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Abstract

Context: 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. Current evidence suggests that band flossing results in performance improvements and may also be an effective method in injury prevention. **Objective:** Previous research has shown that tissue flossing may result in increased ankle ROM, jump and sprinting performance in recreational athletes. The present study aims to extend on this research, within an elite athlete sample. **Design:** counter-balanced, crossover design with experimental and control trials, separated by one week. **Setting:** University laboratory. **Participants:** 14 professional male rugby union athletes (mean ± SD: age; 23.9 ± 2.7). **Intervention:** Application of a floss band to both ankles (FLOSS) for two minutes or without flossing of the ankle joints (CON) on two separate occasions. **Main Outcome Measures:** 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 the floss band or control. **Results:** There were no statistically significant interactions between treatment (FLOSS/CON) and time for any of the measured variables ($p > 0.05$). Effect size analysis revealed *small* benefits for 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. **Conclusion:** Findings from the current study suggest minimal benefits of tissue flossing when applied to the ankle joint in elite athletes for up to 30 minutes following their application.

Keywords: *flossbands, vascular occlusion, ischemic pre-conditioning*

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. [1] 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. [2] 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. [2] In addition, tissue flossing may influence fascia tightness via the fascial mechanoreceptors, therefore reducing muscle activity, resulting in a greater ROM. [3] This mechanism has been suggested for acute changes in ROM observed after applying pressure with a foam roller. [4] Nevertheless, for tissue flossing, these mechanisms remain speculative.

Previous research by Driller and Overmayer [1] supports 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 using a linear position transducer in 52 recreational athletes. Results showed *small* (d = 0.22-0.49), 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. The authors concluded that a limitation was the flossing of only one ankle and that only one time point was assessed (5-minutes post).

In a follow up study, Driller and colleagues 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 minutes post the application of a floss band to both ankles, in 69 recreational athletes. [2] 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 benefits were seen for FLOSS when compared to CON for CMJ force at 45 minutes post (d = 0.21). FLOSS was also associated with significantly faster 15 SPRINT times, and a *small* effect size in comparison to CON at 45 minutes post (d = -0.27).

Researchers have examined the effects of applying floss bands on regional blood flow. [5] In this study, 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, the effect of applying floss bands to both shoulders while concomitantly performing ROM exercises in 17 male recreational athletes has been investigated. [6] The study reported that despite trends towards improvements, there were no significant increases in ROM or upper-body power following the floss band treatment when compared to the control.

In a more recent study, the effect of tissue flossing on elbow ROM in tennis players has been investigated. [7] Twelve elite tennis players participated in this randomized cross-over study whereby they attended two separate testing sessions (floss band or no floss band). There were no significant differences between floss band and no floss band for all ROM 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. [8,9] 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. [8]

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. Given the small changes in ROM and performance in lesser-trained individuals following tissue flossing, we would hypothesise that there would be negligible effects found in a highly-trained athletic population.

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 approved from the Human Research Ethics Committee of the institution and were in the spirit of the Helsinki Declaration.

Design

In a counter-balanced, 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). Athletes were placed in pairs and each performed a different intervention for the first trial, and switched for the second trial. 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 on the floor, with the knees positioned at 180°, all participants were instructed to perform both plantarflexion and dorsiflexion to their extreme ranges of motion (2 seconds for each) 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.

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 (see below). 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. [10] Only one ankle at a time could be measured for the pressure exerted. Researchers were aiming for a target pressure of ~180mmHg, as this is what has been used in previous studies.

Procedures

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. [11] 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 = ~0.5 cm). [11]

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. [12] Participants were then instructed to descend to a self-selected countermovement depth and to jump as high and quickly as possible. [13]

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. [14] 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.

A standard ankle-bandaging technique was used by the researchers to apply the floss band as described previously [1] (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.

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. 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. [15] 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 95% confidence interval overlapped the thresholds for *small* positive and *small* negative effects. [16] 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.

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 for 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 minutes 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 and Overmayer [1] 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 and Overmayer [1] 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 et al. [2] (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. Furthermore, the effect size results in the current study are comparable to those reported in the aforementioned studies. [1,2]

It is possible that these acute responses, when implemented in a chronic setting, may lead to long-term physiological adaptations. Bohlen et al. [5] assessed the benefits of tissue flossing in a chronic (14 day) setting while applying the floss band to one knee during daily exercises. Recent research [1,2,5] 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. Previous mechanisms that have been suggested in ischaemic pre-conditioning literature should be considered, including 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. Future application of the tissue flossing technique in injury rehabilitation settings could also be considered. Given the improvements in ROM properties outlined by previous research, it may be advantageous to investigate whether such a technique could speed up rehabilitation processes via this mechanism of increasing ROM.

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 future studies, the pressure applied to both limbs (rather than just one), should be employed, and control over the pressure applied (e.g. ±2 mmHg) should also be considered.

Conclusion

In conclusion, 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* effect sizes for the sprint and CMJ tests, coupled with the promising results from previous analysis, further research is warranted on this relatively novel technique.

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

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

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Table 2: Comparison of all post measures (5 and 30-minutes) to pre-test values. Data presented as raw difference in values (mean ±95% confidence intervals) with effect sizes (and 95% confidence intervals) 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 ±0.18, *Trivial*	0.0 ±0.5 0.01 ±0.19, *Trivial*
CMJ (N)	90 ±117 0.28 ±0.45, *Small*	-37 ±77 -0.12 ±0.30, *Trivial*
5-m SPRINT (secs)	0.01 ±0.02 0.15 ±0.39, *Unclear*	0.00 ±0.04 0.01 ±0.61, *Unclear*
10-m SPRINT (secs)	-0.02 ±0.03 -0.18 ±0.35, *Trivial*	-0.04 ±0.04 -0.45 ±0.52, *Small*
15-m SPRINT (secs)	-0.01 ±0.05 -0.05 ±0.43, *Unclear*	-0.03 ±0.05 -0.24 ±0.43, *Small*
20-m SPRINT (secs)	0.00 ±0.03 0.00 ±0.18, *Trivial*	-0.02 ±0.03 -0.13 ±0.29, *Trivial*