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Cover Page Footnote

I would like to express my gratitude and acknowledge the guidance and assistance provided from my supervisor Brian O'Rourke throughout the duration of this research project. I am incredibly grateful and have been privileged to have had a supervisor who expressed such interest, time and consideration into the development of this research project. I would like to express my thanks to the participants of this study, all of which were students at the South East Technological University, Carlow. Their participation and time provided was pivotal in this research study. Finally, I would like to acknowledge and thank South East Technological University, Carlow and in particular the Faculty of Science and Health Department to which equipment, facilities and support was provided upon request for the duration of this research project and always maintained to a high standard.

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The Acute effects of Talocrural MWM compared with the application of Soft-tissue of the plantarfascia on chronic Lateral Ankle Sprains for ankle Dorsiflexion R.O.M.

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Abstract

Previous research has looked at various treatment remedies for improving acute ankle Dorsiflexion Range of Motion (DFROM) post chronic Lateral Ankle Sprain (LAS). Mulligan's Mobilisation with Movement (MWM) appears frequently however, the significance and mechanism remain quite conflicting (Gilbreath *et al*., 2015). It is also known that after a LAS, the Lateral Ligament Complex (LLC) is compromised and the calcaneus inverts, increasing stiffness of plantarfascia (Al-Mohrej & Al-Kenani, 2016, Denegar *et* al., 2002, Loudon & Bell, 1996). The objective of this study was to further explore the effectiveness of MWM compared with soft-tissue (ST) application of the plantarfascia on acute ankle DFROM**.** 20 male Gaelic footballers (Mean ± SD: Age = 22.5 ± 1.5 years, Ankle DFROM = 29.9º ± 8.6º) with a history of chronic LAS (>6-months with no current or recent lower-chain injuries and <45º ankle DFROM) were split into two groups using subject-matching: MWM (n=10), plantarfascia (n=10). The main outcome measure was ankle DFROM using a Weight-Bearing Lunge Test (WBLT) both pre-intervention and immediately post-intervention. There was significant evidence to support the utilisation of either treatment for the improvement of acute ankle DFROM post chronic LAS (P≤0.001). Each group saw increases in ankle DFROM (MWM: 5.6%, plantarfascia: 18.5%) however, there was no statistically significant differences between groups (P≤0.001) and only a small effect size was observed (0.4). These results indicate the clinical relevance of incorporating either treatment intervention into the rehabilitation or treatment protocol of chronic LAS. It would be of interest to view the lasting effects of this study or to view how the treatment interventions may have performed once combined and so future research is recommended for greater comprehension.

Keywords: Lateral ankle sprain, Dorsiflexion, MWM, Plantarfascia, GAA

1.0 Introduction

The aim of this study is to investigate the acute effects of improving ankle DFROM using Soft-Tissue (ST) of the plantarfascia compared with MWM of the talocrural joint on male Gaelic Athletic Association (GAA) Athletes. Gaelic footballers are required to accelerate, decelerate, jump, land with a focus on Change of Direction (COD) capabilities (Keane *et al.*, 2010). The ankle is one of the most commonly injured areas in Gaelic footballers accounting for 13.3% of all injuries (Wilson *et al*., 2007). Murphy *et al*., (2012) found that for all ankle injuries, the LLC is the most prevalent accounting for 33.8% of all ankle injuries. After a LAS, a deficit is seen in ankle Dorsiflexion (DF) which increases the risk of a recurrent ankle sprain and limits dynamic balance performance (Abassi *et al*., 2019). There are various modalities for ankle DFROM ranging from stretching, manual therapy and electrotherapy (Terada *et al*., 2013). This study aims to broaden an understanding of two-specific treatment approaches for ankle DFROM in male GAA athletes.

1.1 Arthrokinematics of the LAS and the surrounding structures

The most common cause of a LAS is from excessive inversion and Plantarflexion (PF) which primarily stresses the Anterior Talofibular Ligament (ATFL). This places the ankle mortise in the loose-pack position and imposes internal rotation of the talus (Yeung *et al*., 1994, Bahr *et al*., 1998 and Kristianslund *et al*., 2011). Calcaneofibular Ligament (CFL) injuries occur in only 25% of all LAS and Posterior Talofibular Ligament (PTFL) even less (Anderson *et al*., 2004, Hubbard *et al*., 2010).

After a LAS, the integrity of the LLC is damaged. The foot is positioned in greater inversion as the calcaneus causes misalignment of hindfoot varus resulting in the deltoid ligaments acting as a centre of tibial internal rotation (Sommer *et al*., 1996, Al-Mohrej and Al-Kenani., 2016). With increased calcaneal inversion and due to a lack of muscular attachments to the talus, the talus shifts slightly anterolaterally (Loudon and Bell., 1996, Denegar *et al*., 2002). This imposes pronation of the sub-talar joint; limiting its function as a mobile adapter during walking-gait (Loudon *et al*., 1996). After a LAS, pronation is further increased to unlock the midtarsal joint to achieve mobility, which increases plantarfascia elongation; increasing stress of musculofascial structures. This alters the orientation of the Windlass mechanism imposing instability during the propulsive phase of walking gait, altering the period between the weight acceptance phase through toe-off (Bolgla and Malone, 2004). Repetitive forces while in pronation decreases plantarfascia ability to resist external loading, increasing stiffness (Liu *et al*., 2020). If plantarfascia stiffness is reduced and efficiency of the Windlass mechanism altered, will ankle DF increase?

1.2 Plantarfascia Intervention

Research regarding plantarfascia-intervention post-LAS is relatively limited. The majority of studies focus on plantarfasciitis and furthermore, focus on self-release treatments such as Foam-Rolling (FR). Plantarfasciitis and LAS both experience increased load on the medial foot through excessive pronation and inversion (Lim *et al.*, 2016). Excessive loading increases collagen adhesion formation (Liptan, 2010). Cross Frictional Massage / Deep Frictional-Massage (DFM) allows a rhythmic deep pressure application with gentle stretching which positively impacts the stimulation of mechanoreceptors and allows the breakdown/reduction of collagen adhesions. This causes an overload of cutaneous receptors; resulting in a stretch mechanism which allows for the partial restoration of both the flexibility and the extensibility properties of the Fascia (Callaghan *et al*., 2013, Gala *et al*., 2021, Ranbhor *et al*., 2021). With the fascia under less strain, it reduces the amount of hindfoot varus. As hindfoot valgus allows a greater R.O.M through the midtarsal joint resulting in a flexible foot during the walking gait, it is suggestive to impose an improvement in ankle DFROM by manipulating the soft-tissue properties (Tweed *et al.*, 2008, Blackwood *et al*., 2005). DFM of the plantarfascia on patients with no previous lower limb injuries indicated improvements of 22.1% (P<0.001) on acute ankle DFROM (Yoshimura *et al*., 2020). With increased plantarfascia stiffness, the results are even greater. Ranbhor *et al*., (2021) identified that FR of the plantarfascia on plantarfasciitis patients shows increases of 45.75% (P<0.001).

1.3 MWM Intervention

Radiological findings have identified that after a LAS at the distal tibiofibular joint, the fibula shifts anteroinferior relative to the tibia (Kavanagh., 1999, Weerasekara *et al*., 2021). Mulligan hypothesised that with positional fault correction through repeated movements, the proprioception of the joint can be re-enhanced and painfree R.O.M restored (Mulligan., 1995). Portela, (2020) suggested the mechanism responsible for the effectiveness of MWM follows a neurophysiological approach whereby it is suggested that the joint mobilisation stretches the ligaments and capsule of the ankle, promoting stimulation of mechanoreceptor activity; increasing sensory output and allowing a greater stretch.

MWMs have shown significant improvements in ankle DFROM on chronic LAS. Reid *et al*., (2007) found that post MWM-intervention of the talocrural joint, an increase of 19% (P=0.02) was recorded using a WBLT. Similar to this study, increases of 14.3% (P<0.05) were observed on Chronic LAS patients by Vicenzino *et al*., (2006). The current research however, appears more controversial. Marrón-Gómez *et al*., (2015) found improvements of 17.35% (P<0.001) on Chronic LAS post MWM-intervention when compared with a placebo (-2.3%, P<0.001). Gilbreath *et al*., (2014) however, found improvements were insignificant with increases of 3.8% (P<0.05) recorded on Sub-acute LAS. It is evident that further research may be required here.

1.4 Outcome measures and reliability

The predominant measure being observed is DFROM. The WBLT appeared most appropriate. Two predominant methods of the WBLT were considered due to significance of an Intra-Class Correlation Coefficient (ICC) measuring (1) toe to wall distance and (2) angle between the vertical compared to tibial shaft. Bennell *et al.,* (1998) report an ICC of 0.97 for angle of tibial shaft to the vertical and 0.99 for toe-to-wall distance. The toe-to-wall distance appeared most significant and as evaluated by Konor *et al*., (2012), each 1cm increment was calculated to approximately 3.6º.

1.5 Conclusion

The literature illustrates the positional fault which occurs in conjunction with LAS and remains post-injury. Similarly, it is clear through the arthrokinematics of a LAS, the increased tension placed on the plantarfascia through this positional fault. Both, MWM of the talocrural joint and ST of the plantarfascia have seen significant increases; emphasising their importance in the current ankle rehabilitation industry. MWM has been validated as an efficient method of improving ankle DFROM (Kavanagh, 1999, Weerasekara *et al.,* 2021) and has shown acute improvements of 19% on patients with chronic LAS (Reid *et al.,* 2007). Where plantarfascia stiffness has been seen, ST of the plantarfascia has shown increases of 45.75% (Ranbhor *et al.,* 2021) further elucidating its clinical importance. While questions would remain regarding the long-term implications, this may provide valuable insight for the consideration of LAS.

2.0 Materials and Methods

2.1 Participants

20 male Senior collegiate Gaelic footballers (Mean ± Standard Deviation (SD): Age: 22.5 ± 1.5 years, Ankle DF 29.9 ± 8.6º) volunteered to participate in this study. This testing took place during the competitive break post-Gaelic football season in November.

Inclusion Criteria:

In order to meet the inclusion criteria of this study, participants were required to have a history of a Chronic ankle sprain (>6-months), ≤ 45º of ankle DF, have a minimum of 2-years amateur Gaelic football experience, have no current or recent (last 6-weeks) foot, ankle, knee or hip injuries, aged between 18 and 27 years old and attend the Institute of Technology, Carlow.

Exclusion Criteria:

Anyone which failed to meet the inclusion criteria was excluded from the study.

All participants had read or had read to them both the Participant information form and the Informed consent form in the presence of the main investigator. The study was approved by the Institute of Technology Carlow Ethics Committee prior to conduction and all testing procedures were carried out on the premises of I.T. Carlow.

2.2 Experimental Design

A parallel design study was carried out whereby the objective was to examine the effects of 2 different treatment protocols (MWM treatment (n=10) and plantarfascia treatment (n=10)) on ankle DFROM as measured using a weight-bearing lunge test (WBLT) or commonly referred to as the knee-to-wall test. The design protocol consisted of 3 days of testing which was carried out in the controlled environment of the Physiology Laboratory in the Department of Science and Health in IT Carlow. On all 3 days of testing, a warm-up protocol was implemented which consisted of 5-minutes of cycling at 60 Rotations per minute (RPM) on a cycle ergometer bike (Wattbike Pro, Wattbike LTD., Nottingham, UK). This was incorporated to raise the core temperature and increase blood flow and joint fluid viscosity in the body (Jeffreys, 2006). This remained consistent and was performed at the start of Day 2 and Day 3, respectively.

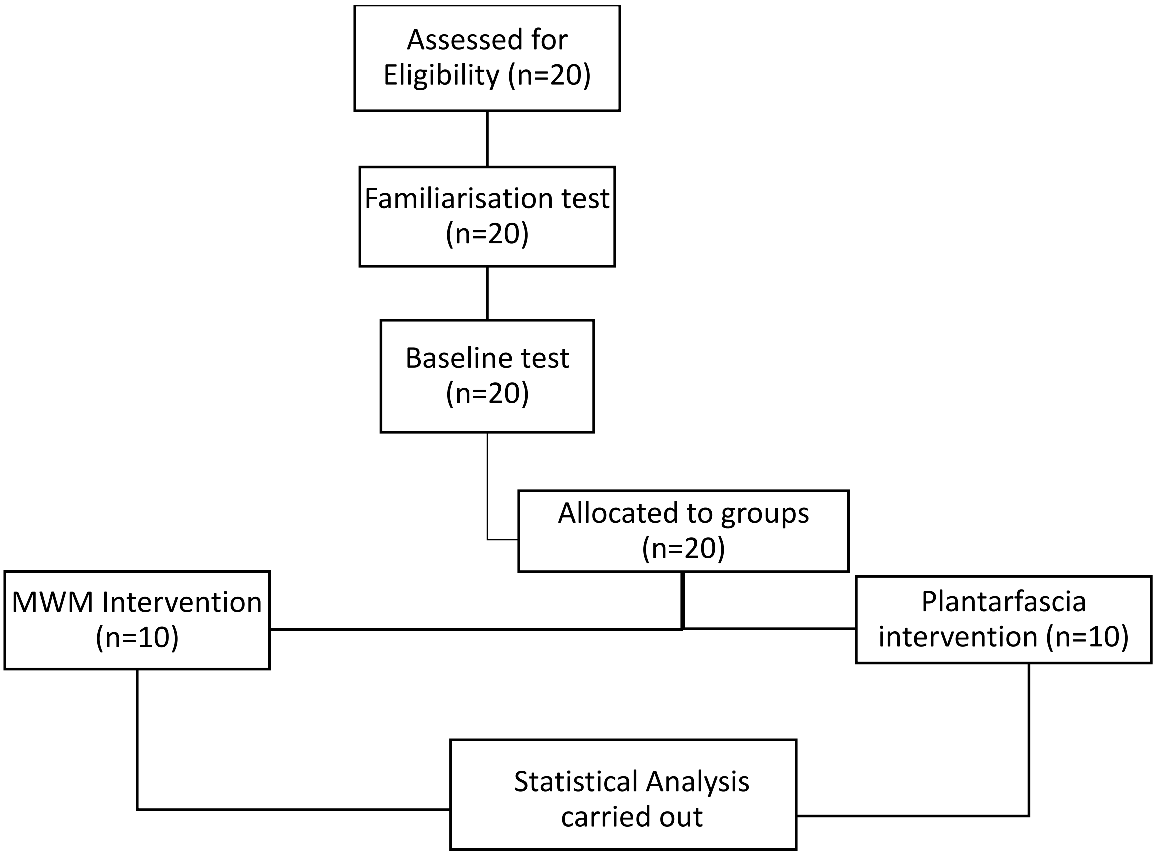

Figure 1: Methodology Flow Chart

Day 1: Screening was carried out using the WBLT and any participant which experienced ankle Dorsiflexion R.O.M >45^{o} in the symptomatic ankle was excluded from the study. Familiarisation was then carried out whereby the participants carried out the warm-up protocol, the WBLT and the 2-treatment interventions.

Day 2: Warm-up was performed and 5-minutes later, a WBLT was performed on the symptomatic ankle and the baseline results were recorded and measured. The 5-minute ‘cooling’ period was to simulate the treatment interventions duration which would take place on Day 3. The WBLT/ Knee to wall test is a standardised measurement protocol used to measure ankle DFROM. Collins *et al*., (2004) and Malliaras *et al*., (2006) used this test to observe and record the baseline measurements. Each participant was required to facilitate 3-attempts and their greatest measurement was recorded. Bennell *et al*., (1998) and Konor *et al*., (2012) validated the reliability of this test as a measurement for ankle DF. Once the data was gathered, participants were split evenly into 2 treatment intervention groups for Day 3 using subject matching (Participants organised in descending numeric order of ankle DFROM and split evenly).

Day 3: The warm-up was carried out and each intervention was carried out on the symptomatic ankle of the respective group (MWM and Plantarfascia group). This lasted for a duration of 5-minutes and the acute effects of ankle DFROM were re-measured using the standardised knee-to-wall test.

2.3 Experimental Protocols

Familiarisation: Participants were informed of the objective measure of the testing protocol which was to measure ankle DFROM and were further informed of the physical demands of the testing process. Participants were familiarised with the warm-up, WBLT and the 2 treatment interventions (MWM and plantarfascia treatment). Participants refrained from any additional sporting activities during this testing process.

Warm-up: A 5-minute cycle warm-up was performed at a cadence of 60rpm on a cycle ergometer bike on all 3-days of testing. This warm-up was adapted by Horia and Georges., (2018) where it was shown to have an increase on physiological benefits prior to Supramaximal cycle training. The duration of this warm-up allowed for an association to be made between the resemblance of the brief 5-minute window for the potentiation phase before the ball is thrown in at a GAA match.

Weight-bearing lunge test: A measuring tape (beginning at 0cm) was laid out perpendicular from the base of the wall. The participants placed the base of their foot parallel to the tape and placed both hands on the wall to allow for stability and maintenance of upright-balance. The participants placed the non-symptomatic foot one foot-length behind the symptomatic foot. This method was shown by Bennell *et al*., (1998) to allow for repeatable measures. The instruction to flex at the knee of the symptomatic leg and lean forward till a point of contact is made with the wall and the anterior portion of the knee was given to the participants. The distance was recorded from the point of the great toe to the wall. Full fore, middle and rear foot contact with the ground was maintained by the participants throughout (See Figure 2). The process was repeated 3-times; each time adjusting dependent of the ease or difficulty of task performance ensuring anterior knee contact was made with the wall and full fore, middle and rearfoot contact with the ground remained. The greatest distance from the 3-attempts was recorded and inserted into a formula previously used in the above paper discussed by Bennell *et al*., (1998) whereby each increment of 1cm equated to approximately 3.6^{o} of ankle DFROM. An approach by Hoch and McKeon, (2011) was further applied where each measurement was calculated to the nearest 0.1cm which allowed for an increase in the reliability of the results and a more accurate measurement of ankle DFROM. This test was carried out both pre- and immediately post-intervention and the acute effects compared.

Figure 2: WBLT (Hoch and McKeown, 2011)

Figure 2 above shows the WBLT used to measure ankle DFROM. The participant aligns their symptomatic foot parallel with the tape perpendicular to the wall beginning at 0cm. The symptomatic foot is placed exactly one foot length in front of the non-symptomatic foot and while maintaining full fore, mid and rear foot contact, the participant flexes at the knee of the symptomatic leg; lunging forward to the wall until contact is made between the anterior surface of the knee and the wall. The distance between the great toe and the wall is recorded. The non-symptomatic foot is free to move and does not have to maintain full foot contact with the ground. This is repeated 3-times and the best measurement taken and calculated to the nearest 0.1cm (Hoch and McKeon., 2011).

2.4 Intervention Programmes

MWM Treatment Group: Participants were required to obtain a position of 90º Hip and Knee flexion of the symptomatic ankle and maintain upright posture in a split-squat position. A non-elastic belt was placed on the symptomatic leg perpendicular to the posterodistal tibia and fibula and ran around the pelvis of the investigator. The investigator utilised an inter-locking hand grip and mobilised both the talocrural and subtalar joint to ensure the maximal increase of posteroanterior translation of the tibia was applied relative to the talus. The participant was required to maintain an axial alignment of the anterior surface of the knee, the talocrural joint and the third-toe respectively to maintain repeatable measures (Collins *et al*., 2004). As MWM requires both mobilisation by the investigator and active facilitation of the participant, the participant performed active ankle DF by lunging forward slowly as the movement was brought to full pain-free end-range by the investigator. The investigator maintained the non-elastic belt perpendicular to the long-axis of the tibia at all times throughout the movement which increased the anterior translation of the tibia in relation to the talus of the ankle joint. 3 sets of 10 repetitions were carried out with 1-minute rest intervals between sets which showed significance in improving ankle DFROM (Collins and Vicenzino, 2004) The treatment intervention endured a total time of 5-minutes which may be closely represented with the duration of the potentiation phase or the team-talk of a match. This remained consistent for all participants (n=10). The participants performed the WBLT immediately after the treatment intervention was applied.

Figure 4: MWM Mid-range (Authors own image)

Figure 3: MWM at end range (Authors own image)

Plantarfascia Treatment Group: Participants performed the 5-minute cycle warm-up at their own self-selected pace. Participants were then required to lie supine on the plinth with the symptomatic foot positioned off the end of the plinth and in neutral. Using the thumb of the investigator, frictions were applied both parallel and then perpendicular to the tissue structures. Where tension was encountered (proximal to the calcaneus enthesis), the participant was asked to dorsiflex actively at the ankle and a gentle passive flexion was applied to the hallux by the investigator. Transverse frictions were applied across these tensile structures and additional force added through the use of the index finger. As this treatment was using the application of DFM, no lubrication was used to facilitate synchronous movement of both the skin and tissue rather than the skin sliding over the tissues and thus; facilitating a deep tissue massage mechanism (Yelverton *et al*., 2019). Finally, stripping and kneading was applied to the plantarfascia with the addition of lubrication due to the many physiological benefits shown such as those by Callaghan *et al*., (1993). The treatment intervention also endured a total time of 5-minutes. This remained consistent for all participants (n=10). The participants performed the WBLT immediately after the treatment intervention was applied.


Figure 6: DFM of plantarfascia (Lateral view), (Authors own image)


Figure 5: DFM of plantarfascia (inferior view), (Authors own image)

2.5 Statistical Analysis

Proposed Statistics:

Two independent variables were present in this study which will be primarily analysed; (1) treatment intervention (MWM vs PF treatment) and (2) time (pre- vs post-treatment). Only one dependent variable was measured and assessed; (DFROM).

Due to the quantitative nature of this study, data and information was gathered and analysed using IBM's SPSS for Windows software[1]. To identify if the data was normally distributed; the skewness of the data was analysed and a Shapiro-Wilks test was conducted. An independent samples T-Test was used to identify differences in results pre- vs. post- treatment intervention. A paired samples T-test was carried out to determine within group effects. Finally, Cohen's D was analysed to determine relative variance of the population.

[1] Statistical Package for Social Sciences; Version 22; SPSS Inc., Chicago, IL.

3.0 Results

The means (μ) and standard deviations (σ) for each time period (Pre-treatment and post-treatment) were calculated and are displayed below in table 1 (P<0.001).

Independent T-Tests:

An independent-samples T-Test was conducted to compare the pre-treatment and post-treatment score of ankle DFROM on male GAA athletes. There was no significant difference in scores for these athletes (pre-treatment: $t(20) = -0.009$, $P=0.993$ two-tailed), (post-treatment: $t(20) = 0.918$, $P=0.371$ two-tailed) The magnitude of the means is not significant (Pre mean difference =-0.036, 95% CI: -8.58 to 8.51), (post- mean difference = 3.82, 95% CI: -4.92 to 12.55) identifying that there is no significant difference in ankle DFROM following a treatment programme between MWM and Plantarfascia treatment groups. Using Cohens D, this population was found to be of medium effect size (0.4).

Table 1: Group statistics [2]

Measurement: μ ± σ					
		Years	Degrees		
Group	n	Age	Pre-intervention	Post-intervention	Change
Plantarfascia	10	22.2 ± 0.79	29.92 ± 9.01**	35.46 ± 8.55**1	5.54 ± 2.57
MWM	10	22.8 ± 1.99	29.95 ± 9.19**	31.64 ± 9.98**1	1.51 ± 1.17

[2] MWM: Mobilisation with Movement. Values are represented as means ± Standard deviation of WBLT in degrees. (****** denotes P ≤ 0.001) and where treatment intervention is significantly greater than baseline is denoted by ****1**.

Paired T-tests:

The quantitative data was analysed using a Shapiro-Wilks test for normality. The null hypothesis was accepted as both pre- and post-test data did not differ significantly from the normal distribution (Pre: 0.134, Post: 0.170; P>0.05). A paired-samples T-Test was conducted to evaluate the impact of each treatment to view within groups effects for ankle DFROM (degrees). The means for both groups pre-test were relatively similar. (MWM: μ = 29.95, σ = 9.19, Plantarfascia: μ = 29.92, σ = 9.01). Post-treatment analysis identified differences between groups. MWM group mean rose by 5.6% post-treatment-intervention (μ = 31.64, σ = 9.98, t(9) = 3.97, P=0.003 (two-tailed)). The plantarfascia group however, saw larger increases in ankle DFROM post-treatment with a mean increase of 18.5% (μ = 35.46, σ = 8.55, t(9) = 6.809, P<0.001 (two-tailed)). These likewise comparisons are represented below in Figure 7

Figure 7 above shows the mean improvements observed in ankle DFROM (degrees) for both

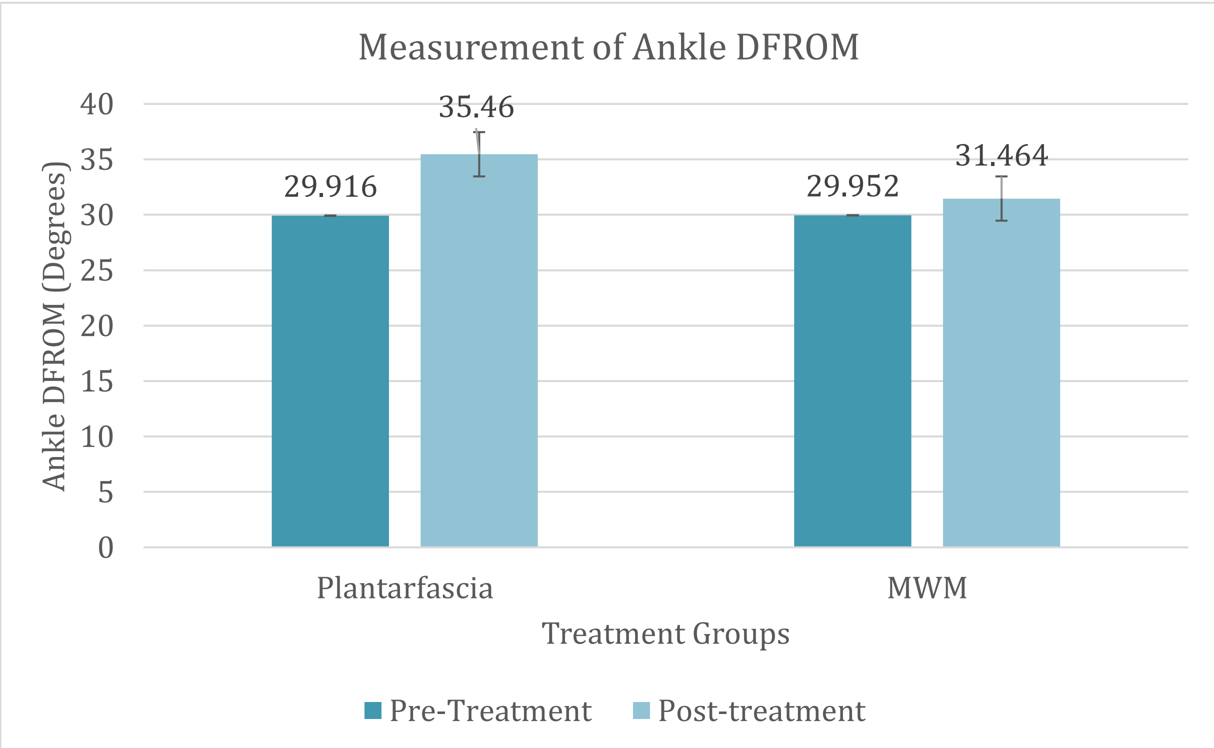

Figure 7: Measurement of ankle DFROM

plantarfascia and MWM groups. Pre-treatment for the plantarfascia group is 29.92⁰ compared to post-treatment (35.46⁰). Pre-treatment for MWM is 29.95⁰ compared to post-treatment (31.46⁰).

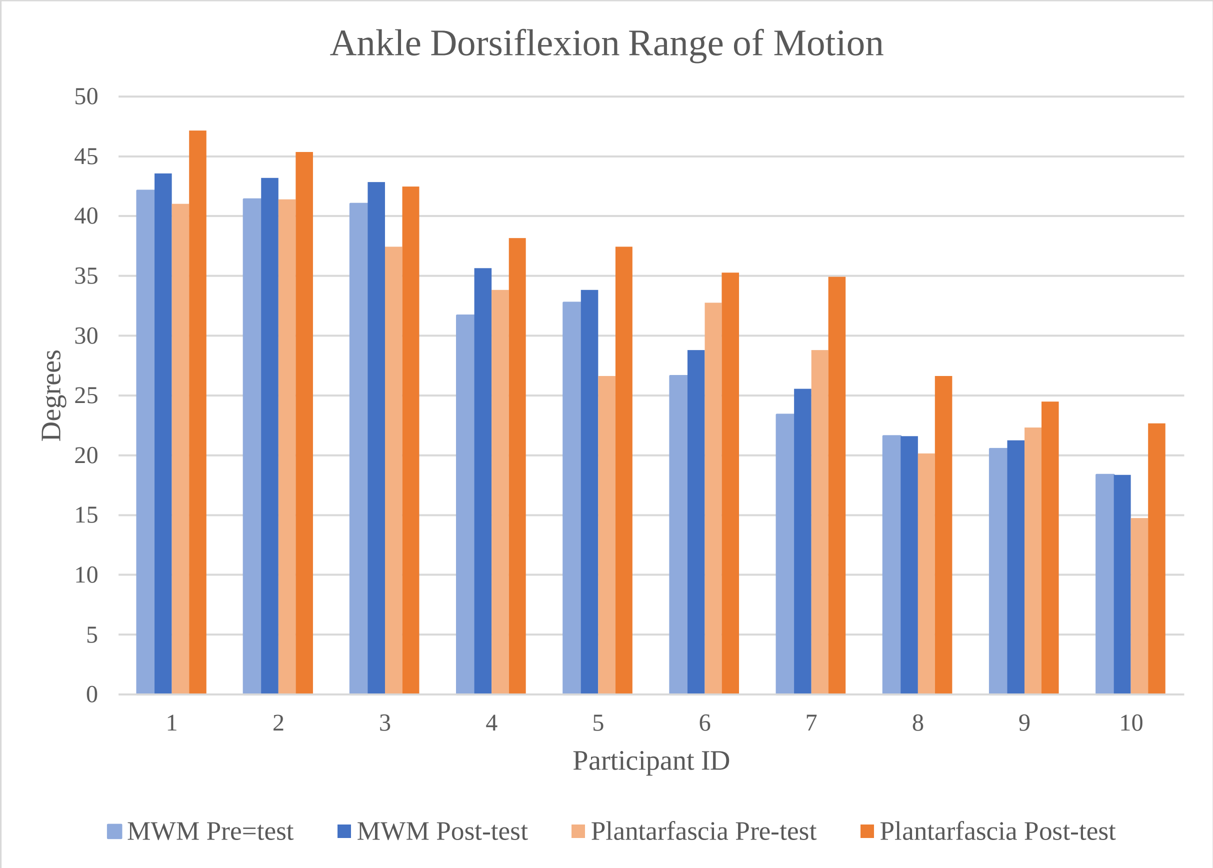

Figure 8: Ankle DFROM across all participants

Figure 8 above shows the scores for each participant (n=20) whereby it can be observed that two participants of MWM treatment saw no increase in ankle DFROM and only the plantarfascia treatment group recorded increases in ankle DFROM greater than 45º (45.36, 47.16).

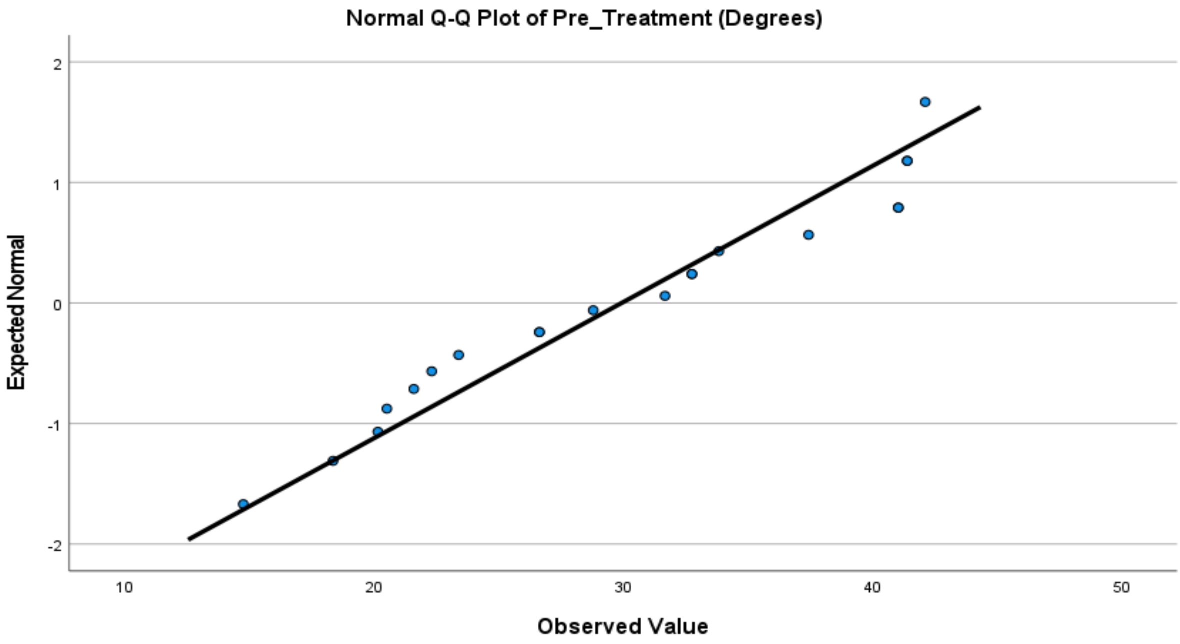

Figure 9: Distribution of pre-treatment ankle DFROM (n=20)

Figure 9 shows pre-treatment ankle DFROM (degrees) of all participants (n=20). The straight-line indicates the normal and each participants deviation from the normal is displayed. Figure 9.1 below shows the post-treatment ankle DFROM (degrees) of all participants (n=20).

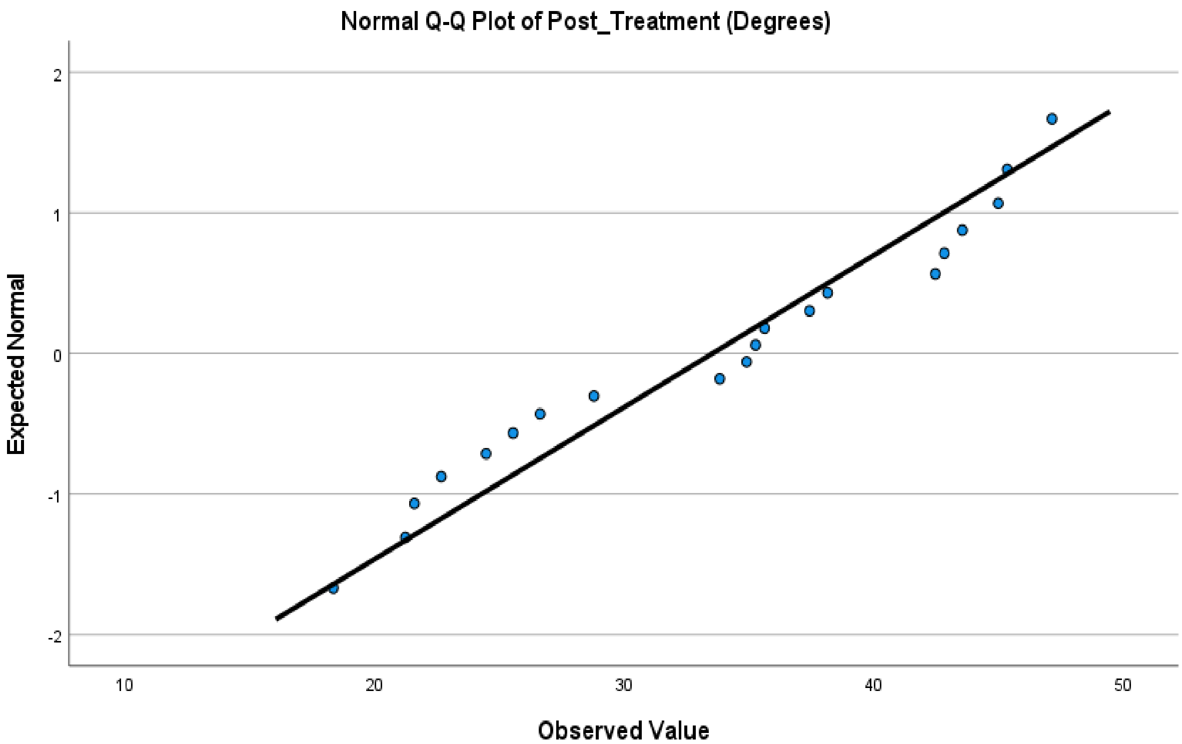

Figure 9.1: Distribution of post-treatment ankle DFROM (n=20)

4.0 Discussion

The primary findings of this study illustrate the positive effects that both MWM and plantarfascia intervention have on the acute improvement of ankle DFROM on male GAA athletes post-chronic LAS. It was hypothesised that the plantarfascia treatment would show greater improvements when comparisons were drawn between the two treatment interventions. While this study did indicate clinically significant differences and relevance within both groups, we reject the hypothesis as there were no statistically significant differences between groups ($P \leq 0.001$). With reference to the study population, only a small effect size was observed.

These findings indicate the relevance of either treatment being used clinically for the acute improvement of ankle DFROM post chronic LAS. When viewing these improvements in the context of injury and the healthy population, it is evident that 30% of patients that received either the MWM or the plantarfascia intervention exceeded what was described by Hoch *et* al., (2011) as normative ankle DFROM values of the healthy population (42.8º - 43.2º). This displays clinical relevance in the rehabilitative context of restoration of ankle DFROM. It can also be noted however, that 20% of the MWM group saw no increase in DFROM and so further research may be required to explore the efficacy of MWM application to the talocrural joint for ankle DFROM.

Regarding MWM application to the talocrural joint, we must ask what does the research say? This topic unfortunately, remains quite conflicting. There is an array of research supporting MWM application for the restoration of ankle DFROM however, on the contrary; there is proportional research neglecting its' significance. The present study supports the use of MWM on chronic LAS for the acute improvement of ankle DFROM. Gilbreath *et al*., (2013) found however, when carrying out MWM of the talocrural joint on LAS, that no significant differences were seen in ankle DFROM. There are several possible explanations regarding the inconsistencies between studies.

The present study design for implementing this treatment derived from Collins and Vicenzino (2004) whereby 3 sets of 10-repetitions were used with 1-minute rest intervals. Gilbreath *et al*., (2013) utilised their MWM approach differently whereby 2-repetitions were performed in 4 sets with each MWM held in a stretch position for 30 seconds. This mechanism places the Gastrocnemius-Soleus complex on a stretch which was suggestive for the increased ROM

(Gilbreath *et al*., 2013). The purpose of an MWM however, is to restore natural joint kinematics through repetition of sustained DF as this has been proposed by Mulligan (1993) to correct the positional fault. Furthermore, it is noted that Gilbreath *et al*., (2013) conducted the study on sub-acute LAS and when compared with chronic LAS, a large contrast is observed. Marrón-Gómez *et al*., (2015) reported improvements of approximately 17% on acute ankle DFROM with MWM application to the talocrural joint. The present study however, shows improvements of only 6%. When making comparisons between the two studies it must be noted that Marrón-Gómez *et al*., (2015) performed the WBLT immediately pre-treatment and immediately post-treatment. This design incorporates the use of a stretching mechanism of the Gastrocnemius-Soleus complex which as evaluated by Radford *et al*., (2006) has shown significant increases in ankle DFROM which may be suggestive of an additional increase in DFROM. The results of the present study suggest clinical relevance as to which approach may be better suited for ankle DFROM and at what stage MWM application may be most effective at restoring DFROM.

The mechanism at play to which the increase in ankle DFROM is seen post-MWM intervention remains unknown. It is suggested by Mulligan, (1993) that the positional fault can be corrected through repeated and sustained movements allowing the glide of the tibia over the anteriorly displaced talus. More recent explanations have taken a neurophysiological approach whereby it is suggested that the joint mobilisation stretches the ligaments and capsule of the ankle, promoting stimulation of mechanoreceptor activity; increasing sensory output and allowing a greater stretch (Portela, 2020).

To the best of my knowledge, this is the first study to focus on the acute effects of ankle DFROM post ST intervention of the plantarfascia on chronic LAS athletes. This evidence may be important in the comprehension of LAS rehabilitation however, there is limited research to draw accurate and in-depth conclusions. The question raised in the introductory section of this research was; if the stiffness of the plantarfascia was reduced would an increase in DFROM be seen? After careful analysis, it is evident the clinical relevance of these improvements with a mean improvement of approximately 19% observed.

In pathologies where plantarfascia stiffness is seen; such as plantarfasciitis, FR of the plantarfascia has shown improvements of 45% in acute ankle DFROM post-intervention (Ranbhor *et al*., 2021). Conversely, where there were no previous lower-limb injuries, FR of the plantarfascia indicated improvements of 20%; which is in line with the present study

(Yoshimura *et al*., 2020). It must be noted that with plantarfasciitis, a large limitation of DFROM and metatarsophalangeal DFROM is associated with pain (Cutts *et al*., 2012). Massage stimulates activity of the parasympathetic nervous system, often altering levels of cortisol and serotonin and causes a decrease in the stimulation of pain sensitivity (Behm & Wilke, 2019). This may be suggestive of how plantarfasciitis patients saw larger increases in acute ankle DFROM compared with the healthy population as shown by the present study and Yoshimura *et* al., (2020); where participants were asymptomatic to pain. The concurrent evidence supports the use of soft-tissue application of the plantarfascia for the improvement of acute ankle DFROM.

Similar to MWM intervention, the mechanism at play is still not fully understood. Both plantarfasciitis and chronic LAS are associated with excessive pronation of the subtalar joint as the calcaneus inverts causing misalignment of hindfoot varus (Bolgla & Malone, 2004, Taunton *et al*., 2002). With repetitive stresses placed on the plantarfascia, the propulsive phase of the Windlass mechanism is altered, reducing DFROM with increased plantarfascia stiffness (Liu *et* al., 2020, Bolgla and Malone, 2004). As discussed above with plantarfasciitis, the massage-intervention offers both a reduction in pain and changes the thixotropic properties of the plantarfascia increasing R.O.M (Behm & Wilke, 2019, Callaghan, 1993). With reference to the LAS participants, it is understood that DFM is involved in the breakdown and removal of collagen adhesions, causing an overload of cutaneous receptors; resulting in a stretch mechanism allowing for a partial restoration of extensibility and flexibility properties of the fascia (Ranbhor *et al*., 2021, Callaghan, 1993). With less strain now placed on the plantarfascia, it is suggestive that the attaching structures of the fascia are now placed under less stress, potentially; reversing the amount of hindfoot varus. As hindfoot valgus allows a greater R.O.M through the midtarsal joint resulting in a flexible foot during walking gait, it is suggestive for an improvement in ankle DFROM (Tweed *et al.*, 2008, Blackwood *et al*., 2005).

In regard to clinical relevance and implication, it is identified that with limited ankle DFROM, the GAA athlete's susceptibility to injury both locally, and further up the biomechanical chain is increased. In other intermittent jumping sports such as volleyball, the likelihood of developing a patellar tendinopathy and/or patellofemoral pain syndrome is increased by 180-280% with $<45^{o}$ of ankle DFROM (Malliaras *et al*., 2006). Other pathologies which are increased with a limited ankle DFROM are injuries such as Chronic Plantar Heal pain and plantar fasciopathy (Irving *et al*., 2006). The benefits of the present study offer treatment-interventions which may be effective in the prevention of such injuries.

4.1 Limitations

It is important to acknowledge the limitations of this study. Firstly, the effect size of the study population was small. The present study was observing the acute/immediate effects of ankle DFROM post-intervention however, a follow-up study may show greater efficacy of long-lasting effects. Similarly, it would be beneficial to see the effects of both treatments in one-intervention. Although large increases were seen in ankle DFROM, it is undisclosed how the increase in DFROM may affect the GAA athletes' functional performance and balance of the ankle. Finally, although each participant reported a chronic LAS (>6-months), the severity of each individual LAS was unknown.

5. Conclusions

In conclusion, it is evident that both the MWM and plantarfascia treatment intervention have a significant effect on the acute improvements of ankle DFROM post chronic LAS. Although there were no statistically significant differences between groups, the clinical relevance is displayed and the importance of improving ankle DFROM for reducing the risk of injury and re-injury is clearly indicated. As this is the first study of its type, it is important further research be carried out to explore the effects in greater detail and long-lasting effects observed. With relation to clinical application, it must be accentuated that rehabilitation programmes often consist of multiple exercises and focus on specific analytics and although these two-treatment interventions display evident improvements in ankle DFROM, the treatment approaches are merely a guide for clinical education and not an entire treatment paradigm for chronic LAS.

6. Future Work

Although it is suggested that post LAS, the foot is left in a greater position of pronation, this was not assessed within this research and further analysis should be carried out on Foot and ankle biomechanics and its effect on the Windlass mechanism. It would be of interest for the long-lasting effects of each treatment to be observed. Similarly, FR of the plantarfascia could be explored to allow the implementation of rehabilitation into the ease of the athlete and compared to FR of the uninjured athletes. A study design which features both treatment-interventions to the same group to view combined effects should be observed. Finally, the effects of functional performance, balance and proprioception of the ankle should be explored with reference to both treatment-interventions.

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