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Robert PRILL, Robert SCHULZ, Sven MICHEL

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Authors:

- M.Sc., B.Sc. PT Robert Prill (corresponding author; Robert.Prill@b-tu.de)

Brandenburg University of Technology, Department of Therapy Sciences II

Robert Prill, +4917……

Universitätsplatz 1

01968 Senftenberg

Germany

- Robert Schulz

Brandenburg University of Technology, Department of Therapy Sciences II

- Univ.-Prof. Dr. habil. Sven Michel

Brandenburg University of Technology, Department of Therapy Sciences II

Contributors:

Leif Jensen, Brandenburg University of Technology, Department of Therapy Sciences II

Marco Stahn, Brandenburg University of Technology, Department of Therapy Sciences II

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ABSTRACT

Objectives: The symptomatic reduction of exercise-induced delayed onset muscle soreness (DOMS) is of great interest in the fields of Sports Medicine and Physical Therapy. At this time, few therapeutic interventions have proven their effectiveness. One of the most promising interventions is Compression Therapy. The object of this study is Tissue Flossing, a therapeutic short-term compression method and whether its post-exercise application can reduce the extent of perceived DOMS.

Design: randomized, controlled, and double-blind pilot cross-over trial

Methods: Participants (n = 17) without any musculoskeletal injuries were recruited from university students. Participants performed an exercise protocol and obtained the intervention subsequently on one of both arms. Participants had to return for a second day to perform the whole procedure again, this time receiving the flossing intervention on the other arm. At both time points their opposite arms served as the control. The primary outcome measure was a patient reported visual analogue scale 100mm.

Results: The mean value of DOMS of the flossed arm was 42mm compared to the non-flossed arm with 48mm. Differences were found to be statistically significant at 24 hours- ($p=0,036$; $\alpha=0.05$), as well as at 48 hours post-intervention ($p=0,035$; $\alpha=0.05$). Effect sizes were $d_z=0,408$ at 24 hours-and $d_z=0,411$ at 48 hours post-intervention. The clean language effect size was 0.66.

Conclusions: Tissue flossing appears to be an effective method for treating DOMS which is slightly less effective but much more practicable than gold standard

treatment.

HIGHLIGHTS

- Post-exercise tissue flossing applied once for about three minutes at the upper extremity, covering the biceps brachii muscle
- With post-exercise tissue flossing, the amount of perceived DOMS can be significantly reduced
- The effects are stable between 24 and 48 hours, post-exercise

Keywords: DOMS, muscle, treatment, physiotherapy

Introduction

High intensity exercise, as well as an increase in training volume, are related to muscle damage (1).

Clinically, the term Delayed Onset Muscle Soreness (DOMS) is used to describe this process, and its related symptoms. In accordance with the Munich Consensus Statement for Classification of Muscle Injury, DOMS is a functional muscular disorder, resulting from overexertion (2).

DOMS appears in the form of generalised muscular pain, as a result of un-acclimated high-intensity, high-force or eccentric exercise (3–6). DOMS is associated with significant reduction in strength and power in athletes, combined with altered muscle activation patterns and impaired neuromuscular function (7), as well as reduced range of motion and a higher risk of further injury (8). Other symptoms can be stiff and swollen muscles, and a temporary reduction in strength. The symptoms of DOMS peak 24 to 48 hours after exercise and subside within 96 hours (5,9–11). Symptoms can last for several days and may affect the athlete's capacity to train at the desired intensity in subsequent training sessions (6). Furthermore, in their prospective investigation, Ekstrand et al. found that the average lay-off time as a result of DOMS in football players was 4,5 days (12). Therefore, DOMS can have a negative impact on the development of an athlete's performance.

Numerous recovery strategies for treating muscle soreness are used in contemporary practice, but most of them, such as stretching, massage, electrotherapy, sonography and pharmaceuticals have shown little evidence in

their efficacy (11,13–15).

Despite there being some forms of cryotherapy producing unfavourable results in treating muscle soreness (16,17), evidence supports the use of whole-body-cryotherapy (WBC) and cold-water-immersion (CWI) because of their effectiveness in relieving subjective symptoms, in spite of their inconsistent impact on preferable biochemical parameters (18–20).

Additionally, compression therapy has consistently shown to be effective in providing some relief of DOMS (6,21).

The tissue-flossing method can be described as a form of short-duration compression-therapy, and is the object of investigation in this trial. Primarily, tissue flossing was invented for increasing short-term range of motion in human joints and also for its analgesic effects (22), but recently a regenerative effect on skeletal muscle was propounded too (23,24). While initial evidence showing positive effects on range of motion (25), there is no published research supporting the idea of a positive, regenerative effect on skeletal muscle so far.

Therefore, the aim of this study is to investigate whether or not the tissue-flossing method promotes reduces DOMS after exercise-induced muscle soreness.

METHODS

Participants

Both, male and female participants were included and needed to be familiar with physical exercise, but they did not need to have any prior experience with strength training. Inclusion criteria required participants to be aged between 18 to 30 years. Exclusion criteria were any diagnosed musculoskeletal pathologies, self-reported

functional deficits, actual pain or dermal pathologies of the upper limbs, rubber- and/ or latex intolerances, any pathologies of the vascular system including hypertension, malignant processes or open wounds. Furthermore, participants affirmed that they followed their normal diet 48h before and after intervention and that they would not strain or fatigue their upper limbs 48h before and after intervention.

All participants were recruited in April 2016 from university students.

Informed consent was obtained in written form from each participant. The study was conducted in accordance with ethical guidelines from the Helsinki Declaration.

Experimental Design

This study was designed as a cross-over trial. Prior to commencing this study, participants generated an individual numerical code for themselves, which was used for data management. Concealed random group allocation was performed through a coin toss. This group allocation determined whether the dominant, or the non-dominant arm received the flossing-intervention on the first day of measuring. Consequently, the other arm received the intervention on the second day. The participants were neither aware as to which group they were allocated, nor what influence the group affiliation would have. After randomly allocating every participant to one of the groups, an exercise protocol for the biceps brachii muscle had to be completed. Afterwards, participants had to assess their perceived exertion of this muscle using a numerical rating scale. Following this, they had 15 minutes to rest, before both groups received the flossing intervention from a flossing trained physiotherapist: one group on the left, the other on the right arm. Each participant had to return seven days later in order to repeat the whole

procedure. Contrary to the first measuring day, in this instance the opposite arm received the flossing intervention, while the non-flossed arm generated the control group data.

The cross-over trial serves to reduce the potential individual influential factors that exist in non-homogenous groups, commonly occurring in studies with small sample sizes. Hence, the statistical power of cross-over trials rises as comparable data is produced (26). In this study, every participant is part of both the intervention group, and the control group.

Figure 1: study design

Due to the self-reported outcomes and the blinding of the participants, the assessor must also be considered as blinded. Furthermore, the analyst of the outcome measures neither knew which data (control or intervention arm) they were analysing, nor to which group the data was related. A blinding of the therapist was not feasible, because the therapist needed to know on which arm they had to perform the tissue flossing.

Due to these precautionary measures, a randomised, controlled and double-blinded trial design was successfully implemented.

Procedures

Exertion protocol

The exertion protocol consisted of a general and a specific warm-up routine followed by the main exercise. Subsequent to the warm-up protocol, the one-repetition-maximum of the unilateral biceps-curl was determined for every participant and was used for determining the resistance in the following exercises.

A precise description of the exertion protocol is presented in table 2. All exercises were performed for three sets, with one minute of rest in between the sets. In every set, the repetitions ranged from five to eight as participants had to continue until repetition failure.

Table 1: exercise protocol

exercise	**mode of contraction**
bent over barbell rows, supinated grip	concentric
bilateral cable pulley biceps curls with horizontal upper arms	concentric
barbell biceps curls, neutral grip,	concentric
sz-barbell biceps curls, supinated grip, supra-maximal load	Eccentric
Supra-maximal unilateral cable pulley biceps curls, supra-maximal load	eccentric
dumbbell-hold in 90° elbow flexion, supinated grip	isometric

Every participant was supervised by a therapist, who observed the execution of the exercises, as well as the number of sets and repetitions. The therapist also assisted in the concentric portion of the supra-maximal exercises.

Following the exertion protocol, the participants had to fill out the modified versions of the Borg rating of perceived exertion scale (RPE). A score below 15 on the RPE, which is defined as hard or heavy exertion (27), served as a cut-off-score and would have led to exclusion from the subsequent intervention. It would be unlikely for participants to develop DOMS after an exertion protocol which subjectively did not feel strenuous. The participants were unaware of the relevance of the report using the modified RPE.

Tissue flossing intervention

After a rest period of fifteen minutes, the participants received the flossing intervention from a physiotherapist. The treatment lasted three minutes and was applied only once. All participants received the intervention from the same trained and experienced therapist.

The tissue flossing intervention was executed using a specific flossing rubber band (Rogue Fitness Inc., Ohio) with a length of seven feet and a width of two inches. It has a maximal stretch of 150% and is made of natural latex rubber. The flossing-band was wrapped around the extended upper arm from distal to proximal. The starting point was three centimetres proximal to the medial epicondyle of the humerus, just above the nodus lymphatici cubitalis. The application ended about

Figure 2: application of the tissue flossing bands

three centimetres under the armpit, and thus just under the nodus lymphatici axillares. In between the starting and ending points, the flossing band was wrapped around the arm circularly. Depending on the length of the upper arm, the band overlapped itself by approximately three to four centimetres. This method of application ensured that the whole muscle belly of the biceps brachii muscle was covered. The applied level of compression was determined by the amount of stretch exerted on the band. The first and last two layers of the flossing band were applied on the arm with a stretch of about 50% of the band's maximum stretch. The layers in between were applied with about 75% of the band's maximum stretch. Upon completion of the flossing band application, participants were instructed to move their arms into elbow-extension; elbow-flexion; internal rotation of the glenohumeral joint with pronation of the forearms; and external rotation of

the glenohumeral joint combined with supination of the forearm, consecutively.

Immediately afterwards, the participants received a questionnaire to self-assess their perceived DOMS, which they had to fill in 24, and then 48 hours after intervention.

Outcome measures

The main outcome measurement was the self-assessed perceived DOMS on a visual analogue scale of 100mm. Measuring DOMS with a self-reported visual analogue scale is widely used in the evaluation of DOMS (17,28,29). Additionally, it was shown that a visual analogue scale is a valid, reliable instrument for measuring pain (30).

The participants assessed their DOMS in the dominant and the non-dominant arm 24 and 48 hours after intervention. Every participant generated four values of perceived DOMS on each measuring day.

Statistical analyses

Statistical analyses were performed using the Statistical Package for Social Science (V. 22.0, IBM SPSS Inc., Chicago, IL).

Descriptive statistics are shown as means ± standard deviations, unless stated otherwise.

According to suggestions from Campbell and Swinscow, results of this cross-over-trial are based on calculation of the two-tailed t-test for dependant samples (31). A paired t-test had to be used because the subjects in this trial served as their own control.

When the results of the control group and the experimental group are based on

the same individuals, the two groups cannot be handled as separate data. Visual analogue scales, especially 100mm scales, produce continuous ratio data and fulfill the requirements of a t-test (32–35).

The comparison was whether or not there is a lower DOMS value at the arm that received the therapeutic flossing in comparison to the arm that did not receive the therapeutic flossing.

Statistical significance was set at $p < 0.05$ for all analyses.

In line with recommendations from the American Psychological Association (36), standardized effect sizes were declared. Considering the dependant sample design, Cohen's d_z was calculated (37). Additionally, the clean language (CL) effect sizes were estimated.

RESULTS

At both 24 and 48 hours after the intervention, the perceived muscle soreness at the tissue-flossing arm was different from that at the control arm (figure 1).

These differences were found to be statistically significant 24 hours post-intervention ($p=0,036$; $\alpha=0.05$), as well as 48 hours post-intervention ($p=0,035$; $\alpha=0.05$). Seventeen healthy participants were included in this study. Two participants did not appear at the second measuring day because they dropped out of university. Therefore, the main outcome was analysed for fifteen of seventeen participants (88%) with an average age of 21,9 (± 2,3). Seven participants were female, and eight were male.

Due to the cross-over-design, fifteen participants generated thirty pairs of data at

figure 3: perceived DOMS 24 and 48 hours postinterventional

24 and 48 hours each.

In total, 62% of the participants experienced reduced symptoms of DOMS with therapeutic flossing when compared to the control arm (figure 2). Standardized effect sizes were d_z=0,408 at 24 hours post-intervention and d_z=0,411 at 48 hours post-intervention. The CL effect sizes indicate that from a randomly selected pair of individuals, the probability that DOMS of a person without tissue flossing being higher than the DOMS of a person with tissue flossing is 66% (CL = 0.66).

No participant had to be excluded resulting from a score below 15 on the Borg-RPE-scale. The scores ranged from 15 to 20 with a mean value of 17,7 (SD ± 1,9).

DISCUSSION

The current study is the first one that investigated the effects of tissue flossing for prevention of DOMS, and shows a significant reduction of DOMS using the flossing treatment compared to the control arm.

The fact that 62% of the participants experienced reduced symptoms of DOMS with therapeutic flossing is consistent with the findings of Hill, Howardson and von Someren, who described that about 66% of people benefit from compression therapy in terms of reducing DOMS (6).

Overall, the participants experienced 12,5% less DOMS in the arm which received the intervention in comparison to the control arm, which did not receive the intervention. Although the flossing intervention was done just once directly after exercise, the effect of fewer perceived symptoms of DOMS is stable compared to the control arm at both 24 and 48 hours post-intervention.

figure 4: perceived DOMS

Although the raw effect-size estimates provide a better overview of the specific

improvements that can be expected, the additional usage of standardized effect sizes is highly encouraged (36,38,39).

In this study, tissue flossing reached small effect sizes of approximately d_z=0,4 (40). This interpretation of the standardized effect sizes is based on benchmarks of Cohen, but should not be interpreted rigidly (38).

These effect sizes are inferior to the reported standardised mean differences (SMD) of the gold standard treatment modalities, namely, whole body cryotherapy (WBC) and cold water immersion (CWI), which are -0.57 (WBC) and -0.55 (CWI) at 24 hours and -0.58 (WBC) and -0.66 (CWI) at 48 hours (19,20).

Nonetheless, it seems that tissue flossing could contribute to diminishment of DOMS. Given the low cost of the necessary equipment, and the minimal amount of time needed for application, especially in comparison to some forms of cryotherapy, tissue flossing appears to be an easy and practicable treatment method. Therefore, tissue flossing could be used by a much wider population as opposed to cryotherapy, which requires access to extreme cold air cabins.

This study was done with a relatively heterogenous group of subjects, in terms of experience with exercise and strength training. Subsequent studies have to determine whether or not the relatively low effect sizes are due to the high standard deviations that were produced by the heterogeneity of the participants, and if the results of this investigation could be reproduced with an even more homogenous group of subjects.

Any influential factors that were not related to the tissue flossing intervention would have occurred in both groups, due to the cross-over-design and would not have any impact on the results.

Carry-over effects were foreclosed by performing the second measuring day, at the earliest, one week after the first measuring day. Due to the diminishment of DOMS within 96 hours, and its dissipation from then on (3,41), carry-over effects in terms of DOMS were ruled out.

The expected preconditioning effects or repeated bout effects could not have any influence on the results, because at both measuring days both arms were exercised, so any potential preconditioning effects would have also occurred at both arms. Since the difference between both arms was analysed, these effects would not have any influence.

As mechanisms of DOMS are not yet fully understood, a final explanation of the effectiveness of compression therapy remains hypothetical (6). It is proposed that symptoms of DOMS are mainly elicited by microstructural damage, and the inherent inflammatory response to that damage (42). This exercise-induced muscle damage is caused by mechanical strain, that is characterized by disruption of the sarcomeres, and an inflammatory response in the days after exercise. The release of prostaglandin sensitises afferent nociceptive fibres, and is the reason for a characteristic dull pain (4,17).

In accordance to the mechanisms of compression therapy, immediate application of therapeutic flossing could reduce the inflammatory response, by reducing the influx of inflammatory mediators. Subsequently, this effect would result in a lower intracellular osmotic pressure that would reduce sensitivity of the nociceptors and could explain the lower perceived DOMS in this trial, and in compression therapy in general (6,43). With better recovery and faster strength recuperation due to a lower amount of DOMS, the athletes are then able to resume training sooner with

decreased risk of further muscular injury.

Future research studies should focus on physiological processes that occur during tissue flossing. With regard to studies on tissue flossing for prevention or reduction of DOMS, a broader variety of outcome measures should be incorporated to cover the multifactorial nature of DOMS, as well as a more homogenous composition of the test group.

CONCLUSION

This randomised, controlled and double-blind trial is the first one investigating the effects of therapeutic flossing on DOMS. This study shows that tissue flossing significantly reduces the perceived DOMS. Regarding the simplicity, quickness and low cost of tissue flossing, this method could be an effective treatment option in athletic training, sports medicine and physiotherapy for the treatment of DOMS.

Ethical approval

The work has been carried out in accordance with the Declaration of Helsinki.

Disclosure Statement

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

None declared.

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Table 2: exercise protocol

exercise	**mode of contraction**
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Supra-maximal unilateral cable pulley biceps curls, supra-maximal load	eccentric
dumbbell-hold in 90° elbow flexion, supinated grip	isometric

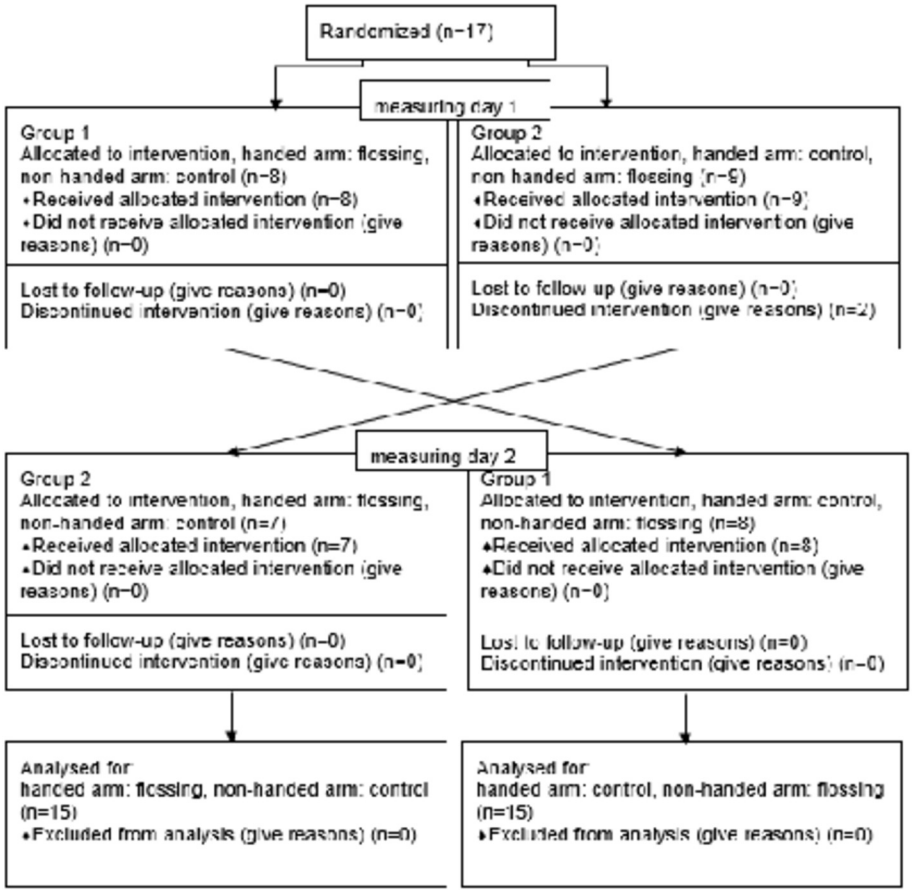


Figure 1: study design

Figure 1: application of the tissue flossing bands

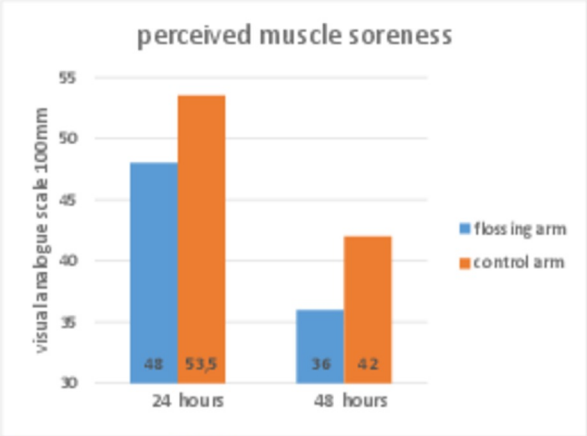
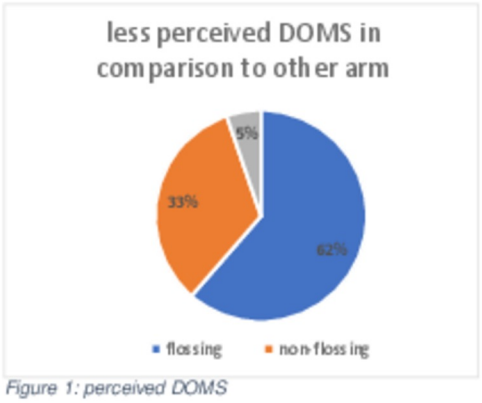


Figure 1: perceived DOMS 24 and 48 hours post-intervention



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