Evaluation of Hydrotherapy, Using Passive Tests and Power Tests, for Recovery Across a Cyclic Week of Competitive Rugby Union

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Abstract

Higgins, TR, Climstein, M, and Cameron, M. Evaluation of hydrotherapy, using passive tests and power tests, for recovery across a cyclic week of competitive rugby union. *J Strength Cond Res* 27(4): 954–965, 2013—In team sports, a cycle of training, competition, and recovery occurs weekly during the competitive season. In this research, we evaluated hydrotherapy for recovery from a simulated game of rugby union tracked over a week of training. Twenty-four experienced male rugby union players (mean ± *SD* age 19.46 ± 0.82 years, weight 82.38 ± 11.12 kg, height 178.54 ± 5.75 cm) were randomly divided into 3 groups: cold water immersion ($n = 8$), contrast bath therapy ($n = 8$), and a control group ($n = 8$). The 2 forms of hydrotherapy were administered immediately after a simulated rugby game. Testing was conducted 1 hour before the game and at 5 intervals postgame: 1, 48, 72, 96, and 144 hours. Dependent variables included countermovement jump, 10- and 40-m sprints, sessional rating of perceived exertion (RPE), flexibility, thigh circumference, and self-reported delayed onset muscle soreness (DOMS). Significant differences in DOMS were found between the cold water immersion and contrast bath groups at 48 hours post intervention ($p = 0.02$), and between the control and contrast bath groups at 72 ($p = 0.03$) and 96 ($p = 0.04$) hours post intervention. Cold water immersion and contrast bath groups reported significantly different RPE at 72 hours ($p = ?$) and 96 hours post ($p = 0.05$) intervention. Athletes' perceptions of muscle soreness and sessional RPE scores for training were greater in the contrast bath group (20%) after the simulated game and throughout the training week. Although results from passive and power tests were inconclusive in determining whether cold water immersion or passive recovery was more effective in attenuating fatigue, results indicated contrast baths had little benefit in enhancing recovery during a cyclic week of rugby union.

Key Words hydrotherapy, team sport, sports performance, rugby union

Introduction

Currently, players of elite sport cycle through habitual activity across the season, usually based on principles of periodization of training (6). During a competitive season, in many team sports, a cycle of training, competition and recovery occurs over each week throughout the season. (15). This cyclic activity may result in players accumulating fatigue as the season progresses; the quick turnaround between training and competition may not provide sufficient time for players to fully recover (15). It is important, therefore, that optimal recovery strategies are identified and implemented to maximize athletic performance through effective recovery.

The weekly activity during rugby union competition includes a competition game and then a period of relative rest, generally between 48 and 72 hours, until training for the next competition game is recommenced. In professional rugby union, the training week usually consists of 4 field sessions including skills, unit work (scrums, line-outs, and backline moves), conditioning, team runs, and 2–3 weight sessions. With the training load and the potential accumulation of fatigue, importance is placed on ensuring that recovery has occurred after the previous game and before commencement of the next competitive game.

Despite the common use of hydrotherapy as a recovery strategy in elite sport there is little research available demonstrating effectiveness (7,9,10,11,16), and a paucity of evidence supporting hydrotherapy to enhance recovery from the training load associated with a typical week in rugby union. Of interest to team coaches, athletes, and strength and conditioning coaches is the actual effectiveness of hydrotherapy relevant to their work, therefore, the purpose of this research was to

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Table 1. Mean scores across dependent variables.*

	Base line		Post 1 h		Post 48 h		Post 72 h		Post 96 h		Post 144 h	
	$\dot{x}$	*SD*	$\dot{x}$	*SD*	$\dot{x}$	*SD*	$\dot{x}$	*SD*	$\dot{x}$	*SD*	$\dot{x}$	*SD*
Flex												
Control	8.94	7.19	7.94	7.06	9.56	6.01	9.00	6.16	9.25	4.80	10.88	5.25
CWI	12.50	8.05	12.00	7.91	13.44	6.76	13.50	7.37	13.88	7.08	13.06	6.41
Contrast	10.31	9.50	9.94	9.82	9.75	8.24	11.13	8.10	10.13	8.76	11.38	8.25
DOMS												
Control	40.68	7.92	30.92	4.58	32.38	5.74	38.34	6.63	32.60	7.92	33.27	5.33
CWI	38.98	8.65	28.98	7.91	33.62	5.60	34.07	2.88	33.28	3.97	28.92	3.97
Contrast	45.03	7.60	30.83	4.16	29.97	6.56	32.88	4.04	32.42	4.07	26.88	7.08
Circumf												
Control	56.13	3.10	56.50	3.27	56.69	4.31	56.25	4.33	57.63	4.45	57.06	4.81
CWI	57.31	4.17	57.81	4.57	58.06	4.29	58.88	4.29	60.31	5.21	59.63	5.36
Contrast	56.50	6.52	56.69	6.77	57.94	5.49	58.75	6.32	59.63	6.45	58.94	5.50
CMJ												
Control	1.27	0.38	1.16	0.42	1.30	0.56	1.41	0.85	1.37	0.93	1.10	0.33
CWI	1.39	0.53	1.18	0.53	1.32	0.49	1.29	0.52	1.29	0.39	1.19	0.36
Contrast	1.15	0.40	1.01	0.33	1.08	0.27	1.18	0.30	1.06	0.25	1.04	0.23

*CWI = cold water immersion; DOMS = delayed onset muscle soreness, measured on a Chatillon gauge with visual analog scale, where higher scores represent greater muscle soreness; Flex = flexibility as measured in a sit-n-reach measured in centimeters; Circumf = measuring swelling in the upper leg circumference brought about by osmotic fluid shift, where higher scores represent greater swelling; CMJ = countermovement jump measured on a portable force platform reported as a ratio of body weight.

evaluate 2 forms of hydrotherapy in promoting recovery across the weekly cycle of game and training in rugby union.

Methods

Experimental Approach to the Problem

Despite the widespread use of cold water immersion and contrast baths as a postmatch recovery strategy in rugby union, there is relatively little evidence supporting its use. To address the null hypothesis that neither cold water immersion or contrast baths protocols would have a significant effect upon muscle pain measures, flexibility, swelling, power performance, and perceptions of load, the between-groups study examined the effectiveness of three different recovery protocols on these markers of fatigue. The aim of this study was to provide information for coaches and highly trained players in rugby union on the effectiveness of hydrotherapy as a recovery protocol from rugby union.

Subjects

This study was performed with highly trained male participants ($n = 24$) from an under-20 rugby union team (mean ± *SD*, age 19.5 ± 0.8 years, body mass 82.38 kg ± 11.12 kg, height 179 SD ± 6 cm). The study was conducted after 26 weeks of training, which included 10 weeks of preseason training (5.5 hours/3 sessions weekly), followed by 16 weeks of the scheduled 22-week competition (6.5 hours/3 sessions-weekly).

Preseaon phase demands. Preseason training included 2 weekly training sessions, a Saturday beach sessions (first 6 weeks) and trial games (weeks 7–9). Training sessions were structured to include a 15-minute warm-up followed by 40 minutes (first 6 weeks) and 20 minutes (weeks 7–10) of conditioning. Conditioning focused on speed and acceleration running drills, contact drills and small-sided games. Work-to-rest ratio ranged from 1: 2–3 (first 6 weeks) to 1:1 and 2:1 (weeks 7–10). After the conditioning phase, training of rugby skills became the focus. Intensity of the conditioning elements ranged between 75% HRmax and 95% HRmax. Skill set drills intensity ranged between 50% HRmax and 70% HRmax.

Beach sessions were structured around conditioning elements only. Each session commenced with a 15-minute warm-up followed by 70 minutes of conditioning. The conditioning included speed and agility drills, wrestling drills, small-sided games, and team-based relay shuttles. Intensity of the beach sessions ranged between 70% HRmax and 90% HRmax with a work-to-rest ratio of 1:3.

After 6 weeks, the beach training sessions where replaced with trial games of rugby union for 3 weeks. The last Saturday before commencement of competition was a scheduled rest day to mark the end of preseason training. Trial games were played with standard rules of the game, but the first 2 trials were played with 20-minute periods. The players would rotate throughout the day, with most players competing in three 20-minute periods. The third trial was played under standard rules with 30-minute periods. The players

Table 2. Analysis of covariance table comparing 144 hours post against 96 hours post.

	Sig. dif	*SD*	$\dot{x}$ Dif	η_p^2
CWI vs. control				
CMJ	0.42	0.36	0.12	0.04
Flexibility	0.01*	6.41	−2.14	0.33†
Circumference	0.92	5.36	0.07	0.00
DOMS	0.15	3.97	−4.25	0.21†
Control vs. contrast bath				
CMJ	0.65	0.23	−0.32	0.04
Flexibility	0.65	8.25	−0.32	0.33†
Circumference	0.98	5.50	0.02	0.00
DOMS	0.04*	7.08	−6.42	0.21†
CWI vs. contrast bath				
CMJ	0.49	0.36	0.10	0.04
Flexibility	0.02*	6.41	−1.82	0.33†
Circumference	0.95	5.36	0.05	0.00
DOMS	0.46	3.97	2.16	0.21†

*Significant difference between 144 hours post scores and 96 hours post scores.
†Identifies a large effect identifying a strong association between time points and group membership.

elements ranged between 85% HRmax and 100% HRmax, with a work-to-rest ratio ranging from 1–3:1. The remainder of the training sessions was structured around skills, rugby union units, team play and semiopposed runs. Intensity ranged from 50% HRmax to 85% HRmax. Distance covered per session during the preseason phase ranged from 6,000 to 7,200 m and throughout the competition phase of the season ranged from 6,000 to 6,500 m.

Study design. The study was conducted over 6 consecutive days during the team's regularly scheduled game time 15:00–16:30 hours and training time 18:00–20:00 hours. Environmental conditions during the week were constant with

would rotate throughout the day, with majority of players competing in two 30-minute periods.

Competition phase demands. During the competition phase, 2 training sessions were conducted each week. Training sessions were structured to include a 10-minute warm-up followed by a conditioning period of 10–20 minutes. Conditioning sessions varied between sprint work and small-sided games. From five seasons of rugby union training sessions with the use of GPS data trackers, intensity of conditioning

no rain. Temperatures ranged from 12 to 15° C at training and 18–20° C during the simulated game.

All the subjects had no history of recent musculoskeletal injury and were free of illness during the testing period. They were instructed not to perform any physical activity (other than incidental walking), use saunas or hot spas, or take any nonsteroidal anti-inflammatory analgesic drugs during the 48-hour period before or during the testing period. The participants were also instructed to refrain from consuming alcohol 48 hours before and during the testing. Each participant signed an informed consent form before taking part in the study design was approved by The Australian Catholic University's Human Research Ethics Committee (N200708-24). We excluded from our participant pool, players who were involved in labor-intensive jobs, and those who had either been injured or suffered an illness within 4 weeks before, or during the study period.

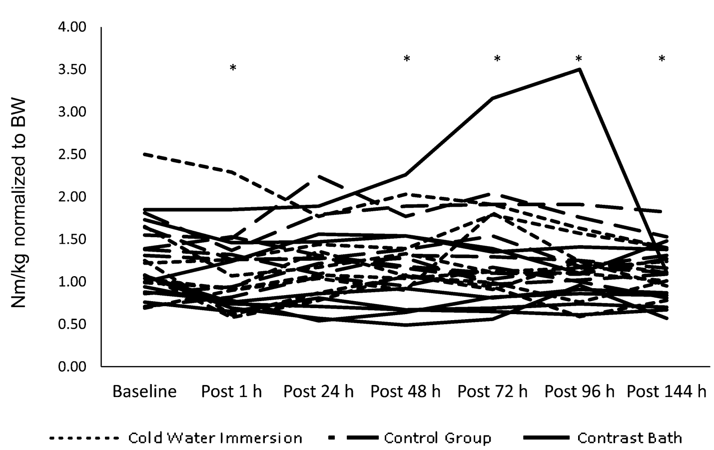

Figure 1. Change in peak force during countermovement jump performance (newton meter per kilogram) during the study. *Significant difference $p < 0.005–0.000$, no treatment interaction.

Measures

Physiological testing began with the sit-n-reach test (12) with the best of 3 attempts recorded. The participants sat with legs straight with shoes off and feet against the sit-n-reach box.

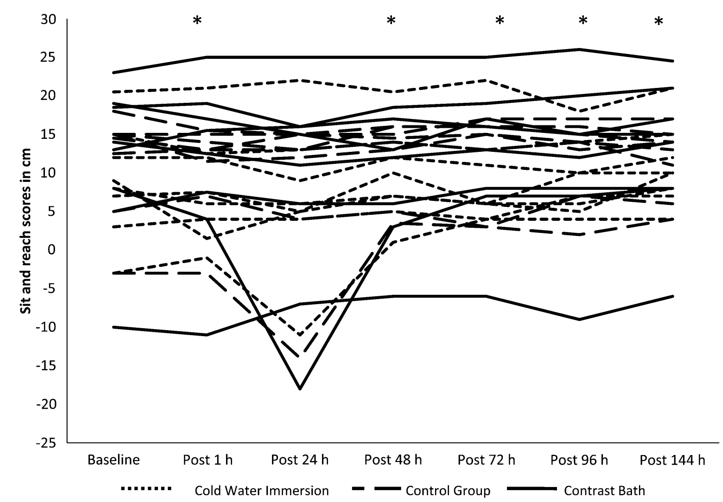

Figure 2. Change in sit-and-reach-flexibility (centimeters) during the study. *Significant difference $p < 0.000$, no treatment interaction.

The participants would place hands one on top of the other before bending forward and pushing the marker along the sit-n-reach box. Circumfrence measurements of both lower limbs were conducted using an anthropometric tape measure (19), to indicate any acute changes in thigh volume previously been reported to occur due to osmotic fluid shifts or inflammation (24). To fix thigh measurement sites, subjects' skin was marked with a permanent felt marker 5 cm above the superior aspect of the patella (17) and then a second anatomical point a further 8 cm superior (17) on both the biceps femoris and rectus femoris.

Individual participants' perception of pain were recorded as pressure to pain threshold measurements associated with delayed onset muscle soreness (DOMS). Using a visual analog scale (VAS; 0–100mm) (17) and a handheld pressure algometer using a 1.2-cm diameter head (Chatillon DFX series, FL, USA), pressure was applied at the midpoint between the top of the patella and the superior iliac crest in the rectus femoris and biceps femoris. The participants were instructed to indicate when the pain reached 5 on the visual analogue pain scale (VAS; 0–10cm). The force in Newtons per meter squared applied to attain a level of 5 was recorded.

After the passive tests were completed, tests of power were conducted. Power output was initially accessed via a countermovement jump (CMJ) using a portable jump mat (Quattro Jump, Kistler, Switzerland) measuring peak force output in Newton meters normalized to body weight (Newton meters per kilogram). Three jumps were conducted with the highest value recorded (8). The participants then performed three 40-m sprint trials (8) through timing gates (Swift Performance, Sydney, Australia). The fastest of the 3 trials was recorded.

Procedure

All the participants performed a warm-up, which was identical to the team's standardized pregame warm-up conducted before competition games. The warm-up commenced with the participants performing a dynamic walking lunge for 25 m followed by a walking sumo squat for 25 m. Dynamic flexibility exercises were conducted in a 30-m grid by all participants simultaneously. Dynamic flexibility exercises included butt kicks, high knees, lateral steps, fast feet, and finally crossovers. The participants then performed 10 swing throughs and 10 swings across with each leg. In addition, participants performed dynamic groin lunges and calf pumps. Total warm-up duration was 25 minutes.

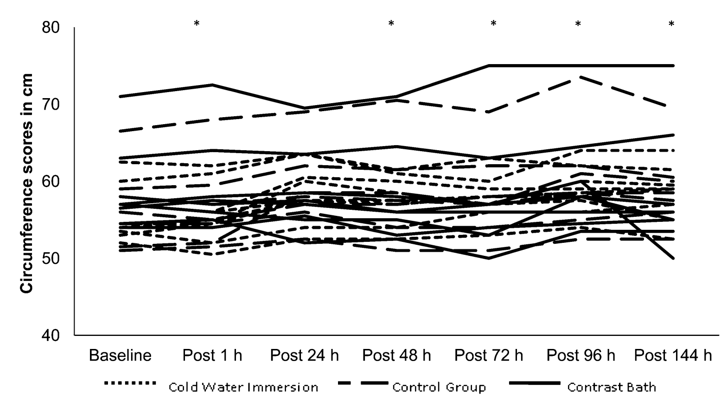

Figure 3. Change in peak thigh circumference (centimeters) during the study. *Significant difference $p < 0.000$, no treatment interaction.

After the warm-up was completed, the participants commenced the simulated game of rugby union. Through the trials

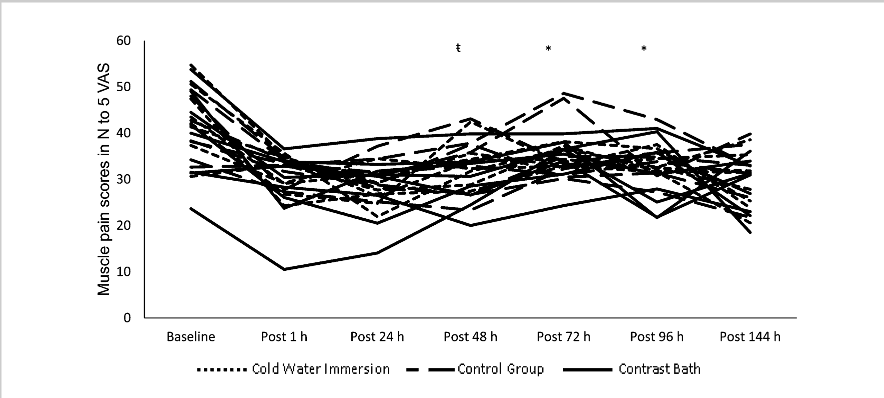

Figure 4. Change in muscle pain during the study. ‡Significant difference CWI vs Contrast $p = 0.02$; *Significant difference Control vs Contrast $p = 0.03$ and 0.04.

and study, each station was staffed by 2 researchers who assisted with data collection. Researchers underwent training and familiarization of each station before the testing.

Immediately after the completion of the circuit, the participants were randomly assigned to 1 of 3 intervention protocols: cold water immersion ($n = 8$), contrast baths ($n = 8$), or passive recovery (control, $n = 8$).

Cold water protocol: Participants were required to climb into the cold water immersion and assume a seated, upright position. Water depth was individualized to each participant's superior iliac spines (17). Temperature ranged between 10 and 12° C (10,22). The participants underwent 2 by 5-minute immersions in the cold water separated by 2.5 minutes seated out of the baths at room temperature (10).

Contrast bath protocol: The contrast bath protocol involved alternating from cold water baths (10–12° C) to warm water baths (38–40° C), spending 60 seconds in each. The participants performed 5 cycles in each bath for a total of 10 minutes (21). Cold water and warm water baths were adjacent to one another. A researcher monitored time using a standard stop watch (Seiko, Japan) and instructed the participants to change recovery conditions, stepping from the cold water immersion bath to the adjacent hot water bath, every minute.

Commercially available 220-L storage tubs were used for the baths (cold water and warm water baths). Temperatures were monitored with floating temperature gauges; ice and hot water respectively, were added when required as temperatures rose to 11.5° C (cold water immersion) or fell to 38.5° C (warm water bath).

The control group undertook a passive recovery strategy involving sitting for 10 minutes in thermoneutral environment. Testing was conducted 1 hour before simulated rugby union game and again 1, 48, 72, 96, and 144 hours postsimulated game.

The participants undertook a weekly training schedule, that included the previously mentioned testing protocols at the commencement of each training session. On each of the 3 training session days, testing went for approximately 30 minutes, followed by 90-minute training sessions. Training loads during these training sessions were quantified using sessional rating of perceived exertion (RPE) scores recorded as arbitrary units (AU) (1). The testing protocol conducted at base line was repeated identically at each of the subsequent test times.

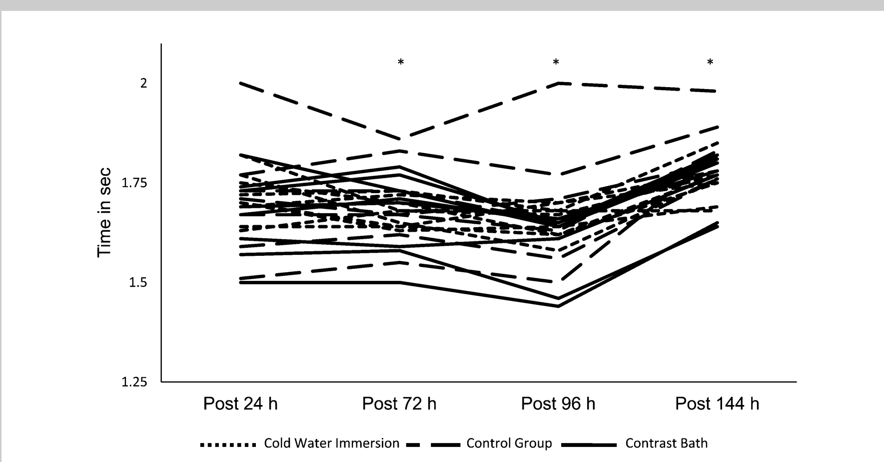

Figure 5. Change in 10-m sprint times during the study. *Significant difference $p < 0.01$, no treatment interaction.

First Training Session, 48 Hours Post

The first training session, conducted 48 hours after the simulated game, was structured in 15-minute blocks with participants allowed 2-minute recovery and hydration breaks between blocks. Water was provided at ambient temperature at the end of each drill. During these breaks, participants were given instructions for the next drill.

In the first drill, the participants conducted 3 sets of six 40-m sprints followed by 60-m

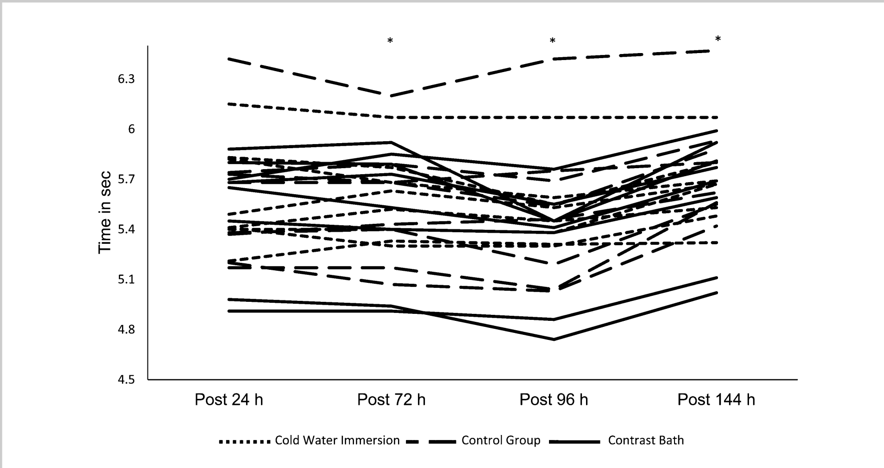

Figure 6. Change in 40-m sprint times during the study. *Significant difference $p < 0.000$, no treatment interaction.

jogging (active recovery), with each sprint performed at 30-second intervals and completed in <7 seconds. Participants were granted a 60-second rest period after each set. The participants performed, in total, 18, 40-m sprints, covering a total of 720-m sprinting and 1,080-m jogging for active recovery.

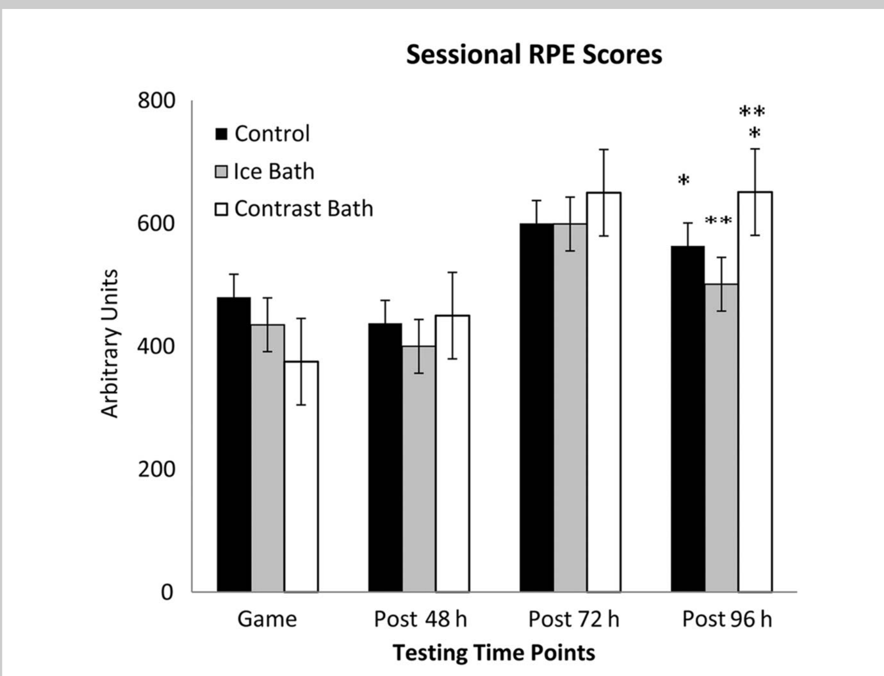

Figure 7. Change in sessional rating of perceived exertion scores during the study. Data are mean ± *SD*. Sessional RPE scores recorded in arbitrary units (Arbitrary units = RPE multi Training time in min). *Significant difference between control group and contrast baths ($p = 0.04$). **Significant difference between cold water immersion and contrast baths ($p = 0.05$).

For the second drill a rectangle, 30 m by 15 m, was set up using 6 cones. Two other cones were placed in the center of the rectangle, 1 m apart. The participants were split into 2 groups, 1 group held hit shields representing the attacking players; the second group represented the defenders. Players started from the same end of the rectangle from opposite corners. At the same time, the first player from each group ran toward the 2 cones in the center. The attacking player straightened up as he ran through the gate, the defending player aligned himself on the inside shoulder as he made his tackle, striking both the shield and player. After the tackle, players swapped groups, attacker handed over the shield to the defender. The 2 groups' cycled through 4 times with the process repeated from each point of the rectangle.

The third drill was a 4-phase fitness drill. A grid 20 m long and 10 m wide was set up with training cones placed every 5 m, dividing the grid into 4 sections. Three tackle bags were placed in the first section and held by the recovery group, with each participant carrying a hit shield.

The players work in threes against an opposing group of 3. The working group started in the first section, while the opposing group rested at tackle bags, each with a hit shield. On the call of up, the working group hit the tackle bags, then ran backwards around the cone to the second section, while the opposing group mirrored their move to the second section. The working group moves up as a defensive line to make tackles on hit shields. The procedure was repeated through the third and fourth sections. Each group cycled through 3 times before swapping with the opposing group.

At the completion of the 3 fitness-based drills, the players broke into forwards and backs

Table 3. Partial eta square values.

	Post 1 h	Post 48 h	Post 72 h	Post 96 h	Post 144 h
CMJ	0.02	0.03	0.04	0.04	0.01
Flexibility	0.02	0.11	0.07	0.12*	0.01
Circumf	0.02	0.04	0.15*	0.09	0.09
DOMS	0.02	0.25*	0.23*	0.04	0.21*

*An effect size indicating large group association.

for unit training. Forwards conducted line out drills, whilst the backs conducted backline plays. Unit drills ran for 20 minutes; the players then spent the final 20 minutes of the session in semicontested play. Semicontested play consists of a competitive game of rugby union, however, instead of full tackles, the players performed a 2-handed grab, with the attacking player accepting the tackle and going to ground.

Second Training Session, 72 Hours Post

The second training session, conducted 72 hours after the simulated game, was structured as per the first training session, in 15-minute blocks with the participants granted a 2-minute recovery and hydration break, and water provided at ambient temperature at the end of each drill. During the break, the participants were given instructions for the next drill.

The first fitness-based drill commenced with a sprint push-up drill, in a grid with training cones placed at 0, 20, and 40 m. Participants lined up on the cones at 0 m, on the call of "go", they sprinted to the 20-m cones then jogged to the 40-m cones, stopped, and turned around to prepare for next sprint. At 10 seconds after the first sprint began, the second one commenced. The series was repeated for 6 sprints. This phase of the drill lasted for 60 seconds, then the sprint/push-up phase commenced. Participants ran to the 20-m mark, performed 8 push-ups, then ran back to the start line. At 20 second intervals, they repeated the format for a total of nine drills over 3 minutes. The participants then perform 6 sprint drills again as above, followed by a 20-m run then 7 crunches at 20-second intervals, 9 times, as per push-up drill.

The second fitness-based drill was a pick'n'go drill, set in a grid 10 m long and 15 m wide. The ruck moved diagonally to the opposite corner. Teams then swapped ball possession. The participants are set in a ruck position, held. One participant is on the ground presenting the ball, participants' bridge and protect ball. Defending participants' position is a tight defensive pattern. Pick'n'go is always to the right. Participants' pick and go tight to the ruck for 2 paces. Attacking participants roll right to protect the ball and pick and go again. Defending participants continue to roll left to defend the pick'n'go.

The third fitness-based drill was a speed endurance drill. A rectangle grid was marked out with training cones 40 m by 20 m. The participants were grouped at each corner post. At the sound of a whistle, the participants run to the next post in an anti-clockwise direction. At the next whistle, they run to the next post. The process was continued for the specified time (15 minutes). Initial interval was 12 seconds, each leg for 4 laps. The next 6 laps were run at an interval of 10 seconds then finally the last 6 laps were run at intervals of 8 seconds. The 40-m leg was the working leg with the 20-m leg an active recovery leg.

As with the first training session, at the completion of the fitness-based drills, the participants broke into 20 minutes of unit skill followed by 20 minutes of a semicontested play, consisting of a game of rugby union.

Table 4. Magnitude of change from base line scores (Cohen's *d*).*

Treatment	Post 1 h	Post 48 h	Post 72 h	Post 96 h	Post 144 h
Control					
CMJ	−0.28	0.08	0.39	0.28	−0.44
Flexibility	−0.14	0.09	0.01	0.04	0.27
Circumf	0.12	0.18	0.04	0.48	0.3
DOMS	−1.23	−1.05	−0.30	−1.02	−0.93
CWI					
CMJ	−0.39	−0.13	−0.17	−0.17	−0.36
Flexibility	−0.06	0.12	0.12	0.17	0.07
Circumf	0.12	0.18	0.38	0.72	0.56
DOMS	−1.16	−0.62	−0.57	−0.66	−1.16
Contrast					
CMJ	−0.35	−0.16	0.08	−0.22	−0.28
Flexibility	−0.04	−0.06	0.09	−0.02	0.11
Circumf	0.03	0.22	0.34	0.48	0.37
DOMS	−1.87	−1.98	−1.60	−1.66	−2.39

*Negative Cohen's *d* indicates posttest scores above base line scores.

Third Training Session, 96 Hours Post

The third training session, conducted 96 hours after the simulated game was structured in 15-minute blocks with participants granted a 2-minute recovery and hydration break, water was provided at ambient temperature at the end of each drill. During this period, the participants were given instructions for the next drill. The fitness-based drills conducted in the first training session were replicated in the third training session.

Statistical Analyses

Statistical power was calculated at 0.60 for a sample size of $N = 24$, with an alpha level of 0.05 and an effect size of 0.8. To verify internal consistency of the simulated game, analysis was conducted during the familiarization process and reported Cronbach's alpha (based on standardized scores) of 0.814, suggesting a relatively high internal consistency.

Independent variables for weekly cyclic activity included 2 treatment groups, contrast baths and cold water immersion and a control group performing seated recovery in a thermal neutral room. The dependent variables included midthigh circumference measurements (CIRCUMF), sit-and-reach test (FLEX), pressure forces (newton meters) via handheld pressure algometer for DOMS scores via VAS, power measurement (normalized to body weight) in CMJ off a portable force platform (Kistler), 10- and 40-m sprint times through timing gates (Swift Performance) and sessional RPE quantified as AU.

Because of initial differences between groups at pretest scores, analysis of covariance (ANCOVA) tests were conducted on posttest scores as the dependent variable, the between-group factor was the treatments and the pretest scores were defined as the covariate. Post hoc analysis may inflate significance, as such and with small sample sizes, Univariate analysis was conducted independently across all variables across each time points to identify changes in between group (treatment) and within group (pretest to posttest). Each time point acted as the covariate against each other time point throughout statistical analysis.

Treatment effects and the level of group association analysis were conducted through effect sizes (Cohen's d and η_p^2). It has been stated that parametric statistical tests based on statistical significant difference fail to address real-world significance of a practical treatment outcome (2,3). Furthermore, effect sizes enable a researcher to interpret measurements, results and intervention outcomes in terms of what is meaningful to the participants (18). Primarily, after an intervention is the participant able to perform more efficiently or function better as opposed to a nonintervention group (18). With this in mind it has been stated that the primary product of research is the measures of effect sizes (4).

Results

Results obtained in this study were passive markers, which included flexibility of the hamstrings (Flex) measured with a sit-n-reach test, DOMS measured in the hamstrings using a VAS chart and a Chatillon gauge, circumference of the upper leg (Circumf) to evaluate osmotic fluid shifts brought about through exercise induced muscle damage and power tests including a CMJ on a portable force platform (Kistler) and 10- and 40-m sprint times. Time points for collection where baseline (pre-1 hour), post 1 hour, post 48 hours, post 72 hours, post 96 hours, and post 144 hours simulated game of rugby union. To analyze and interpret data from this repeated measures design, both omnibus and univariate analyses were applied, and these results are presented consecutively in this section (Table 1).

Given there were differences in pretest scores both between individuals and between groups, a univariate ANCOVA analyses was therefore conducted using baseline scores as covariates. Significant differences in muscle soreness (DOMS) between groups were identified at 1 hour post ($p = 0.05$) and 48 hours post ($p = 0.002$), and limb circumference (CIRCUMF) 1 hour post, 48 hours post, 72 hours post, 96 hours post, and 144 hours post (all comparisons $p < 0.000$). Significant differences were also identified for flexibility (FLEX) between groups at 1 hour post, 48 hours post, 72 hours post, 96 hours post, and 144 hours post (all comparisons $p < 0.000$) (Table 2).

Dependent variables evaluating muscle function for power were CMJ and 10- and 40-m sprint times. Significant differences were identified for CMJ at 1 hour post and 48 hours post ($p < 0.000$), 72 hours post ($p = 0.007$), 96 hours post ($p = 0.005$) and at 144 hours post ($p = 0.007$). Because of technical malfunctions including high dew levels interfering with sensor beams and connection points on timing gates, sprint times at 48 hours post were not available. With available sprint times, significant differences were identified for 10-m sprint times ($p < 0.000$) at 72 hours post and 96 hours post and ($p = 0.01$) at 144 hours post. For 40-m sprint times significant differences were identified at 72 hours post, 96 hours post, and 144 hours post ($p < 0.000$).

Treatment interaction terms were small; suggesting that at the global level there was little variation between groups after the interventions. Across all dependent variables only 3 reported a significant difference. Between-group comparisons identified a significant difference for DOMS at 72 hours post ($p = 0.03$) and 96 hours post ($p = 0.04$) between control and contrast baths. Further significant differences were identified 48 hours post ($p = 0.02$) between cold water immersion and contrast baths (Figures 1–6).

An additional ANCOVA examining the relationship between each dependent variable with each time point acting as the covariate was conducted. Significant differences were identified leading to further post hoc analysis examining treatment interaction being conducted. A significant difference was reported for flexibility between 96 hours post and 144 hours post (cold water immersion versus control, $p = 0.01$ and cold water immersion versus contrast bath, $p = 0.02$). In addition, DOMS reported a significant difference occurring at 48 hours post and 72 hours post (cold water immersion versus contrast, $p = 0.04$ and control vs. contrast bath, $p = 0.03$). Furthermore, a significant difference was identified at 144 hours post (control vs. contrast baths, $p = 0.04$) (Table 4).

To assist in quantifying training loads for statistical analysis, sessional RPE values were recorded 30 minutes postsession and then multiplied with training times in minutes to determine AUs (1). Univariate analysis did not identify significant differences between groups for the simulated game, or for the training sessions at 48 hours post and 72 hours post. A significant difference was recorded between training sessions 72 hours post and 96 hours post ($p = 0.05$) between cold water immersion and contrast baths (Figure 7).

Effect size analysis through partial eta square (η_p^2) identified a large group association for changes from baseline scores for DOMS at 48 hours post, 72 hours post and 144 hours post. Furthermore, a large group association was also identified for circumference at 72 hours post and flexibility at 96 hours post. In relation to other time points, group association was reported to range from only small to medium (Table 3).

Further analysis examining the magnitude of change, via Cohen's *d*, across dependent variables are reported in Table 4. Baseline scores were defined as the control with 1 hour post, 48 hours post, 72 hours post, 96 hours post, and 144 hours post defined as the treatment groups. Magnitude of change is indicative of the physical stressor, the simulated game and the three training sessions having on each dependent variable.

Discussion

The purpose of this research was to examine the efficacy of 2 common hydrotherapy protocols in promoting recovery from a simulated game and a traditional week of activity associated with rugby union. A search through the literature indicated a lack of conclusive results on the recovery protocols despite their common use in professional sporting competitions. Furthermore, research available to date has predominantly examined the acute response to hydrotherapy. With this research, it was expected to identify the efficacy of hydrotherapy as a recovery protocol in field sport across a traditional week of cyclic activity.

At the completion of the last training session (96 hours post), the participants had a rest period of 48 hours coinciding with traditional schedules during competitive seasons. The final testing was scheduled to occur at normal game time. The results indicated that all 3 groups had showed levels of fatigue occurring after the simulated game and continuing fatigue associated with the intensive training held throughout the week. There was a level of residual fatigue still present at 144 hours post regardless of recovery protocol adopted.

Flexibility was the only variable to report scores above baseline levels across all 3 groups at 144 hours post. Scores across each variable indicated each group suffered an immediate deleterious response to scores after the simulated game. Thus, indicating the work load and intensity in the simulated game was sufficient to induce levels of fatigue. Regardless of recovery protocol adopted, all the groups showed trends toward recovery within 48 hours postgame (Figures 1–6). However, this trend toward recovery was somewhat confounded during the training week as a result of continual physical stimulants been applied, in this case, squad training.

Results from this research support research into hydrotherapy for recovery (7,10). Indications are that neither treatments offer a significant response toward recovery over passive recovery when evaluated with traditional measures. Although significant differences were identified between groups in regard to DOMS at 3 time points and flexibility at 1 time point, these findings are insufficient to indicate one recovery protocol to be superior over another.

The large values for group association through partial eta square are in-line with time points and variables that indicated a significant difference. As the remainder of the partial eta square values were between small and medium, again the indications are inconclusive as to identifying one protocol to be superior to another. Although large group associations were identified at 5 time points, there was no consistent pattern toward these results. As previously reported, these results fail to identify a trend toward one protocol over another as being more beneficial in recovery.

When examining the effect of the game simulation upon each variable a detrimental effect was identified for CMJ, Circumf, Flex, and DOMS for each group immediately after the simulated game. All variables reported trivial effects with the exception of DOMS, which reported large effects for each variable. Cohen's *d* values reported were trivial with each group reporting similar trends toward a return to baseline scores across the week, with the exception of DOMS, which continued to report large effects across the week regardless of treatment.

However, in regard to trends reflected by Cohen's *d* for DOMS, both control group and CWI group reported an improvement in DOMS scores across the week indicating trends with the final tests at 144 hours post returning faster toward scores at 1 hour post. Cohen's *d* for the contrast baths group DOMS were indicating a slower return to values reported at 1 hour post. This may indicates a greater level of muscle pain still been recorded by the contrast bath group as a result of the effect of the training week and simulated game.

Muscle soreness scores indicate that the level of muscle soreness remained 20% below baseline scores for the control group and 24% below baseline scores for the CWI group after the weekly schedule. With regard to the contrast bath group, the DOMS readings indicated that scores were 40% below baseline values after the completion of the weekly cycle.

With a substantial difference in muscle soreness reported between both the control group and CWI and the contrast bath group, these findings suggest that contrast baths were least effective in attenuating the effects of DOMS across a weekly cycle, which included a simulated game and squad training.

These findings are in contrast to those of previous research into recovery from simulated team sport (10). Ingram et al. (10) reported that contrast baths facilitated a greater reduction in muscle soreness 24 hours postexercise. However, the difference between timeframes between this study and that of Ingram et al. (10) (24 hours post and weekly) may explain the contrasting findings with regard to DOMS.

With the CMJ, an indicator of lower body power, the control group and CWI group reported a 13% decrease in mean scores with the contrast bath group reporting a decrease of 10%. In contrast, previous research investigating recovery from simulated team sport (10) identified cold water facilitating a more rapid return to isometric forces in the legs (10). The conflicting results may be a result of differing testing protocols with the use of a functional power test with a CMJ in this research as opposed to Ingram et al.'s use of an isometric test. It is the authors' opinion that a functional test is more relevant as a measure for sporting performance.

Of interest during the period from the last training session (96 hours post) to the scheduled next game testing (144 hours post) the control group reported a greater decrease in performance in comparison with both treatment groups. The control group reported a 20% decrease in CMJ compared to CWI (5.5%) and contrast baths (3%).

Circumference measurements of the upper thighs demonstrate similar patterns across all 3 groups (Figure 3). These measurements have previously been used to identify osmotic fluid shifts associated with muscle damage attributed to exercise (21).

At only 1 time point was there any notable difference between circumference measurements between groups, at 72 hours post a notable although nonsignificant ($p = 0.08$) difference between contrast baths and the control group. Contrast baths did display a larger increase in circumference measurement in comparison to the other 2 groups. At the same time point, indications are that the control group had a slight improvement in the osmotic fluid shifts, as displayed by a decrease in circumference measurements, at all other time points, similar trends were reported.

Partial eta squared indicated the recovery treatment had small to large effects on osmotic fluid movements ($\eta_p^2 = 0.02,\ 0.15,\ 0.09$). The link to group association by η_p^2 is more a reflection that contrast baths had less of an effect on osmotic fluid than other groups offering a more beneficial response.

Sessional RPE scores as reported in AU identified a significant difference at 96 hours ($p = 0.015$); further pairwise analysis identified differences between cold water immersion and contrast baths and the control group and contrast baths (Figure 7). Although all the subjects underwent the same squad training with equivalent workloads, as one group, across the 3 training sessions the contrast bath group consistently reported a greater perception of effort culminating with the significant difference at 96 hours post.

As with this research, Rowsell et al. (16) reported that cold water immersion enhanced players perception of leg soreness ($p = 0.004$) and general fatigue ($p = 0.007$) after successive days of competition. The similar findings in both of these studies lead to stronger support for cold water immersion aiding in players perception of effort during successive days of high-intensity activity.

This may be of great importance for coaches and trainers in team sport. With professional rugby union, coaching staff operate on a balance of fitness training, strength training, skill acquisition and team play in preparation for competition. This results in multiple training sessions across the week throughout a competition. If players' perception of back to back, high-intensity sessions can benefit from cold water immersion, players maximum adherence to training tasks may also be maintained.

In percentage terms, the contrast groups' perception of the intensity of work load during squad training sessions was 25% greater than that of the CWI group and 10% greater than that of the control groups. The relevance of these findings may lie in the motivation of the participants at training and their perception of the given task. If player's physical load is governed by their perception of effort while they train, their ability to train at an optimal level may be compromised, if this was to continue throughout the season a situation of ineffectual training by players could eventuate with players subsequent fitness levels falling and with it subsequent game performance.

Mechanisms behind cold water immersion benefitting recovery have been previously reported (10) and include a reduction in edema, neutrophil migration, cell necrosis, and a decrease in cell metabolism. As a result of cold water immersion, the symptoms of DOMS was able to be alleviated to a greater extent than contrast baths. Although the reported mechanisms behind contrast baths may be theoretically possible, which includes aiding removal of metabolic waste products through enhancing the muscle pump via vasoconstriction and vasodilatation, it may be that the time immersed whilst alternating between baths is insufficient to bring significant changes in muscle tissue temperature that would be required to aid in vasoconstriction and vasodilation.

The purpose of this research was to evaluate whether either cold water immersion or contrast baths, would be more beneficial than passive recovery as treatment protocols for recovery from a simulated game of rugby union and a week of high-intensity training. Although the results are inconclusive between cold water immersion and passive recovery this study would indicate that contrast baths have little benefit in enhancing recovery from a simulated game of rugby union and weekly training. Trends indicated that contrast baths proved to be less effective than either cold water immersion or passive recovery in attenuating the effects of leg muscle pain after a cycle weekly activity including a simulated game of rugby union and a week of high-intensity training.

Further, if a player's perception of effort at training is greater than levels coaching staff have assigned to the session, the player may not be able to generate the motivational drive to perform at the required levels. If participants are unable to train at the designated training intensity, generating the optimal levels of a physiological response to enhance and/or maintain athletic performance then performance levels may be compromised. Generally, coaches and trainers design training regimes to meet the requirements of their current competition and if participants underperform at training because of physiological or psychological reasons, resulting athletic performances may be adversely affected.

The absence of a clear indication as to the benefits of hydrotherapy for recovery as measured by traditional one off measurements is in support of previous research into recovery from a simulated team sport (10). Ingram et al. (10) discuss the ability of well-trained athletes to generate near maximal efforts in one of tests. The use of a one off maximal test has traditionally been used to measure recovery of neuromuscular function after performance in laboratory based research. However, in field sport, one off maximal test may not reflect requirements of athletes. Field sports generally require multiple, maximal repeat efforts, as such testing that is more reflective of game situations and performances may be better equipped to identify athletes level of recovery.

Practical Applications

During competitive seasons, athletes undergoing high-intensity fitness training across consecutive days and then conducting 2 cycles of 5 minute cold water immersion after each session may be provided with relief from DOMS and their overall perception of effort at training in comparison to contrast baths. This would allow for coaches and trainers to apply fitness stimulants with an overall intensity high enough to maintain physical performance. However, the further use of contrast baths for recovery across a cyclic week of rugby union needs to be questioned, as indications are that contrast baths offer little benefit in recovery from high-intensity team sport.

Although aiding muscle pump function has been discounted, this would not explain why contrast baths were less effective for recovery than the control group, specifically in regards to DOMS. It has been proposed that short durations of immersion in cold water may increase free-radicals production (25). An increase in free-radicals production above physiological protection and repair mechanisms has been reported to lead to oxidative stress (25). Furthermore, in the event of increasing levels of oxidative stress, subsequent increases in muscle stress would occur. As oxidative stress occurs as a result of aerobic and anaerobic exercise, to induce additional oxidative stress during recovery would delay the recovery process (25). Bleakley and Davison (25) reported the increase in free-radicals production was associated with immersions of less than three minutes. In our research contrast bath immersions included five by one minute immersions, alternating from hot and cold. With the continuing exposure to short durations of CWI, free-radicals production and subsequent increases in oxidative stress would have led to greater stress on muscle than the exercise activity alone. The increase in stress on muscle in the contrast bath group would then have increased the inflammatory response. This increased inflammatory response may be the mechanism explaining the higher scores for DOMS in the contrast bath group compared to both CWI and control groups.

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