The efficacy of ice massage in the treatment of exercise-induced muscle damage

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The purpose of this investigation was to, firstly, examine the effects of repeated applications of ice massage on the indirect markers associated with muscle damage using a within-subjects cross-over design and secondly, to examine how ice massage affects muscle function in both static and dynamic contractions following unaccustomed eccentric exercise. Twelve males performed damaging exercise on two separate occasions. The protocol consisted of three sets of 10 maximal eccentric repetitions of the elbow flexors using isokinetic dynamometry. Subjects were randomly assigned to an ice massage group or placebo group and received treatments immediately post-exercise, 24 and 48 h post-exercise. Muscle function (maximal isometric, slow and fast isokinetic contractions), creatine kinase, myoglobin, muscle soreness, limb girth and range of motion were measured pre, immediately post, 24, 48, 72 and 96 h post-exercise. Significant time effects were observed for all dependent variables (P < 0.05). There were no significant differences between treatments. Ice massage is ineffective in reducing the indirect markers associated with exercise-induced muscle damage and enhancing recovery of muscle function in male exercisers unaccustomed to eccentric biased exercise.

Eccentrically biased exercise has a number of proposed physiological benefits which include increased strength and hypertrophy (Hortobágyi et al., 1996); however this contraction type, when unaccustomed, can result in exercise-induced muscle damage. Little is known with regards to the underlying mechanisms of this pathology, however, exercise-induced muscle damage is known to be manifested as increased serum concentrations of creatine kinase (CK), delayed-onset muscle soreness (DOMS), reduced range of limb movement (ROM) and decreased maximal strength and performance (Newham et al., 1983; Armstrong, 1984; Ebbeling & Clarkson, 1990; Armstrong et al., 1991; Cheung et al., 2003). In light of this phenomenon, a number of interventions have been previously examined in an attempt to alleviate the associated side-effects of this type of exercise (Isabell et al., 1992; Gulick et al., 1996; Eston & Peters, 1999).

Cryotherapy is one such intervention and incorporates the use of a cold medium to diminish the effects of damaging exercise (Knight, 1995). Cryotherapy is proposed to lower tissue temperature, reduce inflammation and consequent edema, reduce pain sensation and decrease time to recovery; for further details of the effects the reader is directed to previous literature reviews (Kowal, 1983; Meeusen & Lievens, 1986; Swenson et al., 1996). Methods of cryotherapy include ice packs, ice massage, cold-water immersion and pain relief sprays, which are effective in reducing subcutaneous temperature. The degree to which each method cools and the application time required to achieve a reduction in temperature varies greatly (Meeusen & Lievens, 1986).

Ice massage is easy to apply, provides cooling of superficial and deep tissues from a relatively short application period when compared with some other methods (Meeusen & Lievens, 1986). Gulick et al. (1996) found that a single treatment with ice massage had an immediate but short-term beneficial effect on muscle soreness following eccentric exercise. In contrast, Yackzan et al. (1984) reported a single treatment of ice massage administered either immediately after, 24 or 48 h post-exercise to be ineffective in reducing muscle soreness. Although repeated administration of cryotherapy is advocated following muscle tissue trauma (Knight, 1995) the majority of studies using ice massage have not followed this advised practice. Both Eston and Peters (1999) and Howatson and van Someren (2003) reported that repeated cold-water immersion and ice massage, respectively, following eccentric exercise were effec-
tive in reducing plasma CK concentrations, although no effect on perceived soreness or strength were found. However, other authors (Isabell et al., 1992) suggested that ice massage administered repeatedly over a 96 h period post-exercise may be contraindicated in the treatment of exercise-induced muscle damage.

It is clear therefore, that current literature addressing the treatment of exercise-induced muscle damage with ice massage is limited and equivocal. Further, existing studies have adopted between-subject designs in which inter-individual variability may have masked discrete, but nonetheless meaningful changes in dependent variables. In addition, to our knowledge, no previous studies have assessed the effect of ice massage on both isokinetic and isometric muscle function following exercise-induced muscle damage. Whilst conventional fatigue from mechanical, electrical and biochemical changes in the muscle are returned to homeostasis relatively quickly (McComas, 1996), torque production and performance can remain reduced for a number of days post-eccentric exercise because of morphological changes from the exercise protocol. Direct evidence for this has been presented in the form of microscopy images provided by Fridén et al. (1983); more recent work has shown convincing evidence to suggest that changes are a reflection of adaptive modelling to the cytoskeleton and myofibrillar structures (Yu et al., 2004; Yu et al., 2003). Warren et al. (1999) suggest maximal voluntary contractions to be the best indirect indicator of muscle damage as this reflects the muscle's capacity for torque production. In addition, exercise is predominantly conducted under dynamic conditions although the assessment of muscle function after a damaging protocol has been predominantly assessed under isometric conditions (Eston & Peters, 1999; Nosaka et al., 2002, for example). Assessment of different contraction types may provide a more comprehensive representation of muscle function and consequent capacity for dynamic exercise following exercise-induced muscle damage.

Therefore, the aims of this study were twofold: Firstly, to investigate the effects of repeated applications of ice massage on the indirect markers associated with muscle damage using a within-subjects, cross-over design. Secondly, to examine how ice massage may affect muscle function in both static and dynamic contractions following unaccustomed eccentric exercise.

Material and methods
Subjects

Twelve physically active males, who were unaccustomed to eccentric biased exercise, participated in this study; age, stature and body mass of the subjects were (mean ± SD) 24.8 ± 5.3 years, 1.80 ± 0.07 m and 86.4 ± 11.3 kg, respectively. Subjects were informed of the procedures, completed a pre-test health-screening questionnaire and provided written informed consent. Experimental procedures were approved by the Institution's Research Ethics Committee in accordance with the Helsinki Declaration (Faculty of Science, Kingston University, London, UK). In addition, participants were asked to refrain from activities that may cause damage, soreness and hence influence dependent variables for the duration of the investigation.

Experimental overview

Subjects performed a damaging bout of exercise using the elbow flexors on two occasions separated by 2 weeks; on the second occasion the contralateral arm was used. Subjects were assigned to treatments of repeated ice massage or a placebo (consisting of a "sham" ultrasound) in a cross-over design. Subjects were unaware that the ultrasound machine was not operating and this acted as a "sham" treatment; however, after completing the protocol all participants were informed that the ultrasound was inactive during the treatment. Dependent variables were measured pre-exercise, immediately post-exercise and at 24, 48, 72 and 96 h post-exercise.

Dependent variables

Dependent variables were DOMS, limb girth, ROM, maximal isometric torque (MVC), maximal slow and fast concentric isokinetic torque, CK and myoglobin (Mb). Mb is a smaller molecule (17 kDa) than CK, which is ~80 kDa dependent on isoform (Sayers & Clarkson, 2003), and as such may efflux from the cell into the circulation at a faster rate than the larger CK molecule (Mair, 1999) because of discrete lesions in the cell membrane. In light of this, Mb may be a more sensitive or earlier marker of muscle damage when compared with CK.

Blood serum samples

A blood sample of ~5 mL was taken from a branch of the basilic vein; it was allowed to clot and was spun to separate serum from the remaining blood constituents. Serum was drawn off and consequently frozen immediately at −70 °C for later analysis. Serum CK concentrations were determined using a VITROS® DT60 II dry slide clinical chemistry system (Ortho-Clinical Diagnostics, Amersham, UK). Mb was analyzed using a Myoglobin STAT immunoassay (Elecsys, 1010 System, Boehringer Mannheim, Indianapolis, IN, USA), both methods reported a CV of <5% for intra-assay precision in human serum.

Perceived muscle soreness rating (DOMS)

Residual muscle soreness was determined using a modified Talag Scale, a subjective visual analogue scale rating from one (no soreness) to seven (unbearably painful) and has been previously used in studies examining exercise-induced muscle damage (Talag, 1973; Isabell et al., 1992; Howatson & van Someren, 2003). The subject stood in anatomical zero with the shoulder of the exercised arm flexed at 90° and the elbow fully extended. Subjects were then asked to select a number from the scale that was consistent to the soreness felt in the biceps area.

Ice massage and muscle damage
Limb girth

Limb girth of the upper arm was taken midway between acromial process and lateral epicondyle of the humerus using an anthropometric tape while the arm was hung naturally at the side of the body. Reference points on the arm were marked with permanent ink to ensure consistency on subsequent days. Previously unpublished data from this laboratory has reported a technical error of measurement (TEM) of 0.27% for this procedure.

ROM

Determination of total elbow joint ROM was assessed by measuring both flexion and extension (a method previously described by Howatson & van Someren, 2003) using a goniometer (Baseline™, Physiomed, Cheshire, UK). Reference points on the arm were marked to ensure consistency. Unpublished data collected from this laboratory demonstrated a TEM of 0.98% for this procedure.

Functional tests

An isokinetic dynamometer (Biodex System 2, Shirley, NY, USA) was set up as recommended by the manufacturer to exercise elbow flexion. MVC was determined by setting the joint angle at 45° from full extension (as determined from pre-exercise ROM), locked in position, and marked to ensure consistency on subsequent testing. Each repetition lasted 3 s with 10 s rest between each contraction; MVC was established by the peak torque generated in any one of three repetitions. Isokinetic testing at a slow speed (three contractions at 60°/s) and a faster speed (three contractions at 210°/s) were conducted in back-to-back fashion, without rest between repetitions. The peak isokinetic torque for each test was determined as the peak torque generated in any one of the three repetitions.

Induction of muscle damage

An exercise protocol designed to induce muscle damage was performed on two occasions, separated by 2 weeks, on the dominant or non-dominant forearm flexors, in a random cross-over order. The dynamometer was assembled for use as previously described and was set to an angular velocity of 30°/s in the passive mode; three sets of 10 maximal eccentric contractions, each set separated by 3 min, was performed by the involved arm. This number of repetitions falls within the recommendations of the American College of Sports Medicine (ACSM) to increase muscle hypertrophy (ACSM, 2002); protocols of a comparable volume and intensity have been shown to elicit damage in a similar subject population (Chen, 2003; Howatson & van Someren, 2003). At full elbow flexion, subjects were instructed to resist maximally through the entire range of motion until full extension had been reached and then relax through the passive flexion phase. Visual feedback from the dynamometer and verbal encouragement from the investigator were given to encourage maximal effort throughout the protocol.

Treatments

Subjects were randomly assigned to an ice massage or placebo treatment on the first occasion, which was undertaken immediately after exercise and then at 24 and 48 h post-exercise. On the second occasion, subjects received the other treatment having performed the same exercise protocol on the contralateral arm.

Ice massage group

Briefly, a polystyrene cup was filled with water and frozen to form an ice ball. A qualified sports masseur applied the ice ball directly to the skin by using circular and stroking motions for a period of 15 min to the elbow flexors, which fell within guidelines recommended by Drez et al. (1981). The water was not wiped away as the ice melted, duplicating previous application time and methodology (Isabell et al. 1992; Howatson & van Someren, 2003).

Placebo group

An ultrasound machine was used for a 5 min “sham” treatment with the power output set to zero. This was designed to blind the subjects to the fact that the placebo involved no treatment modality. The treated area was identical to that in the ice massage treatment.

Statistical analyses

The blood data were transformed to natural log; limb girth and ROM have been normalized by expressing as a percentage change from baseline. Data for all dependent variables were analyzed using a two-factor (treatment, 2 x time, 6) repeated measures analysis of variance, only significant interactions were followed up using a Tukey’s post-hoc test to determine if pair-wise comparisons were evident between treatments. A significance level of $P < 0.05$ was established prior to analyses. All data are presented as mean ± SD.

Results

CK values were returned to natural log (Fig. 1) and showed a significant time effect ($F = 16.175, P < 0.05$), but no treatment or interaction effects.

Both treatments showed a marked increase in CK from pre-exercise levels. The ice massage treatment peaked ($5.77 ± 0.671$ IU/L) at 48 h, whereas the placebo treatment continued to rise until 96 h where a value of $6.06 ± 0.77$ IU/L was observed. A significant time effect ($F = 9.060, P < 0.05$) was also observed.
for log Mb (Fig. 2), no other statistically significant effects occurred.

Table 1 presents data for all torque data. A significant time effect ($F=11.860, P<0.01$) and time by trial interaction effect ($F=3.393, P<0.05$) were observed for MVC. Post-hoc analysis of the interaction effect revealed no pair-wise differences and hence only the time course was different between treatments, which was not the focus of this investigation. Both treatments showed similar trends with decrements at 24 h of 25.22% and 25.23% for placebo and ice massage, respectively. However, after this point isometric torque in the placebo treatment recovered to a greater extent than in the ice massage treatment. At 96 h post-exercise isometric torque was 4.97% below baseline in the placebo treatment and 15.69% below baseline in the ice massage treatment.

Maximal isokinetic torque at 60°/s significantly changed over time ($F=13.097, P<0.01$); a time by trial interaction was also observed ($F=2.383, P=0.05$). Post-hoc analyses of the interaction effect however showed no pair-wise differences between treatments. Both ice massage and placebo treatments reduced from similar values of 54.9 ± 9.3 and 54.1 ± 9.1 Nm, respectively, pre-exercise to 41.2 ± 8.2 and 40.2 ± 9.4 Nm, respectively post-exercise. At 24 h, the torque decrement equated to 16.74% and 23.11% in the placebo and ice massage treatments, respectively. Neither treatment had returned to pre-exercise levels at 96 h post-exercise; the ice massage treatment was some 11.51% from pre-exercise levels vs 2.62% in the placebo treatment.

Torque at 210°/s was found to have a significant time effect ($F=7.439, P<0.01$). Both conditions reduced from pre-exercise levels of 43.3 ± 9.4 Nm for the ice massage treatment and 41.7 ± 12.4 Nm in the placebo treatment to 34.3 ± 8.6 and 36.0 ± 12.4 Nm post-exercise, respectively. No treatment or interaction effects were observed. At 24 h post-exercise, torque had decreased by 8.11% and 14.39% in the placebo and ice massage treatments, respectively. The ice massage treatment recuperated to a lesser extent than the placebo treatment (3.09% below baseline in ice massage treatment vs a 4.38% increase above baseline in the placebo). In addition, the percentage decrement at 24 h in torque at 210°/s was found to be significantly less than the decrement in isometric torque ($P<0.01$).

A significant time effect ($F=26.083, P<0.01$) was found for limb girth (Table 1); However, there were no significant treatment or interaction effects. Limb girth increased immediately post-exercise and decreased to near pre-exercise level at 96 h post-exercise in both treatments.

The percentage change in the total ROM, shown in Table 1, demonstrated a significant time effect ($F=21.722, P<0.01$). ROM decreased immediately post-exercise and made a steady recovery toward baseline; however, at 96 h in placebo and ice massage treatments a 7.13% and 8.38% decrease, respectively, was still evident.

Fig. 2. Ln Mb for both conditions over the 96 h treatment period where a significant time effect ($F=3.726, P<0.05$) was observed; values are mean ± SD. Mb, myoglobin.

Table 1. Results for dependent variables after the damaging intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time(h)</th>
<th>Pre</th>
<th>Post</th>
<th>24 h</th>
<th>48 h</th>
<th>72 h</th>
<th>96 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROM (Δ%)</td>
<td>Placebo</td>
<td>0</td>
<td>9.5</td>
<td>5.2</td>
<td>11.9</td>
<td>5.2</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>Ice massage</td>
<td>0</td>
<td>9.1</td>
<td>4.4</td>
<td>11.1</td>
<td>6.0</td>
<td>12.4</td>
</tr>
<tr>
<td>Girth (Δ%)</td>
<td>Placebo</td>
<td>0</td>
<td>2.1</td>
<td>0.6</td>
<td>1.5</td>
<td>0.5</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Ice massage</td>
<td>0</td>
<td>2.1</td>
<td>0.7</td>
<td>1.5</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>MVC (N.m)</td>
<td>Placebo</td>
<td>62.6</td>
<td>8.1</td>
<td>46.8</td>
<td>8.0</td>
<td>48.3</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>Ice massage</td>
<td>64.4</td>
<td>8.5</td>
<td>48.2</td>
<td>10.8</td>
<td>49.3</td>
<td>10.4</td>
</tr>
<tr>
<td>Slow (N.m)</td>
<td>Placebo</td>
<td>54.9</td>
<td>9.3</td>
<td>41.2</td>
<td>8.1</td>
<td>45.0</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Ice massage</td>
<td>54.1</td>
<td>9.1</td>
<td>40.2</td>
<td>9.4</td>
<td>41.2</td>
<td>10.5</td>
</tr>
<tr>
<td>Fast (N.m)</td>
<td>Placebo</td>
<td>41.7</td>
<td>12.4</td>
<td>36.0</td>
<td>10.4</td>
<td>37.2</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>Ice massage</td>
<td>43.3</td>
<td>9.4</td>
<td>34.3</td>
<td>8.5</td>
<td>36.3</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Limb girth and ROM are expressed as a percentage change from pre-exercise levels. Muscle function data are tabulated as peak torque; all dependent variables showed a significant time effect ($P<0.05$); all values are mean ± SD. ROM, range of movement; MVC, maximal isometric torque.
Howatson et al.

A significant time effect ($F = 25.628, P < 0.001$) was observed for soreness (Fig. 3). All subjects commenced the protocol during both conditions with no soreness. After the exercise bout, soreness increased and peaked at 48 h; however, no significant treatment or interaction effects occurred. These reported values in the placebo and ice massage treatments fell to $2.25 \pm 1.14$ and $2.33 \pm 1.13$, respectively, at 96 h.

**Discussion**

This investigation showed significant time effects in all variables indicating that exercise-induced muscle damage was evident. These data concur with previous research and lend further evidence that unaccustomed eccentric exercise results in elevation of indirect markers of muscle damage and soreness (Armstrong, 1984; Clarkson & Tremblay, 1988; Cleak & Eston, 1992; Sorichter et al., 1999). No significant treatment effect occurred in any dependent variable as a result of repeated ice massage, which is in agreement with Yackzan et al. (1984), who found no positive effect as a result of a single application. Likewise, other investigators (Isabell et al., 1992) have reported similar findings with repeated applications of cryotherapy; however, in contrast, Eston and Peters (1999) did find some benefit from repeated applications of a different method of cryotherapy (cold-water immersion) in treating exercise-induced muscle damage.

Non-significant differences in blood markers between treatments in this study indicate the ice massage intervention had no effect on stemming the efflux of intramuscular proteins into systemic blood flow. These data concur with previous findings (Isabell et al., 1992) where cryotherapy had no effect on CK levels following exercise-induced muscle damage when compared with a control and other treatments. However, in contrast, other investigators (Eston & Peters, 1999) found CK to be reduced with repeated applications of cold-water immersion and proposed that cryotherapy reduced the mediated inflammatory response and rate of post-exercise damage. Although ice massage has been shown to be more beneficial in reducing tissue temperature at various depths when compared with cold-water immersion (Meeusen & Lievens, 1986), perhaps the main difference for these observations was the increased application frequency used by Eston and Peters (1999) (once every 12 h for a total of seven treatments). Although the efficacy of ice massage in reducing tissue temperature may be greater, the frequency of application may need to be increased to observe any benefit in indirect measures. The current study also analyzed serum Mb concentration, which to the best of our knowledge has not been previously reported in studies investigating the effects of cryotherapy on exercise-induced muscle damage, although it has been previously used as a marker of muscle damage in some research (Nosaka & Clarkson, 1995). Mb is a smaller molecule than CK and may be more sensitive to discrete lesions in the cellular membrane. Mb efflux significantly increased over time, but did not demonstrate a treatment effect. Thus, it would appear that ice massage had no effect on any discrete lesions in the sacrolemma. Both blood markers used in this investigation are cytosolic and therefore are subject to efflux through similar pathways; the time course of these variables are also similar suggesting that Mb is no more sensitive a marker than CK.

A unique aspect of this study was the investigation of how ice massage affected isometric and isokinetic functions following unaccustomed eccentric exercise; no differences between treatments were found for any contraction type. A decrease in all functional measures were observed immediately post-exercise, thereafter returning toward pre-exercise levels at 96 h post-exercise in both treatments. These findings support previous research showing that unaccustomed eccentric exercise affects maximal strength (Sargeant & Dolan, 1987; Clarkson & Tremblay, 1988; Cleak & Eston, 1992), and that function is not hastened to normality with repeated applications of cryotherapy (Isabell et al., 1992; Eston & Peters, 1999).

The decrease in muscle function following exercise may be due, in part, to the protective mechanism of pain. However, pain did not follow the same time course as muscle function in this study and is therefore unlikely to have significantly affected torque production. A more plausible explanation is Z-band streaming and disruption to stress-susceptible contractile units causing functional impairment, which has been previously observed with eccentric exercise (Fridén et al., 1983); the mechanisms for this have been discussed by Fridén and Lieber (1992).
Ice massage was found to have no effect on muscle soreness in this study, concurring with earlier work (Yackzan et al., 1984) that reported a single treatment of ice massage had no sustained effect on perceived pain. Our results contrast with those of Eston and Peters (1999) who reported reduced muscle soreness following repeated cold-water immersion; these differences may be because of previously highlighted methodological disparity. However, five treatments of iced water immersion separated by 1 h used by other investigators (Paddon-Jones & Quigley, 1997) did not produce significant reductions in soreness. Our data fail to support the analgesic effect of ice application, which has been reported to result in reduced neural conductivity and excitability (Kowal, 1983; Gulick et al., 1996). The inimitable properties associated with eccentric exercise and consequent damage seem to have a different underlying pathology to conventional injuries such as muscle strain; as a result, ice massage would not appear to have the same therapeutic effects reported for acute traumatic injury (Cheung et al., 2003).

Limb girth displayed similar changes over the 96 h period in both treatments, indicating that ice massage had no significant effect on swelling. The increase in the limb girth on this occasion may be partly attributed to increased blood flow immediately post-exercise. However, pre-exercise levels were not reached by 96 h post-exercise indicating that some swelling/edema was still evident.

Meesuon and Lievens (1986) highlighted in review that cryotherapy has been shown to increase the ROM following muscle damage, through cold-induced neural relaxation. Eston and Peters (1999) found that relaxed arm angle was increased after eccentric exercise with the application of cryotherapy and concluded the change was because of reduced spasticity resulting from decreased firing rate of muscle spindle afferents. In this study however, ice massage had no significant effect on flexion, extension or ROM over the 96 h period following exercise. It is possible that by increasing the frequency of ice application some change may have occurred.

When compared with a placebo, repeated applications of ice massage did not reduce the signs and symptoms associated with muscle damage induced by eccentric exercise. Further, to our knowledge, this is the first examination of both isokinetic and isometric function consequent to eccentric exercise and repeated applications of ice massage. These data suggest that ice massage has no benefit to exercise-induced muscle damage if the purpose of application is to accelerate the recovery of muscle function from exercise-induced muscle damage. Further research is required to elucidate how the application of ice massage (and other cryotherapeutic mediums) when applied more frequently over a longer time period may benefit or hinder recovery. Practitioners may need to express caution when evaluating muscle soreness; if it has derived from unaccustomed or eccentric exercise, ice massage may be an inappropriate intervention if the aim is to accelerate the return of muscle function to normality.

**Perspectives**

Eccentric exercise forms an integral part of exercise training for injury prevention and muscle hypertrophy. This contraction type does have problems associated with it (especially when the activity is novel) and can reduce the capacity for subsequent exercise. Ice massage, in the cases of strains and tears, has been advocated in reducing symptoms of damage and returning the function of skeletal muscle to normality; however, it does not return function or reduce any other sign or symptom of exercise-induced muscle damage after high-intensity eccentric exercise. In light of this, when eccentric exercise is prescribed, the protocol intensity should be reduced in the initial bout to alleviate/reduce the damaging effects and concerns over the capacity for exercise in the following days. Perhaps a more frequent application of ice, administered over a longer time period may prove beneficial and could be an avenue for future research.

**Key words:** cryotherapy, eccentric exercise, muscle function.

**References**


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