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Section: Original Investigation

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Journal: *International Journal of Sports Physiology and Performance*

Acceptance Date: November 2, 2016

DOI: http://dx.doi.org/10.1123/ijspp.2016-0127

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International Journal of Sports Physiology and Performance

Cold water immersion and contrast water therapy do not improve short-term recovery following resistance training

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Original Investigation

Running Head: CWT & CWT following resistance training

Abstract Word Count: 246
Text-only Word Count: 3243
Number of Figures: 3
Number of Tables: 2

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Abstract

Purpose: An athlete's ability to recover quickly is important when there is limited time between training and competition. As such, recovery strategies are commonly used to expedite the recovery process. The purpose of this study was to determine the effectiveness of both cold water immersion (CWI) and contrast water therapy (CWT) compared to control on short-term recovery (<4h) following a single full-body resistance training session. **Methods:** Thirteen males (age, 26 ± 5 years; weight, 79 ± 7 kg; height, 177 ± 5 cm) were assessed for perceptual (fatigue and soreness) and performance measures (maximal voluntary isometric contraction (MVC) of the knee extensors, weighted and unweighted countermovement jumps) prior to and immediately following the training session. Subjects then completed one of three 14 minute recovery strategies (CWI, CWT, or passive sitting, CON), with the perceptual and performance measures reassessed immediately following recovery, two hours post-recovery, and four hours post-recovery. **Results:** Peak torque during MVC and jump performance were significantly decreased ($P < 0.05$) following the resistance training session and remained depressed for at least four hours post recovery in all conditions. Neither CWI nor CWT had any effect on perceptual or performance measures over the four hour recovery period. **Conclusions:** CWI and CWT did not improve short-term (<4h) recovery following a conventional resistance training session.

Key Words: Hydrotherapy, Weight Training, MVC, Countermovement Jump.

Introduction

The ability of an athlete to recover quickly can be crucial for subsequent performance,[1] especially in sports that compete multiple times throughout the day. For example, during a Rugby 7's tournament, players can be expected to compete again within three hours of a match finishing.[2] Similarly, many athletes will train multiple times a day in order to improve the multi-faceted aspects of athletic performance e.g. weight training in the morning and team training in the afternoon.[3] If an athlete is better recovered between training sessions, subsequent training quality, volume or intensity may improve, potentially serving as a stimulus to enhance long-term training adaptations.[4]

Water immersion is widely used by athletes in an attempt to expedite the recovery process following training and/or competition.[5] Although the mechanisms for improvement are largely unknown, both cold water immersion (CWI; ≤ 20°C) and contrast water therapy (CWT; alternating between hot (≥ 36°C) and cold water) have been reported to improve recovery from a variety of exercise modes.[5, 6] However, evidence supporting the use of water immersion to improve short-term recovery (i.e. less than four hours) is limited.[7-16] Roberts and colleagues[16] reported that compared to an active recovery, CWI did not alter the recovery of maximal strength and power measures over a four hour period following resistance exercise. Similarly, Pournot and colleagues[7] reported that there were no significant differences in performance measures (countermovement jump, isometric quadriceps maximal voluntary contraction (MVC), 30 second all out row) between CWI, CWT, temperate water immersion (36°C), and a passive control one hour post intermittent anaerobic fatiguing exercise. In contrast, Pointon and colleagues[8] reported that CWI significantly improved MVC compared to a passive control immediately post recovery following simulated team sport activity. However, at two hours post recovery, no significant differences between groups remained. As such, due to the contrasting results on the effects of water immersion on recovery two to four hours post-exercise, further research is required. Additionally, the above literature has typically investigated recovery following intermittent protocols, and data on short term recovery following resistance exercise is lacking.

A number of studies have examined the effect of water immersion following eccentric exercise, large volumes of plyometric exercise, or single exercise resistance training.[14, 15, 17-20] Findings from these studies may not be directly applicable to conventional resistance training performed by most athletes, which typically consists of multiple exercises targeting several major muscle groups, and utilise a range of complex multi-joint exercises.[21] Only a limited number of studies have examined the effect of water immersion on recovery of performance following a conventional resistance training session.[16, 21, 22] Gonzalez and colleagues[21] reported that performing CWI following a conventional resistance training session did not improve squat repetitions performed 24-48 h post-exercise, as compared with a passive control. Similarly, Roberts and colleagues[16] reported that CWI following a resistance training session did not improve recovery of maximal strength or power compared to an active recovery up to four hours post recovery. Due to the limited research investigating the effects of water immersion on a conventional resistance training session, more evidence is required before appropriate conclusions can be made.

Importantly, very little is known regarding the effects of water immersion on recovery two to four hours post-resistance exercise, the time at which successive training sessions and/or competition may occur. Thus, the purpose of this study was to examine the effects of two common water immersion strategies (cold water immersion and contrast water therapy) on the acute recovery kinetics of performance measures following a conventional resistance training session, as compared with a passive control. Given the paucity of research in this area, the findings from this study will help determine 1) the benefits of water immersion on a short (four hour) recovery period, and 2) the effects of water immersion following a conventional resistance training session.

Methods

Subjects

Thirteen male volunteers (age, 26 ± 5 years; mass, 79 ± 7 kg; height, 177 ± 5 cm) participated in this study. Informed consent was obtained before participation, and only subjects with six months (minimum) of systematic weight training experience were included in the study. All procedures were approved by the Australian Institute of Sport Research Ethics Committee.

Design

The overview of the design is presented in Figure 1. This study utilised a randomised controlled study design. Subjects reported to the laboratory on four occasions each separated by seven days, in order to examine the effects of CWI, CWT, and a passive control (CON) on a number of perceptual and performance measures following a resistance training session. Each testing occasion consisted of subjects being assessed for knee extensor isometric MVC, bodyweight (BWCMJ) and 40 kg weighted (40CMJ) countermovement jump. These measures were assessed prior to (Baseline) and two minutes following (Post-Ex) the resistance training protocol; five minutes post recovery (Post-Rec), two hours post recovery (2h Post-Rec) and four hours post recovery (4h Post-Rec). Subjects completed a familiarisation session on the first of the four occasions consisting of the entire testing and training protocol excluding the four hour rest period. During the familiarisation session, subjects also trialled the two water immersion protocols. On the remaining three sessions, subjects completed the full protocol and performed one of the three recovery strategies in a counterbalanced fashion. For the remainder of this paper the term 'water immersion' will include both CWI and CWT collectively.

Subjective Ratings

Subjects were asked to rate their perceived fatigue and soreness on an eleven point visual analogue scale [23], anchored with the following labels; 0 = None at all, 0.5 = Extremely low, 1 = Very low, 2 = Low, 3 = Moderate, 5 = High, 7 = Very high, 10 = Extremely high. Subjects were asked to perform a half squat prior to giving their soreness rating, thus providing a soreness rating during contraction rather than at passive rest.

Performance Measures

Maximal Voluntary Isometric Contraction (MVC) Test

Subjects lay supine on a massage table with their knee flexed at 90° (0° = knee fully extended) over the end of the table. Muscle strength of the right leg knee extensors was measured using a force transducer (S1W, Xtran, Australia) attached to the shank (immediately superior to the malleoli) and aligned with the longitudinal axis of the leg. The other end of the transducer was connected to a vertically adjustable steel pole attached to the table and positioned perpendicular to the floor. The distance from the axis of rotation of the knee joint and the centre of the ankle strap was measured to ensure consistency of subsequent trials. During the MVC the subject crossed their arms over their chest. Due to subjects laying supine on the table, no additional straps (other than the ankle strap) were required to hold subjects in place. Following an initial warm-up of four sub-maximal (20, 40, 60, and 80% MVC) and one maximal (100% MVC) repetition, subjects were instructed to complete two maximal four-second isometric contractions. The recovery period between contractions was thirty seconds for sub-maximal efforts and sixty seconds for maximal efforts. The MVC that produced the highest force was used for analysis.

Countermovement Jumps

For both the BWCMJ and 40CMJ, subjects performed a set of four warm-up jumps (1x80%, 2x90%, 1x100% perceived effort), followed by a set of four maximal jumps. Each repetition was separated by ten seconds, and each set by 2 minutes. As such, a total of 4 sets were completed in the following order: BWCMJ warm-up, BWCMJ maximal effort, 40CMJ warm-up, 40CMJ maximal effort jumps. A position transducer (GymAware, Kinetic Performance Technology, Canberra, Australia) was connected to a 1-kg aluminium pole (BWCMJ) or a 20-kg Olympic weightlifting bar with 10 kg plates each side (40 kg total) (40CMJ) held across the posterior deltoids at the base of the neck. Subjects were monitored during each repetition to ensure arm swing was prevented. Subjects lowered themselves to a self-selected depth and then jumped for maximal height with no pause between eccentric and concentric movements.[24] The maximal jump height, mean concentric velocity and mean concentric force from the four jumps in the unweighted and weighted conditions were used for analysis. As such, the variables (height, velocity, force) may have come from separate jumps within the four attempts.

Resistance Training Protocol

To simulate a typical resistance training session, a range of multi-joint lower-body and upper-body exercises were performed utilizing a spectrum of repetition ranges. This structure was chosen to stimulate both higher force requirements for motor unit recruitment and to be metabolically challenging[25] (Table 1). Following the familiarisation session, subjects performed an additional training session in their own gymnasium. This additional familiarisation session was performed to determine the appropriate load and intensity for the experimental training sessions. During the experimental training subjects were instructed to select a load that ensured they reached the required repetitions, but were unable to perform an extra two repetitions. During each experimental training session, the load was adjusted (if required) for each set so the prescribed repetitions and intensity were achieved. This adjustment was made by the experienced coach in consultation with the subject. Each testing session was performed seven days apart at the same time of day and took approximately 50 minutes. Subjects refrained from all other training 48 hours prior, and caffeine 24 hours prior to testing. Subjects replicated their diet in the 24 hour period prior to each testing occasion. Subjects were provided with a standardised meal and snack following training and during the recovery period.

Recovery Protocol

Two minutes following the end of the post-exercise testing, subjects completed one of three recovery strategies. During CWI subjects fully immersed their body (excluding the head and neck) in cold water (15°C) for fourteen minutes. CWT consisted of subjects alternating between hot water (38°C) for one minute and cold water (15°C) for one minute for a total of seven cycles (fourteen minute total). The change over time from hot to cold and vice versa took approximately 3-4 seconds, in which the stopwatch was stopped during this time. All water immersion was performed in the subjects own swimwear. The control group sat passively for fourteen minutes (room temperature 23°C). The subjects were then given six minutes to towel dry and get back into their training clothing. During the periods between Post-Rec, 2h Post-Rec, and 4h Post-Rec testing, subjects sat passively.

Statistical Analysis

Data are presented as mean ± SD. A two-way (exercise x treatment) repeated measures ANOVA was used to analyse all data. The least significant difference test was used for post-hoc comparisons. Effect size (ES, partial eta squared) was determined for ANOVA to determine the magnitude of effects. Statistical significance was accepted at $P < 0.05$.

Results

There were no significant differences (P > 0.05, ES = 0.14) in load lifted in each of the resistance training sessions (10330 ± 1500 kg, CON; 10590 ± 1500 kg, CWT; 10500 ± 1300 kg, CWI). Peak torque during the MVC showed a main effect for exercise (P < 0.001, ES = 0.18), with MVC decreased below baseline after exercise, and remaining depressed up to four hours post-recovery (P < 0.001, Figure 2). The decrease in MVC was consistent across all conditions. There was no significant exercise x group interaction for MVC (P > 0.05, ES = 0.06,).

All performance measures were depressed up to four hours in all conditions. Main effects for exercise were observed for BWCMJ height (P < 0.001, ES = 0.37), mean velocity (P < 0.001, ES = 0.33) and mean force (P < 0.001, ES = 0.41). Main effects for exercise were also observed for 40CMJ height (P < 0.001, ES = 0.30), mean velocity (P < 0.001, ES = 0.52) and mean force (P < 0.001, ES = 0.48). Jump height, mean velocity, and mean force decreased after exercise (P < 0.001), and were still depressed compared to baseline four hours after exercise (P < 0.001, Figure 3). There were no significant exercise x group interactions for BWCMJ height (P > 0.05, ES = 0.10), mean velocity (P > 0.05, ES = 0.02) or mean force (P > 0.05, ES = 0.04). An exercise x group interaction was observed for 40CMJ height (P < 0.05, ES = 0.12), however post-hoc tests revealed no differences between groups at any time point. There were no significant exercise x group interactions for 40CMJ mean velocity (P > 0.05, ES = 0.08) or mean force (P > 0.05, ES = 0.08).

Subjective Ratings

All subjective ratings were increased (negatively) up to four hours in all conditions. Main effects for exercise were observed for subjective ratings of fatigue (P < 0.001, ES = 0.58) and soreness (P < 0.001, ES = 0.41). Perceived fatigue and soreness each increased from baseline immediately post-exercise ($p<0.001$), then decreased from post-exercise values immediately post- recovery ($p<0.05$). Both ratings remained elevated above baseline at two hours and four hours after exercise ($p<0.001$). There were no significant exercise x group interactions for fatigue ($P > 0.05$, ES = 0.05) or soreness ($P > 0.05$, ES = 0.06).

Discussion

The major finding of this study was that despite a significant reduction in lower-limb muscle function (knee extensor strength and countermovement jump measures) following a conventional resistance training session, post-exercise CWI or CWT did not improve the short-term recovery (< 4 h) of these measures as compared with passive control. Similarly, subjective ratings of fatigue and soreness were not improved in the CWI or CWT conditions. As such, the findings from the current study suggest that water immersion is not effective in improving short-term recovery of either performance or perceptual measures following a resistance training session.

The first aim of this study was to determine the benefits of water immersion within a short (four hour) recovery period. The current study demonstrates that both CWI and CWT provided no benefit to the recovery of muscle strength and jump height within four hours post-exercise. Research investigating the short-term recovery benefits of water immersion following resistance training is limited, and from the authors' knowledge, this is the first study to investigate the effect of CWT on short-term recovery following resistance exercise. Roberts and colleagues[16] reported that CWI following a conventional resistance training session (consisting of back squats, front squats, walking lunges and drop jumps) did not improve recovery of maximal strength and power at two or four hours post recovery compared to an active recovery. Jakeman and colleagues[15] reported that following ten sets of ten countermovement jumps, CWI provided no additional benefit compared to the control group one hour post intervention. Vaile and colleagues[14] reported that there were no significant differences in performance (isometric squat or jump measures) between CWT or a control group approximately fifteen minutes following a heavy leg press protocol. Similar findings have been reported following short-term recovery periods in water immersion studies utilising other modes of fatiguing exercise.[7-13] For example, Higgins and colleagues[9] reported that neither CWI or CWT were more beneficial than a passive seated control one hour following a simulated rugby union match. Additionally, Pointon and Duffield[8] reported that CWI did not improve recovery of MVC two hours following a repeat effort running and rugby tackling training session. These findings are in line with a meta-analysis in trained athletes examining the effects of different cooling methods (including ice packs, cryogenic chambers, and CWI).[6] Poppendieck and colleagues[6] reported that there were negligible differences (-1%) in performance following short-term (two-three hours) recovery periods.

One potential reason for the lack of improvement in the short-term is due to the mechanisms in which water immersion is suggested to improve recovery. Indeed, it has been suggested that water immersion improves the recovery process via a reduction in inflammation following exercise.[5, 26] However, reductions in performance due to inflammation may take longer than several hours to transpire, as seen in the bimodal recovery pattern of skeletal muscle.[27] As such, the benefits of the water immersion following the resistance training session may not have been observed until a later time when a greater degree of inflammation had occurred.[27, 28] This bimodal recovery pattern may also explain why water immersion did not improve short-term recovery following simulated[8] or match play[9] likely to induce contusion injuries from tackling and other contact; but did however improve the recovery following a muscle damaging resistance training protocol 24-72 hours post intervention.[14, 17]

The second aim of this study was to examine the effects of water immersion following a conventional resistance training session, as this type of training stimulus, and the subsequent recovery from this stimulus may have greater application to athletes. The current study observed significant reductions in performance that remained depressed for at least four hours post recovery. Similar to the findings in the current study, Gonzalez and colleagues[21] also employed a conventional resistance training session and reported that no significant differences in performance were observed between a CWI or control group 24 hours post exercise. Furthermore, in a semi-conventional resistance training session consisting of six sets of ten back squats at a load equalling bodyweight, French and colleagues[29] reported that CWT did not provide any additional performance recovery benefits when compared to a passive control 48 hours post training. Roberts and colleagues[16] reported that CWI following a conventional resistance training session did not improve recovery of maximal strength or power compared to an active recovery up to four hours post recovery. However, when a submaximal task (six sets of squats at 80% 1RM) was performed six hours post recovery, there was a significant improvement in the total volume of load lifted in CWI group compared to an active recovery.

From these findings, it could be speculated that water immersion does not enhance the recovery of maximal output, but it may have some benefit in improving the total work performed in submaximal efforts. However, more research is required to support this suggestion.

The positive effect of water immersion reported in the literature appears to occur when excessively demanding non-conventional resistance training protocols are utilised. Vaile and colleagues[17] had subjects perform five sets of ten repetitions of eccentric leg press at 120% 1RM followed by two sets of ten repetitions at 100% 1RM. It was reported that both CWI and CWT were more effective at improving recovery of isometric squat and jump squat 24-72 hours post intervention than a control group.[17] In a separate study utilising a similar fatiguing protocol, Vaile and colleagues[14] also reported improved recovery of isometric squat and jump squat following CWT compared to the control group 24-48 hours post intervention.

Interestingly, when excessively demanding upper-body resistance training is performed there appears to be no beneficial effect on performance of water immersion as a recovery strategy.[18-20] For example, Paddon-Jones and Quigley[20] reported that there were no beneficial effects of CWI on performance following eight sets of eight repetitions of eccentric elbow flexion at 110% of concentric 1RM. It should be noted that dissimilarities in the recovery protocol may have accounted for some of the differences observed. Indeed, in the investigations by Vaile and colleagues,[14, 17] subjects were required to immerse their entire lower-body,[14] or full-body (excluding head and neck)[17] whereas the upper-body eccentric based training investigations only immersed the working arm. In the meta-analysis by Poppendieck and colleagues[6] it was reported that full-body CWI was more effective in improving performance than partial immersion. Based on the existing literature, water immersion only appears to be more effective than passive recovery (for improving maximal strength and power) when it involves whole body immersion, and is used after severe lower-body muscle-damaging exercise.

Interestingly, Roberts and colleagues[30] recently assessed both the short-term anabolic signalling and long-term adaptations in muscle to strength training with CWI or an active recovery. It was reported that CWI blunted the activation of key proteins and satellite cells (which regulate hypertrophy) in skeletal muscle up to two days after strength exercise, and also attenuated long-term gains in muscle mass and strength compared to an active recovery. Given that our findings showed no improvement in recovery following water immersion, it may be speculated that there may have been a possibility of attenuated strength gains had this been a long-term training program.

No significant perceptual benefits of soreness and fatigue following the water immersion strategies were observed compared to the control. In support of these findings, Gonzalez and colleagues[21] reported that CWI provided no additional benefit following a typical resistance training session. Similarly, findings from a meta-analysis performed by Leeder and colleagues[31] suggested that CWI provides no additional benefit for alleviating soreness following eccentric exercise 24 hours post exercise. In a similar vein, CWT has also been shown to have no statistical benefit on perceptual measures, even following excessively fatiguing tasks such as supra-maximal eccentric leg press.[14] However, Leeder and colleagues[31] reported that cold water may improve soreness following other forms of fatiguing exercise, such as basketball, netball, repeat sprint exercise and cycling.

Practical Applications

As neither CWI nor CWT improved the short-term recovery following a resistance training, coaches and athletes should reconsider the scheduling of hydrotherapy where there is limited time between training or competition (<4 hours).

Conclusions

Neither CWI or CWT improved recovery of physical or perceptual measures following a conventional resistance protocol compared to a control intervention up to four hours post recovery.

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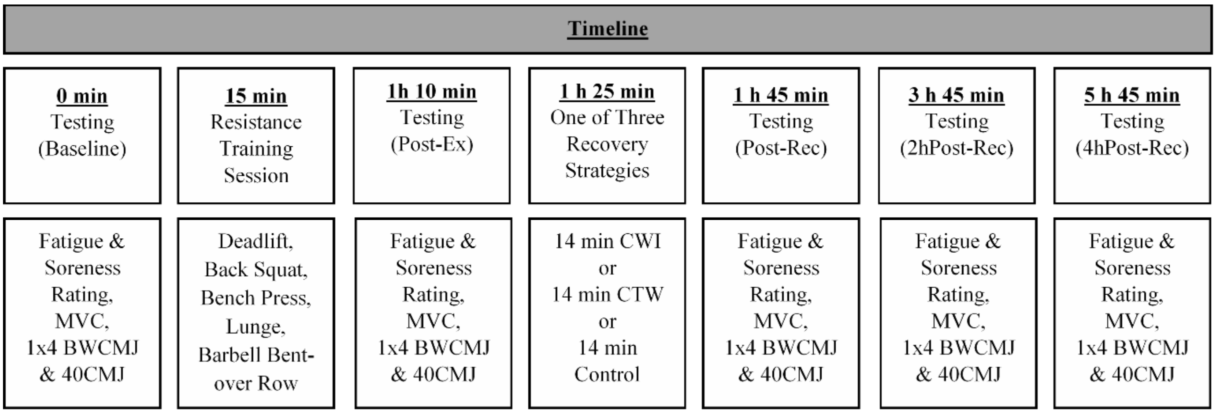

Figure 1. Timeline of testing, training and recovery. Post-Ex, immediately post resistance training; Post-Rec, 5 minutes post recovery; 2h Post-Rec, two hours post recovery; 4h Post-Rec, four hours post recovery; CWT, contrast water therapy; CWI, cold water immersion; MVC, maximal voluntary contraction; BWCMJ, bodyweight countermovement jump; 40CMJ, 40-kg countermovement jump.

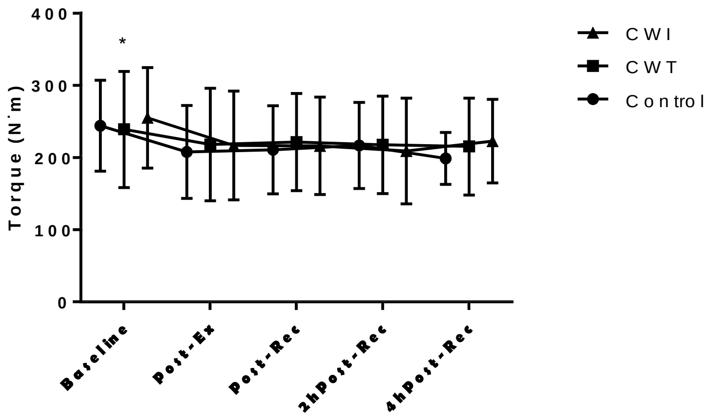

Figure 2. Changes in knee extensor maximal voluntary contraction following a resistance training session and different recovery strategies. CWI, cold water immersion; CWT, contrast water therapy; Post-Ex, post-exercise; Post-Rec, post-recovery. * Baseline data significantly different (P <0.001) to all time points in all conditions.

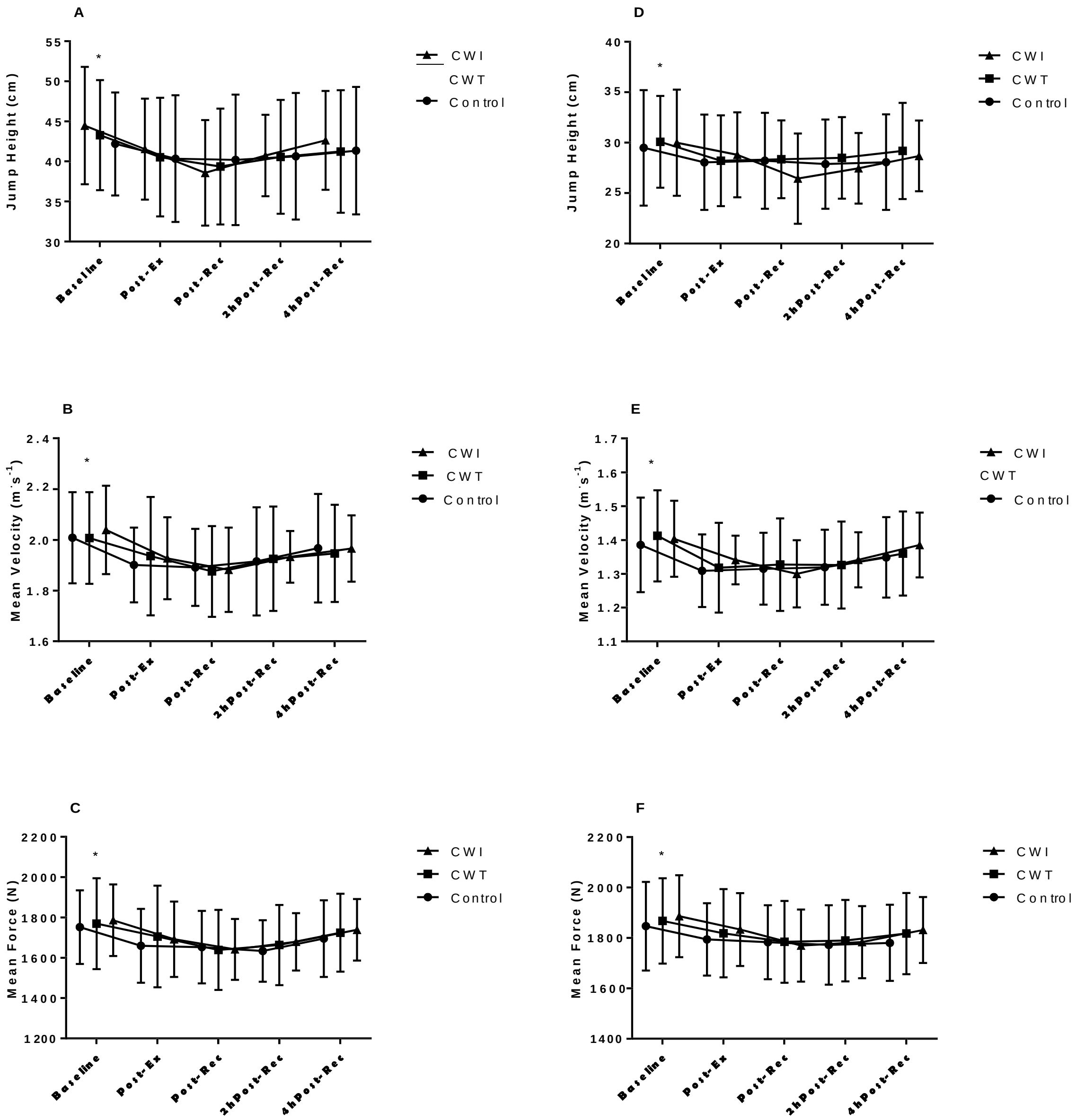

Figure 3. Changes in countermovement jump variables following a resistance training session and different recovery strategies. A-C, measures taken from bodyweight countermovement jumps. D-F, measures taken from 40 kg countermovement jumps. CWI, cold water immersion; CWT, contrast water therapy; Post-Ex, post-exercise; Post-Rec, post-recovery. * Baseline data significantly different (P <0.001) to all time points in all conditions.

Table 1. Resistance training protocol.

Exercise	Sets x Repetitions	Intensity	Rest
Deadlift	3x5	6 RM	4 min
Back Squat	3x10	11RM	3 min
Bench Press	3x10	11RM	2 min
Barbell Lunge	3x10 Each Leg	11RM	3 min
Barbell Bent-over Row	3x10	11RM	2 min

RM = Repetition maximum.

Table 2. Measures of perceived fatigue and soreness prior to and following a resistance training session and recovery strategy.

		Baseline	Post-Ex	Post-Rec	2hPost-Rec	4hPost-Rec
Fatigue*^ (AU)	Control	1.6 ± 0.9	5.3 ± 2.2	3.9 ± 1.7	3.3 ± 1.4	3.3 ± 1.2
	CWT	1.9 ± 1.0	5.6 ± 1.9	3.2 ± 1.3	2.7 ± 1.2	2.6 ± 1.3
	CWI	1.7 ± 0.8	5.1 ± 2.2	2.8 ± 1.2	2.8 ± 0.9	3.0 ± 1.0
Soreness*^ (AU)	Control	1.7 ± 0.8	5.0 ± 2.1	4.3 ± 1.5	4.4 ± 1.7	3.7 ± 1.1
	CWT	1.8 ± 0.8	4.2 ± 2.0	3.5 ± 1.4	3.5 ± 1.6	3.0 ± 1.8
	CWI	2.0 ± 1.2	3.8 ± 2.1	3.4 ± 1.8	3.3 ± 1.2	3.6 ± 1.7

Post-Ex, immediately post a resistance training session; Post-Rec, immediately post one of three recovery strategies; 2hPost-Rec, two hours post one of three recovery strategies; 4hPost-Rec, four hours post one of three recovery strategies; CWT, contrast water therapy; CWI, cold water immersion; AU, arbitrary units. * Values increased significantly ($p<0.05$) compared to baseline at all time points in all conditions; ^ values decreased significantly ($p<0.05$) compared to Post-Ex at all time points in all conditions.