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

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4

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6

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10

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1 **ABSTRACT**

2 Training and athletic competition frequently results in exercise induced muscle damage
3 (EIMD). The purpose of this study was to investigate the efficacy of repeated cold water
4 immersion (CWI) on recovery following a simulated rugby union match. Sixteen male, club
5 level rugby players were matched for body mass and randomly assigned to either a CWI
6 group or control (CON) group. Following the simulated rugby match the CWI group
7 underwent 2 x 5 min immersions at a temperature of 10°C separated by 2.5 min seated at
8 room temperature, whilst the CON group remained seated for 15 min. Creatine kinase (CK),
9 perceived muscle soreness, counter movement jump (CMJ) and maximal voluntary isometric
10 contraction (MVIC) of the knee extensors were measured pre-exercise, post-exercise, 24 h
11 and 48 h following exercise. Large effect sizes were observed for muscle soreness at 24 and
12 48 h post exercise with lower soreness values observed in the CWI group. Large effect sizes
13 were observed for CMJ at all time points and at 24 and 48 h post for MVIC with improved
14 recovery of muscle function observed in the CWI group compared to the CON group. Lastly
15 a moderate effect size was observed for CK immediately post exercise followed by large
16 effect sizes at 24 and 48h post exercise, with CK concentration blunted in the CWI group.
17 Overall these findings provide some support for the use of CWI to enhance recovery from
18 EIMD following a simulated rugby union match.

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

20

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23

24 **INTRODUCTION**

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

30

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

42

43 Optimal recovery modalities include the use of compression garments (10,11), antioxidant
44 supplementation (14, 17), massage (9) and more recently cold water immersion (CWI)
45 (16,19). Recently there has been an increase in the popularity of CWI and it has become a
46 regular component of post game and training recovery (26). CWI is commonly undertaken

47 following high-intensity activity to promote recovery and diminish muscle soreness to aid the
48 return to training (4,15,24). It has been speculated that the increase in popularity is due to the
49 positive physiological mechanisms associated with temperature and pressure induced changes
50 experienced during CWI, that allow athletes to resume training in a fully recovered state (16).
51 The effect of CWI decreases in tissue temperature is thought to reduce cell necrosis, oedema,
52 neutrophil migration and consequently secondary muscle damage (1,4). Additionally, the
53 resultant reduction in the inflammatory response causes a decrease in nerve conduction
54 velocity and activity of muscle spindle function, this decreases the stretch reflex response,
55 reducing the pain-spasm cycle and thus muscle soreness (4,6,16).

56

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

68

69 In addition all rugby related studies have focused on single applications of CWI with the
70 exception of Higgins et al. (7), in this study the authors found CWI to have positive effects

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

86

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

94

95 **METHODS**

96 **Experimental Approach to the Problem**

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

106

107 **Subjects**

108 Sixteen, club level, male rugby union players (mean \pm sd; age, height, and body mass $20 \pm$
109 1.2 yrs, 180 ± 5.5 cm, and 86.2 ± 6.9 kg respectively) volunteered to participate in this
110 investigation which was approved by St Mary's University Ethics Committee in accordance
111 with the Declaration of Helsinki. All participants were informed of the risks and benefits of
112 taking part in the study prior to completing a health screening questionnaire and giving
113 written informed consent in order to participate. Any subjects with a history of
114 musculoskeletal injury, inflammatory disorders or any other illness were excluded from
115 taking part.

116

117

118 **Procedures**

119 All participants completed the Bath University Shuttle Test (BURST), a rugby union specific
120 match play protocol based on the physical demands for elite rugby union forwards (20). The
121 protocol comprised 4 x 19 min exercise blocks split into 16 x 278 s exercise periods. Blocks
122 1 and 3 were followed by a 4-min break, 2 min allocated to standing and walking. A 10-min
123 half-time break, comprising 7 min and 3 min of sitting and walking followed block 2. The
124 protocol began with a 10-minute warm-up, including 5-mins of jogging and stretching
125 followed immediately by the first 315 s period of block 1. Each 315 s period included a cycle
126 of walking, cruising, and jogging interspersed with a contact task of scrummaging, rucking or
127 mauling. A total of 5 cycles made up a 278 s period with scrummaging in cycles 1 and 3,
128 rucking in cycles 2 and 4, and mauling in cycle 5 (Figure 1). The scrummaging task required
129 subjects to drive a scrummaging machine (120 kg Rhino, London, UK) 1.5 m. The rucking
130 task required subjects to carry a 20 kg tackle bag (Gilbert, UK; dimensions: 140 cm height,
131 40 cm diameter) 5 m at a marked point on the bag to standardise shoulder contact.

132

133 ****Figure 1****

134

135 All variables were measured pre-exercise and 1, 24 and 48 h following the match simulation.
136 Measurements took place at the same time of day during testing to reduce the effects of
137 diurnal variation and participants were asked to maintain their normal dietary habits for the
138 duration of the study. Plasma CK was sampled from a fingertip blood sample. The index
139 fingertip of the subject was cleaned using a sterile alcohol swab and allowed to dry. Capillary
140 puncture was made and a sample of whole blood (~300 μ L) was collected into a lithium-

141 heparin microvette (Sarstedt AG & Co, Numbrecht, Germany). The whole blood was
142 centrifuged at 3000 rpm (4°C) for 5 min in an Eppendorf 545C centrifuge to ensure
143 separation of plasma serum (Eppendorf UK, Ltd, Histon, Cambridge, UK), plasma was
144 removed and stored at -80°C until subsequent analysis. The determination of plasma CK was
145 measured using a clinical chemistry analyser (Rx Monza, Randox Laboratories Ltd., Crumlin,
146 Antrim, UK), a 10 µL plasma sample was assayed with 500 µL of a clinical chemical reagent
147 CK-NAC (Randox Laboratories Ltd., Crumlin, Antrim, UK). The intra-sample CV of the
148 analyser is <4% at high and low concentrations and the expected baseline sample range is 37-
149 2755 IU.L⁻¹ for CK, according to manufacturers guidelines. To eliminate inter-assay variance,
150 all samples were analysed in the same assay run.

151

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

157

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

165 Subjects were instructed to perform three maximal contractions, each separated by 1 min.
166 Each contraction lasted for approximately 3 s and the highest recorded value was recorded as
167 MVIC (9). Subjects received standardized verbal encouragement throughout. Calculated
168 intraclass correlation coefficients (ICCs) demonstrated excellent reliability for MVIC (ICC =
169 0.83) and CMJ (ICC = 0.81), with CK analysis (ICC = 0.33) showing weaker reliability, this
170 is likely due to the large subject variation within this measure.

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

180

181 **Statistical Analysis**

182 In order to account for inter-individual variation MVIC, and CMJ performance were
183 expressed as a percentage change from baseline. Data were analysed using magnitude based
184 inferences following the methods recommended by Hopkins et al (13). The threshold value
185 for the smallest worthwhile change was the smallest standardised change in the mean
186 (Cohen); 0.2 times the between subjects SD for baseline values of all participants, consistent
187 with previous recommendations (3). Qualitative descriptors were used to represent
188 quantitative chances of benefit and harm as follows: <1% almost certainly none; 1-5% very

189 unlikely; 5-25% likely; 25-75% possibly; 75-95% likely; 95-99% very likely; and >99%
190 almost certainly (12). Effect sizes were calculated using Cohen *d* threshold values (0.2 small,
191 0.5 moderate, 0.8 large). Data are presented as mean \pm SD change from baseline, unless
192 otherwise stated. Effects were deemed unclear if 90% confidence limits extended beyond the
193 threshold for the smallest beneficial and smallest harmful effects.

194

195 **RESULTS**

196 Effect sizes and respective qualitative inferences can be observed in Table 1. Both the CWI
197 and CON group showed an increase in DOMS following the simulated rugby protocol (figure
198 2). Soreness peaked immediately post exercise in the CWI group and at 24 h post in the
199 CON group. Large effect sizes were observed for changes in DOMS from baseline to 24 and
200 48 h post exercise, there was a respective likely and very likely benefit of CWI in reducing
201 soreness compared with CON at these time points.

202

203 ****Table 1****

204 ****Figure 2****

205

206 MVIC was decreased immediately post exercise in both the CWI and CON groups (table 2).
207 Peak reductions in strength occurred immediately post exercise in the CWI group and at 24h
208 post in the CON group. There was a possible benefit of CWI ($-5.7 \pm 7\%$) in limiting
209 reductions in strength at 24 h post exercise compared to CON ($-16.2 \pm 15.9\%$), with a likely

210 benefit occurring at 48 h post (0.4 ± 11.5 and $14.2 \pm 15.2\%$ in the CWI and CON
211 respectively). Effect sizes observed at these time points were both large.

212

213 ****Table 2****

214

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

221

222 A possible benefit of CWI in blunting the increase in CK was observed immediately post
223 exercise (figure 3). Effects appeared to be more pronounced at later time points where an
224 almost certain response was observed at 24 h between the CWI ($41.1 \pm 25.8 \text{ U}\cdot\text{L}^{-1}$) and CON
225 ($113.1 \pm 28.9 \text{ U}\cdot\text{L}^{-1}$) and a very likely response observed at 48 h between the CWI ($51.9 \pm$
226 $26.5 \text{ U}\cdot\text{L}^{-1}$) and CON ($111.4 \pm 27.4 \text{ U}\cdot\text{L}^{-1}$).

227

228 ****Figure 3****

229

230

231 **DISCUSSION**

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

236

237 Tests of muscle function, which include counter movement jump height (CMJ) and maximal
238 voluntary isometric contraction (MVIC), have been deemed applicable and reliable
239 measurement tools for quantifying exercise induced muscle damage (1,25). CMJ is an
240 indicator of lower body power, the current investigation observed decreases in this measure
241 after the simulated rugby protocol. This follows a similar trend to previous research using
242 CMJ as a measure of power (7, 23, 26). Large effect sizes for CMJ were observed at all time
243 points with jump height consistently higher in the CWI group indicating a restorative benefit
244 of the treatment. Notably, CMJ values in the CWI group returned to baseline at 48 h ($100 \pm$
245 7.13%) compared to the CON group where jump height was still reduced ($92.2 \pm 9.52\%$).
246 This observation is similar to previous research (26).

247

248 MVIC was used to assess quadriceps strength, large effect sizes were observed for MVIC at
249 24 and 48 h post exercise with strength recovering at an accelerated rate compared to the
250 CON group. Similarly at 48 h post exercise MVIC in the CWI group returned to baseline
251 ($100.4 \pm 11.52\%$) compared to the CON group who only achieved $85.8 \pm 15.21\%$ of baseline
252 values. To date, only one other study has examined the effect of collision-based exercise on
253 MVIC, observing similar decrements in strength immediately following exercise alongside

254 improved recovery with the application of CWI (19). The authors of this study indicated that
255 improved recovery of MVIC following collision based exercise was potentially due to an
256 interaction between improved recovery of peripheral contractile function and enhanced
257 central activation (19). Consequently, the large effect sizes observed for CMJ and MVIC
258 suggest that the use of repeated CWI has a positive effect on the recovery of muscle function
259 following a simulated rugby protocol.

260

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

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

278 at lower water temperatures are important considerations for the efficacy of CWI following
279 rugby.

280

281 Previous research investigating the effects of CWI on the CK response has reported
282 inconsistent findings with some studies observing reductions in CK concentrations following
283 CWI (15) and other studies reporting no effect (19). The present study observed a blunted CK
284 response in the CWI group at all time points, a moderate effect size was observed
285 immediately post exercise with large effect sizes observed at 24 and 48h post exercise. Whilst
286 the exact mechanisms for this response remain unclear, CWI has been speculated to reduce
287 CK efflux via decreased membrane permeability due to a reduced inflammatory response
288 (1,4,6).

289

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

299

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

307

308 ***PRACTICAL APPLICATIONS***

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

318

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381

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385 article. The results of the present study do not constitute endorsement of the product by the
386 authors or the NSCA.

387

388

389 **FIGURES**

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

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

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

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

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

403

ACCEPTED

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·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·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·L ⁻¹)	-59.5 ± 11.1	Very likely lower (98%)	-2.20 (large)

^aMean effect refers to CWI minus the placebo trial.

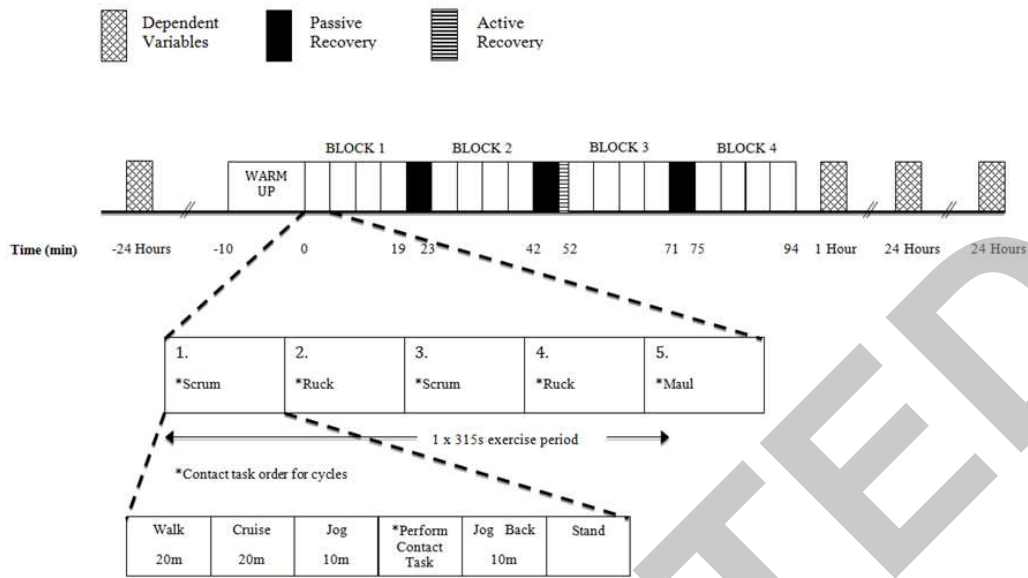
^bInference about the magnitude of the effect.

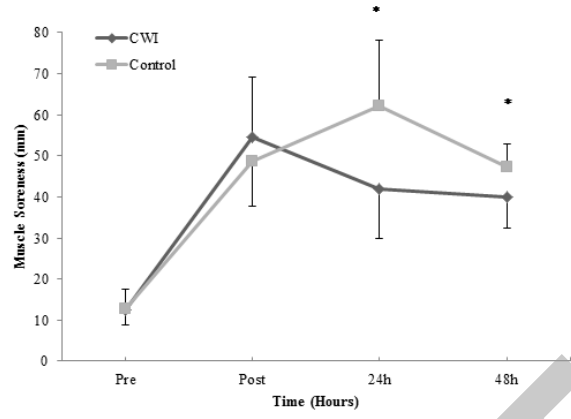
90% CI, 90% confidence interval.

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

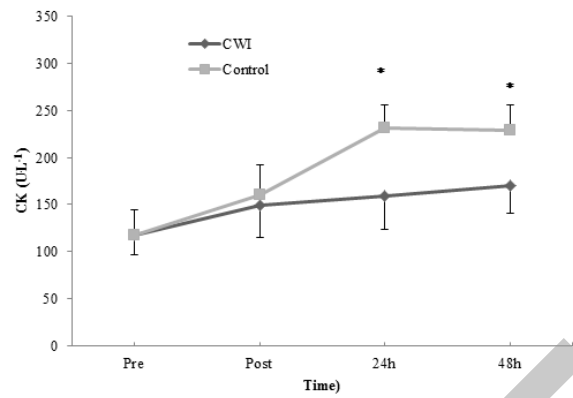
Variable	Group	Pre-exercise	Post-exercise	24 h	48 h
CMJ	CWI	100 \pm 0	94.0 \pm 1.72	96.4 \pm 4.00	100.0 \pm 7.13
	Control	100 \pm 0	96.2 \pm 2.67 *	87.5 \pm 8.57 *	92.20 \pm 9.52 *
MVIC	CWI	100 \pm 0	88.2 \pm 10.47	94.4 \pm 7.020	100.4 \pm 11.52
	Control	100 \pm 0	90.4 \pm 11.05	83.8 \pm 15.88 *	85.80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

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