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EFFECTS OF MANUAL MASSAGE ON MUSCLE-SPECIFIC SORENESS AND SINGLE LEG JUMP PERFORMANCE AFTER DOWNHILL TREADMILL WALKING

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Abstract

Introduction: This study examined the effect of massage on delayed onset muscle soreness of quadriceps muscles and single leg vertical jump performance after downhill treadmill walking.

Methods: Seven moderately active females (age: 19 ± 1 yr, height: 168 ± 3 cm, body mass: 63.9 ± 5.5 kg) completed a 20 min downhill walk (speed: 6.4 km·h^{-1}, gradient: –25%) as they carried a load equal to 10% of their body mass followed by one leg receiving massage for 25 min. Before, 24, 48 and 72 hr after downhill walking, delayed onset muscle soreness on a scale of 1-10 from rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL) muscles and changes in single leg vertical jump performance were measured for both legs.

Results: Delayed onset muscle soreness was reduced by massage 48 hr post-exercise in the RF and VL (P<0.05) but not in the VM. Jumping performance of each leg declined after downhill walking (P<0.001). At 24 hours, jumping height was decreased by 19% and 21% in control and massaged leg, respectively (P<0.05). However, at 48 and 72 hr post-exercise, the massaged leg showed improved recovery in jumping performance.

Conclusions: Reductions in delayed onset muscle soreness of quadriceps muscles by massage after downhill walking were muscle-specific. Massage improved functional recovery after downhill walking.

***Key words**: downhill walking, massage, delayed onset muscle soreness, muscle injury, jump height*

Introduction

Unaccustomed exercise involving eccentric actions results in immediate functional impairments and delayed onset muscle soreness (1). The delayed onset muscle soreness, also known as DOMS, commonly peaks in the following days post-exercise (e.g. 2). Various treatment strategies for DOMS, either as preventative measures or aids to recovery, have been tested with varying and often conflicting results (for a review see 3,4). These include acupuncture (5), non-steroidal anti-inflammatory drugs (e.g. ibuprofen) (6), cryotherapy (7), dexamethasone iontophoresis (8), electromagnetism (9), hyperbaric oxygen therapy (10), light concentric exercise (11), stretching (12), transcutaneous electrical nerve stimulation (13), transdermal ketoprofen (14), ultrasound (15), compression garments (16), and prior eccentric exercise (17).

Massage therapy has frequently been used as a palliative treatment; it is simple to apply, non-invasive, and free from unwanted side-effects. Numerous experimental studies have examined the efficacy of massage on recovery from exercise (18-26). Some of these studies reported less pain in the massaged limb muscles (18,19,23,24). However, as far as the authors' know, no experimental studies have examined the effects of manual massage on DOMS of individual muscles. For the most part, DOMS values reported were the results collapsed among several muscles (e.g. 19). Furthermore, studies on the effects of massage on a non-sporting whole body activity that results in muscle injury are generally absent, the only exception being the study by Farr et al. (19) on the effects of massage in downhill treadmill walking, using male subjects. In addition, Farr et al. (19) recognized the amount of exercise during the recovery period could have influenced the lack of an effect of massage on functional recovery (see also 11).

The purpose of the present study was therefore to examine the effect of manual massage on DOMS and single leg vertical jump performance (SVJ) that results from downhill treadmill walking in female subjects. We examined DOMS in individual muscles from the quadriceps femoris: the vastus medialis, vastus lateralis and rectus femoris muscles. Such information could illuminate the susceptibility of particular muscles to DOMS resulting from non-sporting whole body activities. It was hypothesized that massage would reduce DOMS and improve functional recovery.

Methods

Subjects

The study was approved by the University of Chichester Ethical Committee and was carried out in accordance to the Declaration of Helsinki. Seven females volunteered and provided written informed consent after explanation of the protocol and related health and safety issues. Sample size was based on detecting a 10% change in jump height in the leg without massage at 24 hours (19) with 80% power (i.e. type II error of 20%). We determined sample size using Graphpad Statmate version 2.00 for Windows (Graphpad Software, San Diego, CA, USA). Calculations for sample size were based on equations by Cohen (27). All female subjects were moderately active but not involved in any formal training program. None had any involvement in physical activity or exercise that involved unaccustomed eccentric muscle actions over the past six months and had no history of knee or ankle injuries. Participants visited the laboratory on five occasions (1 familiarization and 4 testing sessions). Physical characteristics of the subjects were (mean ± SD) age: 19 ± 1 yr, height: 168.1 ± 2.5 cm, and body mass: 63.9 ± 5.5 kg. All subjects abstained from any form of additional exercise and did not take any pain medication during the study.

Measurements

Measurements of DOMS and SVJ were recorded in both legs and taken before and 24, 48 and 72 hr after one downhill walking session. DOMS was assessed in the rectus femoris, vastus medialis and vastus lateralis muscles whilst sitting relaxed in a chair. A leg blood pressure cuff of an Accoson sphygmomanometer was wrapped around a golf ball [adapted from (28)] placed on the mid-belly of either rectus femoris, vastus medialis or vastus lateralis. The bellies of quadriceps femoris muscles were suggested to be most suitable area for DOMS measurements (29). A standard pressure of 100 mmHg was applied to allow consistent assessment of DOMS in the individual muscles. As a pressure of 100 mm Hg was reached, the subjects indicated the intensity of DOMS on a 1-10 visual ordinal scale (1 = no soreness, 10 = unbearable soreness) (30). Functional consequences of muscle injury for each leg were recorded by a SVJ. All subjects were familiarized with one-legged jumping tests in a separate session. Three SVJ's were performed on each leg with a 30 s recovery period between each effort. For each jump, subjects squatted to 90 degrees on a single leg, jumped as high as possible, and landed on two feet. High reliability has been reported for single-leg countermovement jumps (31). Height measurement was recorded from the contact point of a talced middle finger of stretched arm and fingers on a board with mm ruler gradation. An average height of the three jumps was recorded.

Downhill treadmill walking

A 2 min warm-up at 0% gradient and 4 km·h^{-1} preceded two 10 min periods of downhill walking on a Woodway treadmill (Woodway Ergo ELG 70 Series 410199, Cranlea & Co, Birmingham, UK) at a -25% decline and at a rate of 6.4 km·h^{-1} (32) interspersed by one minute rest, as they wore backpacks that held weights which represented 10% of subject's body mass (19). Six subjects completed 20 minutes walking and one subject stopped after 16 minutes. All subjects were included in the analysis.

Massage

Before the study, subjects identified their dominant leg (i.e. preferred kicking leg). The dominant leg of four subjects and the non-dominant leg of three subjects acted as the leg receiving manual massage. No therapeutic intervention occurred in the contralateral leg. As subjects laid prone on their back on a massage table, the treatment leg received a 25 min massage from a trained sports therapist. Timing of massage does not seem to trend with outcome measures (33) so massage was provided immediately following the downhill treadmill walk. The massage involved effleurage (5 minutes), petrissage and tapotement (10 minutes), finishing with effleurage (10 minutes).

Statistical analysis

Statistical analyses were carried out using SPSS for Windows version 16.0. Data are presented as means ± SD. Two-way ANOVAs with repeated measures (treatment x time) were used comparing massage and control legs at each time point for each of the three muscles for DOMS recorded and jumping performance values. Bonferroni post-hoc paired sample t-tests identified any significant differences found ($P < 0.05$).

Results

Delayed onset muscle soreness

Ratings for DOMS were significantly higher over time (Figures 1-3). The results of the ANOVAs for each muscle group were rectus femoris ($F_{(3,18)}$=5.797, P=0.006), vastus medialis ($F_{(3,18)}$=7.391, P=0.002) and vastus lateralis ($F_{(3,18)}$=7.866, P=0.001). The differences in DOMS values were significant at a) 24 and 48 hr in all muscles compared to baseline (Figures 1-3); b) at 48 hr between control and massaged limb in rectus femoris and vastus lateralis, c) at 72 hr in the vastus medialis of the massaged limb compared to 48 hr; and d) at 72 hr where the DOMS values of control vastus lateralis and rectus femoris were lower than at 48 hr. DOMS at 48 hr post-exercise between limbs was 19% lower both in the rectus femoris and vastus lateralis muscles of the massaged limb [($F_{(1,6)}$=7.317, P=0.035) and ($F_{(3,6)}$=10.676, P=0.017), respectively] but not in the vastus medialis muscle (Figures 1-3). At this time-point, 5 out of 7 subjects provided lower DOMS values both for vastus lateralis and rectus femoris muscles.

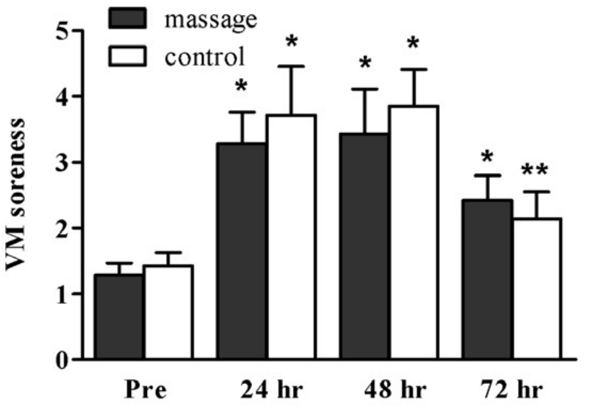

Fig 1. *Delayed onset muscle soreness of vastus medialis (VM) muscle prior to and 24hr, 48hr and 72hr following downhill walking. *, indicates significant difference from baseline (P<0.05); **, indicates significant difference with the 48 hr value (P<0.05)*

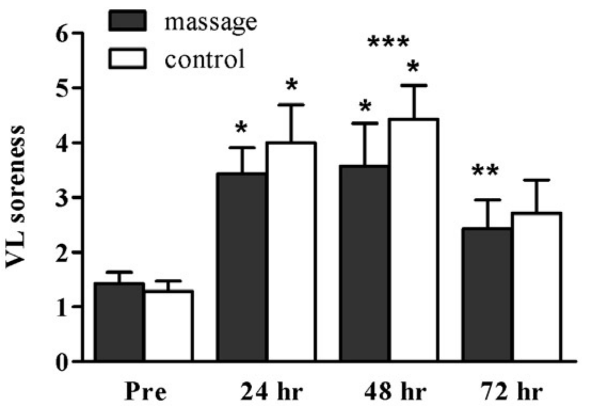

Fig 2. *Delayed onset muscle soreness of vastus lateralis (VL) muscle prior to and 24hr, 48hr and 72hr following downhill walking. *, indicates significant difference from baseline (P<0.05); **, indicates significant difference with the 48 hr value (P<0.05); ***, indicates significant difference between legs (P<0.05)*

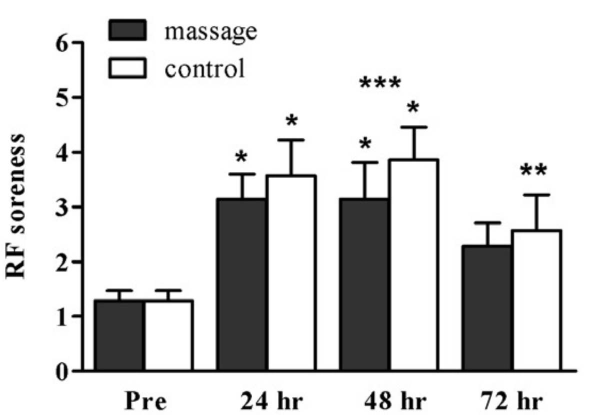

Fig 3. *Delayed onset muscle soreness of rectus femoris (RF) muscle prior to and 24hr, 48hr and 72hr following downhill walking. *, indicates significant difference from baseline (P<0.05); **, indicates significant difference with the 48 hr value (P<0.05); ***, indicates significant difference between legs (P<0.05)*

One-legged vertical jump height

There was a significant decline in vertical jump height against baseline measurements for both legs over time ($F_{(3,18)}$=12.917, *P*=0.0001) (Figure 4). The control limb vertical jump height at all three post-exercise times was significantly lower than the baseline measurement (control limb: 26.71±4.64cm; massaged limb: 28.71±6.32cm). Compared to baseline measures, at 24 hr there was a 19% decrease in vertical jump height (-5.71±4.11cm; mean±SD, *P*<0.05) in the massaged limb; at 48 hr the difference was -3.85±4.06cm (i.e. 13%) (*P*<0.05); by 72 hr it was -2.71±2.98cm (not significant). At the same times in the control limb, the differences were -5.57±2.91cm (i.e. 21%), -4.28±3.24 cm (i.e. 16%), and -3.29±3.20 cm (i.e. 12%), all of which were statistically significant (*P*<0.05) from baseline. At 48 hr the experimental limb's vertical jump height had recovered significantly compared to 24 hr post-exercise, and was significantly better than the control limb ($F_{(1,6)}$=8.992, *P*=0.024). Although the reliability of the vertical jump test in our study is not known, it is interesting to note that at 48 hr, all seven subjects had higher jump heights with the massaged leg. The difference between the experimental limb's baseline and 72 hr vertical jump height value was not statistically significant.

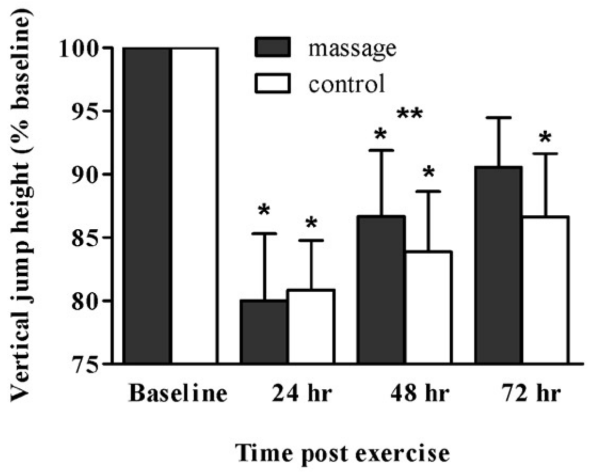

Fig 4. *Changes in one-legged vertical jump height as a percentage of baseline 24hr, 48hr and 72hr following downhill walking. *, indicates significant difference from baseline (P<0.05); **, indicates significant difference between legs (P<0.05)*

Discussion

This study showed the efficacy of massage on functional recovery from exercise-induced muscle injury by downhill walking. The downhill walk decreased jumping performance for both legs. During recovery, one leg jumping performance improved more in the massaged leg. However, because jump performance was not measured immediately after exercise, we do not know whether the effects of fatigue and/or injury resulted in similar jumping performance decrements in both legs. To the author's knowledge, only Farr et al. (19) used downhill treadmill walking as an exercise model to induce DOMS. Decreases in vertical jump height seem to be slightly smaller in Farr et al. (19), compared to our study and no effects of massage on functional recovery were shown in that study. However, comparisons to Farr et al. (19) are complicated by methodological differences. Walking speed and treadmill grade, which were higher and steeper in our study compared to Farr et al. (19), could have resulted in higher eccentric forces inducing more muscle damage (34). However, our study was in females with potential gender-related effects on recovery from exercise-induced muscle injury (35) complicating the comparison with Farr et al. (19). Although our study found a beneficial functional effect of massage, other studies did not always find that effects of massage impacted functional measurements (20,24,33). For example, Tiidus and Shoemaker (24) carried out daily massage on four occasions and found no difference in muscle torque between treated and untreated limbs. Others found no effect of massage on DOMS and functional measurements (21). However, differences in gender, exercise model, duration, frequency and kinds of therapeutic treatment administered make straightforward comparisons difficult. As far as the authors' know, tissue analysis after downhill walking to determine muscle damage has not been done yet. However, DOMS values of our study were comparable with Ahmadi et al (36) in which participants completed a 40 min downhill walk (speed: 6.4 $km \cdot h^{-1}$, gradient: –25%) with 5% body mass. In that study, decreases in isometric force of maximal voluntary contractions were reported indicative of muscle damage.

Reduced perceived DOMS confirms the findings with pain measures from other studies in which manual massage was used as therapeutic treatment following exercise (e.g.18,22-24). The 25 min massage in the present study focused only on the quadriceps as the major extensor muscle group, whereas in the Farr et al. (19) the 30 min massage involved the anterior and posterior muscles of the entire limb. The effectiveness of the latter massage protocol on the quadriceps is open to question. The final difference, and possibly the most important one, lies in the volume of exercise performed in each study – i.e. 4 sessions of 28 separate actions over 120 hr compared to 3 one-legged SVJs on three occasions over 72 hr – enhanced the recovery process. The importance of post-DOMS exercise activity on recovery from DOMS and function (11) was recognized by others (19,37,38).

Our study showed an effect of massage on DOMS in quadriceps muscles by an apparent reduced effect on the vastus medialis compared to rectus femoris and vastus lateralis. It may be possible that in vastus medialis the discharge of A-fiber and C-fiber sensory afferents, involved in pain from tissue injury (39), were reduced less versus the rectus femoris and vastus lateralis due to massage. However, we cannot exclude the occurrence of increased injury in vastus medialis compared to rectus femoris and vastus lateralis resulting from the downhill treadmill caused a larger inflammatory response in vastus medialis. Interestingly, a recent study by Hedayatpour et al. (40) indicated region-specific susceptibility for injury by eccentric contractions of the quadriceps muscles. In general, present study observations indicate under the conditions described, therapeutic massage reduced the perceived DOMS, and improve the impaired muscle function associated with DOMS in our downhill walking model.

Ernst (41) warned against the use of one leg as the massaged limb and the other as a control. Such an approach is based on the assumption that the effects of massage are not local. However, to the author's knowledge, there are no known systemic effects of manual massage that would jeopardize our experimental design of one leg for massage and the contralateral for control, with some evidence even pointing towards non-systemic effect (37). Shoemaker et al (37) reported that manual massage does not increase arterial blood flow. However, Ernst (41) suggests that enhanced local micro-circulatory blood and lymph flow results from the direct mechanical pressure on the experimental limb, and leads to a reduction in oedema, ischaemia and pain. In the light of the Shoemaker et al's (37) findings, it is difficult to see how these effects can transfer to a distant control limb that receives no comparable localised mechanical pressure. It is also difficult to know what effects, beneficial or deleterious, any systemic response might have on the outcome measures of the control limb. Additionally, an unfortunate consequence of this form of experimental design makes the quest for the larger sample sizes called for by Ernst (41) even more problematic. Indeed, Hilbert et al. (20) reveal that, given the variability in their muscle function data of nine subjects, they needed a sample size of $n > 55$ to achieve a power = 0.8. The small group size is evident in our study ($n = 7$) and Farr et al. (19) ($n=8$), with the potential for statistical problems. In addition, the outcome measures of mood states (POMS), and the intensity and unpleasantness of DOMS via the Differential Descriptor Scale (DDS) adopted by Hilbert et al. (20) may provide more complete information on the effects of DOMS than the simple scale used in our study. However, our study still revealed significant differences in DOMS at 48 hr between the experimental and control limbs' rectus femoris and vastus lateralis muscles. This agrees with Hilbert et al. (20) who reported significant difference in the intensity of hamstring soreness at 48 hr. More importantly, POMS responses may reveal psychological responses to post-exercise pain, an issue addressed with elite amateur boxers (42) and others (43,44). Hilbert et al. (20) recorded greater mood disturbances in both groups 24 hr post exercise. The authors went on to argue that massage did not significantly affect mood, but that any effects that were present may be more psychological than physiological. The reduced soreness intensity at 48 hr was regarded as sufficient evidence for this claim. Thus, the effectiveness of therapeutic massage on DOMS may have to take into account psychological influences as massage lowered the intensity of the soreness (20). Potential psychological effects of our protocol were ignored. The above claim raises the twin issues of the Hawthorne phenomenon and the placebo effect. The consequences are twofold. In the Hawthorne phenomenon, positive results may ensue irrespective of any treatment modality. The placebo effect leads to a sub-conscious expectation that a treatment can be deleterious or beneficial; in the case of massage, the expectation is the latter. Interestingly, placebo effects of expected pain relief, although with medication, have been reported (45). It is difficult, may be impossible, to design experiments involving the mechanics of manual massage that can effectively counter the Hawthorne phenomenon or placebo effect, singly or in combination. These phenomena may particularly affect the psychological outcome measures.

In conclusion, massage improved functional recovery and reduced DOMS in female subjects following exercise-induced muscle injury by downhill walking. The reduced DOMS at 48 hr was muscle-specific and present in the vastus lateralis and rectus femoris muscles but not in the vastus medialis. However, as we assumed similarity of DOMS values in muscles of both legs when no treatment was provided, we suggest future studies to incorporate a control group to allow comparison of DOMS values of both legs following downhill treadmill walking.

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