

WHOLE-BODY CRYOTHERAPY FOR RECOVERY AFTER PLYOMETRIC EXERCISE

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Abstract

The purpose of this study was to examine the effects of whole-body cryotherapy (WBC) on pain and performance parameters during the 5-day recovery period after intensive plyometric exercise. Eleven male subjects completed a bout of plyometric exercise for the hamstring muscles on two separate occasions (control and experimental condition) separated by 10 weeks. The experimental condition consisted of WBC every day during the recovery period. WBC included single 3-minute daily exposures to low temperatures (-140 to -195 °C) in the cryo-cabin. During the recovery period, subjects were tested for perceived pain sensation, maximal isometric torque production and maximally explosive isometric torque production. There was a significant interaction between the control and WBC conditions for: maximal torque production, and the rate of torque development. Pain and performance measures indicated substantial differences between the WBC and the control condition after the exercise. Results of this study are supportive to the use of WBC for recovery enhancement after strenuous training.

Keywords: EIMD, DOMS, regeneration, performance

Introduction

After unaccustomed exercise, a sensation of discomfort within skeletal muscle, accompanied by a decrease in muscle force, range of motion and physical performance, can appear in elite or novice athletes (Proske & Morgan, 2001). This sensation also referred to as delayed onset muscle soreness is one of the most common recurrent forms of sports injury and is associated with exercise-induced muscle damage (EIMD).

The question of whether to use any recovery modality when a muscle has been damaged after strenuous exercise has been repeatedly addressed (Barnett, 2006; Bleakley et al., 2012) though the data on which modality to use for recovery is inconclusive. Cryotherapy has gained increasing popularity as a means of improving recovery after strenuous training (Barnett, 2006; Bleakley et al., 2012; Leeder, Gissane, van Someren, Gregson, & Howatson, 2012). It can be administered in a number of different ways (locally or more generally) and is frequently purported to reduce symptoms that are apparent following a damaging bout of exercise. Recently, a new form of cryogenic therapy, called whole-body cryotherapy (WBC), has been offered to athletes as an alternative to cold water immersion or other cold exposure (Banfi, Lombardi, Colombini, & Melegati, 2010). WBC involves exposing minimally dressed participants to very cold air (-110 °C), either in a specially designed chamber for a short period of time, or in a specially designed cabin, in which the head and hands are not exposed. In sports medicine, WBC has gained wider acceptance as a method to improve recovery from muscle injury.

To the authors' knowledge, only the studies by Costello, Algar, and Donnelly (2012) and Hauswirth et al. (2011) examined the effects of WBC on performance measures (isometric muscle strength) after EIMD. They reported inconsistent results of WBC as a recovery modality after damaging exercise. Therefore, the aim of the present study was to examine the effects of WBC on biochemical markers, pain and performance parameters during a 5-day recovery period after a damaging plyometric

exercise. It has been hypothesized that WBC would have beneficial effects on muscle recovery after such an exercise bout.

Method

Eleven healthy young male adults (age [mean \pm SD] 26.9 ± 3.8 years, height 184.5 ± 7.7 cm, and weight 90.5 ± 3.8 kg) who were regularly involved in moderate physical activity (agility and endurance) participated in this study. The interview, during which the details of the study were presented, was carried out prior to the start of the experiment. The study was approved by the Slovenian Medical Ethics Committee (Approval no. 108/01/12) and all subjects signed a statement of informed consent at enrolment. Subjects were randomly assigned into two groups and exposed to a crossover study design. The experiment was performed on two separate occasions whereby one group undertook the WBC condition (experimental condition) in the first session, while the other group did not use the recovery modality (control condition). After ten weeks, on the next occasion, the groups were changed and the second group performed the WBC, while the first group underwent the control condition.

One day before the damaging exercise, subjects were tested for baseline values. The next day each subject performed a bout of plyometric exercise consisting of drop jumps and leg curls (i.e. damaging protocol). Damaging protocol consisted of five sets of 10 drop jumps from a 0.6 m box with an emphasis on hip flexion-extension movement (range of motion $\sim 100^\circ$) were performed. Subjects were instructed to execute active amortization and maximally explosive push-off. Drop jumps were followed by five sets of 10 repetitions of bilateral leg curls (75% of concentric 1RM) in the prone-lying position (hips at 20° flexion). Leg curl range of motion was $\sim 90^\circ$, with fast eccentric-concentric coupling at $\sim 10^\circ$ knee flexion angle. Finally, an additional set of 10 repetitions of eccentric leg curls (130% of concentric 1RM; 3-second eccentric action with manually assisted lift) was performed in the same position. The series of drop jumps and leg curl exercises were separated by one-minute breaks. During the WBC condition subjects performed the WBC one hour after the damaging exercise and at the same time of the day for the next six days. For each WBC a subject was exposed for three minutes to low temperatures (from -140 to -195°C) using a cryo-cabin (model: Space Cabin; Criomed, Ltd, Kherson, Ukraine). The feet were protected with warm shoes, while the hands and head were not exposed. The subjects were instructed to turn around continuously in the cabin as recommended by the manufacturer. All dependent variables were taken after the WBC.

Perceived pain sensation was assessed using a 10 cm visual analogue scale from 0 to 10, with 0 indicating no pain and 10 indicating severe pain. Precision of the scale was 1 centimeter. Maximal torque production and explosive contractions were performed on a static knee flexion measurement dynamometer bench (S2P Ltd., Ljubljana, Slovenia). Subjects were positioned prone on the bench with hip flexion of 45° and knees fixed at 60° of flexion. All tests were performed bilaterally. Custom-made software developed in LabVIEW 2010 (National Instruments, Austin, Texas, USA) was used for acquisition and analysis of the signals. The force signal was acquired at 1000 Hz and 20 Hz low-pass filtered (2nd order Butterworth). For the voluntary maximal torque production, the peak average torque on a one-second time interval was calculated. Maximally explosive contractions of knee flexion were performed to evaluate the rate of torque development in the first 200 ms (start of torque rise at 3% of peak). Out of the three repetitions the repetition with the highest value was used for later analysis. Descriptive statistics were used for variables of pain sensation. Differences in other measured variables between conditions and trials were analyzed with 2-way repeated measure ANOVA (Treatment (2) x Time (7)), using treatment as the inter-subject factor and time as the intra-subject factor. Bonferroni *post hoc* tests were performed for each parameter to test for significant change for each day compared to baseline values and for significant change between groups for each day separately. The level of significance for all tests was set at $p < 0.05$. All statistical analyses were performed using the IBM SPSS statistics 19.0 software (Armonk, NY, USA).

Results

Absolute data for all dependent variables are presented in Table 1. There were no statistically significant changes in baseline values between the two conditions for any of the measured parameters. A substantial difference was observed between the conditions for pain sensation during rest and during squat. Values of both pain sensation tests differed substantially between the control and WBC condition 1 to 72 hours after the exercise. At all of these time points pain values for the WBC condition were lower compared to the control condition, with the differences peaking at 48 hours after the exercise. There was a statistically significant interaction between the conditions for maximal torque production ($F = 2.321$; $p = 0.044$) and rate of torque development ($F = 2.663$; $p = 0.023$). Statistically significant differences in the rate of torque development between the control and WBC condition were evident 24 hours after the exercise ($p = 0.012$).

Table 1. Changes in pain sensation, maximal torque and maximally explosive torque, reported as mean (standard deviation).

	Control	WBC	p-value
Pain rest [cm]			
Baseline	0.0 (0.0)	0.0 (0.0)	N/A
1h	0.8 (0.9)	0.1 (0.3)	N/A
24h	1.7 (1.2)	0.5 (0.5)	N/A
48h	1.9 (1.2)	0.8 (0.7)	N/A
72h	1.3 (0.7)	0.2 (0.6)	N/A
96h	0.2 (0.4)	0.0 (0.0)	N/A
120h	0.1 (0.3)	0.0 (0.0)	N/A
Pain squat [cm]			
Baseline	0.0 (0.0)	0.0 (0.0)	N/A
1h	2.3 (1.7)	0.8 (1.1)	N/A
24h	4.4 (1.6)	2.6 (1.2)	N/A
48h	4.7 (2.1)	2.8 (1.7)	N/A
72h	3.1 (1.7)	1.5 (1.3)	N/A
96h	0.8 (1.0)	0.4 (0.5)	N/A
120h	0.4 (0.5)	0.4 (0.5)	N/A
Max torque [Nm]			
	TE p = 0.000	TE p = 0.032	Time × Group = 0.044
Baseline	215 (41)	195 (35)	0.101
1h	187 (48)*	178 (37)	0.446
24h	180 (43)*	180 (44)	0.431
48h	185 (45)*	194 (52)	0.408
72h	198 (45)*	203 (45)	0.604
96h	197 (37)*	200 (44)	0.725
120h	203 (45)	208 (43)	0.503
RTD 200 ms [Nm/s]			
	TE p = 0.000	TE p = 0.116	Time × Group = 0.023
Baseline	718 (114)	686 (129)	0.376
1h	645 (132)*	604 (128)	0.305
24h	586 (133)*	655 (143)	0.012
48h	604 (145)*	659 (174)	0.021
72h	635 (104)*	688 (169)	0.131
96h	661 (121)*	695 (136)	0.194
120h	676 (102)*	706 (150)	0.306

RTD, rate of torque development

TE, time effect within group; * $p \leq 0.05$ Bonferroni *post hoc* paired t-test compared to Baseline

Time x Group, interaction

Discussion

The present study examined the efficiency of repeated WBC to enhance recovery from EIMD. In line with the research hypothesis, the WBC protocol used in this study showed some enhancements in the recovery process following the damaging exercise as compared to the referent recovery in the control condition.

According to Warren, Lowe, and Armstrong (1999), perceived pain sensation parameters should be discouraged for the purpose of quantifying EIMD and/or functional impairment. Nevertheless, pain inhibits motor cortex excitability (Cheong, Yoon, & Lee, 2003) and, together with inhibitory effects originating from groups III/IV afferents (Bottas, Miettunen, Komi, & Linnamo, 2010), reduces the maximal voluntary neuromuscular activation (Graven-Nielsen, Lund, Arendt-Nielsen, Danneskiold-Samsøe, & Bliddal, 2002). This could explain the drop in performance measures also in the present study. A tendency towards enhanced recovery in the WBC condition was evident for maximal isometric torque production, which could be explained by reduced nociceptive signaling. The ability to develop high forces/torques over short time intervals underlies sport-specific movement requirements such as speed, agility and quickness. It has been reported that a rapid increase in motor unit discharge rates and a high incidence of discharge doublets in the early phase of explosive contraction play a crucial role in the rate of torque development (Van Cutsem, Duchateau, & Hainaut, 1998).

In our study, rate of torque development recovered significantly faster in the WBC condition compared to the control condition. In line with the above-mentioned neurophysiology, this could probably be explained by the decrease in III and IV afferents inhibitory effects and reduced intra-cortical inhibitory circuits (Cheong et al., 2003). It has been reported (Pournot et al., 2011) that multiple WBC exposures can enhance recovery by decreasing the acute phase inflammatory response after damaging exercise with release of anti-inflammatory cytokines and blocked pro-inflammatory cytokines, thus contributing to its beneficial role in muscle tissue protection from secondary muscle damage.

To the authors' knowledge, the present study is the first study performed using a cryo-cabin and not a cryo-chamber, as used in the majority of the previously published studies (Banfi et al., 2010; Banfi et al., 2009; Costello et al., 2012; Hausswirth et al., 2011; Pournot et al., 2011). The main difference between the cabin and the chamber is in the type of exposure and the temperature. In the present study we used temperatures between -140 and -195 °C, while in the cryo-chambers used in other studies (Banfi et al., 2010; Banfi et al., 2009; Costello et al., 2012; Hausswirth et al., 2011; Pournot et al., 2011; Wozniak, Wozniak, Drewa, Mila-Kierzenkowska, & Rakowski, 2007), the mean temperature used was approximately between -110 and -140°C.

The results of the present study provide promising results for the use of WBC as a technique to enhance functional recovery after EIMD. WBC hastens the recovery from EIMD by limiting the loss of maximal isometric torque production, explosive torque production and subjective sensations of pain.

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