The effect of tissue flossing on ankle range of motion, jump and sprint performance in elite rugby union athletes

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Abstract

The anecdotal use of floss bands amongst athletic populations is becoming a popular strategy to increase joint range of motion (ROM), enhance both injury prevention and rehabilitation and improve overall athletic performance, despite limited evidence for its efficacy. Such a technique has been described as ‘tissue flossing’ and involves wrapping a thick band of rubber (floss band) tightly around a joint or muscle group, to partially occlude blood flow to the area. Recently, research has been conducted regarding the use of tissue flossing to acutely enhance the athletic qualities of ankle mobility and jumping and sprinting performance in a recreationally trained population. Research from our laboratory (see appendices), expanded on this work by investigating the time-course of potential benefits following floss band application, also in recreationally trained athletes. The work in this thesis aimed to add knowledge to current literature and to further investigate the use of tissue flossing for improved sport performance in an elite-athlete setting.

The study contained in Chapter 2 of this thesis is the first to investigate the use of tissue flossing on athletic performance in an elite setting. As part of the study, a counterbalanced crossover design was implemented whereby fourteen professional rugby union athletes (age [mean ± SD)] 24 ± 2 years) performed two experimental trials separated by one week. Each trial assessed measures of ankle dorsiflexion using a unilateral weight bearing lunge test (WBLT), bilateral countermovement jump (CMJ) height and 20m sprint times. These assessments were made at baseline and at 5 and 30 minutes following the application of floss bands on both ankles.

Analysis revealed that there were no statistically significant interactions between treatment (FLOSS or CON) and time (pre / 5 min post / 30 min post) for any of the measured variables ($p > 0.05$). Effect size analysis revealed *small* benefits for the FLOSS condition in comparison to CON for CMJ performance 5 mins post and for 10m and 15m sprint time, 30 mins post. All other measures resulted in *trivial* or *unclear* effect sizes. In conclusion, the findings from this study suggest limited support for the use of tissue flossing for improved athletic performance measures, for up to 30 minutes post application in a professional rugby union population.

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Abbreviations

AROM – Active range of motion

CMJ – Countermovement jump

CON – Control

GH – Growth hormone

IPC – Ischaemic pre-conditioning

MVC – Maximal voluntary contraction

RE – Resistance exercise

RM – Repetition maximum

ROM – Range of motion

WBLT – Weight-bearing lunge test

Thesis Overview

The format of this thesis includes a chapter presented in the style of an individual journal article in its submitted format and consequently, some information may be repeated. This thesis is comprised of three chapters; Chapter 1 briefly introduces the technical and physical demands of rugby union and introduces two possible methods to improve rugby performance: ischaemic pre-conditioning and tissue flossing. Chapter 2 includes the main study of the thesis and describes the effect of tissue flossing on ankle range of motion, jump and sprint performance within an elite rugby union population. This chapter appears in the same format that was required by the journal where it was submitted: *Physical Therapy in Sport*. The final chapter summarises the overall findings and provides both practical applications and suggested areas for further research. The appendices of this thesis includes a study that was performed during my candidature that informed the design and purpose of the study in Chapter 2. This study was recently published in *Physical Therapy in Sport*, and therefore, appears in the format which it was accepted by the journal.

Chapter 1:

Literature Review

Introduction

Rugby Union is a contact team sport that is popular worldwide at both an amateur and professional level and is most commonly competed for between two teams of fifteen players (Jones, Smith, Macnaughton, & French, 2016). It is a collision and evasion based sport requiring players to be fast, mobile and powerful to endure high levels of repeated game efforts (Jones et al., 2016). In addition to these demands, there are a number of complex and highly specific activities involved in rugby union which can influence the outcome of a match. Some of the more common and frequent activities for both backs and forwards that occur during match play include linear and non-linear high-intensity sprinting and running, jumping, change of direction and tackling (Gamble, 2004). To achieve success whilst also reducing the risk of injury when performing these activities, high levels of both horizontal and vertical force production capabilities, and the appropriate level of ankle mobility, are thought to be advantageous.

There is currently a wealth of knowledge and literature available that acknowledges both traditional and modern-day training methods that have been reported to enhance these athletic qualities mentioned, to help optimise sporting performance. In addition to these methods, the anecdotal use of floss bands amongst athletes is becoming a popular strategy to further augment some performance measures via a method termed ‘tissue flossing’. The mechanisms associated with tissue flossing using a floss band may be similar to that of ischemic pre conditioning (IPC) or blood flow restriction training, whereby reperfusion of blood to the occluded area may be associated with both favourable health and performance outcomes (Driller, Mackay, Mills, & Tavares, 2017).

The following review of literature aims to (1) introduce the concept of IPC, (2) report the current IPC methods that have been suggested to and/or show positive signs to enhance the athletic qualities of strength and power, (3) provide an overview of tissue flossing, and (4) analyse the available literature regarding the use of tissue flossing practices for enhanced joint range of motion and muscle force production, with specific implications for rugby union.

Ischaemic Pre Conditioning

First described by Murray et al (1986), IPC was originally used in the medical setting. The aim of IPC was to mitigate potential and lethal cell damage following a sudden medical occurrence, such as myocardial infarction (Liu et al., 1991). Therefore, the IPC theory and some of the methods associated with it have been well-researched and administered in a clinical setting on animals however, its effects on humans is less convincing. In previous studies involving humans, IPC has generally been administered through the use of a cuff or tourniquet placed tightly around a limb, interspersed with periods of reperfusion (Hodeaux, 2017). It has been proposed that brief periods of IPC preoperatively, may improve skeletal muscle blood flow by inducing conduit artery vasodilation and preserving endothelial and microvascular function during times of stress (Reeves et al., 2006). With this in mind, IPC could lead to a lower formation of muscle damage following orthopaedic surgery, supposedly through a reduced formation of metabolic stress and inflammatory responses (Liu et al., 1991). IPC has also been suggested to improve metabolic efficiency by attenuating adenosine triphosphate (ATP) and glycogen depletion, and lactate production during prolonged ischemia (Incognito, Burr, & Millar, 2016).

Although the underlying mechanism(s) for IPC are still not uniformly understood, research suggests that this type of intervention may act to protect vital organs via an enhancement of oxygen utilisation properties and therefore, act to prevent further damage to both cardiac and skeletal muscle cells, following a medical incident. To add to the clinical relevance of IPC, recent studies have investigated the potential for muscle function to be acutely enhanced with the use of IPC immediately before exercise (Kilduff, Finn, Baker, Cook, & West, 2013). This has seen the implementation of IPC move into an athletic-performance setting. Increases in growth hormone and catecholamine responses (Reeves et al., 2006), enhanced muscle force and contractility and increased efficiency of excitation-coupling in the muscles are just some examples of the reported performance benefits following an IPC protocol being administered.

Review of current IPC methods used for strength and power enhancement

Whilst there is a growing body of literature that has reported improvements in aerobic capacity mechanisms utilising various IPC strategies, evidence for its use to enhance the more anaerobic alactic properties of strength and power, are in limited supply.

In a study by Barbosa et al (2015) it was concluded that an IPC protocol applied to the lower limbs delayed the development of fatigue during a hand grip exercise with constant load, in 13 recreational male participants. The protocol involved occlusion cuffs being placed proximally around each thigh (mid) that were simultaneously inflated to 200 mmHg for 5 minutes and deflated for 5 minutes of reperfusion. This procedure was repeated three times. CON was similar but inflated to only 10 mmHg, which did not cause arterial or venous occlusion and ischemia. All participants performed two separate trials, separated by one day. Following this IPC procedure, subjects then performed maximum voluntary contractions (MVC) with their dominant hand whilst standing in the supine position. Subjects squeezed a dynamometer to a maximal force within 1-2s and were instructed to maintain this level for 2-3s. Three trials were performed, with 1 minute recovery between each repetition. The MVC was measured as the greatest force achieved among trials that ranged within 5% from each other. The development of fatigue was evaluated by the measurement of contraction and relaxation rates throughout a constant workload rhythmic hand grip exercise, and performance was evaluated by the time of failure to maintain the target force level during the protocol (i.e. time to task failure). In addition to a delay in fatigue development, this protocol also prolonged the time to task failure which was determined once the target force of 45% of MVC could no longer be attained. Barbosa and colleagues therefore suggest this protocol could have a beneficial effect on exercise performance (Barbosa et al., 2015).

In a randomised, crossover design involving three separate testing conditions (IPC, placebo and control), Marocolo (2015) investigated the effects of an IPC intervention on leg extension performance in 13 healthy and recreationally trained men. A 12-repetition maximum (RM) load for the leg extension exercise was assessed through test and retest sessions before the first experimental session. The IPC sessions consisted of 4 cycles of 5 minutes of occlusion at 220 mmHg of pressure alternated with 5 minutes of reperfusion at 0 mmHg, for a total of 40 minutes. The PLACEBO session consisted of 4 cycles of 5 minutes of cuff administration at 20 mmHg of pressure alternated with 5 minutes of pseudo-reperfusion at 0 mmHg, for a total of 40 minutes. The occlusion and reperfusion phases were conducted alternately between the thighs with subjects remaining seated. No ischaemic pressure was applied during the CON session and subjects sat passively for 40 minutes. Eight minutes after IPC, PLACEBO or CON, subjects performed 3 sets to failure of the leg extension with 2 minutes rest between sets, with the pre-determined 12RM load. The number of repetitions per set, total volume, and fatigue index (considered as the degree of decline in number of repetitions during the 3 sets of leg extension, expressed as a percentage change) were measured after each leg extension session. Four minutes after the third set, blood lactate was assessed. The main finding was that the IPC and placebo conditions significantly increased the number of repetitions for the leg extension vs. the CON condition and all conditions showed a similar fatigue index. It was therefore suggested by Barbosa et al (2015), that IPC and PLACEBO may have small, beneficial effects on lower body resisted exercise. However, the IPC intervention used in this study was no more effective than the PLACEBO condition. Consequently, the researchers recommended that coaches and other practitioners experiment by applying a small amount of pressure as in the PLACEBO condition, to assess the effects on performance during training phases.

In a counter-balanced, crossover study design, Lisboa et al. (2017) investigated the effect of ischaemic preconditioning (IPC) on successive sprint swimming performance in three 50m swimming trials. On two separate days, 11 competitive male swimmers performed three successive 50m trials, preceded by intermittent bilateral cuff inflation

(4 × 5 min of blood flow restriction + 5 min of cuff deflation) at either 220 mmHg for thighs and 180 mmHg for arms (IPC) or 20 mmHg for both limbs (control-treatment). The 50m trials were conducted 1, 2, and 8 hours after the procedure. While no ergogenic effect of IPC was observed for 1 hour (0.4%, 95% confidence limits: ± 0.6%, $p = 0.215$), there were clear beneficial effects of IPC at 2 and 8 hours (1.0 ± 0.6% and 1.2 ± 0.6% respectively; $p \leq 0.002$) post IPC.

Takarada and colleagues investigated the hormonal and inflammatory responses to low intensity exercise performance, following vascular occlusion. Subjects ($n = 6$) performed bilateral leg extension exercise in the seated position, with the proximal end of their thigh compressed at 214 ± 7.7 mmHg throughout the session by means of a pressure tourniquet. Mean intensity and quantity of the exercise were 20% of 1RM and 14 repetitions x 5 sets, respectively. In each set, the subjects repeated the movement until exhaustion. The present study reported that resistance exercise when combined with vascular occlusion, even at an extremely low intensity, causes enhanced muscular electrical activity and endocrine responses. These results imply that the intramuscular condition to be satisfied for muscular hypertrophy to occur e.g. acute hypoxia and accumulation of metabolites, can be achieved with such an IPC intervention . With this in mind and on the basis of the present methodology, this IPC protocol could therefore be useful for athletes in a rehabilitation setting where heavy resistance training cannot safely be applied.

In a review of twenty one investigations into the use of various IPC methods on healthy humans, it was concluded by Incognito and colleagues that IPC is a safe and effective method to improve some qualities of athletic performance. The mode of exercise performed following an IPC protocol, differed dramatically between these studies. However, to help stratify the results, exercise modes were grouped by duration and predominant energy systems utilised. Although, large between-study variability existed, the most consistent benefit of IPC from the studies analysed in this review was for an improvement in time-trial performance in exercise tests which predominantly stressed the aerobic capacity system (Incognito et al., 2016). It was reported that the

IPC protocols used in the studies analysed by Incognito et al. (2016) had no significant effect on subsequent measures of alactic anaerobic capacity such as 30m sprint time. Gibson, Mahony, Tracey, Fawkner, and Murray (2015) reported no effect, whilst Patterson, Bezodis, Glaister, and Pattison (2015) reported a 2.3% increase in peak power output during repeated 6s cycling sprints with similar protocols, following IPC. Detrimental effects were shown by Paixao, da Mota, and Marocolo (2014) for measures of peak anaerobic power and capacity, following a cycling wingate test (30s max test). In this review, Marocolo, da Mota, Simim, and Appell Coriolano (2016) also noted that IPC had no effect on three sets of submaximal bilateral knee extension strength to failure. Overall, of the twenty one studies reviewed by Ingonito, eight assessed the impact of IPC on anaerobic alactic qualities. Of these, only three studies showed small but non-significant evidence for increases in lower body peak power output, during cycling sprints.

In a systematic review of 22 studies, Marocolo et al. (2016) further investigated the impact of various IPC methods on performance and physiological variables. Of these studies, five measured the effects of IPC on the anaerobic alactic qualities of max power, peak power, sprinting time and jump height. The testing protocols included wingate and maximal incremental cycling, 10, 20 and 30m sprinting and squat and counter-movement jumps. Overall, the majority of the variables from the selected studies showed non-significant differences for performance or physiological variables ($p = 0.97$) (Marocolo et al., 2016).

Overall, whilst there are some promising reports for the use of IPC to augment some aspects of strength and power, more work is required for this to be accepted as a recommended intervention for these areas of performance to be further enhanced.

Overview of tissue flossing

A relatively new tool in both clinical and athletic performance environments, is the floss band. Commonly, a long (~7 foot) and two inch thick band made from latex rubber, the floss band was initially developed for its use in both the weight lifting and cross-fit training communities (Starrett & Cordoza, 2013). Unlike previous IPC research which has predominantly used pressure cuffs, a floss band allows a joint or muscle to be wrapped while ROM exercises are performed, making it more practical in an athletic setting.

The floss band has subjectively been reported to be unique from other common compressive bands such as the ACE ™ wrap for example, and in comparison has been suggested to adhere more effectively to the skin without slipping, once applied (Kiefer, Lemarr, Enriquez, Tivener, & Daniel, 2017). Furthermore, the floss band has been reported to provide a tighter and therefore stronger, direct pressure on applied tissue, compared to alternative wrapping options (Castro-Sanchez et al., 2011). In addition to its previous use predominantly in the strength and conditioning community only, the floss band is now also being considered by medical professionals in recovery, treatment and rehabilitation settings (Kiefer et al., 2017). In some instances, clinicians are also using the floss band as a mode of myofascial release. This technique aims to provide the appropriate amount of compression in order to anecdotally enhance conditions such as increased blood flow, muscle length and range of motion and to reduce muscle soreness (Kiefer et al., 2017).

Tissue flossing involves wrapping the floss band around a joint or muscle to partially occlude blood-flow to the area while concomitantly performing low intensity range of motion (ROM) tasks for one to three minutes (Driller & Overmayer, 2017). While current research studies regarding tissue flossing are currently limited, the mechanisms responsible for the proposed athletic improvements to date are thought to be similar to those of the more extensively researched of IPC. In addition to this, the fascial shearing and joint lubrication that is likely to occur whilst performing active tasks with the band/s applied, possibly enhances ROM of the joints that are covered by the floss bands (Fong, Blackburn, Norcross, McGrath, & Padua, 2011).

Review of tissue flossing studies for enhanced joint ROM and muscle force production

To the author’s knowledge, the extent of research examining the effect of tissue flossing in an athletic setting is currently limited to three studies published as conference proceedings and thesis (Bohlen et al., 2014; Hodeaux, 2017; Plocker, Wahlquist, & Dittrich, 2015); and two further studies recently published as journal articles (Driller & Overmayer, 2017) and (Driller et al., 2017). In addition, Kiefer et al (2017) investigated the psychological effects of a band therapy intervention (voodoo floss band) on gleno-humeral flexibility.

Bohlen et al. (2014) examined the effects of 14 days of band flossing combined with joint mobilization and RE on calf blood flow and plantar/dorsiflexion strength in five participants. Subjects performed unloaded squats, heel raises, active dorsiflexion and passive ankle mobilization with floss bands applied to one knee while the contralateral leg acted as control. Results showed that dorsiflexion peak torque increased 22% in the treatment leg ($p = 0.06$), while there was no change in the control leg.

Plocker et al. (2015) studied the effect of applying floss bands to both shoulders in 17 male athletes in an acute setting. Subjects attended an experimental session whereby the researchers wrapped both shoulders with a floss band and lead subjects through shoulder ROM exercises. Upon band removal, ROM measures (internal and external rotation) were taken using a goniometer. A 3D accelerometer was then used to measure upper extremity power during the bench press. The control session involved the same shoulder exercises without the use of the floss band modality. The study reported that despite trends towards improvements, there were no significant increases in ROM or upper-body power ($p > 0.05$) following the floss band treatment when compared to the control. Researchers concluded that it was difficult to cover the entire shoulder (rotator cuff complex) with the wrapping technique, potentially limiting the effectiveness of improving shoulder ROM following a floss band intervention.

Hodeaux (2017) investigated the effect of floss band/s on elbow ROM in tennis players. Twelve elite tennis players participated in this randomised cross-over study design. Subjects attended two separate testing sessions. Passive ROM measures were taken with a standard goniometer for elbow flexion and extension and forearm pronation and supination. For each session, baseline ROM was initially taken and subjects were instructed to enter a separate room to have their intervention applied (floss band or no floss band). After the intervention was applied, ROM was re-measured. On their second visit, participants received the intervention that was not previously applied. A paired sample t-test revealed no significant difference ($p > 0.05$) between floss band and no floss band, for all measures and it was concluded that these results revealed that floss bands do not significantly improve elbow ROM.

Driller and Overmayer (2016) evaluated the use of floss bands when applied to the ankle joint, on subsequent ankle ROM and single leg jump height and velocity in recreational athletes (N=52), 5 minutes after floss band application. Pre and post measures included a weight-bearing lunge test (WBLT), ankle dorsiflexion and plantar flexion and single leg vertical jump height and velocity. The results from this study revealed significant enhancements in all test measures pre to post ($p < 0.01$) for the tissue flossing group, whilst no significant changes pre to post for the control group ($p > 0.05$) were observed. All pre to post changes were associated with *small* effect sizes for the flossing group compared to the control group. It was therefore suggested by Driller (2016) that floss band/s may be used to enhance injury prevention and athletic performance strategies.

In a follow up study (see appendices), our group investigated the time-course benefits of tissue flossing on the ensuing ankle ROM, countermovement jump (CMJ) force and 15m sprinting performance, in recreational athletes (n=69) (Driller et al. 2017). Participants performed a WBLT, countermovement jump (CMJ) and a 15m sprint test pre and at 5, 15, 30 and 45 minutes post application of a floss band to both ankles (FLOSS) or without flossing of the ankle joints (CON). Results showed that there was a significant intervention x time interaction in favour of the flossing group (FLOSS) when compared to the CON group for the WBLT ($p < 0.05$). These results were associated with trivial to small affect sizes at all time points. Small, but non-significant ($p > 0.05$) benefits were seen for FLOSS when compared CON for CMJ force and 15m sprint times at 45 minutes post intervention.

Kiefer and colleagues investigated the psychological effects of floss band/s on gleno-humeral ROM. Results showed that whilst there were no statistically significant gains in gleno-humeral flexion, the participants subjectively felt as if the floss band/s positively impacted movement ability about the shoulder joint (Kiefer et al., 2017). These findings indicate that a clinician would possibly be able to use a floss band as a means of creating a placebo effect in their patients to think that they are able to increase their joint ROM. When a patient perceives a treatment to be effective, their adherence to a treatment plan is often higher (Kiefer et al., 2017). Therefore, even though the floss band was not demonstrated to have a positive effect on gleno-humeral ROM in this study, an athletic professional may still find use in utilizing this tool to achieve soft tissue flexibility goals with their patients or athletes (Kiefer et al., 2017).

Limitations and future directions

Whilst IPC and tissue flossing seem a simple intervention that could possibly be applied in a variety of performance settings, results from the literature regarding their use for improved joint ROM and muscle force production, are contradictory. The major limitation with regard to being able to establish tissue flossing as a method to enhance the above properties, is the current lack of published research in this area. Another limitation is related to the IPC protocol/s utilised for IPC, which differed dramatically between the studies reviewed. This included variations in the site of application, the duration of the IPC intervention chosen and the mode of exercise performed following the IPC intervention e.g. a strength, power and / or strength-endurance measures. This lack of standardisation between studies makes it challenging to compare, contrast and ultimately identify the potential value of the IPC protocols reviewed, for enhanced ROM and muscle force production. Future research should aim to extend on the current work completed with regard to tissue flossing whilst replicating some of the testing protocols and procedures that have already shown some promise, for enhanced ROM and muscle force production.

Conclusion

Rugby union athletes require maximum and explosive force production capabilities for the contact (e.g. scrummaging, rucking, mauling, tackling) and sprinting aspects of the game. In addition to this, it is essential that rugby players are able to effectively jump and land which requires the appropriate levels of ankle mobility. Therefore, when considering these physical requirements for rugby success and some of the encouraging findings from the literature reviewed, tissue flossing could be an effective intervention to augment ROM, strength and power production properties, in a rugby union context. To help optimise the potential impact, future work should attempt to further investigate the potential benefits of tissue flossing within an elite athletic population.

Chapter 2:

Study: The effect of tissue flossing on ankle range of motion, jump and sprinting performance in elite rugby union athletes

Mills, B., Driller, M. W., Tavares, F., & Mayo, B. Tissue flossing on ankle range of motion, jump and sprint performance in elite rugby union athletes. Submitted to *Physical Therapy in Sport.*

Abstract

Objectives: Previous research has shown that tissue compression and partial vascular occlusion using band flossing may result in increased ankle ROM, jump and sprinting performance for up to 45 minutes, following the application of floss bands, in recreational athletes. The current study aims to extend on this research, within an elite athlete sample.

Design: Randomised crossover trial separated by one week.

Setting: University laboratory.

Participants: 14 professional male rugby union athletes (mean ± SD: age; 23.9 ± 2.7, mass; 102.4 ± 11.4 kg, height; 188 ± 8 cm).

Main outcome measures: Participants performed a weight-bearing lunge test (WBLT), a countermovement (CMJ) jump test and a 20m sprint (SPRINT) test pre and at 5 and 30 minutes-post application of a floss band to both ankles (FLOSS) or without flossing of the ankle joints (CON) on two separate occasions.

Results: There were no statistically significant interactions between treatment (FLOSS/CON) and time (pre/5 min post/30 min post) for any of the measured variables

($p > 0.05$). Effect size analysis revealed *small* benefits to FLOSS in comparison to CON for CMJ performance 5 mins post ($d = 0.28$) and for 10m ($d = -0.45$) and 15m ($d = -0.24$) sprint time 30 mins post (Table 2). All other measures resulted in *trivial* or *unclear* effect sizes.

Conclusion: Findings from the current study suggest only minimal benefits of floss bands when applied to the ankle joint to improve ROM, jump and sprint performance in elite athletes for up to 30 minutes following their application.

Keywords: *flossbands, vascular occlusion, ischemic pre-conditioning, range of motion.*

Introduction

The anecdotal use of floss bands amongst athletes is becoming a popular strategy to increase joint range of motion (ROM), enhance prevention and rehabilitation from injury and improve athletic performance, despite limited evidence for its efficacy (Driller & Overmayer, 2017)**.** Tissue flossing involves the wrapping of a thick rubber band around a joint or muscle, partially occluding blood flow while concomitantly performing ROM tasks for 1-3 minutes (figure 1) (Driller et al., 2017). The effects of blood reperfusion to an occluded area via tissue flossing has been reported to augment exercise performance mechanisms such as growth hormone, catecholamine responses, muscle force contractility and the efficiency of excitation-contraction coupling in the muscles (Driller et al., 2017). Furthermore, limited evidence suggests that performing active tasks with the floss band applied, may enhance ROM of the joints (Driller & Overmayer, 2017).

Previous research by Driller et al. (2016), support the use of tissue flossing on ankle ROM and single-leg jumping performance in recreational athletes. This study investigated the use of floss bands when applied to one ankle joint (with the other ankle acting as the control) on dorsiflexion and plantarflexion ROM and subsequent single-leg vertical jump performance in 52 recreational athletes. Results showed *small* but significant ($p < 0.05$) improvements in all ROM measures (dorsiflexion, plantarflexion and a weight-bearing lunge test) as well as single-leg jump velocity, 5 minutes after the application of a floss band to an average pressure of 182 ± 38 mmHg for ~2 minutes.

In a follow up study, Driller et al. (2017) investigated the time-course benefits on bilateral ankle ROM, weight-bearing lunge test (WBLT), countermovement jump (CMJ) and sprinting performance at 5, 15, 30 and 45 mins post the application of a floss band to both ankles, in 69 recreational athletes. Results showed significant increases in WBLT compared to CON ($p < 0.05$) following the application of floss bands to an average pressure of 178 ± 18mmHg for ~2 minutes. These results were associated with *trivial* effect sizes at all time points ($d = 0.15$-0.18), except for 5 minutes post, where there was a *small* effect in favor of FLOSS ($d = 0.20$). *Small*, but non-significant ($p > 0.05$) benefits were seen for FLOSS when compared to CON for CMJ force at 45 mins post ($d = 0.21$). FLOSS was also associated with significantly faster 15 SPRINT times ($p < 0.05$), and a *small* effect size in comparison to CON at 45 mins post ($d = -0.27$).

Researchers (Bohlen et al. 2014) have examined the effects of applying floss bands on regional blood flow. Five subjects participated in 14 days of tissue flossing, combined with joint mobilization and resistance exercise. The authors reported that dorsiflexion peak torque increased by 22% in the treatment leg ($p = 0.06$), whilst there was no change in the control leg and no change in blood-flow parameters between legs following the intervention. In contrast, Plocker et al. (2015) studied the effect of applying floss bands to both shoulders while concomitantly performing ROM exercises in 17 male recreational athletes. Upon removal of the floss band, ROM measurements and upper extremity power during the bench press were determined. The study reported that despite trends towards improvements, there were no significant increases in ROM or upper-body power ($p > 0.05$) following the floss band treatment when compared to the control. However, researchers concluded that it was difficult to cover the entire shoulder with the floss bands, potentially limiting the effectiveness of improving shoulder ROM.

In a more recent study, Hodeaux (2017) investigated the effect of tissue flossing on elbow range of motion in tennis players. Twelve elite tennis players participated in this randomized cross-over study whereby they attended two separate testing sessions (floss band or no floss band). Passive ROM measures were taken with a standard goniometer for elbow flexion and extension and forearm pronation and supination. There were no significant differences ($p > 0.05$) between floss band and no floss band for all measures, with the authors deeming the intervention as being ineffective at improving ROM.

Other than the proposed ROM and performance benefits, tissue flossing may also be an effective method in injury prevention. Reduced ankle ROM is reported to be a risk factor for the development of patellar tendinopathy and other lower-limb injuries of the ankle and foot such as anterior cruciate ligament rupture and stress fractures (Fong et al., 2011; Malliaras, Cook, & Kent, 2006). Therefore, being able to appropriately dorsiflex at the ankle is an important component in the safe and effective absorption of lower limb load when landing from a jump (Malliaras et al., 2006).

Given that the literature involving the relatively novel technique of tissue flossing is currently lacking despite some encouraging findings in preliminary studies, this technique clearly requires further research, especially regarding athletic performance in highly-trained individuals. Therefore, the aim of the current study was to further investigate the use of tissue flossing on athletic performance and ROM in professional rugby union athletes.

Methods

Participants

Fourteen elite, male rugby union athletes (mean ± SD; age: 23.9 ± 2.7 years, mass 102.4 ± 11.4 kg, height; 188 ± 8.0 cm) volunteered to participate in the current study. All athletes were from the same rugby union squad, which played in New Zealand's top provincial competition. The study took place during the pre-season phase of competition, which included 8 weeks of training prior to this study. All athletes were free from lower-limb injuries (hip, knee or ankle) that may have affected their ability to perform the tests. Written informed consent was obtained from each participant, and ethical approval was obtained from the Human Research Ethics Committee of the institution.

Experimental Design

In a randomised, crossover trial, participants attended a sport science laboratory for testing on two separate occasions and performed a number of tests pre and post application of a floss band (Life Flossbands, Sydney, Australia). Prior to testing, participants performed a standardized warm up which consisted of 5 minutes of progressive and continuous running, selected dynamic and mobility movements (which included one-leg standing knee flexion, bodyweight calf raise, squat and countermovement jump) and progressive 20m sprints.

The two trials were performed separated by seven days: control (CON), where no floss bands were applied and FLOSS, where a floss band was applied to both ankle joints. Following the pre-tests, researchers applied a floss band to both ankles of participants in the FLOSS group. Then, in a seated position, all participants were instructed to perform both plantarflexion and dorsiflexion to their extreme ranges of motion and to complete these mobility exercises for two minutes. The floss bands were then removed and the tests were performed at 5 and 30 minutes later and in the same order as the pre-tests. The order of tests for all participants were as follows: weight bearing lunge test (WBLT), counter-movement jump test (CMJ) and 20m sprint test (SPRINT). Performance tests were selected as they are applicable to most team-sports and cause minimal fatigue when re-measured multiple times with adequate recovery.

Weight-bearing lunge test (WBLT)

The WBLT was performed as a measure of dorsiflexion range of motion on both right and left ankles. Participants placed their foot along a measuring tape which was secured to the floor, with their big toe against the wall and both their toe and heel on the centerline of the measuring tape. Participants were then asked to progressively move their toe further back from the wall on the measuring tape, repeating the lunge movement until the maximum distance at which they could tolerably lunge their knee to the wall without heel lift, was found. Measurement was made using the tape measure from the tip of their big toe to the wall, in centimeters. The weight-bearing lunge test (WBLT) is a functional and reliable method to indirectly assess dorsiflexion by measuring the maximal advancement of the tibia over the rear foot in a weight-bearing position (Bennell et al., 1998). Previous investigators have reported robust inter-tester and intra-tester reliability associated with the assessment of WBLT performance in healthy adults, with high levels of test-retest reliability demonstrated (standard error of measurement = 1.1°, 95% CI = 2.2) (Bennell et al., 1998).

Countermovement jump test (CMJ)

Data regarding the peak force (N) during a countermovement jump were measured using a force plate. Countermovement jumps were performed and the best of three attempts at each time point, determined by peak force (N), was recorded and used for subsequent analysis. Participants performed three maximal CMJ's with ~3 seconds between each jump. Two force plates (PASCO PS 2142, Roseville, CA, USA) were used to measure peak force at a sample rate of 500Hz. The force plates were connected to an analogue-to-digital converter (SPARKlink), which was then connected to a PC and the Pasco Capstone v1.4.0 software (PASCO, Roseville, California, USA) through a USB port. Each trial started with the subjects standing on top of the force plates with their knees fully extended and their hands on their hips to eliminate the influence of arm swing (Cormack, Newton, McGuigan, & Doyle, 2008). Participants were then instructed to descend to a self-selected countermovement depth and to jump as high and quickly as possible (Secomb et al., 2015).

Sprint test (SPRINT)

The straight-line sprint tests were performed indoors on a synthetic running track. During each trial, participants were asked to sprint as quickly as possible over 20m. Dual-beam electronic timing gates (Smartspeed, Fusion Sport, QLD, Australia) were positioned each 5m in order to obtain 5m, 10m, 15m and 20m split times. Participants began each sprint from a standing position with their front foot 0.50m behind the first timing gate (Buchheit, Simpson, Peltola, & Mendez-Villanueva, 2012). Time was measured to the nearest 0.01 second, with the fastest time obtained from two trials at each time point of assessment (pre, 5 and 30 minutes post) and used for later analysis.

Application of floss band

A standard ankle-bandaging technique was used by the researchers to apply the floss band accordingly: across the transverse of the foot, aligned with the distal head of the metatarsals of the foot. The wrap circulated around the foot twice, followed by 3 wraps completed in a figure 8 (to lateral malleolus, around the achilles, to medial malleolus, towards the distal head of the 5th metatarsal, around the bottom of the foot and back to the beginning). Each subsequent wrap overlapped the previous by ~50%, before securing the remainder of the band underneath the final wrap (Figure 1). Once the floss bands were applied to both ankles, in a seated position, participants performed the active ROM task which included continuous repetitions of plantarflexion and dorsiflexion for two minutes (taken to the extreme ranges of motion). Both the FLOSS and CON conditions performed the active ROM task, with the only difference between groups being the floss band application. After two minutes, the floss band was then removed and the participants were instructed to stand up and walk around for one minute to allow for blood flow to return to the foot.

Figure 1: The floss band ankle bandaging technique used by researchers.

Kikuhime pressure measurement

For the FLOSS condition, interface pressure between the skin and the floss band was measured to assess the level of compression (mmHg) achieved by the wrapping technique. The Kikuhime pressure monitor (MediGroup, Melbourne, Australia) sensor was placed on the anterior aspect of the tibia on the midline between the lateral and medial malleolus (Figure 1). The Kikuhime pressure monitor has been shown to be a valid (ICC = 0.99, CV = 1.1%) and reliable (CV = 4.9%) tool for use in the sport setting (Brophy-Williams, Driller, Halson, Fell, & Shing, 2014).

Results

Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Science (V. 22.0, SPSS Inc., Chicago, IL). A two-way repeated measures ANOVA was performed to determine the effect of different treatments (FLOSS or CON) over time (pre/5-min post/30-min post) on all measured variables, with a Bonferroni adjustment if significant main effects were present. Analysis of the studentized residuals was verified visually with histograms and also by the Shapiro-Wilk test of normality. A Student's paired t-test was used to determine pre to post differences for each condition and also between treatments for pre-test values. Descriptive statistics are shown as means ± standard deviations unless stated otherwise. Standardized changes in the mean of each measure were used to assess magnitudes of effects and were calculated using Cohen's *d* and interpreted using thresholds of 0.2, 0.5, 0.8 for *small, moderate and large*, respectively (Cohen, 1988). An effect size of ±0.2 was considered the smallest worthwhile effect with an effect size of <0.2 considered to be *trivial*. The effect was deemed *unclear* if its 90% confidence interval overlapped the thresholds for *small* positive and negative effects (Batterham & Hopkins, 2006). Statistical significance was set at $p < 0.05$ for all analyses.

Results

Mean pressure (± SD) applied by the floss band in a cohort of the study population (n=14), as identified using the Kikuhime pressure monitor, was 178 ± 22 mmHg. There were no significant differences between FLOSS and CON for any of the measured variables pre-test ($p > 0.05$). There were no statistically significant interactions between treatment (FLOSS/CON) and time (pre/5 min post/30 min post) for any of the measured variables ($p > 0.05$, Table 1). Effect size analysis revealed *small* benefits to FLOSS in comparison to CON for CMJ performance 5 mins post ($d = 0.28$) and for 10m ($d = -0.45$) and 15m ($d = -0.24$) sprint time 30 mins post (Table 2). All other measures resulted in *trivial* or *unclear* effect size.

Table 1: Comparison of all pre and post measures (5 and 30-minutes) for experimental (FLOSS) and control (CON) trials. Data presented means ± SD.

	Pre		5-min Post		30-min Post	
	FLOSS	CON	FLOSS	CON	FLOSS	CON
WBLT (cm)	9.9 ± 3.4	9.7 ± 4.0	10.3 ± 3.5	10.1 ± 3.5	10.3 ± 3.2	10.1 ± 3.4
CMJ (N)	2926 ± 288	2894 ± 307	2965 ± 265	2843 ± 345	2930 ± 255	2936 ± 326
5-m SPRINT (secs)	0.99 ± 0.07	0.99 ± 0.06	1.01 ± 0.08	0.99 ± 0.07	0.99 ± 0.07	0.98 ± 0.08
10-m SPRINT (secs)	1.77 ± 0.11	1.75 ± 0.09	1.76 ± 0.10	1.76 ± 0.09	1.74 ± 0.09	1.77 ± 0.11
15-m SPRINT (secs)	2.42 ± 0.15	2.41 ± 0.12	2.42 ± 0.13	2.41 ± 0.14	2.39 ± 0.13	2.42 ± 0.13
20-m SPRINT (secs)	3.06 ± 0.18	3.07 ± 0.15	3.07 ± 0.17	3.07 ± 0.18	3.06 ± 0.16	3.08 ± 0.18

Table 2: Comparison of all post measures (5 and 30-minutes) to pretest values. Data presented as raw difference in values (mean ±90% confidence intervals) with effect sizes for comparison between experimental (FLOSS) and control (CON) trials.

	5-min Post ΔFLOSS - ΔCON Effect size	30-min Post ΔFLOSS - ΔCON Effect size
WBLT (cm)	0.0 ±0.5 0.01, *Trivial*	0.0 ±0.5 0.01, *Trivial*
CMJ (N)	90 ±117 0.28, *Small*	-37 ±77 0.12, *Trivial*
5-m SPRINT (secs)	0.01 ±0.02 0.15, *Trivial*	0.00 ±0.04 0.01, *Unclear*
10-m SPRINT (secs)	-0.02 ±0.03 -0.18, *Trivial*	-0.04 ±0.04 -0.45, *Small*
15-m SPRINT (secs)	-0.01 ±0.05 -0.05, *Unclear*	-0.03 ±0.05 -0.24, *Small*
20-m SPRINT (secs)	0.00 ±0.03 0.00, *Trivial*	-0.02 ±0.03 -0.13, *Trivial*

Discussion

In the current study, the use of floss bands when applied to both ankle joints revealed *small* but non-significant ($p > 0.05$) benefits to FLOSS in comparison to CON for CMJ performance 5 minutes post and for 10m and 15m sprint time at 30 minutes post application. Whilst there may be some trends toward improvements, the overall findings from our study showed negligible differences between FLOSS and CON for any of the measured variables. While this is the first study to evaluate the effect of floss bands on the ankle joint in elite athletes, the *small* trends towards improved performance within this sample, are somewhat surprising and warrant future research.

At the final time point tested in this study (30 mins post), the floss band trial was associated with a *small* effect in comparison to the control group for 15m sprint time. *Small*, but non-significant benefits were also seen for FLOSS when compared to CON for countermovement peak jump force 30 minutes after application of the floss bands. In comparable research, Driller (2016) reported *small* but significant effects in favour of FLOSS for improvements in a weight bearing lunge test, dorsiflexion and plantarflexion ROM and single leg vertical jump height directly after a tissue flossing intervention in lesser trained participants. Furthermore, Driller (2017) reported a significant treatment and time interaction for FLOSS when compared to CON for a WBLT. The baseline ROM, sprint and jump test results in the current study were considerably higher/faster than in the previous study by Driller and colleagues (9.9 vs 8.9cm for WBLT, 2926 vs 1708 N for CMJ, 0.99 vs 1.14s for 5m SPRINT, 1.77 vs 1.96s for 10m SPRINT and 2.42 vs 2.71s for 15m SPRINT). Given that the current study population was highly-trained, the changes observed following tissue flossing may have left less potential for improvement when compared to the recreational groups tested in previous studies. Indeed, it can be assumed that when there is less room for improvement due to the training status of the participants, any intervention is less likely to have a significant effect in comparison to a lesser-trained group.

It is possible that these acute responses, when implemented in a chronic setting, may lead to long-term physiological adaptations. Bohlen (2014) assessed the benefits of tissue flossing in a chronic (14 day) setting while applying the floss band to one knee during daily exercises. Similar to some of the findings of Driller et al. 2016 and Driller et al. 2017, Bohlen reported benefits to dorsiflexion measures (in this case, peak torque) following the experimental period. With this in mind, the *small* trend toward improved performance observed in the current study following a tissue flossing intervention, warrants further investigation in a chronic setting, to assess whether the potential benefit could be additive across multiple applications/sessions.

Of the current literature available that has investigated the effects of tissue flossing on athletic performance measures, it is difficult to determine the physiological mechanisms that may have contributed to the ambiguous findings to date. This is a significant limitation of the current and previous tissue flossing studies and has not yet been investigated. Therefore, any theories on their impact following a tissue flossing intervention are only speculative. Future research should aim to investigate the influence of such physiological mechanisms and their impact, following a tissue flossing intervention. To help guide this, previous mechanisms that have already been discussed in current IPC literature should be considered initially. Altered hormonal and catecholamine responses, muscle force contractility and the efficiency of excitation-contraction coupling within the muscle, are examples of possible mechanisms to investigate further.

Another limitation of the current study was the lack of a placebo/sham condition. The psychological advantage that may be associated with the use of tissue flossing should not be discounted. However, the experimental intervention in this case is difficult to provide a placebo condition for, therefore future studies could investigate different levels of pressure applied by the bands, in a cross-over design (e.g. <50mmHg, 100mmHg, 150mmHg, >200mmHg). This would allow for the optimal pressure of tissue flossing to be determined, and also give greater insight into the possible mechanism and their impact.

In conclusion, whilst tissue flossing seems a simple intervention that could possibly be applied in a variety of performance settings, results from the literature and the current study regarding their use for improved joint ROM and muscle force production, are contradictory. Overall, the findings from this study suggest limited support for the use of tissue flossing for improved ROM, CMJ and sprinting performance, for up to 30 minutes post application in elite rugby union athletes. However, given the small trend towards improvements in our study, coupled with the promising results from previous analysis, further research is warranted on this relatively novel technique.

Chapter 3:

Summary, Practical Applications and Future Research Directions

Summary

The study included in Chapter 2 of this thesis is the first to investigate the use of floss bands applied to both ankle joints on dorsiflexion, jumping and sprinting performance in an elite athletic setting. Overall, the findings from this study suggest limited support for the use of tissue flossing for improved ROM, countermovement jump and sprinting performance, for up to 30 minutes post application in elite rugby union athletes. However, given the trends towards improvements in our study, coupled with the results from previous research, further research is warranted on this relatively novel technique.

Practical Applications

- Whilst there were *small* trends towards enhancement, the evidence from this research provides minimal support for the use of tissue flossing for improved ROM, CMJ and sprinting performance for up to 30 minutes post application, in elite rugby union athletes. In comparison, previous tissue flossing research has reported more favourable results in lesser-trained counterparts. Therefore, further research is justified to continue to examine the potential performance benefits of this innovative technique in both acute and chronic settings in elite athletes.

Future Research Directions

- Future research should aim to investigate the impact of the physiological mechanisms and their impact, following a tissue flossing intervention. To help guide this, the mechanisms that have been discussed most frequently from current IPC and recent tissue flossing literature should be considered initially as a focal point.

- In addition to the acute research already completed, prospective analysis should aim to investigate the chronic impact of tissue flossing on performance measures, within a highly trained athletic population. For example, investigating the impact of a tissue flossing intervention before exercise, 3 times per week, for a 6 week trial period. This type of inquiry would help further extend some of the recent work completed by Driller and colleagues regarding the time-course benefits of tissue flossing and would therefore be useful for athletes where the competitive season extends ≥ a period of 6 weeks.

- Future research could investigate and provide a within study comparison of the impact of a tissue flossing intervention against an IPC intervention on the knee, ankle, or a combination of both joints, on athletic performance measures. As has been mentioned in tissue flossing literature to date, some of the proposed mechanisms responsible for improvements observed following a tissue flossing intervention, are speculated to be similar to those experienced, following an IPC intervention. This comparison would help to identify and assess the value of a tissue flossing or IPC intervention and allow choices to be made as to the more effective method to adopt for enhanced athletic performance measures.

- The psychological advantage that may be associated with the use of tissue flossing should not be discounted. Therefore, future studies could investigate different levels of pressure applied by the floss bands, in a cross-over design (e.g. <50mmHg, 100mmHg, 150mmHg, >200mmHg). This could allow for the optimal pressure of tissue flossing to be determined, to positively impact performance.

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Appendices

Appendix 1 – Participant information sheet

Participant Information:

Dear participant,

You are being invited to take part in my thesis study. Before you volunteer to take part in the study please take the time to read the following information carefully and if there is anything that is not clear or you would like more information on, please feel free to contact myself, Blair Mills or my supervisor, Dr Matt Driller.

Purpose

The aim of the study is to examine three questions:

1) Does the use of tissue floss bands improve ankle range of motion?
2) Does the use of tissue floss bands improve vertical jump height?
3) Does the use of tissue floss bands improve sprinting time?

Significance

Until the current date, research exploring the effects of flossing in an athletic population is resumed to upper-body performance. Therefore, the findings of this research will help to understand if the beneficial effects from flossing observed on upper-body performance are extended to lower-body.

Selection Criteria and Information:

To be eligible in this study you must be:

- In the Bay of Plenty Rugby Academy and / or Mitre 10 Cup training squad
- Over 18 years of age

For each participant, the ankle that has no flossband serves as the control (CON) for pre and post testing, while the ankle with the flossband (FLOSS) serves as the experimental condition. Once the flossband is applied, in a seated position, participants perform 20 repetitions of plantarflexion and dorsiflexion, simultaneously on both the CON and FLOSS ankles. Participants will be instructed to perform both plantarflexion and dorsiflexion to their extreme ranges of motion and to complete the mobility exercises within two minutes. The flossband will then be removed and the following post tests will be performed:

Weight-bearing lunge test (WBLT):

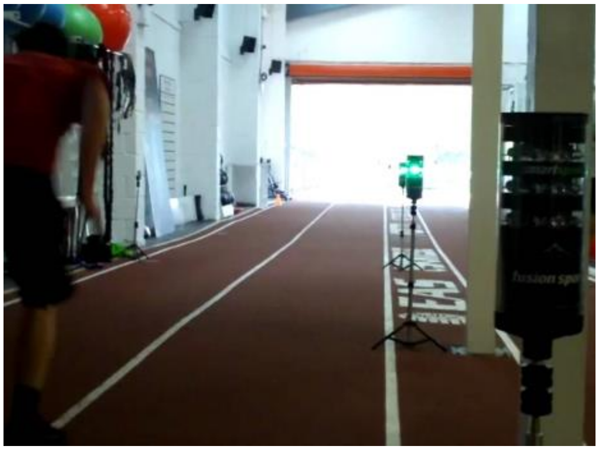
The WBLT is performed as a measure of dorsiflexion range of motion on both right and left legs. Participants place their foot along a measuring tape on the floor, with their big toe against the wall and both their toe and heel on the centerline of the measuring tape. Participants are then asked to progressively move their toe further back from the wall on the measuring tape, repeating the lunge movement until the maximum distance at which they can tolerably lunge their knee to the wall without heel lift is found. Measurement is made using the tape measure from the tip of their big toe to the wall, in centimeters.

Countermovement jump test (CMJ):

Data regarding the peak force (N) during a countermovement jump will be measured using a forceplate. Countermovement jumps will be performed and the best of three attempts at each time point, determined by peak force (N), will be recorded and used for subsequent analysis. Participants will perform three maximal CMJ's with ~3 seconds between each jump. Two force plates (PASCO PS 2142, Roseville, CA, USA) will be used to measure peak force (PF) at a sample rate of 500Hz. Each trial starts with the subjects standing on top of the force plates with their knees fully extended and their hands on their hips to eliminate the influence of arm swing (Cormack et al., 2008). Participants will then be instructed to descend to a self-selected countermovement depth and to jump as high and quickly as possible (Secomb et al., 2015).

Sprint test (SPRINT):

The straight-line sprint test will be performed indoors on a synthetic running track. During each trial, participants will be asked to sprint as quickly as possible over 20m. Dual-beam electronic timing gates (SmartSpeed timing gate system, SmartSpeed, QLD Australia) will be positioned each 5m in order to obtain 5m, 10m, 15m and 20m split times. Participants begin each sprint from a standing position with their front foot 0.50 m behind the first timing gate (Buchheit et al., 2012). Time is measured to the nearest 0.01 second, with the fastest time obtained from two trials at each time point (pre, 5, 15, 30, 45 mins post) used for later analysis.



Application of floss band:

A standard ankle-bandaging technique will be used by researchers by applying the floss band accordingly: Across the transverse of the foot, aligned with the distal head of the metatarsals of the foot. The wrap circulates around the foot twice, followed by 3 wraps completed in a figure 8 (to lateral malleolus, around the achilles, to medial malleolus, towards the distal head of the 5th metatarsal, around the bottom of the foot and back to the beginning). Each subsequent wrap overlaps the previous by ~50%, before securing the remainder of the band underneath the final wrap (Figure 1). Once the floss bands are applied to both ankles, in a seated position, participants perform an active ROM task - continuous repetitions of plantarflexion and dorsiflexion for two minutes (taken to the extreme ranges of motion). Both the FLOSS and CON groups performed the active ROM task, with the only difference between groups being the floss band application. After two minutes, the floss band will then be removed and the participants will be instructed to stand up and walk around for one minute to allow for blood flow to return to the foot.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. If you decide to take part you are still free to withdraw until March 2017 and without giving a reason.

What you will gain from participating in the study?

As a participant, you will benefit from experience with the research process and gain knowledge about the area of research. After all data being collected you will receive a summary of the effect of tissue flossing on ankle mobility, jump performance and sprint times. As per normal, you will also receive the results of your performance tests. A group presentation will be given to summarise the main results of the research. When the data is published, you will be notified. You will be able to access the final research once it has been completed in the research commons from the University of Waikato.

All information collected about you during the course of the research project will be kept strictly confidential. You will be identified by a code number and all personal information will be kept private. Analysis of the data will occur in March 2017, and you have until this point to withdraw your data from the study.

*This study is part of a Master's thesis, which will be submitted for a degree at the University of Waikato. The study may also be used in presentations, and will be published.*Any inquiries regarding requirements and procedures used in this study are encouraged. Please contact me in the first instance if you have any questions.

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Appendix 2 – Research consent form – Tissue flossing on ankle range of motion, jump and sprinting performance in elite rugby union athletes

Informed Consent form

Principal Researchers: Blair Mills, Francisco Tavares, Brad Mayo, Matt Driller.

This is to indicate that I,_______________________ hereby agree to participate as a volunteer in a scientific investigation as an authorised part of a research project contributing to my masters studies at The University of Waikato, under the supervision of Dr. Matt Driller.

The investigation and my part in the investigation have been defined and fully explained to me by________________________and I understand the explanation. A copy of the procedures of this investigation and a description of any risks and discomforts has been provided to me and has been discussed in detail with me.

- I have been given an opportunity to ask whatever questions I may have had and all such questions and inquires have been answered to my satisfaction.
- I understand that I am free to withdraw consent and to discontinue participation in the project or activity at any time, without disadvantage to myself, by informing the principal researcher.
- I understand that I am free to withdraw my data up until the point of analysis (July 2017) without disadvantage to myself.
- I understand that any data will remain anonymous with regard to my identity through a coding system, a code will be given to the participant, which will be used throughout the project, as the reference to a participant as opposed to using their name. The code will be used when, gaining the data, analysing the data and the writing up of the results. The data will be made publishable in a thesis, publications and presentations, so every effort will be made to ensure anonymity, however this cannot be guaranteed. The results of the study will also be presented in a group presentation to the athletes involved in the study.
- I am participating in this project of my own free will and I have not been coerced in any way to participate.

Signature of Subject: ___________________________________Date: ____/____/____

I, the undersigned, was present when the study was explained to the subject/s in detail and to the best of my knowledge and belief it was understood.

Signature of Researcher: _________________________________Date: ____/____/____

Appendix 3 – Ethics approval

The University of Waikato
Private Bag 3105
Gate 1, Knighton Road
Hamilton, New Zealand

Human Research Ethics Committee
Julie Barbour
Telephone: +64 7 838 9336
Email: julie.barbour@waikato.ac.nz

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

15th May 2017

Blair Mills
Dr. Matt Driller

Dear Blair,

UoW HREC(Health)#2017-15: The effects of tissue flossing on ankle range of motion, jump and sprinting performance

Thank you for submitting your amended application for ethical approval. We are now pleased to provide formal approval for your project including:

- a randomised crossover trial of 15-20 athletes from premier rugby clubs in the Waikato/BOP region to assess the effects of flossbands on range of motion, jump and sprinting performance.

Please contact the committee if you wish to make changes to your project as it unfolds, quoting your application number, with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,

Julie Barbour PhD
Chairperson
University of Waikato Human Research Ethics Committee

Appendix 4 – Tissue flossing on ankle range of motion, jump and sprinting performance: A follow-up study.

Tissue flossing on ankle range of motion, jump and sprint performance: A follow-up study

Original Investigation

Matthew Driller[1], Kelsi Mackay[1], Blair Mills[1,2] & Francisco Tavares[1,2]

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Abstract

Objectives: Previous results from our laboratory suggest that tissue compression and partial vascular occlusion using band flossing results in increased ankle range of motion (ROM) and jump performance 5-minutes following application. However, the time-course of such benefits is yet to be examined.

Design: In a randomised, parallel group design, participants performed a number of ROM and performance tests pre and 5-mins, 15-mins, 30-mins and 45-mins post the application of a floss band to both ankles (FLOSS, n =38) or without the flossing of the ankle joints (CON, n = 31).

Participants: 69 recreational athletes (32 male/37 female, age 19 ± 2 yrs).

Main outcome measures: Pre and post measures included a weight-bearing lunge test (WBLT), a counter-movement jump on a forceplate (CMJ) and a 15m sprint test, with splits measured at 5, 10 and 15m (SPRINT).

Results: FLOSS resulted in significant increases in the WBLT compared to CON ($p < 0.05$). These results were associated with *trivial* effect sizes at all time points ($d = 0.15$-0.18), except for 5-mins post, where there was a *small* effect in favour of FLOSS ($d = 0.20$). *Small*, but non-significant ($p > 0.05$) benefits were seen for FLOSS when compared to CON for CMJ force at 45-mins post ($d = 0.21$). FLOSS was also associated with significantly faster 15m SPRINT times ($p < 0.05$), and a *small* effect size in comparison to CON at 45-mins post ($d = -0.27$).

Conclusion: Findings from the current study would support the use of floss bands applied to the ankle joint to improve ROM, jump and sprint performance in recreational athletes for up to 45-minutes following their application. This may have significant implications for practitioners considering using this technique during a warm-up prior to exercise.

Keywords*: flossbands, mobility bands, vascular occlusion, ischemic pre-conditioning, ROM*

Introduction

Tissue flossing involves the wrapping of a thick rubber band around a joint or muscle, partially occluding blood-flow while often concomitantly performing range of motion (ROM) tasks for 1-3 minutes (Driller & Overmayer, 2017). The mechanisms involved with tissue flossing using a floss band may be similar to that of ischemic preconditioning or blood-flow restriction training, whereby reperfusion of blood to the occluded area may be associated with subsequent increases in growth hormone and catecholamine responses, enhanced muscle force and contractility and increased efficiency of excitation-contraction coupling in the muscles (Reeves et al., 2006; Takarada et al., 2000 Lawson & Downey, 1993 Pang et al., 1995). In addition to this, the fascial shearing and joint lubrication that is likely to occur while performing active tasks with the band applied, possibly enhances ROM of the joints (Starrett & Cordoza, 2013). Previous results from our laboratory would support the use of tissue flossing on ankle ROM and single-leg jumping performance in recreational athletes (Driller & Overmayer, 2017), however, the time-course associated with such benefits is yet to be investigated.

Our previous study investigated the use of floss bands applied to one ankle joint (with the other ankle acting as the control) on dorsiflexion and plantarflexion ROM and subsequent single-leg vertical jump performance in 52 recreational athletes (Driller & Overmayer, 2017). Results showed significant improvements in all ROM measures (dorsiflexion, plantarflexion and a weight-bearing lunge test) as well as single-leg jump performance following the application of a floss band to an average pressure of 182 ± 38 mmHg for ~2 minutes. Tissue flossing was associated with *small* but significant ($p < 0.05$) effects for the dorsiflexion, weight-bearing lunge test and jump velocity tests when compared to the control leg, 5-minutes after removing the floss band. While this was a somewhat novel finding, the practical application of such a technique is still limited by the fact that the tests were only performed a short time after removal of the bands, posing the questions of how long the benefits may last for. Furthermore, performance results in this study were limited to a jump test, which may not be applicable to all sports.

To the authors knowledge, other than our previous work, the only other study to have investigated the use of tissue flossing in an acute setting was by Plocker et al. (2015). This study investigated the effect of applying floss bands to both shoulders in 17 male athletes. Participants had both shoulders wrapped with a floss band while concomitantly performing ROM exercises. Upon removal of the floss band, ROM measurements and upper extremity power during the bench press were determined. The study reported trends towards improvements (non-significant) in ROM, but not for upper-body power when compared to the control trial. However, researchers concluded that it was difficult to cover the entire shoulder with the floss bands, potentially limiting the effectiveness of improving shoulder ROM. Given the results of this study are limited to a published conference proceeding, it is difficult to ascertain the exact protocols, including the pressure applied by the floss-band and the duration after which the measures were performed.

Other than the proposed ROM and performance benefits, tissue flossing may also be an effective method in injury prevention. Indeed, ankle dorsiflexion is an important component in the absorption of lower limb load when landing from a jump, as common in most sports (Malliaras et al., 2006). Reduced ankle ROM is also a risk factor for the development of patellar tendinopathy and other lower-limb injuries in athletes (Fong et al., 2011; Malliaras et al., 2006). However, given it is uncertain as to how long the benefits of tissue flossing may last, limited information is available to practitioners. For example, it is unknown if this technique would be useful to incorporate into a warm-up before exercise, if the benefits only last for ~5-minutes.

Therefore, given the relatively novel technique of tissue flossing is currently lacking in the research literature despite some positive findings in preliminary studies, the modality clearly requires further research. The aim of the current study was to expand that of our previous work and investigate the use of tissue flossing on ankle (talocrural joint) ROM, jumping and sprinting performance at different time points following the application of the floss bands in recreational athletes.

Methods

Participants

69 recreational athletes (32 male / 37 female, mean ± SD; age: 19 ± 2 years) volunteered to participate in the current study. Participants were recruited through a University sport science under-graduate program. All participants were participating in regular physical exercise sessions (~3 times per week) and were free from lower-limb injuries (hip, knee or ankle) that may have affected their ability to perform the jump or sprint tests. Written informed consent was obtained from each participant, and ethical approval was obtained from the Human Research Ethics Committee of the institution.

Experimental Design

Participants were randomly split into two groups; an experimental group (FLOSS, n = 38) or a control group (CON, n = 31). Participants attended a sport science laboratory for a single testing session. Prior to any testing, participants performed a standardized warm-up consisting of a 5-minute jog and dynamic stretches (e.g. one-leg standing knee flexion, bodyweight calf-raises, bodyweight squats, bodyweight countermovement jumps). Following the pre tests, researchers applied a floss band (Life Flossbands, Sydney, Australia), to both ankles of participants in the FLOSS group. Post tests (5, 15, 30 and 45 minutes) were then performed in the same order as the pre tests. The order of tests for all participants were as follows: the weight bearing lunge test (WBLT), the counter-movement jump test (CMJ) and the 15m sprint test (SPRINT). Performance tests were selected as they are applicable to most team-sports and cause minimal fatigue when re-measured multiple times with adequate recovery.

Methodology

Weight-bearing lunge test (WBLT)

The WBLT was performed as a measure of dorsiflexion range of motion on both right and left legs. Participants placed their foot along a measuring tape on the floor, with their big toe against the wall and both their toe and heel on the centerline of the measuring tape. Participants were then asked to progressively move their toe further back from the wall on the measuring tape, repeating the lunge movement until the maximum distance at which they could tolerably lunge their knee to the wall without heel lift was found. Measurement was made using the tape measure from the tip of their big toe to the wall, in centimeters. The weight-bearing lunge test (WBLT) is a functional and reliable method to indirectly assess dorsiflexion by measuring the maximal advancement of the tibia over the rear foot in a weight-bearing position (Bennell et al., 1998). Previous investigators have reported robust inter-tester and intra-tester reliability associated with the assessment of WBLT performance in healthy adults, with high levels of test-retest reliability demonstrated (standard error of measurement = 1.1°, 95% CI = 2.2) (Bennell et al., 1998).

Counter-movement jump test (CMJ)

Data regarding the peak force (N) during a countermovement jump were measured using a forceplate. Countermovement jumps were performed and the best of three attempts at each time point, determined by peak force (N), was recorded and used for subsequent analysis. Participants performed three maximal CMJ's with ~3 seconds between each jump. Two force plates (PASCO PS 2142, Roseville, CA, USA) were used to measure peak force (PF) at a sample rate of 500Hz. The force plates were connected to an analog-to-digital converter (SPARKlink), which was then connected to a PC and the Pasco Capstone v1.4.0 software (PASCO, Roseville, California, USA) through a USB port. Each trial started with the subjects standing on top of the force plates with their knees fully extended and their hands on their hips to eliminate the influence of arm swing (Cormack et al., 2008). Participants were then instructed to descend to a self-selected countermovement depth and to jump as high and quickly as possible (Secomb et al., 2015).

Sprint test (SPRINT)

The straight-line sprint test was performed indoors on a wooden-surface basketball court. During each trial, participants were asked to sprint as quickly as possible over 15m. Dual-beam electronic timing gates (Speedlight TT, Swift Performance, Lismore, Australia) were positioned each 5m in order to obtain 5m, 10m and 15m split times. Participants began each sprint from a standing position with their front foot 0.50 m behind the first timing gate (Buchheit et al., 2012). Time was measured to the nearest 0.01 second, with the fastest time obtained from two trials at each time point (pre, 5, 15, 30, 45 mins post) used for later analysis.

Application of floss band

A standard ankle-bandaging technique was used by researchers by applying the floss band accordingly: Across the transverse of the foot, aligned with the distal head of the metatarsals of the foot. The wrap circulated around the foot twice, followed by 3 wraps completed in a figure 8 (to lateral malleolus, around the achilles, to medial malleolus, towards the distal head of the 5th metatarsal, around the bottom of the foot and back to the beginning). Each subsequent wrap overlapped the previous by ~50%, before securing the remainder of the band underneath the final wrap (Figure 1). Once the floss bands were applied to both ankles, in a seated position, participants performed an active ROM task - continuous repetitions of plantarflexion and dorsiflexion for two minutes (taken to the extreme ranges of motion). Both the FLOSS and CON groups performed the active ROM task, with the only difference between groups being the floss band application. After two minutes, the floss band was then removed and the participants were instructed to stand up and walk around for one minute to allow for blood flow to return to the foot.

Figure 2: The floss band ankle bandaging technique used by researchers.
Figure obtained from Driller & Overmayer (2017).

Kikuhime pressure measurement

In a selection of participants (n = 12), interface pressure between the skin and the floss band was measured to assess the level of compression (mmHg) achieved by the wrapping technique. The Kikuhime pressure monitor (MediGroup, Melbourne, Australia) sensor was placed on the anterior aspect of the tibia on the midline between the lateral and medial malleolus (Figure 2). The Kikuhime pressure monitor has been shown to be a valid (ICC = 0.99, CV = 1.1%) and reliable (CV = 4.9%) tool for use in the sport setting (Brophy-Williams et al., 2014).

Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Science (V. 22.0, SPSS Inc., Chicago, IL). A two-way mixed ANOVA was performed to determine the effect of different treatments (FLOSS or CON) over time (pre, 5min, 15min, 30min and 45min post) on all measured variables. There were no outliers in the data, as assessed by inspection of a boxplot and examination of studentized residuals and all data was normally distributed, as determined by Shapiro-Wilk's test ($p > 0.05$). A Student's paired t-test was used to determine pre to post (5, 15, 30, 45 mins) differences for each condition within groups and an independent t-test was used to compare groups for pre test values. Descriptive statistics are shown as means ± standard deviations unless stated otherwise. Standardized changes in the mean of each measure were used to assess magnitudes of effects and were calculated using Cohen's *d* and interpreted using thresholds of 0.2, 0.5, 0.8 for *small, moderate and large*, respectively (Cohen, 1988). An effect size of ±0.2 was considered the smallest worthwhile effect with an effect size of <0.2 considered to be *trivial*. The effect was deemed *unclear* if its 90% confidence interval overlapped the thresholds for *small* positive and negative effects (Batterham & Hopkins, 2006). Statistical significance was set at $p < 0.05$ for all analyses.

Results

Mean pressure (± SD) applied by the floss band in a cohort of the study population (n=12), as identified using the Kikuhime pressure monitor, was 178 ± 18 mmHg.

There were no significant differences between FLOSS and CON groups for any of the measured variables pre test ($p > 0.05$, Table 1).

There were no significant differences ($p > 0.05$) between right and left legs for the WBLT, therefore the mean value from both sides combined was used for analysis. There was a statistically significant interaction between groups and time points for the WBLT ($p = 0.02$, Table 1, Figure 1). These results were associated with *trivial* effect sizes at all time points ($d = 0.15$-0.18), except for 5-mins post, where there was a *small* effect in favour of FLOSS ($d = 0.20$, Table 2).

There were no significant time x intervention interactions for CMJ force between FLOSS and CON groups across time points ($p = 0.21$). However, there were *small* benefits associated with FLOSS when compared to CON at the 30-min ($d = 0.32$) and 45-min ($d = 0.21$) post time points (Table 2, Figure 1).

There were no statistically significant interactions between the groups and time points on 5m ($p = 0.05$) or 10m ($p = 0.08$) split times during the SPRINT (Table 1). However, there was a statistically significant interaction between groups and time points for the

15m split time during SPRINT ($p = 0.02$). At 45-mins post, FLOSS was associated with a significant ($p < 0.05$) improvement in SPRINT time at the 5, 10 and 15m time splits, when compared to pre values (Table 1, Figure 2). The differences in 15m time between groups were associated with *small* effect sizes in favour of FLOSS for all time points (d = -0.21 to -0.27, Table 2).

Table 3: Comparison of all pre and post measures (5, 15, 30 and 45-minutes) for experimental (FLOSS) and control (CON) groups.

Data presented means ± SD. * Represents significant difference between groups ($p < 0.05$). $^{\#}$ Represents significant difference to pre within-group value.

	Pre		5-min Post		15-min Post		30-min Post		45-min Post	
	FLOSS	CON	FLOSS	CON	FLOSS	CON	FLOSS	CON	FLOSS	CON
WBLT (cm)	8.9 ± 3.6	8.3 ± 3.3	9.7 ± 3.7$^{\#}$	8.3 ± 3.7	9.7 ± 3.7$^{\#}$	8.5 ± 3.7	9.7 ± 3.6$^{\#}$	8.4 ± 3.5	9.6 ± 3.6$^{\#}$	8.2 ± 3.7
CMJ (N)	1708 ± 381	1649 ± 454	1747 ± 392	1624 ± 477	1783 ± 398$^{\#}$	1668 ± 465	1803 ± 373$^{\#}$	1609 ± 552	1789 ± 422$^{\#}$	1648 ± 466
5-m SPRINT (secs)	1.14 ± 0.08	1.14 ± 0.07	1.15 ± 0.07	1.15 ± 0.08	1.14 ± 0.06	1.16 ± 0.09	1.15 ± 0.07	1.16 ± 0.09	1.14 ± 0.06	1.16 ± 0.08
10-m SPRINT (secs)	1.96 ± 0.13	1.99 ± 0.14	1.96 ± 0.12	2.00 ± 0.15	1.95 ± 0.13	2.01 ± 0.15	1.96 ± 0.13	2.02 ± 0.16$^{\#}$	1.95 ± 0.15	2.02 ± 0.15
15-m SPRINT (secs)	2.71 ± 0.22	2.76 ± 0.24	2.67 ± 0.19*	2.78 ± 0.23	2.68 ± 0.21	2.78 ± 0.23$^{\#}$	2.69 ± 0.21	2.80 ± 0.26$^{\#}$	2.69 ± 0.21*	2.81 ± 0.23$^{\#}$

Table 4: Comparison of all post measures (5, 15, 30 and 45-minutes) to pre test values. Data presented as raw difference in values (mean ± SD) with effect sizes for comparison between experimental (FLOSS) and control (CON) groups.

	5-min Post ΔFLOSS - ΔCON Effect size	15-min Post ΔFLOSS - ΔCON Effect size	30-min Post ΔFLOSS - ΔCON Effect size	45-min Post ΔFLOSS - ΔCON Effect size
WBLT (cm)	0.7 ± 0.3 0.20, *Small*	0.6 ± 0.4 0.15, *Trivial*	0.7 ± 0.5 0.18, *Trivial*	0.7 ± 0.5 0.18, *Trivial*
CMJ (N)	69 ± 67 0.16, *Trivial*	56 ± 70 0.13, *Trivial*	135 ± 148 0.32, *Small*	89 ± 101 0.21, *Small*
5-m SPRINT (secs)	-0.02 ± 0.02 -0.23, *Small*	-0.02 ± 0.02 -0.30, *Small*	-0.03 ± 0.02 -0.35, *Small*	-0.03 ± 0.02 -0.40, *Small*
10-m SPRINT (secs)	-0.01 ± 0.02 -0.09, *Trivial*	-0.02 ± 0.02 -0.16, *Trivial*	-0.03 ± 0.02 -0.19, *Trivial*	-0.03 ± 0.03 -0.23, *Small*
15-m SPRINT (secs)	-0.05 ± 0.03 -0.21, *Small*	-0.05 ± 0.03 -0.23, *Small*	-0.06 ± 0.03 -0.27, *Small*	-0.06 ± 0.04 -0.27, *Small*

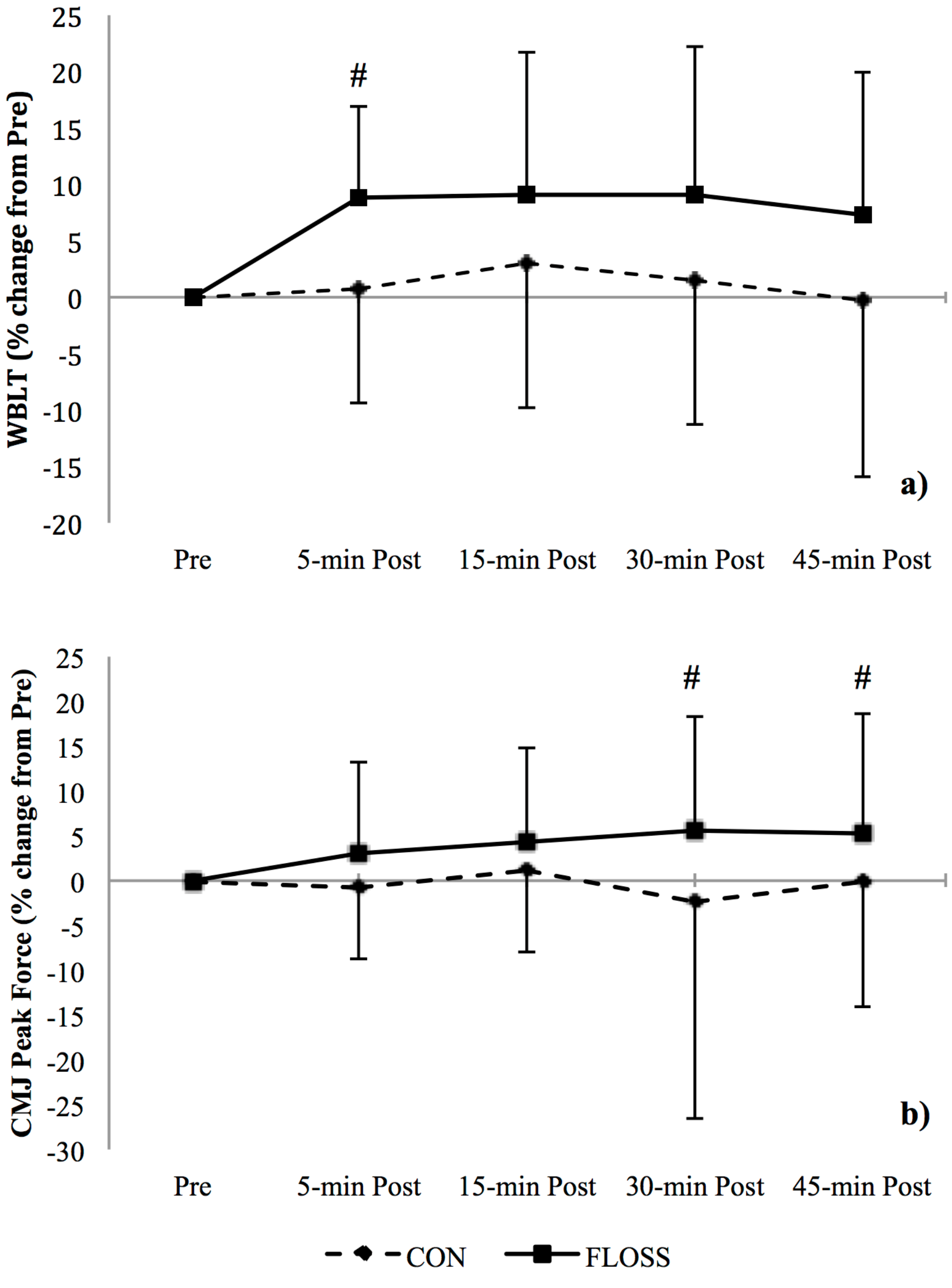
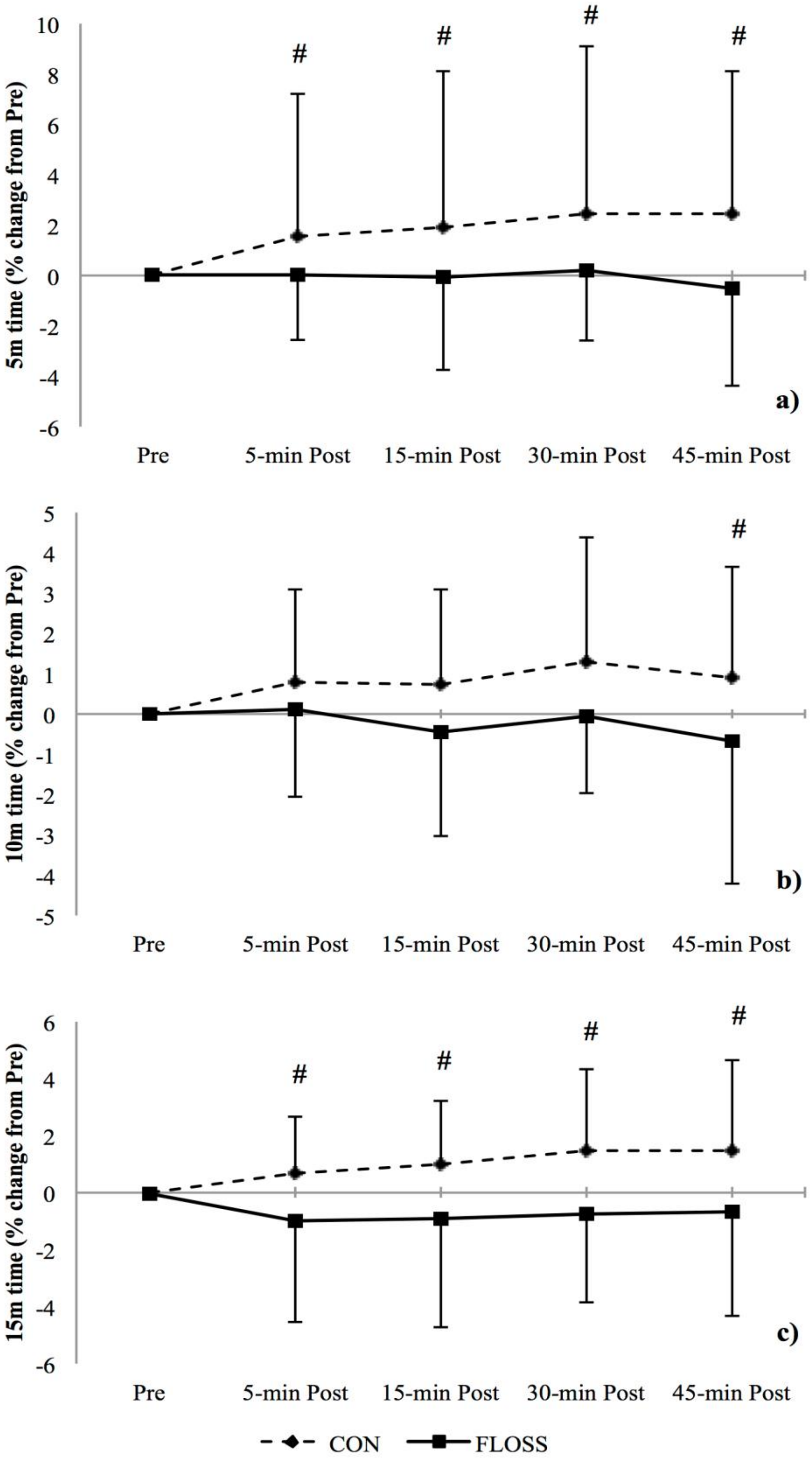


Figure 1 – Percentage change from pre-test (baseline) values for the experimental (FLOSS) and control (CON) groups for a) the weight bearing lunge test, measured in cm (WBLT), and b) countermovement jump peak force measured in N (CMJ). Dashed line represents CON, solid black line represents FLOSS. # represents *small* effect size between groups.



5m time (% change from Pre)
10
8
6
4
2
0
-2
-4
-6
#
#
#
#
a)
Pre
5-min Post
15-min Post
30-min Post
45-min Post
10m time (% change from Pre)
5
4
3
2
1
0
-1
-2
-3
-4
-5
#
b)
Pre
5-min Post
15-min Post
30-min Post
45-min Post
15m time (% change from Pre)
6
4
2
0
-2
-4
-6
#
#
#
#
c)
Pre
5-min Post
15-min Post
30-min Post
45-min Post
CON
FLOSS

Figure 2 – Percentage change from pre-test (baseline) values for the experimental (FLOSS) and control (CON) groups for the SPRINT test across the different splits: a) 5m time, b) 10m time, and c) 15m time. Dashed line represents CON, solid black line represents FLOSS. # represents *small* effect size between groups.

Discussion

Findings from the current study would support the use of floss bands applied to the ankle joint while performing two minutes of ROM exercises to improve ankle ROM, countermovement jump and 15m sprint performance in 69 recreational athletes for up to 45-minutes following their application. The floss band trial resulted in significant increases in the weight bearing lunge test across time points compared to the control trial. At the final time point tested in the current study (45-mins post), the floss band trial was associated with a *small,* yet significant ($p < 0.05$), effect in comparison to the control group for 15m sprint time. *Small,* but non-significant benefits were also seen for the floss group when compared to the control for countermovement jump peak force 45-minutes after application of the floss bands. These results may have significant applications for practitioners considering the use of tissue flossing via floss bands for injury prevention and performance.

The results in the current study are in agreement with previous research from our laboratory (Driller & Overmayer, 2017), showing benefits to both ROM and jump performance following the application of floss bands to the ankle joint. The current study extends these findings by showing benefits to sprint performance and also by highlighting benefits that last longer than the 5-minutes post application reported in our previous study. While the mechanisms related to the improvements have not been measured in either of our studies, previous research investigating other methods of occlusion (e.g. tourniquets, blood pressure cuffs) have reported the physiological responses. More specifically, Takarada et al. (2000) reported growth hormone and norepinephrine levels were significantly increased after a tourniquet on the upper-leg (~214mmHg) was released. It has been suggested that elevated norepinephrine is associated with improved vertical jump ability (Morales et al., 2014). Therefore, while we can only speculate, it is possible that hormonal responses following the release of the floss bands (178 ± 18mmHg) in the current study could have contributed to enhanced jump and sprint performance. The mechanisms relating to increased ankle ROM in the FLOSS group are also relatively unknown, however, it is reasonable to assume that the fascial shearing mechanisms that are likely to occur during the active dorsiflexion/plantarflexion movements while having the floss bands attached, could have increased dorsiflexion at the talocrural joint, and improved the weight-bearing lunge test scores. As the technique of band flossing becomes increasingly popular, further mechanistic research is needed.

Future research should also consider testing this technique in highly-trained athletes, utilizing sport specific tests and a range of sporting populations (e.g. team and individual sports) and across different joints (e.g. knee, hip, shoulder, elbow). Further research may also include the use of tissue flossing in a chronic setting prior to or during exercise sessions. Indeed, preliminary pilot work would suggest that this may be effective for improving both ROM and performance. Bohlen et al., (2014) examined the effects of 14 days of band flossing combined with joint mobilization and resistive exercise on plantar/dorsiflexion strength in five participants. Participants performed lower limb exercises with floss bands applied to one knee while the contralateral leg acted as the control. Their results showed that dorsiflexion peak torque increased 22% in the treatment leg (p=0.06), while there was no change in the control leg after the 14-day period. Given jump and sprint performance were improved in the current study up to 45-minutes following floss band application, it could be speculated that improving performance during training sessions in a chronic setting, may lead to greater physiological adaptations, and therefore, performance.

A limitation in the current study was the lack of a placebo/sham condition. The psychological advantage that may be associated with the use of band flossing can not be discounted. However, the experimental intervention in this case is difficult to provide a placebo condition for, therefore future studies could investigate different levels of pressure applied by the bands, in a cross-over design (e.g. <50mmHg, 100mmHg, 150mmHg, >200mmHg). This would allow for the optimal pressure of band flossing to be determined, and also give greater insight into the possible mechanisms, for example, whether or not the benefits are likely to be associated with a blood-flow occlusion effect. Another limitation of the current study was the time points used (up to 45-minutes post application of the floss bands). While the results would suggest that sprint performance had returned close to baseline values at 45-minutes post in the FLOSS group, it could be argued that both jump performance and the weight-bearing lunge test were still above baseline levels. Therefore, it may have been useful to extend the time frame and repeat these measures until they returned to baseline values.

The current study adds support and new information to the relatively novel technique of tissue flossing to improve ROM and athletic performance. It extends our previous work by demonstrating that the potential acute benefits of applying floss bands to the ankle (talocrural) joint for 2 minutes, may improve ROM, jump and sprint performance for up to 45-minutes after removing the bands. These results may have significant implications for practitioners considering using this technique during a warm-up prior to exercise. Not only has increased ankle ROM been shown to decrease the likelihood of lower-limb injuries (Fong et al., 2011; Griffin et al., 2006; Hewett et al., 2005), but the potential performance benefits to both team and individual athletes must be considered. Future research to determine whether these same benefits are evident in highly-trained athletes is warranted.