *Phys Ther Sport*. 2019;38:30-35. doi:10.1016/j.ptsp.2019.04.015

25. Collins N, Teys P, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on dorsiflexion and pain in subacute ankle sprains. *Man Ther*. 2004;9(2):77-82. doi:10.1016/S1356-689X(03)00101-2

26. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *J Orthop Sports Phys Ther*. 2006;36(7):464-471. doi:10.2519/jospt.2006.2265

27. Reid A, Birmingham TB, Alcock G. Efficacy of mobilization with movement for patients with limited dorsiflexion after ankle sprain: a crossover trial. *Physiotherapy Canada*. 2007;59(3):166-172.

28. Hoch MC. *The Effect of Joint Mobilization on Functional Outcomes Associated with Chronic Ankle Instability*. University of Kentucky; 2011.

29. Cruz-Diaz D, Lomas Vega R, Osuna-Perez MC, Hita-Contreras F, Martinez-Amat A. Effects of joint mobilization on chronic ankle instability: a randomized controlled trial. *Disabil Rehabil*. 2015;37(7):601-610. doi:10.3109/09638288.2014.935877

30. Marron-Gomez D, Rodriguez-Fernandez AL, Martin-Urrialde JA. The effect of two mobilization techniques on dorsiflexion in people with chronic ankle instability. *Phys Ther Sport*. 2015;16(1):10-15. doi:10.1016/j.ptsp.2014.02.001

31. Stanek JM, Pieczynski AE. Effectiveness of clinician-and patient-applied mobilisation with movement technique to increase ankle dorsiflexion range of motion. *Int J Ther Rehabil*. 2020;27(4):1-11.

32. Radford JA, Burns J, Buchbinder R, Landorf KB, Cook C. Does stretching increase ankle dorsiflexion range of motion? A systematic review. *Br J Sports Med*. 2006;40(10):870-875; discussion 875. doi:10.1136/bjsm.2006.029348

33. Youdas JW, McLean TJ, Krause DA, Hollman JH. Changes in active ankle dorsiflexion range of motion after acute inversion ankle sprain. *J Sport Rehabil*. 2009;18(3):358-374. doi:10.1123/jsr.18.3.358

34. Meyer JE, Rivera MJ, Powden CJ. The evaluation of joint mobilization dosage on ankle range of motion in individuals with decreased dorsiflexion and a history of ankle sprain. *J Sport Rehabil*. 2020:1-6. doi:10.1123/jsr.2020-0114

35. Whitman JM, Cleland JA, Mintken PE, et al. Predicting short-term response to thrust and nonthrust manipulation and exercise in patients post inversion ankle sprain. *J Orthop Sports Phys Ther*. 2009;39(3):188-200. doi:10.2519/jospt.2009.2940

36. Zito M, Driver D, Parker C, Bohannon R. Lasting effects of one bout of two 15-second passive stretches on ankle dorsiflexion range of motion. *J Orthop Sports Phys Ther*. 1997;26(4):214-221. doi:10.2519/jospt.1997.26.4.214

37. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi:10.1016/j.jclinepi.2007.11.008

38. Portney LG, Watkins MP. *Foundations of Clinical Research : Applications to Practice*. Prentice Hall; 2000.

39. Team RC. *A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing; 2012. https://R-project.org.

40. Team R. *RStudio: Integrated Development for R*. Boston, MA: RStudio, Inc; 2015. https://rstudio.com.

41. Ho J, Tumkaya T, Aryal S, Choi H, Claridge-Chang A. Moving beyond P values: data analysis with estimation graphics. *Nat Methods*. 2019;16(7):565-566. doi:10.1038/s41592-019-0470-3

42. Hing W, Hall T, Mulligan B. *The Mulligan Concept of Manual Therapy: Textbook of Techniques*. Elsevier; 2020.

43. Denegar CR, Hertel J, Fonseca J. The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. *J Orthop Sports Phys Ther*. 2002;32(4):166-173. doi:10.2519/jospt.2002.32.4.166

44. Donovan L, Hertel J. A new paradigm for rehabilitation of patients with chronic ankle instability. *Phys Sportsmed*. 2012;40(4):41-51. doi:10.3810/psm.2012.11.1987

45. 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(4):984-994.

46. Gribble PA, Bleakley CM, Caulfield BM, et al. 2016 consensus statement of the International Ankle Consortium: prevalence, impact and long-term consequences of lateral ankle sprains. *Br J Sports Med*. 2016;50(24):1493-1495. doi:10.1136/bjsports-2016-096188

47. Hubbard TJ, Hertel J. Mechanical contributions to chronic lateral ankle instability. *Sports Med*. 2006;36(3):263-277. doi:10.2165/00007256-200636030-00006

48. Safran MR, Benedetti RS, Bartolozzi 3rd AR, Mandelbaum BR. Lateral ankle sprains: a comprehensive review: part 1: etiology, pathoanatomy, histopathogenesis, and diagnosis. *Med Sci Sports Exerc*. 1999;31(7 Suppl):S429-37. doi:10.1097/00005768-199907001-00004

49. Safran MR, Zachazewski JE, Benedetti RS, Bartolozzi 3rd AR, Mandelbaum R. Lateral ankle sprains: a comprehensive review part 2: treatment and rehabilitation with an emphasis on the athlete. *Med Sci Sports Exerc*. 1999;31(7 Suppl):S438-47. doi:10.1097/00005768-199907001-00005

50. Medina McKeon JM, Hoch MC. The ankle-joint complex: A kinesiologic approach to lateral ankle sprains. *J Athl Train*. 2019;54(6):589-602. doi:10.4085/1062-6050-472-17

51. Medeiros DM, Martini TF. Chronic effect of different types of stretching on ankle dorsiflexion range of motion: Systematic review and meta-analysis. *Foot (Edinb)*. 2018;34:28-35. doi:10.1016/j.foot.2017.09.006

52. Wikstrom EA, McKeon PO. Manipulative therapy effectiveness following acute lateral ankle sprains: A systematic review. *Athl Train Sports Health Care*. 2011;3(6):271-279. doi:10.3928/19425864-20110131-02