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Review Article

Evidence of cold water immersion in team sports recovery: a systematic review

Evidência de imersão em água fria na recuperação de esportes coletivos: uma revisão sistemática

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Abstract

Objective: Systematically reviewing the effects of cold water immersion recovery on performance of team sports. *Methods:* Was searched the electronic database National Library of Medicine (PubMed), without date limitations with the following descriptors: cryotherapy and “cold water immersion” combined with sports, “recovery strategies”, “muscle damage”, soft tissue injuries and athletic performance. Eligible studies should be original research, involve team sports, and apply cold water immersion after the exercise session in lower limbs. *Results:* In all, 22 studies were identified. Large heterogeneity in methodological design and exercise protocols was identified. The population in the studies included rugby athletes; basketball players; football players; futsal players; soccer, handball, hockey and volleyball athletes and team-sport athletes unspecified. *Conclusions:* From the current results, suggests positives effects of cold water immersion on perception of recovery. To power, sprint, force production and heart rate the results are less clear. Further studies should be conducted to evaluate only the acute effect of CWI after exercise protocols.

Keywords: athletic performance, cryotherapy, recovery of function.

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Conflict of interest

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Introduction

Many team sports are frequently exposed to exhaustive training and competition, with limited rest, without allowing adequate time for a natural recovery. Failure to appropriately recover between intense sessions may result in physiological and psychological stresses that can impair performance and increase the risk of injury[1,2].

Interventions to assist the recovery process are therefore crucially important and frequently applied in sporting situations[3]. The use of recovery strategies ensures enhanced performance in subsequent exercise sessions (training and/or competition), and less commitment by persistent muscle pain or decreases in power or speed of movement[4].

Cold water immersion (CWI) has become a popular post exercise recovery intervention used by athletes in various sports and events, following strenuous exercise, to hasten a return to optimal performance[5]. However, results the performance and perceptual effects of cold therapy are varied[2,3].

Vaile et al.[2] reported that exercise-induced delayed onset muscle soreness, isometric strength and squat jump performance improved with CWI recovery. The recovery of sprint performance and maximal voluntary contraction also enhanced 48 h after CWI following 80 min of simulated team sport exercise compared with contrast water immersion and passive recovery[6].

On the other hand, Rowsell et al.[7] identified that ice baths to delay the perception of fatigue and leg soreness in junior elite soccer players over a week of tournament play, although no clear beneficial effect on physical performance was identified.

Controversies in the ability de CWI to facilitate local muscle recovery may be in part explained by divergences in the water immersion protocols, athletes of differing training levels, variable measures of recovery that may not be related to athletic performance, gender effects and the fact that the mechanisms responsible for the beneficial effects of CWI are not fully known[8].

Then, we performed a systematic review of evidence on the effectiveness of CWI as suitable recovery strategies following strenuous exercise, especially on recovery performance in team sports.

Methods

We conducted a systematic review with selection and subsequent analysis of the manuscripts about cryotherapy or CWI in sports performance.

In February of 2014 were collect and analyze publications related to the topic of interest. Searched for articles in the electronic database of National Library of Medicine (PubMed), [advanced search], [all fields], without date limitations for the following descriptors: cryotherapy and "cold water immersion" combined with, sports, "recovery strategies", "muscle damage", soft tissue injuries and athletic performance. Was used the logical operator AND to the combination of the terms used during the search of publications (Table 1).

Table 1
Details of search strategy (articles found).

1. Cryotherapy (503)
1.1 Cryotherapy and Sports (351)
1.2 Cryotherapy and Recovery Strategies (5)
1.3 Cryotherapy and Muscle Damage (31)
1.4 Cryotherapy and Soft Tissue Injuries (61)
1. 5 Cryotherapy and Athletic Performances (55)
2. Cold water Immersion (201)
2.1 Cold Water immersion and Sports (132)
2.2 Cold Water immersion and Recovery Strategies (7)
2.3 Cold Water Immersion and Muscle Damage (21)
2.4 Cold Water Immersion and Soft Tissue Injuries (2)
2.5 Cold Water immersion and Athletic Performances (39)

Specific inclusion criteria identified before dada analysis included (a) original studies; (b) team sports (c) application CWI after the exercise session; (d) in lower limbs; (e) performance analysis. Were excluded systematic review articles, meta-analysis, studies with animals and immersion of whole body.

Initially were conducted the reading of the titles and abstracts of articles found in the search. Subsequently, obtained the selected articles in full and examined according to established inclusion criteria e assessed the methodological quality of studies (Figure 1).

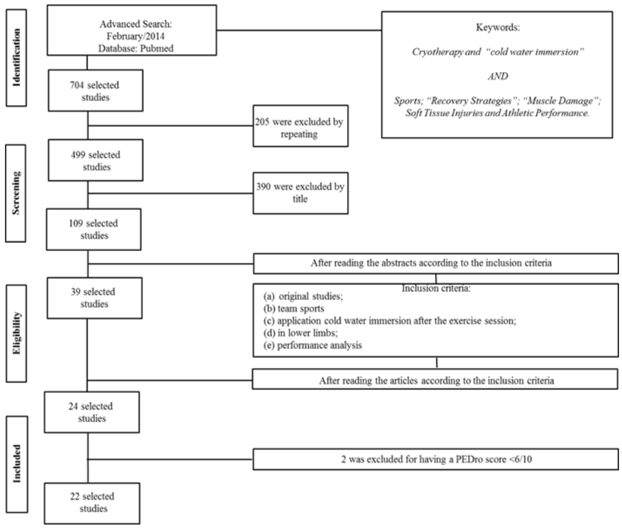

Figure 1. Flow chart of inclusion process of articles used in the systematic review. PEDro (Physiotherapy Evidence Database Scale).

Quality assessment was performed using the Physiotherapy Evidence Database (PEDro) Scale, which is a valid measure of the methodological quality of clinical trials[9]. Each study was rated according to ten separate criteria on the PEDro scale that assess a study's internal validity and statistical reporting, and then totaled to give a score out of 10 (Table 2). Two reviewers applied the PEDro scale to each included study independently, and any scoring discrepancies were resolved through a consensus meeting, with a third reviewer available if necessary. Articles were not included if they scored lower than 6 of possible 10 on the scale. A score of 6/10 was chosen because complete blinding of participants and therapists is impossible when assessing cooling modalities.

Table 2
Physiotherapy Evidence Database scale.

1.	Eligibility criteria were specified (no points awarded).
2.	Subjects were randomly allocated to groups or order in which treatments were received.
3.	Allocation was concealed.
4.	The groups were similar at baseline regarding the most important prognostic indicators.
5.	There was blinding of all subjects.
6.	There was blinding of all therapists who administered the therapy.
7.	There was blinding of all assessors who measured at least 1 key outcome.
8.	Measures of at least 1 key outcome were obtained from 85% of the subjects initially allocated to groups.
9.	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least 1 key outcome were analyzed by "intention to treat."
10.	The results of between-groups statistical comparisons are reported for at least 1 key outcome.
11.	The study provides both point measures of variability for at least one key outcome.

For the analysis of the studies were considered the following aspects: study authors; sample size, population, exercise protocol; intervention used, the variables investigated and performance results.

Results

Two studies were eliminated because of PEDro score[10,11]. The lack of blinding was the most evident methodological flaw in the studies; failure to conceal allocation also was another general methodological limitation of the studies (Table 3). As a result, 22 original studies were included for this review, as shown in Table 4.

The sample sizes of the studies ranged from of 6 to 41 athletes, obtaining a total number of 413 athletes evaluated, with the majority of studies presenting crossover design. The average age of the athletes was 20.22 ± 2.88 years.

The populations in the studies included in this review were rugby athletes; basketball players; football players; futsal players; soccer, handball, hockey and volleyball athletes and team-sport athletes unspecified.

Table 3
Physiotherapy Evidence Database (PEDro) scale scores for each study.

References	Factor 1	2	3	4	5	6	7	8	9	10	11	Total score
Bahnert et al.[10]	1	0	0	1	0	0	0	1	1	1	1	05/10
Cook and Beaven[12]	1	1	0	1	0	0	0	1	1	1	1	06/10
Delextrat et al.[13]	1	1	0	1	0	0	0	1	1	1	1	06/10
Elias et al.[14]	1	1	0	1	0	0	0	1	1	1	1	06/10
Higgins et al.[15]	1	1	0	1	0	0	0	1	1	1	1	06/10
Minett et al.[16]	1	1	0	1	0	0	0	1	1	1	1	06/10
Webb et al.[17]	1	1	0	1	0	0	0	1	1	1	1	06/10
Bastos et al.[18]	1	1	0	1	0	0	0	1	1	1	1	06/10
Elias et al.[19]	1	1	0	1	0	0	0	1	1	1	1	06/10
Higgins et al.[20]	1	1	1	1	0	0	0	1	1	1	1	07/10
Pointon and Duffield[21]	1	1	0	1	0	0	0	1	1	1	1	06/10
Pointon et al.[22]	1	1	0	1	0	0	0	1	1	1	1	06/10
Rupp et al.[23]	1	1	1	1	0	1	1	1	1	1	1	09/10
Ascensao et al.[24]	1	1	0	1	0	0	0	1	1	1	1	06/10
Brophy-Williams et al.[25]	1	1	0	1	0	0	0	1	1	1	1	06/10
De Nardi et al.[26]	1	1	0	1	0	0	0	1	1	1	1	06/10
Higgins et al.[27]	1	1	0	1	0	0	0	1	1	1	1	06/10
Leal Junior et al.[28]	1	1	1	1	1	1	1	1	1	1	1	06/10
Pournot et al.[29]	1	1	0	1	0	0	0	1	1	1	1	06/10
Rowsell et al.[11]	1	0	0	1	0	0	0	0	1	1	1	04/10
Ingram et al.[6]	1	1	0	1	0	0	0	1	1	1	1	06/10
Kinugasa and Kilding[30]	1	1	0	1	0	0	0	1	1	1	1	06/10
Rowsell et al.[7]	1	1	0	1	0	0	0	1	1	1	1	06/10
Montgomery et al.[31]	1	1	0	1	0	0	0	1	1	1	1	06/10

Throughout the varying methods, CWI resulted in an increase in exercise performance in 15 of the 22 different studies [6,12–14,16–22,24,25,29,31].

A range of CWI protocols were employed (Table 5). The water temperature ranged in 5 – 15 ^{0}C, with an average of 11.06 ± 2.08. The depth of immersion ranged between iliac crest for 6 studies, superior iliac spine for 5 studies, mesosternale for 6 studies, umbilicus and xiphoid process for two studies each and gonadal region for one study each. The protocols CWI time ranged from 3 - 20 min, and protocol lasting 15 min was mostly used.

Additionally, in general, studies found examined the effect of chronic CWI in athletes, with assessments ranging from 24 h before exercise to 144 h after exercise. However, the studies that evaluated the effect of CWI immediately after the intervention, few found effective.

Considering the population investigated, beyond sport rugby have the largest number of published studies, can be characterized as the most recent studies in the area of sport CWI and evaluating the performance among 2008 to 2013.

Discussion

A comparison of the protocols presented in the reviewed studies highlights differences in the method of application and time in which an athlete spends in CWI. The efficacy of CWI still has not been clearly established despite the large volume of research. Therefore this systematic review of literature has provided insight into the potential benefits conferred by such interventions that allow practitioners to make an informed decision on their efficacy and application.

Several studies showed improvements in perceived recovery[7,12–15,17,19,21,22,24–26,31]. On the other hand, only two studies failure to find such beneficial of CWI[23,27].

Table 4
Includes studies.

Author(s) and Publication Date	Subjects	Exercise protocol	Intervention	Criterion measures	Conclusions
Cook and Beaven[12]	Male semiprofessional rugby union athletes N = 12 (23.3 ± 1.4 years) Crossover design	60 min high-intensity gym and track-based conditioning session.	CWI; WWI; CON;	1. Core temperature (Tc); [before and after the exercise, 0, 30, 60 min and 24h post ntervention] 2. Subjective ratings of the recovery intervention; [within 5 min post intervention] 3. 5 × 40 m repeated sprint; [24 h after recovery session].	The association between physiological and psychological indices provides improved subsequent performance and important role of individual perception in enhancing training recovery.
Delextrat et al.[13]	Basketball players N = 16 (22.5 ± 3 years)	Three practice sessions basketball (120 min)/one match per week.	CWI; MAS; CON.	1. Perception of overall fatigue; 2. Leg soreness; 3. Perception of pain; [at immediately after the match, immediately and 24 after the intervention] 2. CMJ; 3. Repeated-sprint ability test; [at 24 h after the intervention].	CWI is more useful than MAS in the recovery from basketball matches.
Elias et al.[14]	Australian football players N = 24 (19.9 ± 2.8 years)	Full practice match of Australian football - 75 min.	CWI; CWT; PAS.	1. Repeat-sprint ability (6 x 20 m); 2. Static jump; 3. Countermovement jump; [pre-match and immediately, 24 h and 48 h after the match]. 3. Perceived soreness and fatigue; [immediately, 1 h, 24 h, and 48 h after the match].	CWI was more successful at restoring physical performance and psychometric measures than CWT, with PAS being the poorest.
Higgins et al.[15]	Under-20 rugby union team N = 24 (19.5 ± 0.82 years)	Simulated rugby union game.	CWI; CWT; CON.	1. CMJ; 2. 10 and 40 m sprints; 3. Rating of perceived exertion (RPE); 4. Sit-and-stretch flexibility test; 5. Thigh circumference; 6. DOMS; [at 1 h before the game and at 5 intervals post game: 1, 48, 72, 96, and 144 h].	CWT had little benefit in enhancing recovery during a cyclic week of rugby union.
Minett et al.[16]	Male team-sport athletes N = 9 (21 ± 2 years)	2 x 35 min bouts (bouts 1 and 2) of intermittent-sprint exercise, interspersed by a 15 min mid-exercise passive recovery period.	CWI; MIX; CON.	1. Voluntary force and activation - cerebral oxygenation; 2. Skin temperature (Tsk); [pre and post-exercise, post intervention, 1h and 24 h post exercise] 3. Heart rate (HR) ; Tc; [at 5, 10 min intervals, during exercise, and every 5 min throughout the intervention] 4.Creatine Kinase (CK); C-reactive protein (CRP); [pre, post, 1 h , 24 h post session, pre and post exercise, post intervention, and 1 h and 24 h post exercise] 5. Testosterone; Cortisol [pre, post, 1 h and 24 h post exercise] 6. RPE; [every 5 min during the exercise protocol] 7. Perceived thermal sensation [at 5 min intervals within exercise/intervention]	Improvements in neuromuscular recovery after post-exercise cooling appear to be disassociated with cerebral oxygenation, rather reflecting reductions in thermoregulatory demands to sustain force production.

Table 4 *(continuation)*

Author(s) and Publication Date	Subjects	Exercise protocol	Intervention	Criterion measures	Conclusions
Webb et al.[17]	Professional rugby league players N = 21 (23.5 ± 2.6 years)	Three consecutive National Rugby League competition.	CWI; CWT; ACT.	1. CK; 2. Countermovement jump height (JH); 3. Perceived muscle soreness (PMS); [at 24 h pre-match, 1 h, 18 and 42 h post match].	CWT recovery is recommended post-match for team rugby sports.
Bastos et al.[18]	Young male athletes (soccer, basketball and handball) N = 20 (21 ± 2 years)	High-intensity exercise - constant velocity exhaustive test	CWI; ACT; PAS.	1. Blood lactate concentration ([Lac]); [2 min prior to test, at 3, 5, 7, 9, 11, 13 and 15 min after test] 2. Heart rate variability (HRV) indices [at baseline as well as at 15, 30, 45, 60, 75 and 90 min after test]	CWI results in some improvement in post exercise cardiac autonomic regulation compared to ACT and PAS. Further, ACT is not recommended if the aim is to accelerate the parasympathetic reactivation.
Elias et al.[19]	Australian football players N = 14 (20.9 ± 3.3 years) Crossover design	3 week standardized training of Australian football (AF).	CWI; CWT; PAS.	1. Repeat-sprint ability (6 x 20 m); 2. Countermovement and squat jumps; 3. PMS; 4. Fatigue; [pre training, immediately training and over 48 h post training].	14 min of CWI should be used after AF training.
Higgins et al.[20]	Under-20 rugby union team N = 24 (19.5 ± 0.8 years)	Two simulated rugby union games.	CWI; CWT; CON.	1. Times at each sprinting station; 2. HR; 3. Mean HR; 4. Peak HR; [during simulated game].	CWI and CWT may be more advantageous to athlete's recovery from team sport than CON between successive games of rugby union.
Pointon and Duffield[21]	Male rugby athletes N = 10 (21.0 ± 1.7 years)	Simulated collision sport exercise - 3 sessions (with either tackling (T) or no tackling (CON).	TCWI; TPAS; CON.	1. Sprint time and distance covered; 2. Maximal voluntary contraction (MVC); 3. Voluntary activation (VA); 4. Electromyogram (root mean square RMS); 5. Ratings of perceived muscle soreness (MS); 6. Lactate (La); pH; bicarbonate (HCO3); CK; CRP; aspartate aminotransferase (AST) [before and after exercise, immediately, 2 h and 24 h after recovery].	CWI results in a faster recovery of MVC, VA, and RMS and improves muscle contractile properties and perceptions of soreness after collision-based exercise.
Pointon et al.[22]	Male team-sport athletes (rugby league/union) N = 10 (19.9 ± 1.1 years) Crossover design.	Two sessions of 2 x 30 min intermittent-sprint exercise (ISE).	CWI; CON.	1. Voluntary and evoked neuromuscular function; 2. MS; 3. La; pH; HCO3; CK; CRP; AST; Tc; HR; RPE; 4. Thermal strain and thirst; [at pre- and post-exercise, immediately, 2 h and 24 h post-recovery].	Despite improved acute recovery, CWI resulted in an attenuated MVC 24 h post-recovery.
Rupp et al.[23]	Division I collegiate soccer players N = 22 (19 ± 1.1 years)	Yo-yo intermittent recovery test (YIRT) - at baseline and again 48 h later.	CWI; CON.	1. CMJ; [before YIRT, immediately post- YIRT, and 24 and 48 h post-YIRT] 2. Visual analog scale (VAS) - Perceived fatigue (PF); [immediately, 24 h and 48 h post-YIRT].	CWI performed immediately and 24 h after induced volitional fatigue did not affect subsequent physical performance estimates.
Ascensao et al.[24]	Male soccer players N = 20 (18.2 ± 1.3years)	One match soccer.	CWI; TWI;	1. CK; Myoglobin; CRP; 2. CMJ; Sprint abilities; 6. Maximal isometric quadriceps strength; 7. DOMS; [before, within 30 min of the end, and 24 and 48 h after the match].	CWI immediately after a one-off soccer match reduces muscle damage and discomfort, contributing to a faster recovery of neuromuscular function.
Brophy-Williams et al.[25]	Well trained male athletes (Australian Rules football, n = 7, hockey, n = 1) N = 8 (20.9 ± 1.2 years)	High intensity interval exercise session (HIIS) at 90%Vo2max	CWI ((0)) - 0h CWI (3)) - 3h CON	1. Yoyo Intermittent Recovery test [Level 1] (YRT); 2. Muscle soreness; 3. Totally quality recovery perception (TQRP) questionnaire ; [24 h after HIIS] 3. CRP; [pre-HIIS and pre-YRT]	Immediate CWI resulted in superior next-day YRT performance compared to CON, while delayed (3 h) CWI was also likely to be beneficial. Qualitative analyses suggested that CWI(0) resulted in better performance than CWI(3).
De Nardi et al.[26]	Soccer players N= 18 (15.5 ± 1.0 years)	30 min of training at low intensity, small side's games (4 x 4 min), for a total time of 140 min per day.	CWI; CWT; PAS.	1. Uric acid concentration; Leukocytes; Hemoglobin; Reticulocytes and CK; [before and post training] 2. Axillary temperature; [before training session] 3. RPE; [before daily session] 4. HR; [during exercise] 5. CMJ; 6. 12 x 20 sprints with 20s between sprints; 7. 5' shuttle run; [before training and after recovery].	CWI and CWT did not negatively influence the performances of the athletes. CWI was a reduced perception of fatigue after the training session.

Table 4 *(continuation)*

Author(s) and Publication Date	Subjects	Exercise protocol	Intervention	Criterion measures	Conclusions
Higgins et al.[27]	Under 20 rugby union team N= 26 (19.17 ± 0.83 years)	Warm-up (20 min), fitness training (30 min), skill session (45 min), and opposed team run (20 min).	CWI; CWT; CON.	1. 300-m test; [Wednesday of week 1 of the study and on the fifth week of the study.] 2. Phosphate decrement test; [Monday of week 1 of the study and on the fifth week of the study.].	Effect scores across CWT, CWI and PAS along with subjective reports indicate a trend toward CWT benefiting recovery in rugby. The continued use the 5 min CWI for recovery should be reconsidered based on this research because trends suggest a detrimental effect.
Leal Junior et al.[28]	Male futsal players N = 6 (20.67 ± 2.96 years) Crossover design	Three Wingate cycle tests.	CWI; Active LEDT; Placebo LEDT.	1. La; CK; CRP; [at pre-exercise, post-exercise, and post-treatment];	LEDT has better potential than 5 min of CWIT for improving short-term post-exercise recovery.
Pournot et al.[29]	Highly trained (Football, Rugby, Volleyball) male subjects N = 41 (21.5 ± 4.6 years)	20 min of exhaustive, intermittent exercise.	CWI; TWI; CWT; PAS.	1. 30-s rowing test (P30s); 2. CMJ; 3. MVC of the knee extensor muscles; [at pre-exercise, immediately after the exercise, 1 h after and 24 h later] 4. Leukocyte count; 5. CK; Lactate dehydrogenase (LDH); 6. DOMS; [at pre-exercise, post 1 h and post 24 h].	The practice of CWI and CWT are more effective to promote a faster acute recovery of maximal anaerobic performances (MVC and 30" all-out respectively) after an intermittent exhaustive exercise.
Ingram et al.[6]	Male team-sport athletes N = 11 (27.5 ± 6.0 years)	80 min of simulated team sports exercise + 20 m shuttle run test to exhaustion.	CWI; CWT; CON.	1. 10m × 20m sprints; 2. Isometric strength of quadriceps, hamstrings and hip flexors; [at baseline and 48h] 3. RPE; 4. Self-ratings of muscle soreness of the quadriceps; 5. CK; CRP; [at baseline, 24 h and 48 h].	CWI following exhaustive simulated team sports exercise offers greater recovery benefits than CWT or CON.
Kinugasa and Kilding[30]	Youth soccer players N = 28 (14.3 ± 0.7 years) Crossover design	Three 90 min soccer matches (45 min per half) over 1 week.	CWT; COMB: CWI + ACT; PAS;	1. CJM; 2. HR; Tympanic temperature; 4. Perceived quality of recovery; [at before each match, 10 min after each match, after each recovery method, and after 24 h].	COMB (CWI + ACT) may be effective for young players after intense soccer match play for perceived quality of recovery.
Rowsell et al.[7]	High-performance male junior soccer players N = 20 (15.9 ± 0.6 years)	4 day simulated soccer tournament.	CWI; TWI.	1. JH; 2. HR; 3. RPE after a standard 5 min run; 4. 12 x 20 m repeated sprint test; 5. Intracellular proteins; 6. La and CK; [90 min before each match and 22 h after the final match] 7. Perceptual measures of recovery; [22 h after each match]	Immediate post-match CWI does not affect physical test performance or indices of muscle damage and inflammation but does reduce the perception of general fatigue and leg soreness between matches in tournaments.
Montgomery et al.[31]	Male basketball players N = 29 (19.1 years)	3 day mini tournament involving one full 48-min game per day	CWI CG Carbohydrate + stretching	1. YRT; 2. 20 m acceleration; 3. Basketball line-drill; 4. Basketball-specific agility test; 5. Sit-and-reach flexibility test [pre-tournament, post 4 day] 6. Vertical jump; [pre-tournament, daily competition game - 3 day tournament, post 4 day] 7. Body mass 8. General fatigue scale 9. Visual analogue scale 10.Mid-thigh and mid-calf girths [3 day tournament]	CWI appears to promote better restoration of physical performance measures than carbohydrate + stretching routines and CG.

It is believed that the CWI can improve the perception of recovery and wellness through reduction in nerve conduction velocity associated with increased pain tolerance[32] improves parasympathetic reactivation[33] reduced inflammatory response34 or reduced muscle blood flow[35].

Kinugasa and Kilding[30] showed effects between CWI combined with active recovery (ACT) into perceived quality of recovery, but not had a substantial effect on performance when compared with CWT and PAS (passive recovery). Leal Junior et al.[28] evaluated the effect the light emitting diode therapy (LEDT) and CWI, whereas LEDT present better results than CWI for improving short-term post-exercise recovery.

Higgins et al.[20] indicated that ice baths may be more advantageous to athlete's recovery from team sport than passive rest. Until now, evidence outlining performance benefits of CWI as a recovery strategy remain varied. Of the 22 studies that we analyzed, only three showed improvement related to heart rate (HR) and heart rate variability (HRV). Minett et al.[16] and Pointon et al.[22] showed in their studies that the CWI reduced HR after exercise while Bastos et al.[18] found that CWI results in some improvement in post exercise cardiac autonomic regulation. The CWI may assist recovery from exercise is by restoring cardiac autonomic nervous system (ANS) function, accelerating parasympathetic reactivation following a single bout of submaximal[36] and supramaximal exercise[37].

Jump, sprint abilities and muscle strength are frequently used as reliable means of quantifying exercise-induced muscle damage[38]. Ascensao et al.[24], Delextrat et al.[13], De Nardi et al.[26], Higgins et al.[15] and Rowsell et al.[7] evaluated the effect of CWI on the performance of sprints and no find positive results. Only Cook and Beaven[12], Elias et al.[14], Elias et al.[19], Ingram et al.[6] and Montgomery et al.[31] find that the CWI facilitated a more rapid return to baseline repeated sprint performance.

Table 5
Summary of cold-water immersion protocols.

Author(s) and Publication Date	Temperature (⁰C)	Duration	Depth of immersion	When cooled?
Cook and Beaven[12]	14	15 min	Anterior superior iliac spine	5 min after the exercise
Delextrat et al.[13]	11	5 x 2 min followed by 2 min rest in ambient air	Iliac crest	After the exercise
Elias et al.[14]	12	14 min	Xiphoid process	12 min following exercise
Higgins et al.[15]	10 - 12	2 x 5min followed by 2.5 at room temperature	Superior iliac spines	After the exercise
Minett et al.[16]	10 ± 0.4	20 min	Mesosternale	10 min following exercise
Webb et al.[17]	10 - 12	5 min	Anterior superior iliac spine	1 h following each exercise
Bastos et al.[18]	10 - 15	6 min	Anterior superior iliac spine	After the exercise
Elias et al.[19]	12	14 min	Xiphoid process	After the exercise
Higgins et al.[20]	10 - 12	2 x 5 min followed by 2.5 at room temperature	Superior iliac spines	After the exercise
Pointon and Duffield[21]	9.2 ± 0.2	2 x 9 min followed by 1 min at room temperature	Iliac crest	10 min following exercise
Pointon et al.[22]	8.9 ± 0.9	2 x 9 min followed by 1 min at room temperature	Iliac crest	10 min following exercise
Rupp et al.[23]	12	15 min	Umbilicus	After the exercise and 24 h later
Ascensao et al.24	10	10 min	Iliac crest	After the match
Brophy-Williams et al.[25]	15 ± 1.0	15 min	Mid-sternum	After the exercise and 3 h later
De Nardi et al.[26]	15 ± 0.5	8 min	Iliac spine	After each exercise protocol
Higgins et al.[27]	10 – 12	5 min	Above the waistline	After the exercise
Leal Junior et al.[28]	5 ± 1	5 min	Gonadal region	5 min after the exercise
Pournot et al.[29]	10	15 min	Iliac crest	After the exercise
Ingram et al.[6]	10	2 x 5 min followed by 2.5 at room temperature	Umbilicus	After the exercise and 24 h later
Kinugasa and Kilding[30]	12	3 min	Mesosternale	After exercise
Rowsell et al.[7]	10 ± 0.5	5 x 1 min followed by 1 min at room temperature.	Mesosternale	20 min after the end of each of the four matches
Montgomery et al.[31]	11	5 x 1 min followed by 2 min rest in ambient air	Mesosternale	After the exercise

However, the effect of CWI acting specifically to recovery of muscle power and not muscle strength is an interesting finding with no obvious explanation, so the following proposed mechanisms are speculative. Inter-individual differences in muscle strength are predominated by muscle cross-sectional area46 whereas muscle power involves an intricate interaction of muscle cross-sectional area and excitation-relaxation kinetics[47].

The majority of studies reporting a performance benefit of CWI also report an improved subjection perception of recovery5. Nevertheless, the behavior of cardiac frequency, production of muscle strength, sprint and jump performance after CWI need to be better elucidated in team sports.

Conclusion

This systematic review, suggests positives effects of CWI on perceptual measures recovery in trained athletes. However, power, sprint, force production and heart rate could be improved after CWI, but it is not unanimous.

It must be noted that in the available studies, few investigated the effects of CWI immediately after exercise, presenting controversies, regarding the improvement of performance. There is no consensus on the utilization of CWI immediately following after exercise, in that more studies should be conducted to evaluate the acute effect after exercise.

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