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The Efficacy of Repeated Cold Water Immersion on Recovery Following a Simulated Rugby Union Protocol

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ABSTRACT

Training and athletic competition frequently results in exercise induced muscle damage (EIMD). The purpose of this study was to investigate the efficacy of repeated cold water immersion (CWI) on recovery following a simulated rugby union match. Sixteen male, club level rugby players were matched for body mass and randomly assigned to either a CWI group or control (CON) group. Following the simulated rugby match the CWI group underwent 2 x 5 min immersions at a temperature of 10°C separated by 2.5 min seated at room temperature, whilst the CON group remained seated for 15 min. Creatine kinase (CK), perceived muscle soreness, counter movement jump (CMJ) and maximal voluntary isometric contraction (MVIC) of the knee extensors were measured pre-exercise, post-exercise, 24 h and 48 h following exercise. Large effect sizes were observed for muscle soreness at 24 and 48 h post exercise with lower soreness values observed in the CWI group. Large effect sizes were observed for CMJ at all time points and at 24 and 48 h post for MVIC with improved recovery of muscle function observed in the CWI group compared to the CON group. Lastly a moderate effect size was observed for CK immediately post exercise followed by large effect sizes at 24 and 48h post exercise, with CK concentration blunted in the CWI group. Overall these findings provide some support for the use of CWI to enhance recovery from EIMD following a simulated rugby union match.

Key words: *team sport, muscle damage, exercise, cryotherapy.*

INTRODUCTION

Rugby union is a high contact, team sport involving periods of intermittent submaximal activity interspersed with short high-intensity bouts (20,23). In addition, during competitive matches players are repeatedly exposed to forceful collisions associated with tackling. The combination of high intensity activity and repeated blunt force trauma have been linked to substantial muscle damage (18).

The impact of muscle damage on performance has therefore been suggested to impact recovery (2,7). Recovery is further compounded by the added weekly habitual training activity, which usually commences after 48 h of rest, in preparation for the next match. As such, the short rest times between competition and training may not provide the players with sufficient time to fully recover (7). Consequently, the detrimental effects of under recovery can lead to several negative implications for the players and the team, which may impact coaching practices. Furthermore, the cumulative effect of under recovery from one week to the next can lead to the accumulation of fatigue, predisposing the players to potentially more significant injuries throughout the season (5). These factors coupled with the additional pressure of consistent performance make it imperative that optimal recovery strategies are identified and implemented so that any detrimental effects are nullified (5).

Optimal recovery modalities include the use of compression garments (10,11), antioxidant supplementation (14, 17), massage (9) and more recently cold water immersion (CWI) (16,19). Recently there has been an increase in the popularity of CWI and it has become a regular component of post game and training recovery (26). CWI is commonly undertaken following high-intensity activity to promote recovery and diminish muscle soreness to aid the return to training (4,15,24). It has been speculated that the increase in popularity is due to the positive physiological mechanisms associated with temperature and pressure induced changes experienced during CWI, that allow athletes to resume training in a fully recovered state (16). The effect of CWI decreases in tissue temperature is thought to reduce cell necrosis, oedema, neutrophil migration and consequently secondary muscle damage (1,4). Additionally, the resultant reduction in the inflammatory response causes a decrease in nerve conduction velocity and activity of muscle spindle function, this decreases the stretch reflex response, reducing the pain-spasm cycle and thus muscle soreness (4,6,16).

Leeder et al. (16) conducted a systematic review and meta-analysis exploring the efficacy of CWI as a recovery modality. The authors divided research into two categories; eccentric exercise and high intensity exercise, based on how the muscle damage was induced. Findings indicated CWI had a minimalistic effect following eccentric exercise, whilst a positive effect following high intensity exercise was found, reflecting both game and training situations. Despite this evidence, only a handful of studies have examined the efficacy of CWI in promoting recovery after team contact sports (5,8,21,26). Specifically, in rugby there has been a paucity of research that helps coaches and trainers identify optimal return to training scenarios because of inconsistencies in CWI protocols, exercise modalities, dependent variables and training status, thus findings remain equivocal making practical application unclear (23).

In addition all rugby related studies have focused on single applications of CWI with the exception of Higgins et al. (7), in this study the authors found CWI to have positive effects across the weekly cycle of game and training. However, there are several aspects within the methodology that remain unclear, such as the protocol used in the match simulation. This is of importance as the extent of muscle damage is dependent on the number of direct impacts and bodily contacts (21, 22). Therefore, it might be suggested that the muscle damage induced by the simulation was less than that of an actual match. However, Takeda et al. (23) found that an 80 min simulated rugby match was successful in inducing muscle damage, and recovery using CWI had positive effects on subjective feelings of fatigue and some muscle function tests (50 m dash, reaction time and side step ability). In addition, there is a growing body of literature linking the increases in CK activity to the repeated eccentric muscle contractions and collisions involved in rugby union (5, 21, 22). The study of Higgins et al. (7) is limited by the exclusion of blood markers such as CK. In addition, throughout the research protocol subjects continued with the teams weekly training schedule at 48 h, 72 h and 96 h following the simulated match. It is made clear within the methodology that these sessions involved contact events, suggesting that additional muscle damage was induced from one training session to the next.

Based on the current literature, no research has examined the effects of a multiple CWI protocol following a simulated rugby match during recovery periods exceeding 24 h and whether this would aid the return to training as indicated by reductions in indices of muscle damage or a return to normalised indices of strength and performance measures, thus allowing coaches to monitor players readiness to train more accurately. Therefore, the aim of this study was to investigate the effects of multiple bouts of CWI on indices of recovery following a simulated rugby match.

METHODS

Experimental Approach to the Problem

Using a between groups study design, participants were matched for body mass and randomly assigned to either a CWI group (N=8) or a control group (CON) prior to undertaking a simulated rugby protocol. Dependent measures including CK, muscle soreness, CMJ and MVIC and were measured pre-protocol, post-protocol, 24 h and 48 h post protocol in order to compare recovery with and without CWI. The study was conducted in February on week 18 following a one-week break in the 22-week competition season (3 sessions weekly including a match). This was done to ensure subjects were well rested. Subjects were asked to refrain from any training, activity or recovery strategies such as therapeutic treatments for the duration of testing.

Subjects

Sixteen, club level, male rugby union players (mean ± sd; age, height, and body mass 20 ± 1.2 yrs, 180 ± 5.5 cm, and 86.2 ± 6.9 kg respectively) volunteered to participate in this investigation which was approved by St Mary's University Ethics Committee in accordance with the Declaration of Helsinki. All participants were informed of the risks and benefits of taking part in the study prior to completing a health screening questionnaire and giving written informed consent in order to participate. Any subjects with a history of musculoskeletal injury, inflammatory disorders or any other illness were excluded from taking part.

Procedures

All participants completed the Bath University Shuttle Test (BURST), a rugby union specific match play protocol based on the physical demands for elite rugby union forwards (20). The protocol comprised 4 x 19 min exercise blocks split into 16 x 278 s exercise periods. Blocks 1 and 3 were followed by a 4-min break, 2 min allocated to standing and walking. A 10-min half-time break, comprising 7 min and 3 min of sitting and walking followed block 2. The protocol began with a 10-minute warm-up, including 5-mins of jogging and stretching followed immediately by the first 315 s period of block 1. Each 315 s period included a cycle of walking, cruising, and jogging interspersed with a contact task of scrummaging, rucking or mauling. A total of 5 cycles made up a 278 s period with scrummaging in cycles 1 and 3, rucking in cycles 2 and 4, and mauling in cycle 5 (Figure 1). The scrummaging task required subjects to drive a scrummaging machine (120 kg Rhino, London, UK) 1.5 m. The rucking task required subjects to carry a 20 kg tackle bag (Gilbert, UK; dimensions: 140 cm height, 40 cm diameter) 5 m at a marked point on the bag to standardise shoulder contact.

****Figure 1****

All variables were measured pre-exercise and 1, 24 and 48 h following the match simulation. Measurements took place at the same time of day during testing to reduce the effects of diurnal variation and participants were asked to maintain their normal dietary habits for the duration of the study. Plasma CK was sampled from a fingertip blood sample. The index fingertip of the subject was cleaned using a sterile alcohol swab and allowed to dry. Capillary puncture was made and a sample of whole blood (~300 μL) was collected into a lithiumheparin microvette (Sarstedt AG & Co, Numbrecht, Germany). The whole blood was centrifuged at 3000 rpm (4°C) for 5 min in an Eppendorf 545C centrifuge to ensure separation of plasma serum (Eppendorf UK, Ltd, Histon, Cambridge, UK), plasma was removed and stored at -80°C until subsequent analysis. The determination of plasma CK was measured using a clinical chemistry analyser (Rx Monza, Randox Laboratories Ltd., Crumlin, Antrim, UK), a 10 μL plasma sample was assayed with 500 μL of a clinical chemical reagent CK-NAC (Randox Laboratories Ltd., Crumlin, Antrim, UK). The intra-sample CV of the analyser is <4% at high and low concentrations and the expected baseline sample range is 37-2755 $IU.L^{-1}$ for CK, according to manufacturers guidelines. To eliminate inter-assay variance, all samples were analysed in the same assay run.

Perceived muscle soreness was determined using a 200 mm visual analogue scale with the far left point of the scale representing ‘no pain’ and the far right point ‘unbearable pain’ similar to previous research (11). Subjects were asked to stand with feet approximately shoulder width apart and hands on hips. The subjects were then instructed to squat down to 90° knee flexion, return to the standing position and mark their subjective feeling of pain on the scale.

Counter movement jump (CMJ) was assessed using a jump mat (Vertical Jump Mat, Probotics Inc., Huntsville, AL, USA). Participants were instructed to stand with their hands on their hips and drop down to a self-selected level before jumping maximally. A total of three singular CMJ were performed and the highest value was taken as maximum jump height. MVIC was assessed using a strain gauge (MIE Medical Research Ltd., Leeds, UK). Subjects were seated on a platform ensuring 90° of flexion at the hip and knee joint. The strain gauge was attached 2 cm above the malleoli on the ankle of the non-dominant leg.

Subjects were instructed to perform three maximal contractions, each separated by 1 min. Each contraction lasted for approximately 3 s and the highest recorded value was recorded as MVIC (9). Subjects received standardized verbal encouragement throughout. Calculated intraclass correlation coefficients (ICCs) demonstrated excellent reliability for MVIC (ICC = 0.83) and CMJ (ICC = 0.81), with CK analysis (ICC = 0.33) showing weaker reliability, this is likely due to the large subject variation within this measure.

Subjects in the CWI group were required to climb into a convenience bath (88 cm depth, 60.1 cm width, and 110 cm height) and lower themselves until their entire lower body was immersed up to the level of the superior iliac spine. The CWI protocol consisted of 2 x 5 min immersions separated by 2.5 min seated out of the bath at room temperature. Water temperature was maintained at 10°C by the addition of crushed ice. Subjects in the CON group remained seated at room temperature and were given a dilute fruit juice mixture which they were told would aid recovery in order to attempt to control for a potential placebo effect. Subjects were told that it was an isotonic sports drink and were instructed to drink a third every 5 min.

Statistical Analysis

In order to account for inter-individual variation MVIC, and CMJ performance were expressed as a percentage change from baseline. Data were analysed using magnitude based inferences following the methods recommended by Hopkins et al (13). The threshold value for the smallest worthwhile change was the smallest standardised change in the mean (Cohen); 0.2 times the between subjects SD for baseline values of all participants, consistent with previous recommendations (3). Qualitative descriptors were used to represent quantitative chances of benefit and harm as follows: <1% almost certainly none; 1-5% very unlikely; 5-25% likely; 25-75% possibly; 75-95% likely; 95-99% very likely; and >99% almost certainly (12). Effect sizes ware calculated using Cohen *d* threshold values (0.2 small, 0.5 moderate, 0.8 large). Data are presented as mean ± SD change from baseline, unless otherwise stated. Effects were deemed unclear if 90% confidence limits extended beyond the threshold for the smallest beneficial and smallest harmful effects.

RESULTS

Effect sizes and respective qualitative inferences can be observed in Table 1. Both the CWI and CON group showed an increase in DOMS following the simulated rugby protocol (figure 2). Soreness peaked immediately post exercise in the CWI group and at 24 h post in the CON group. Large effect sizes were observed for changes in DOMS from baseline to 24 and 48 h post exercise, there was a respective likely and very likely benefit of CWI in reducing soreness compared with CON at these time points.

Table 1

Figure 2

MVIC was decreased immediately post exercise in both the CWI and CON groups (table 2). Peak reductions in strength occurred immediately post exercise in the CWI group and at 24h post in the CON group. There was a possible benefit of CWI (-5.7 ± 7%) in limiting reductions in strength at 24 h post exercise compared to CON (-16.2 ± 15.9%), with a likely benefit occurring at 48 h post (0.4 ± 11.5 and 14.2 ± 15.2% in the CWI and CON respectively). Effect sizes observed at these time points were both large.

Table 2

Changes in CMJ followed a similar response to MVIC with peak declines in jump height observed immediately post for the CWI group compared to 24 h for the CON group (table 2). There was an almost certain benefit of CWI (-6.0 ± 1.7%) in limiting the decline in jump height immediately post exercise compared to CON (-3.8 ± 2.7%). In addition a possible decrease and a likely decrease were observed at 24 and 48 h respectively. All observed effect sizes were large.

A possible benefit of CWI in blunting the increase in CK was observed immediately post exercise (figure 3). Effects appeared to be more pronounced at later time points where an almost certain response was observed at 24 h between the CWI (41.1 ± 25.8 $U \cdot L^{-1}$) and CON (113.1 ± 28.9 $U \cdot L^{-1}$) and a very likely response observed at 48 h between the CWI (51.9 ± 26.5 $U \cdot L^{-1}$) and CON (111.4 ± 27.4 $U \cdot L^{-1}$).

Figure 3

DISCUSSION

The aim of this investigation was to assess the efficacy of repeated CWI on recovery from a simulated rugby match. The main finding was that repeated CWI was associated with improved muscle function over 48 h, when compared to a control group. In addition CWI also appeared to attenuate the exercise induced increased in muscle soreness and CK activity.

Tests of muscle function, which include counter movement jump height (CMJ) and maximal voluntary isometric contraction (MVIC), have been deemed applicable and reliable measurement tools for quantifying exercise induced muscle damage (1,25). CMJ is an indicator of lower body power, the current investigation observed decreases in this measure after the simulated rugby protocol. This follows a similar trend to previous research using CMJ as a measure of power (7, 23, 26). Large effect sizes for CMJ were observed at all time points with jump height consistently higher in the CWI group indicating a restorative benefit of the treatment. Notably, CMJ values in the CWI group returned to baseline at 48 h (100 ± 7.13%) compared to the CON group where jump height was still reduced (92.2 ± 9.52%). This observation is similar to previous research (26).

MVIC was used to assess quadriceps strength, large effect sizes were observed for MVIC at 24 and 48 h post exercise with strength recovering at an accelerated rate compared to the CON group. Similarly at 48 h post exercise MVIC in the CWI group returned to baseline (100.4 ± 11.52%) compared to the CON group who only achieved 85.8 ± 15.21% of baseline values. To date, only one other study has examined the effect of collision-based exercise on MVIC, observing similar decrements in strength immediately following exercise alongside improved recovery with the application of CWI (19). The authors of this study indicated that improved recovery of MVIC following collision based exercise was potentially due to an interaction between improved recovery of peripheral contractile function and enhanced central activation (19). Consequently, the large effect sizes observed for CMJ and MVIC suggest that the use of repeated CWI has a positive effect on the recovery of muscle function following a simulated rugby protocol.

An acute onset of muscle soreness was observed in both groups immediately post exercise (figure 2), the large effect sizes observed at 24 and 48 h post exercise suggest CWI is effective in alleviating soreness, compared to a control group. This finding corroborates previous investigations following intermittent shuttle running (1) and simulated team sport exercise (15). The observed response has been attributed to several mechanisms, these include an analgesic effect of CWI which elicits a drop in intramuscular temperature, reducing nerve conduction velocity, thereby inhibiting the pain spasm cycle and thus pain tolerance (1,6); and a decrease in capillary permeability and blood flow which reduces fluid diffusion into the interstitial spaces and thereby attenuates inflammation (16). The decreased inflammatory response leads to a reduction in soreness by reducing the osmotic pressure of exudate, which alleviates pressure on nociceptors and thus the sensation of pain (1,16).

In contrast to our findings some investigations have observed no effects of CWI on muscle soreness (4,6). This may be due to differing treatment protocols, specifically related to water temperature and the number of immersions. Reports suggesting CWI had no effect on muscle soreness used single applications coupled with higher water temperatures of 15°C (4,6). In contrast reports using a similar 2 x 5 min protocol at 10°C observed significant reductions in muscle soreness with the use of CWI (7,15). As such, it is possible that repeated immersions at lower water temperatures are important considerations for the efficacy of CWI following rugby.

Previous research investigating the effects of CWI on the CK response has reported inconsistent findings with some studies observing reductions in CK concentrations following CWI (15) and other studies reporting no effect (19). The present study observed a blunted CK response in the CWI group at all time points, a moderate effect size was observed immediately post exercise with large effect sizes observed at 24 and 48h post exercise. Whilst the exact mechanisms for this response remain unclear, CWI has been speculated to reduce CK efflux via decreased membrane permeability due to a reduced inflammatory response (1,4,6).

The results from this current study appear to support the use of CWI following a simulated rugby match, however, it is important to note that results may have been influenced by a potential placebo effect. Whilst the study did try to control for a placebo effect with the use of a drink that participants were told would aid recovery, it is possible that results could have been affected by participant’s belief that CWI has a positive effect on recovery. Whilst the placebo effect may affect measures of muscle function and perceptual measures such as muscle soreness it is unlikely that it could affect changes in CK concentration. Therefore, despite a possible placebo effect, the repeated CWI protocol used within this study appears to benefit performance.

In conclusion, the findings of this investigation lend support to the use of repeated CWI on recovery following rugby union. The CWI protocol was beneficial in blunting increases in muscle soreness and serum concentrations of CK, and facilitated the recovery of muscle function over 48 h compared to a control group. However, it is likely that the effects of CWI are influenced by the degree of muscle damage and muscle temperature achieved following CWI, therefore more research is required to clarify any potential interactions. This will aid in the prescriptive guidance of CWI for best practice in sport.

PRACTICAL APPLICATIONS

Athletes and coaches are constantly looking for effective recovery modalities that may alleviate the negative symptoms associated with EIMD. Strategies that reduce or alleviate these symptoms and enhance the recovery process are desirable as they may enable the athlete to tolerate higher training loads (2). The use of CWI as a recovery strategy is growing in popularity, however literature investigating the efficacy of CWI is conflicting. This study observed an improved recovery profile with the use of a repeated CWI protocol following a simulated rugby match and therefore provides support for the use of CWI in rugby. For coaches looking to implement recovery strategies following training or game situations, repeated CWI may provide a beneficial option.

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FIGURES

Figure 1. A schematic adapted from Roberts et al. (2010) (19) and Roberts et al. (2011) (20) of the match simulation protocol.

Figure 2. Perceived muscle soreness response to a simulated rugby protocol in CWI and CON groups. Values are reported as mean ± SD. * Denotes large effect size observed for changes from baseline between CON and CWI

Figure 3. Serum CK response to a simulated rugby protocol in CWI and CON groups. Values are reported as mean ± SD. * Denotes large effect size observed for changes from baseline between CON and CWI

Table 1. Summary of the differences between CWI and CON for recovery indices following a simulated rugby protocol.

Table 2. Percentage changes in counter movement jump (CMJ) and maximal voluntary contraction (MVIC) from pre-exercise values (values are means ± SD). * Denotes large effect size observed for changes from baseline between CON and CWI

Table 1. Summary of the differences between CWI and CON for recovery indices following a simulated rugby protocol.

Comparison	Mean effect[a] ± 90% CI	Qualitative inference[b] (% Likelihood)	Effect size
Change form baseline to post			
Muscle Soreness (mm)	6.1 ± 4.8	Unclear	0.52 (moderate)
MVIC (%)	-2.3 ± 4.4	Unclear	-0.21 (trivial)
CMJ (%)	-2.2 ± 0.9	Almost certainly higher (100%)	-0.99 (large)
CK ($U{\cdot}L^{-1}$)	10.2 ± 7.2	Possibly lower (37%)	-0.58 (moderate)
Change form baseline to 24 h			
Muscle Soreness (mm)	-20.1 ± 6.6	Likely lower (87%)	-1.26 (large)
MVIC (%)	10.6 ± 0.86	Possibly higher (69%)	0.86 (large)
CMJ (%)	8.9 ± 2.7	Possibly higher (55%)	1.33 (large)
CK ($U{\cdot}L^{-1}$)	-72.0 ± 11.3	Almost certainly lower (100%)	-2.63 (large)
Change form baseline to 48 h			
Muscle Soreness (mm)	-7.1 ± 3.6	Very likely lower (99%)	-0.82 (large)
MVIC (%)	14.6 ± 5.5	Likely higher (88%)	1.08 (large)
CMJ (%)	7.8 ± 3.5	Likely higher (76%)	0.93 (large)
CK ($U{\cdot}L^{-1}$)	-59.5 ± 11.1	Very likely lower (98%)	-2.20 (large)

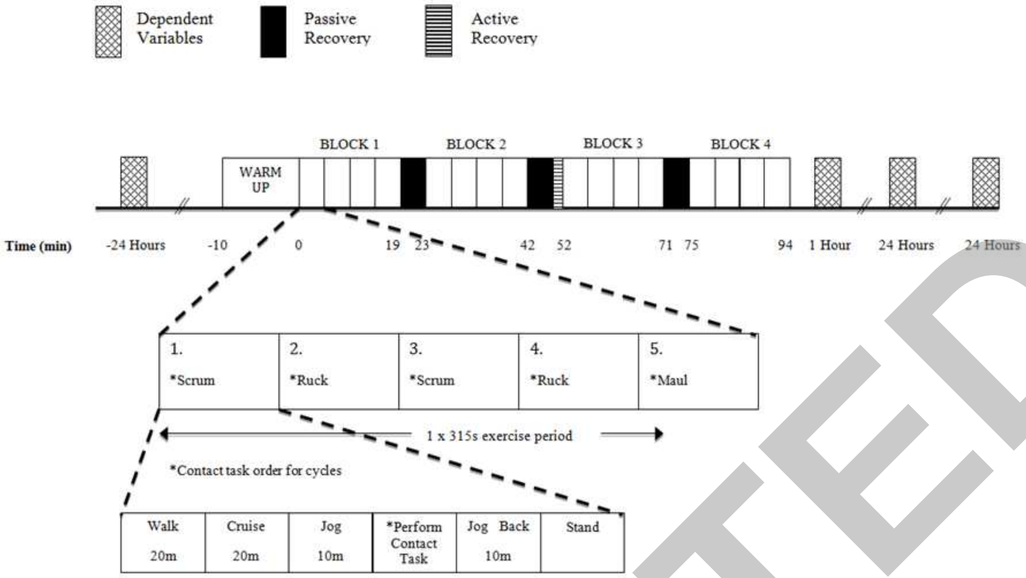
[a]Mean effect refers to CWI minus the placebo trial.

[b]Inference about the magnitude of the effect.

90% CI, 90% confidence interval.

Table 2. Percentage changes in counter movement jump (CMJ) and maximal voluntary contraction (MVIC) from pre-exercise values (values are means ± SD). * Denotes large effect size observed for changes from baseline between CON and CWI

Variable	Group	Pre-exercise	Post-exercise	24 h	48 h
CMJ	CWI	100 ± 0	94.0 ± 1.72	96.4 ± 4.00	100.0 ± 7.13
	Control	100 ± 0	96.2 ± 2.67 *	87.5 ± 8.57 *	92.20 ± 9.52 *
MVIC	CWI	100 ± 0	88.2 ± 10.47	94.4 ± 7.020	100.4 ± 11.52
	Control	100 ± 0	90.4 ± 11.05	83.8 ± 15.88 *	85.80 ± 15.21*


Dependent Variables
Passive Recovery
Active Recovery
WARM UP
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BLOCK 2
BLOCK 3
BLOCK 4
Time (min)
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23
42
52
71
75
94
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*Scrum
2.
*Ruck
3.
*Scrum
4.
*Ruck
5.
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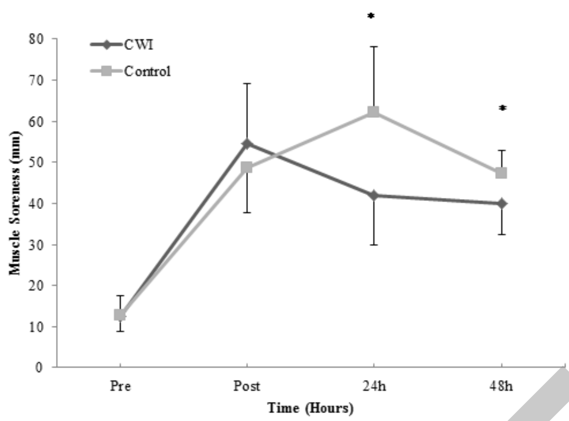
*Perform Contact Task
Jog Back
10m
Stand


CWI
Control
Muscle Soreness (mm)
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Pre
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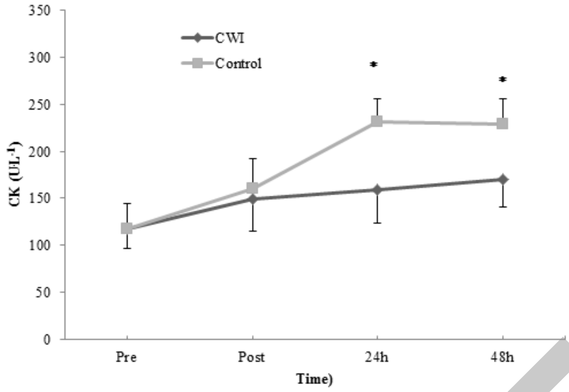
24h
48h
Time (Hours)


350
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