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The use of thermal imaging to assess the effectiveness of ice massage and cold-water immersion as methods for supporting post-exercise recovery

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ABSTRACT

Cold water immersion (CWI) and ice massage (IM) are commonly used treatments to prevent the delay onset of muscle soreness (DOMS); however, little is known on their relative benefits and effectiveness to lower tissue temperature. This study was designed to evaluate the effectiveness of IM and CMI on tissue temperature and potential benefit to preventing DOMS. The research encompassed 36 subjects divided into three groups of twelve depending on the form of recovery: ice massage (IM), cold-water immersion (CWI), or passive recovery (PAS). All the participants were asked to jump as high as possible from a full squat for one minute. Thermal imaging was conducted at rest, immediately following the exercise, immediately after the trial, following the recovery treatment, and after 30 min of rest. Their pain levels were assessed using the Visual Analogue Scale (VAS). After applying the selected method for supporting recovery, the LA level decreased by 4.25 mmol/L in the IM group, and by 4.96 mmol/L in the CWI group (IM vs. CWI $p > 0.05$). The 2.75 mmol/L decrease in lactate concentration in the PAS group was significantly lower than in the other groups (IM vs. PAS $p < 0.05$/ CWI vs. PAS $p < 0.01$). In both groups, T_{sk} after 30 min was significantly lower ($\Delta T_{sk} \sim 0.5$ °C) than at rest ($p < 0.05$). In turn, T_{sk} in the PAS group returned to the resting values ($p > 0.05$). Seventy-two hours after the exercise, a clear decrease in discomfort was observed in the IM and CWI groups compared to the PAS group. The two applied treatments have proven to be effective both in utilizing lactate and preventing DOMS. Depending on training requirements, we recommend the use of IM when athletes experience localized muscle fatigue. One the other hand, CWI is recommended in situations of global or generalized muscle injury or fatigue.

1. Introduction

The undertaking of physical activity, especially of a higher intensity and prolonged duration (performed mainly in the area of anaerobic and lactic acid changes), is associated with a significant increase in lactate concentration. It is one of the causes of the deteriorating exercise capacity and sense of fatigue that occur after a workout (Kristensen et al., 2005). Many authors have reported that the most effective drop in blood lactate levels can be expected in the first ten minutes of recovery (Greenwood et al., 2008; Ali Rasooli et al., 2012).

Another factor connected with intense exercise is delayed onset muscle soreness (DOMS), which is experienced after physical effort. DOMS is primarily induced during eccentric efforts. Additionally, important factors leading to the above-mentioned problems are the introduction of a new set of exercises to a workout, or the undertaking of an activity after a several-week-long break or just after first contact with the exercise (Cheung et al., 2003). Presently, it is assumed that DOMS is related to the microdamage of muscle fibers or connective tissue and the subsequent inflammation, which in turn is necessary for tissue regeneration (Conolly et al., 2003; Bleakley et al., 2012).

It is widely believed that the cause of DOMS is lactic acid, which is produced and accumulated in muscles when exercising. Lactate levels do increase during physical activity, but they also rapidly decrease, returning to their resting values as quickly as an hour or two following exercise. In contrast, DOMS does not occur directly after activity, but only after a delay of six to twelve hours, and its peak is between the 24th and 48th hour after exercise. In

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addition to pain, other characteristic symptoms of delayed onset muscle soreness include stiffness, limited range of motion in the muscle group, loss of power, fatigue, tenderness, and sometimes also swelling (Thibault and Péronnet, 2006). Regardless of the strength of the correlation between lactate concentration and DOMS, both phenomena constitute a key challenge for a post-exercise recovery strategy.

Although there are many post-exercise recovery treatments, only a few of them have been scientifically confirmed. The following are given as examples of methods that influence the pace and quality of regeneration (Sellwood et al., 2007; Vaile et al., 2008a, 2008b; Eliakim et al., 2012; Lee et al., 2015; Mankovsky-Arnold et al., 2013; Singla et al., 2015; Johar et al., 2012): stretching, massage, cold treatment, transcutaneous muscle stimulation (TENS), kinesiotaping, music therapy, low-intensity exercise, and pharmacological agents, among others.

Cold treatment is often used to manage muscle soreness after exercise and speed up recovery time. Cold treatment involves treatment with cold water at a temperature below 15 °C, and other forms of cold which involves temperatures at or below 0 °C (Lateef, 2010). The initial response to treatment is vasoconstriction. After about two to six minutes, the situation is reversed, followed by vasodilation, which leads to a several-fold increase in blood flow through the tissues. This condition can last up to six hours. The resulting hyperemia provides conditions for improving metabolism, increasing oxygen supply, eliminating waste products such as lactate or histamine, and increasing concentrations of bradykinin and angiotensin (Vaile et al., 2007, 2008b; Sellwood et al., 2007). The blood content also changes, with an increase in levels of hemoglobin, leukocytes, and platelets. The particular analgesic significance of cold treatment results from a decline in nerve excitability, which translates into a reduction in pulse flow velocity in some unmyelinated fibers. Furthermore, there is an increase in β-endorphin secretion by the pituitary gland and a decrease in nociceptive pulsation of mechanoreceptors, mainly in C fibers. The effect of the reactions described above is the reduced perception of pain and a higher pain threshold (Sellwood et al., 2007). In conclusion, cold treatment in sports is applied to speed up the regeneration of tissues and prepare the player for a faster return to training or participation in another activity (Barnett, 2006).

One of the most popular interventions for preventing DOMS and promoting recovery after exercise is cold-water immersion (CWI). The treatment allows for the impact of a low temperature over the entire surface of the body (Roberts et al., 2014). Ice massage (IM) treatment is applied in therapy for overuse syndrome, overcoming excessive muscle tension, and relieving the pain associated with injuries and microinjuries in the skeletal, articular, and muscular systems. A few minutes of ice massage reduces swelling and pain in the cooled area of the body (Howatson et al., 2005).

The evaluation of the effectiveness of cold treatment strategies remains open; however, according to Matos et al. (2015), thermography seems to be an efficient, reliable, and safe method for monitoring skin temperature during cold treatment. The purpose of the study was to evaluate the effectiveness of ice massage and cold-water immersion for supporting recovery and preventing DOMS after maximal physical effort, as well to assess the applicability of thermography in this evaluation.

2. Material and methods

2.1. Participants

The study included 36 physically active men aged 20–27 who were not professional athletes. The biometric characteristics of the participants are presented in Table 1. Each subject was characterized by sound health and full efficiency of the musculoskeletal system. Diseases of the cardiovascular system and other disorders that could deteriorate throughout the implementation of the research were excluded.

Table 1.
Biometric characteristics of the participants divided into groups.

Group	Age [years]	Body height [cm]	Body mass [kg]
Ice massage (IM) n=12	22.5 ± 0.9	181.1 ± 6.0	80.6 ± 7.8
Cold water immersion (CWI) n=12	22.5 ± 0.8	183.0 ± 8.0	79.3 ± 6.4
Passive (PAS) n=12	22.1 ± 0.7	182.9 ± 7.7	81.2 ± 8.0

The participants were randomly divided into three twelve-person groups in which different post-exercise recovery methods were applied. The first group was treated with ice massage (IM). The second group benefited from the cold-water immersion (CWI) of their lower limbs. The third group was the control group, and they rested passively (PAS) following the physical activity.

Participants were informed about the risks and provided their written informed consent. The study was approved by the Research Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw (No. SKE 01-28/2012).

2.2. Procedures

All of the subjects were asked to jump as high as possible from a full squat for one minute. The trial was designed in such a way that in a short time and without using a large space, it would cause significant fatigue of a glycolytic nature (Adamczyk et al., 2014). During preliminary research we also measured CK activity 24 h following the same exercise. The mean CK values ranged between 300 and 500 U L^{-1} that strongly suggests high intensity exercise and possible occurrence of DOMS.

Prior to the trial, each of the men took about 20 min to adapt to the conditions in the room where they were about to undergo the trial in order to achieve thermal equilibrium (Fernández-Cuevas et al., 2015). All of the participants were dressed in shorts.

Thermograms of the front (FS) and back (BS) surface of lower limbs for each subject were taken in a standing position. The front surface was scanned from the deflection in the hip joint to the ankle (without knee) and the back surface from the gluteal folds to the ankle (including popliteal fossa) (Fig. 1). ROI's were marked with markers to ensure the analysis used the same surface for each thermogram. No clothing was worn on the scanned parts. The mean temperatures (T_{sk} °C) of the measurement areas for front and back side were used for further analysis. Participants from IM and CWI groups were imaged four times (each time separate image for front and back side of lower limbs): at resting conditions after adaptation to the ambient temperature, immediately after trial, immediately after cold treatment and after 30 min of rest. The passive group was imaged three times.

A thermal imaging camera (FLIR A325, FLIR Systems, Sweden) was used for all infrared (IR) measures. The camera has a measurement range from −20 to +350 °C, an accuracy of ±2 °C or ±2%, a sensitivity below 0.05 °C, an infrared spectral band of 7.5–13 μm, a refresh rate of 60 Hz, and a resolution of 320–240 pixels Focal Plane Array. The distance between the camera and the photographed object was set on 2.5 m. The analysing was done with the use of Researcher 2.9 Pro software designed for use with the thermal camera.

Blood lactate (LA) was measured at rest (after the previous adaptation) and then at the 30th minute of recovery (Baldari et al., 2015). Blood lactate concentration was measured in a capillary