ACUTE EFFECTS OF MASSAGE ON PASSIVE ANKLE STIFFNESS FOLLOWING AN EXHAUSTIVE STRETCH-SHORTEN CYCLE TASK: A PILOT STUDY

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This preliminary study evaluated the effect of massage on the passive stiffness of the calf muscle complex following single-leg hopping to volitional exhaustion. Four young and healthy male participants had their ankle taken through full joint excursion to determine the resistance to ankle dorsiflexion both prior to and immediately following hopping. A 10 minute rest and massage were then applied in a random order and follow up measures taken immediately after each intervention. Calf muscle stiffness increased in three of the four participants following hopping and two participants had a decrease following massage. This study suggests that changes in calf muscle stiffness are sensitive to both exercise and massage. It is important to determine the underlying mechanism(s) to changes in calf stiffness following exercise and whether massage offers any benefit.

KEY WORDS: petrissage, effleurage, fatigue, calf muscle stiffness.

INTRODUCTION: Massage is a commonly used treatment modality which has been thought to provide various effects on the body's tissues (Weerapong, Hume, & Kolt, 2005). Among these are mechanical effects, such as improved flexibility or reduced stiffness of muscles (Weerapong et al., 2005). In contrast, individuals with higher passive stiffness have been shown to be more susceptible to exercise-induced muscle damage (McHugh et al., 1999) Thus, massage is often used prior to or during sport in order to improve performance or recovery (McHugh et al., 1999; Weerapong et al., 2005). Despite this, there has been minimal evidence to suggest massage provides such mechanical effects. Studies investigating the effect of massage on the flexibility of the triceps surae and hamstring muscles found small significant improvements to range of motion, however, these would not likely be considered clinically relevant (Hopper et al., 2005; McKechnie, Young, & Behm, 2007). Additionally, massage was shown to provide no significant effect to either the flexibility or passive stiffness of the triceps surae musculotendinous unit (MTU) as measured by an instrumented footplate (Thomson, Gupta, Arundell, & Crosbie, 2015). Therefore it appears that massage provides no functionally relevant mechanical effects to the healthy MTU.
Whilst the evidence suggests that there was no benefit of massage to the MTU, it is important to note that the previously conducted studies only investigated participants who were healthy and had not performed any rigorous activity. It remains unclear as to whether massage may provide a mechanical effect to individuals who have short or long-term changes in MTU stiffness. Such changes in muscle stiffness may be found in individuals following stretch-shorten cycle exercises performed to exhaustion (Ishikawa et al., 2006). Some studies have reported psychological or physiological benefits of massage for individuals with delayed onset muscle soreness induced following eccentric exercise. However, these studies did not evaluate the mechanical effects on the MTU (Tiidus & Shoemaker, 1995; Zainuddin, Newton, Sacco, & Nosaka, 2005). Thus, it is unclear whether massage may alter the mechanical characteristics of the MTU which may be stiffer following strenuous exercise. The purpose of this study was to investigate whether massage changed the passive stiffness of the triceps surae MTU when there was a short-term change in MTU stiffness following an exhaustive stretch-shorten cycle task.

METHODS: Four healthy recreationally active males aged between 22 to 26 years of age completed an exhaustive stretch-shorten cycle task, then received both a 10 minute massage and 10 minute rest period in a randomised order. Passive stiffness measures of the triceps surae were obtained from a custom-built, instrumented force plate (Thomson et al., 2015). Force and angle data were collected at 200 Hz. Surface electromyography (sEMG) activity of the tibialis anterior and soleus muscles were also recorded (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000) and any trials recording an EMG signal (±2SD) discarded from processing.

Passive stiffness measures were obtained by rhythmically oscillating the instrumented footplate at a frequency of 0.5 Hz, as controlled by an audible metronome (Thomson et al., 2015). With the knee extended, the foot was secured in the instrumented footplate and fifteen cycles of continuous dorsiflexion-plantarflexion were performed for each participant. Initial measures of passive stiffness were completed prior to (Pre) and immediately after (PostEx) a fatiguing exercise task. Following the exercise task, participants received both deep soft-tissue massage and a 10 minute rest period in a random order. Passive stiffness measures were taken immediately after each intervention (Post1 and Post2). The fatiguing task involved participants complete three sets of on-the-spot, single-leg hopping at 2.2 Hz to volitional exhaustion, maintaining landing in synchrony with an audible digital metronome. Five minute rest periods were provided between sets and volitional exhaustion was defined as the point when the participant could no longer maintain the required performance outcome of hopping cadence. Single-leg hopping represented a task predominantly modulated by the triceps surae muscles, utilising the stretch-shorten cycle (Lamontagne & Kennedy, 2013). Massage was applied to the calf muscle complex and consisted of petrissage strokes, with linking effleurage (Thomson et al., 2015). A 10 minute rest period was included as a control for the effects of time.

Due to the small sample size a single-participant analysis was performed. A mean of calf passive stiffness (upward gradient of the torque – displacement curve) was calculated from all cycles (no sEMG activity) between the sixth to the fifteenth cycle at each time point (Pre, PostEx, Post1 and Post2) for each participant. A 4 x 1 repeated measure ANOVA was used to determine differences in passive stiffness between time periods for each participant. Post-hoc pairwise multiple comparisons were made to further explore differences between each time period. Alpha levels were set *a priori* with significance accepted at $p < 0.05$. *Cohen's d* effect sizes were calculated and thresholds of 0.2, 0.5 and 0.8 used to qualitatively describe small, moderate and large effect sizes (Cohen, 1988).

RESULTS: Participant one was allocated massage then rest and all other participants were allocated rest then massage. For participant 1, PostEx was significantly less than Post1 ($p < 0.01$, $d > 0.08$). For participants 2, 3 and 4, Pre was significantly less than PostEx ($p < 0.01$, $d > 0.8$), Post1 ($p < 0.01$, $d > 0.8$) and Post2 ($p \leq 0.01$, $d > 0.08$). Massage only provided a significant decrease in stiffness for participant 3, as Post2 was significantly less than PostEx ($p < 0.005$, $d = -2.61$) and Post1 ($p < 0.001$, $d = -2.29$) (Figure 1; Table 1).

Table 1.
Passive calf stiffness ($Nm.kg^{-1}$) calculated from cycles six to fifteen (mean (SD)) for each participant at each time point. * *p* < 0.05 compared to PRE. † *p* < 0.05 compared to PostEx. ‡ *p* < 0.05 compared to Post1.

	Pre	PostEx	Post1	Post2
Participant 1	8.78 (0.49)	8.09 (0.32)	8.54 (0.32)†	8.28 (0.63)
Participant 2	7.09 (0.27)	7.55 (0.39)*	7.82 (0.40)*	7.53 (0.42)*
Participant 3	6.74 (0.51)	8.19 (0.24)*	8.60 (0.45)*†	7.57 (0.45)*†‡
Participant 4	7.43 (0.41)	8.10 (0.19)*	8.09 (0.55)*	8.18 (0.49)*

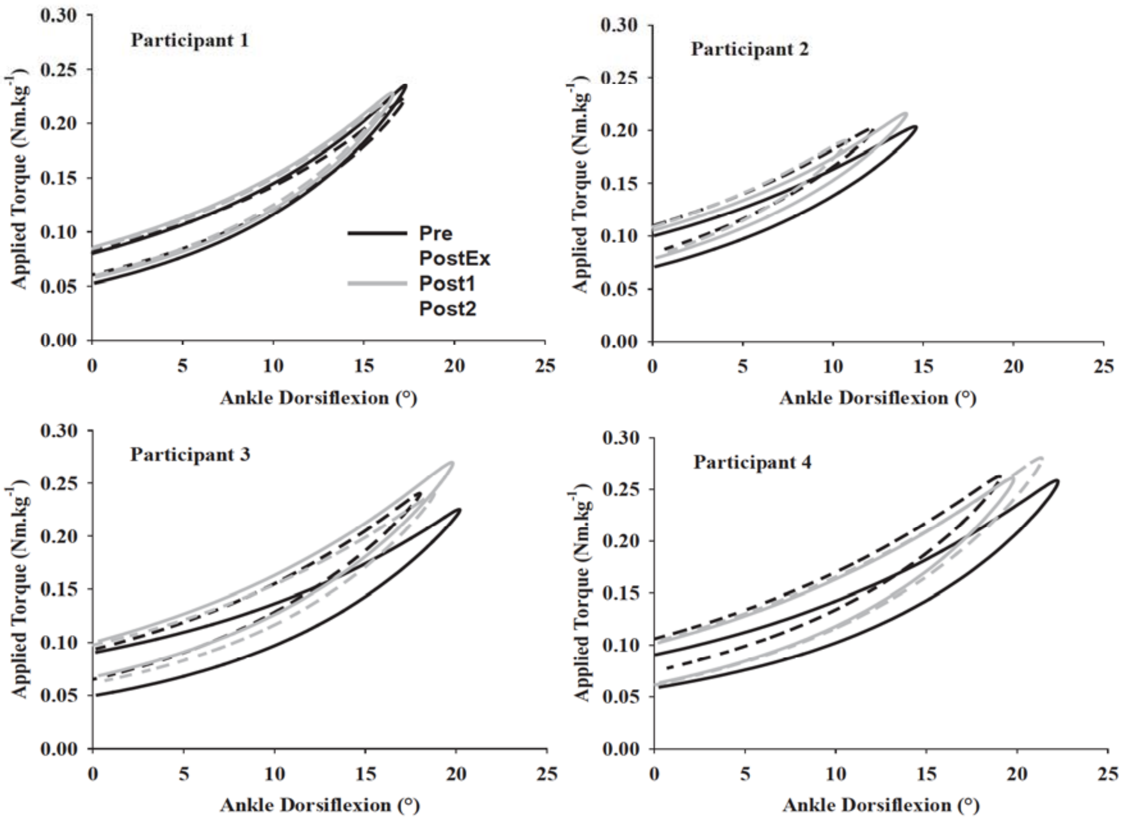

Figure 1: Mean torque – ankle displacement curves for each participant at each measurement period. The mean curves for cycles six to fifteen at Pre-exercise (solid black), Post-exercise (dashed black), Post-treatment 1 (solid grey) and Post-treatment 2 (dashed grey) are overlayed. Passive calf passive stiffness was calculated as upward gradient of the torque – displacement curve.

DISCUSSION: The results of this study revealed two participants who increased calf stiffness following single-leg hopping also had a decrease in passive calf stiffness immediately after massage. However, these results were not consistent across all participants. This suggests that massage may provide a mechanical effect for individuals who have short-term changes in calf stiffness following an exhaustive stretch-shorten cycle task. Despite this, further research is needed to determine whether any such effects may be clinically significant or beneficial.

Passive stiffness of the triceps surae MTU increased in three out of four participants immediately following an exhaustive bout of single-leg hopping. These results are consistent with a previous study (Ishikawa et al., 2006) and it was speculated that an exhaustive stretch-shorten cycle task may cause a weakening of the non-contractile elements in the muscle that might lead to a different passive stiffness slope (Ishikawa et al., 2006). In contrast, a non-significant change in passive calf stiffness after exercise for participant one may be reflective of the variability between individuals in response to fatigue. The protocol in the current study was appropriate to induce a short-term change in calf muscle stiffness. The variable effects of massage on passive calf stiffness make it difficult to draw conclusions on being able to determine whether massage can induce a meaningful change to calf stiffness. However, the effect in two participants provides impetus to further explore this issue within a larger sample population.

It is important to note that due to the study design, it is uncertain as to whether the observed changes in stiffness were solely due to massage. It remains possible that changes in stiffness across time periods may be the result of a time effect following the fatiguing protocol (Ishikawa et al., 2006). In order to draw such a conclusion, future studies may look to employ a suitable control group which undergoes a period of rest and does not receive massage following the fatiguing task.

CONCLUSION: This preliminary study does demonstrate that passive calf stiffness increases immediately following a bout of exhaustive exercise. There may also be some change in this altered stiffness following massage. Future studies need to examine these changes in a larger cohort as well as investigate whether any change in stiffness following massage is in fact of any clinical benefit.

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