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Using hydrotherapy at different temperatures for promoting recovery in professional athletes

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Abstract
The authors discuss possible uses of hydrotherapy in promoting recovery in professional athletes and provide an overview of literature presenting its current application in sports, whilst emphasizing the need for further research. Understanding the mechanism of action of water used at different temperatures on post-exercise recovery and examining the effectiveness of hydrotherapy methods in athletes will enable the development of optimal treatment regimens.

KEYWORDS: hydrotherapy, post-exercise recovery, cold water immersion, contrast water treatment, hot water immersion.

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Hydrotherapy is commonly used in order to alleviate or remove the effect of intensive cardio workout [3, 12, 25, 41, 42] and to quickly restore a good psychophysical condition in sportspeople [1, 2, 14, 31, 39]. It provides an alternative to other post-exercise recovery-promoting physiotherapy treatments, such as massage, sauna or cryotherapy [11, 12, 30]. Full and partial immersion baths [1, 2, 5, 6, 9, 10, 25, 26, 34, 37, 38, 41, 49, 50, 54] and showers [10, 11, 28, 38] are the most common hydrotherapy procedures. Treatments can be performed at various post-exercise time [16].

It was noted that the efficacy of hydrotherapy in promoting post-exercise recovery may be affected by not only the choice of a procedure, but a number of other factors, such as: the method [1, 10, 11, 22, 26], including water temperature [7, 21, 49, 50, 55] and treatment duration [1, 2, 21, 51], as well as the interval between the end of training and the treatment [1, 9, 11, 39] or individual characteristics, e.g. sex [12]. At the same time, the research focuses on the effects of a one-off treatment [1, 2, 5, 6, 9, 20, 24, 26, 39, 55] or a series of treatments [14, 16, 18, 25, 28, 37, 49, 52].

A number of water-related factors which affect the body, not only temperature, but water pressure (hydrostatic or hydrodynamic), as well as active or passive behaviour during the bath (buoyancy, resistance) need to be considered when planning the use of hydrotherapy in post-exercise recovery [47] (Figure 1). It was also emphasized that optimum strategies for supporting biological regeneration will vary between individuals, depending on the type of fatigue, training intensity and individual efficiency, as well as the bodily ability to adapt to and counteract the effect of such stress [27]. The individual bodily response to treatments also needs to be taken into account [5, 42, 46].

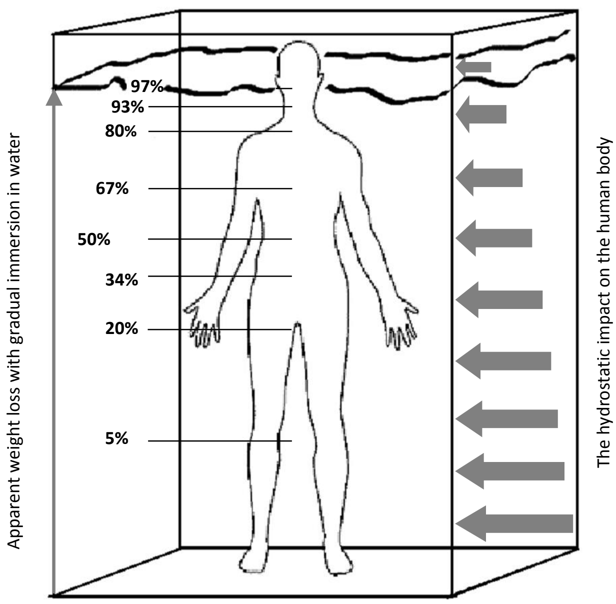


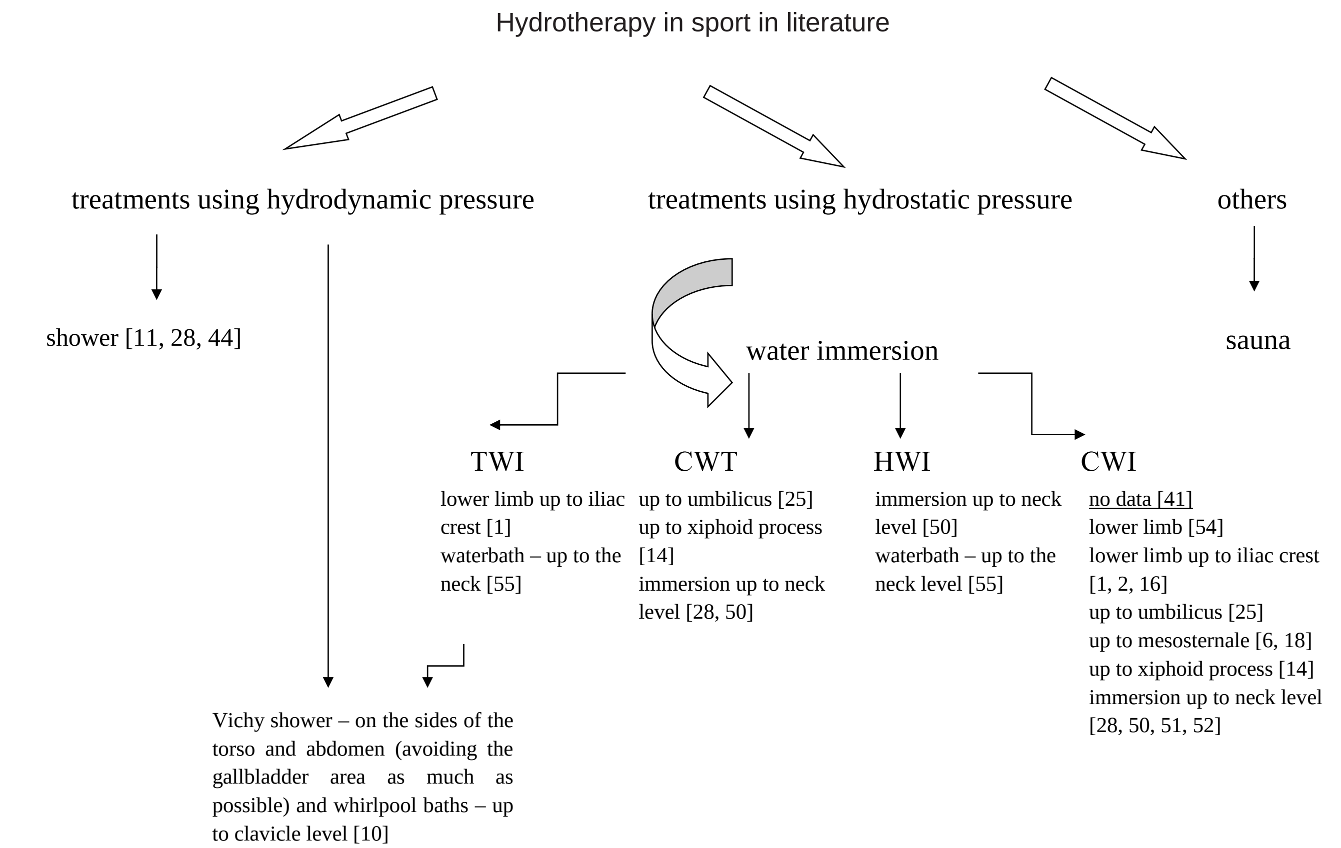
Figure 1. The influence of water environment on the human body [46]

A number of research papers assessing the efficacy of hydrotherapy in alleviating the effect of intense sports training have been published. The effect of promoting recovery in sports was evaluated by objective measures like: performance, core temperature, heart rate, creatine kinase (CK), lactic acid/lactate dehydrogenase (La/LDH) levels and subjective measures like: delayed onset muscle soreness (DOMS) syndrome, rating of percived exertion (RPE), or thermal sensation.

The most common treatment classification used by different authors is based on water temperature: CWI – cold water immersion (≤20°C), HWI – hot water immersion (≥36°C), CWT – contrast water therapy (alternating CWI and HWI), and TWI – temperate water immersion [36, 37, 48, 49, 52] (Figure 2).

Cold water immersion (CWI)

Cold water immersion is currently one of the popular methods for promoting regeneration in athletes after intense physical exercise [3, 6, 23, 32, 37, 41, 48]. There



Note: TWI – thermoneutral water immersion; CWT – contrast water therapy; HWI – hot water immersion; CWI – cold water immersion

Figure 2. Various application of hydrotherapy in sport [46]

are immersion baths for lower limbs [1, 2, 6, 9, 12, 14, 16, 24, 25, 26, 39, 43, 53] or full baths [37, 41, 48, 49] and the water temperature usually ranges between 5°C and 16°C, although there is a report of using water at 23°C [37].

Cold water immersion performed immediately after intensive training leads to greater cardiovascular recovery in athletes [5, 18], observed as the decrease of heart rate [24], blood pressure [18, 28, 39] or core body temperature [18]. It also suppresses inflammation processes [6], decreases the excessive neurotransmitter levels [1] and blood concentration of creatine kinase or lactates [18, 28, 39, 49]. Therefore CWI supports rapid resolution of post-exercise fatigue, thus facilitates smooth return to a good psychophysical condition [1]. Although the mechanisms through which cold water accelerates recovery after intense exercise have not been fully understood yet, research shows that CWI may give better results as compared to such treatments as massage [12], temperate water immersion (TWI) [1] or contrast water therapy (CWT) [1].

Rowsell et al. [39] challenged the efficacy of TWI and CWI in junior male soccer players. In this study cold water (10°C) or thermoneutral water immersion (34°C) was used in five alternating exposures: 60 s immersion and 60 s seated rest on a chair. There were no beneficial effects of CWI over TWI for the removal of muscle damage and inflammation markers but on the other hand CWI seems to be useful for reducing the perception of general fatigue and leg soreness over successive matches.

It was noted that CWI may be more beneficial or facilitate the adaptation to environmental factors in preselected individuals. Delextrat et al. [12] demonstrated superiority of CWI over lower limb massage. This study revealed slight, mainly subjective, sex differences with women presenting a lower perception of general fatigue with cold-water immersion than massage, as well as a slightly greater benefit of both recovery methods on the perception of leg soreness at 24 h after the interventions. One review highlighted that women had lower thermolytic capacities than men after exercise, suggesting that they benefit more from cold-water immersion after exercise [19].

In their recent research, Stephens et al. [45] showed that body composition affected physiological responses to CWI and enhanced performance recovery in the high fat group only. Cold water immersions can also be used as a safe method for the regeneration of athletes after intensive physical exercise in the heat [18]. CWI (repeated three times, each 60 seconds long, at 11.5°C) significantly decreases the heart rate and body core temperature, whilst not altering other metabolic and endocrine markers.

The studies evaluated such parameters as creatine kinase (CK), lactate (La), lactate dehydrogenase (LDH) or myoglobin (Mb) levels, along with heart rate (HR), maximum voluntary isometric contraction (MVIC), muscle strength (MS) and parameters, which cannot be directly quantified, e.g. delayed muscle pain syndrome, or psychophysical wellbeing. There is high variability of reported post-CWI CK and La/LDH levels as well as DOMS symptoms, including both significant ($p < 0.05$) and non-significant between-group differences (Table 1).

Santos et al. [41] demonstrated significant between-group differences in body temperature, lactate level, muscle pain and strength. Milder muscle strength reduction was observed after CWI. Lower pain perception was associated with decreased levels of lactate dehydrogenase and creatine kinase.

Vieira et al. [53] found a significant between-group difference in a countermovement jump only. The recovery

Table 1. Sample research on the possible use of the CWI for promoting recovery in athletes

Study (author, year)	Type of hydrotherapy	No. of tests/ level of engagement in sport/ mean age/ type of exercise	Type of treatment/ water temperature/ treatment duration (minutes) vs. CONTROLS: type, parameters	Assessed parameters and time of measurement (hours)	Conclusions
Santos et al. 2012 [41]	ice bath athletes were immersed in an ice bath – level of immersion unknown	4/ 9 ju-jitsu fighters/ 23.0 ± 4.4 years/ professional athletes, 2 training sessions at a 2-day interval	CWI/ 5 ± 1ºC/ 19 (4 cycles 4 minutes each, with 1-minute break between them) vs. PR	DOMS: prior to exercise, post-exercise, after recovery intervention, after muscle strength test CK: prior to exercise, after recovery intervention LDH: prior to exercise, after recovery intervention MS: prior to exercise, after recovery intervention	post-exercise CWI caused: reduction in serum concentration CK and LDH, hypoalgesia and maintenance of isometric strength endurance

Vieira et al. 2016 [53]	lower limbs immersed in iced water for 20 minutes	42/ college-age men/ mean age of 22.1 ± 2.5 years for CWI at 5ºC and 20.2 ± 2.5 for CWI at 15ºC/ 5 × 20 drop-jumps amateurs	CWI at 5ºC – lower limbs immersed for 20 minutes CWI at 15ºC – lower limbs immersed for 20 minutes vs. PC	MVIC: 24, 48, 72, 96, 168 Countermovement jump: 24, 48, 72, 96, 168 CK: 24, 48, 72, 168 DOMS: 24, 48, 72, 96, 168	CWI promotes recovery of stretch-shortening cycle performance, but does not influence the recovery of maximal contractile force; immersion at warmer temperatures may be more effective than colder temperatures promoting recovery from strenuous exercise
Ascensão et al. 2011 [1]	full immerse of lower limbs in a water bath – up to the iliac crest	20/ soccer players/ mean age of 18 ± 1.8 years/ football match professional athletes	CWI at 10ºC for 10 minutes (N10) vs. TWI at 35ºC for 10 minutes (N10)	DOMS: 0.5, 24, 48 CK: 0.5, 24, 48 CRP: 0.5, 24, 48 Mb: 0.5 MVIC of quadriceps femoris: 0.5, 24, 48 neuromuscular function (squat jump and sprint)	CWI used immediately after the match reduces muscle damage and discomfort, possibly contributing to a faster recovery of neuromuscular function
Bailey et al. 2007 [2]	immerse of the lower limbs, over the iliac crest level	20/ daily activity/ mean age of 22.3 ± 3.3 years/ physically active amateurs	CWI at 10ºC for 10 minutes vs. PR	DOMS: 24, 48 CK: 24, 48 MVIC for knee extension and flexion repeated sprint squat jump HR Haemoglobin Haematocrite changes in plasma volume Mb Core temperature Body weight Cold perception RPE	CWI used immediately after exercise prolongs intermittent shuttle running and reduces some indices of exer-cise-induced muscle damage (DOMS, MVIC, haemoglobin)
Ingram et al. 2009 [25]	immersion for both water conditions was to each participant's umbilicus	11/ professional athle-tes/ mean age of 27.5 ± 6 years/ 80-minute simulated team exercise professional athletes	CWI at 10ºC for 10 minutes vs. PR CWT: at 10ºC for 2 minutes × 3 and at 40ºC for 2 minutes × 3 vs. PR	DOMS: 24, 48 CK: 24, 48 MVIC for leg exten-sion, leg flexion and hip flexion repeated sprint Haemoglobin Haematocrite changes in plasma volume	CWI facilitated a more rapid return to baseline repeated sprint performances CWI following exhaustive simulated team sports exercise offers greater recovery benefits than CWT or control treatments
Halson et al. 2008 [18]	subjects were immersed in water at 11.5 ± 0.3°C to the level of the mid--sternum	11/ endurance trained cyclists/ mean age of 23.8 ± 1.6 years/ 2 approx. 40-minute time trials at 34.3ºC ± 1.1ºC professional athletes	CWI at 11.5ºC 1 minute repeated three times (with 2-minute break between each cycle) vs. PR (24.2ºC ± 1.8ºC)	CK: collection time unknown HR: assessment time unknown Glucose level La Blood gases Hormones: testosterone, cortisol, growth hormone, prolactin, adrenaline, noradrenaline CRP IGF1 IL-6	CWI did not result in hypothermia and can be considered safe following high intensity cycling in the heat; CWI caused reduction in HR and core temperature

Elias et al. 2012 [14]	immersion up to xiphoid process	24/ professional footballers/ mean age of 20.9 ± 3.3 years/ football training professional athletes	CWI at 12ºC for 14 minutes vs. PR CWT – 7 cycles: 1 minute at 38ºC followed by 1 minute at 12ºC (total exposure time of 14 minutes)	DOMS: 24, 48 Repeat-sprint ability Static and countermovement jump performance Fatigue	CWI effectively restores physical-performance and psychometric measures after football training
Goodall et al. 2008 [16]	seated immersion (up to iliac crest)	18/ physically active male subjects/ mean age of 24 ± 5 years/ 5 × 20 drop jumps physically active male subjects	CWI at 15ºC/ 12 minutes every 24 hours for 3 days vs. PR	DOMS: 24, 48, 72 MVIC of the knee extensors CK: 24, 48, 72, 96 ROM Limb girth	although single CWI treatment may be beneficial (effects were seen for MVIC, CK, DOMS and limb girth), repeated CWI do not enhance recovery from a bout of damaging eccentric contractions
Brophy-Wiliams et al. 2011 [6]	submerging the body to the mid-sternum in water	8/ well-trained athletes/ mean age of 20.9 ± 1.2 years/ HIIS (high intensity interval exercise session) (8 × 3 minutes) professional athletes	CWI at 15ºC for 15 minutes vs. PR	DOMS: 0, 3 Yo-Yo intermittent recovery test (YRT) HR CRP (c-reactive protein) La Perceived recovery	immediate CWI resulted in superior next-day YRT performance compared to PR, while delayed (3 hours) CWI was also likely to be beneficial
Vaile et al. 2008 [49]	subjects immersed their entire body (excluding head and neck)	38/ strength trained males (12 – CWI, 15 – CWT, 11 – HWI)/ active: high intensity cycling/ ND/ high intensity cycling professional athletes	CWI at 15ºC for 14 minutes vs. PR CWT – 7 cycles: 1 minute at 15ºC followed by 1 minute at 38ºC vs. PR HWI at 38ºC for 14 minutes vs. PR	DOMS: 0, 24, 48, 72 CK: 0, 24, 48, 72 LDH: 0, 24, 48, 72 Mb: 0, 24 IL-6 (interleukin 6): 0, 24 MS: 0, 24, 48, 72 MVIC for squats	CWI and CWT are effective restoring muscle strength and reducing physiological and functional DOMS--related deficits HWI is only effective in muscle strength recovery

Note: CWI – cold water immersion; CWT – contrast water therapy; HWI – hot water immersion; TWI – thermoneutral water immersion; PC – passive control (not performing the training over 24 hours); PR – passive recovery; ND – no data; CK – keratin kinase; HR – heart rate; La – lactates; LDH – lactate dehydrogenase; Mb – myoglobin; ROM – range of motion, RPE – rating of perceived exertion, DOMS – delayed onset muscle soreness; MS – muscle strength; MVIC – maximum voluntary isometric contraction

was quicker in CWI group as compared to the control group. Elias et al. [14] observed improved quality of jumps after CWI along with a reduction in muscle pain and tiredness after 24 and 48 hours. Vaile et al. [49] demonstrated significantly enhanced squat jump performance and isometric force recovery at 48 and 72 hours post-exercise following CWI.

Bailey et al. [2] observed significant between-group differences in several parameters and at different times, for instance, muscle pain and myoglobin level at 1 hour, as well as DOMS and maximum muscle strength after 24 and 48 hours. In the study by Ingram et al. [25], the onset of significant differences in DOMS was at 48 hours following treatment; they additionally observed lower loss of muscle strength in CWI-treated subjects. Halson et al. [18] noted significant heart rate decrease in CWI-treated subjects.

Brophy-Williams et al. [6] demonstrated that in subjects after high intensity interval session (HIIS) immediate CWI resulted in superior next-day Yo-Yo intermittent recovery test (YRT) performance compared to passive recovery group (CON) ($p = 0.017$). Same study showed that delayed (3 h) CWI was also likely to be beneficial. Ascensão et al. [1] indicated the superiority of CWI treatment comparing to TWI in cold sensation assessed at 0.5 hours and in the maximum isometric voluntary contraction assessed at 24 hours.

Additionally, many authors observed beneficial, albeit non-significant, improvements in different parameters. King and Duffield [28] used 15-min ice bath (9°C) observing a beneficial effect on vertical jump, 20-m sprint, 10-m sprint, and total circuit time after 24 hours. There is no precise indication as to the duration of the interval between the end of the training session and the beginning of the recovery intervention. Ascensão et al. [1] noted a positive effect on creatine kinase, myoglobin, and C-reactive protein levels, as well as jumps and sprints after full submerge of subjects' lower limbs (to the iliac crest) in a stirred cold-water bath for 10 minutes. In this study, the recovery intervention was started immediately after the physical exercise. Delextrat et al. [12] noticed that CWI consisting of five 2 min intermittent immersions of the lower limb (up to the iliac crest), in the cold-water bath (11°C), separated by 2 min rest in ambient air (sitting, room temperature of 20°C) used as a recovery intervention within five minutes following the completion of the exercise, resulted in a higher efficiency of jumping and sprinting in men and decreased fatigue in women. Halson et al. [17] found that 20 min ice bath up to the mid-sternum, at 11.5°C used 20 minutes after exercise had a beneficial effect on reducing body and skin temperature, as well as decreasing creatine kinase level.

Contrast water therapy CWT

Contrast water treatment (CWT) involves alternating warm (or hot) and cold-water baths. It usually involves whole-body immersion [20, 21, 28, 37, 48, 50, 52] or contrast water showers [31, 44]. However, partial body immersion protocols involving body submerging up to xiphoid process [14] or the mid-sternum [28] were also reported. Additionally, it is possible to use partial immersion CWT on lower limbs submerging them only up to the anterior superior iliac spine [15], the iliac crest [35], or 5 cm above the knee [33]. The temperature of water used for CWT usually varies between 10-15°C for cold water and 35-38°C for hot water. However, some studies, e.g. the one by Gill et al. [15], used cold water at 8-10°C and hot water at 40-42°C. Robey et al. [38] also used higher temperature for hot water in their study [38].

CWT is considered an alternative to cryotherapy and cold water immersion (CWI) [20, 29]. Although its mechanisms of action remain unknown, it is seen as an effective method for reducing the symptoms of muscle damage and associated DOMS [49]. Body exposure to alternating high and low temperatures is believed to accelerate blood circulation, which facilitates metabolite elimination [27]. Contrast water therapy causes significantly higher lactate reduction, as compared to passive recovery [28]. It can also eliminate fatigue, restoring general wellbeing [51]. Its efficacy may be additionally enhanced by using compression garments or exercise [15]. Vaile et al. [49] showed that CWT can effectively restore muscle strength. Pournot et al. [36] showed that by contributing to faster clearance of metabolites, CWT may be an effective method for all-out anaerobic performance restoration.

The studies conducted up to date have focused on a number of different factors, such as lactate (La), lactate dehydrogenase (LDH) and myoglobin (Mb) levels, along with heart rate (HR), muscle strength (MS), DOMS, fatigue reduction or improved general wellbeing. There is high variability of reported post--CWT parameters, including both significant and non--significant between-group differences (Table 2).

King et al. [28] observed a significant difference in post-CWT lactate level. Stanley et al. [44] observed a significant reduction in fatigue and leg soreness after CWT. Myrer et al. [34] investigated the effect of CWT on intramuscular temperature in legs of 28 healthy, uninjured students, not professional athletes. It showed

Table 2. Sample research on the possible use of the CWT for promoting recovery in athletes

Study (author, year)	Type of hydrotherapy	No. of tests/ level of engagement in sport/ mean age/ type of exercise	Type of treatment/ water temperature/ treatment duration (minutes) vs. CONTROLS: type, parameters	Assessed parameters and time of measurement (hours)	Conclusions
King et al. 2009 [28]	ice bath/ water immersion (excluding head and neck)	10/ professional female netball players/ mean age of 19.5 ± 1.5/ simulated netball exercise circuit	CWI at 9ºC for 5 minutes + 2.5 minutes at air temperature – repeated twice vs. PR (15 minutes) CWT – 1 minute at 10ºC and 2 minutes at 39ºC vs. PR ACT: 15 minutes of exercise vs. PR	DOMS: 24 sprint + vertical counter-movement jumps HR body weight core temperature La bicarbonate blood pH RPE	immediate post-exercise application of CWI and CWT did not significantly enhance peak exercise performance

Stanley et al. 2012 [44]	shower	18/ well trained cyclists/ mean age of 27.7 ± 7 years/ /60-minute high intensity cycling	CWT (10 minutes total): 14.2ºC for 1 minute + 35.5ºC for 2 minutes – a sequence repeated × 3 + 14.2ºC for 1 minute vs. PR and CWI	DOMS at 3.25 hours peak power output at 3.25 hours HR change at 3.25 hours	although there were no significant CWI and CWT effects on performance, the beneficial effects on perceptions of recovery seems to support the use of these strategies
Versey et al. 2011 [50]	bath of entire body (excluding head and neck) in a seated posture	11/ trained male cyclists/ mean age of 32.1 ± 7.6 years/ 75-minute cycling protocol professional athletes	CWT for 6, 12 or 18 minutes: 1 minute at 14.6ºC and 1 minute at 38.4ºC vs. PR	cycling performance core temperature HR thermal sensation RPE DOMS: 2	CWT improves thermal sensation, whole body fatigue and muscle soreness; the results suggests that CWT for up to 12 minutes duration can assist recovery in cyclists
Versey et al. 2012 [51]	immersed in a pool (excluding head and neck) in a seated posture	10/ runners/ mean age of 36.8 ± 9.2 years/ 4 trials: 3000-meter time trial + 8 × 400-meter intervals with 1 minute of recovery professional athletes	CWT for 6, 12 or 18 minutes: 1 minute cold at 14.6ºC and 1 minute hot at 38.4ºC vs. PR	running performance HR algometer measures RPE thermal sensation whole body fatigue DOMS: 0.5, 0.75, 1, 1.5	efficacy of CWT for 6 minutes from high--intensity running is confirmed, CWT duration did not have a dose-response effect
Vaile et al. 2008 [49]	subjects immersed their entire body (excluding head and neck)	38 (12 – CWI, 15 – CWT, 11 – HWI)/ active: high intensity cycling/ ND/ high intensity cycling professional athletes	CWI at 15ºC for 14 minutes vs. PR CWT – 7 cycles: 1 minute at 15ºC followed by 1 minute at 38ºC vs. PR HWI at 38ºC for 14 minutes vs. PR	DOMS: 0, 24, 48, 72 CK: 0, 24, 48, 72 LDH: 0, 24, 48, 72 Mb: 0, 24 IL-6: 0, 24 perceived pain (VAS) MS: 0, 24, 48, 72 MVIC for squats	CWI and CWT are effective restoring of isometric force and dynamic power and reducing physiological and functional DOMS--related deficits HWI is only effective in the recovery of isometric force

Note: CWI – cold water immersion; CWT – contrast water therapy; HWI – hot water immersion; TWI – thermoneutral water immersion; ACT – active recovery; PR – passive recovery; CK – keratin kinase; HR - heart rate; La – lactates; LDH – lactate dehydrogenase; Mb – myoglobin; RPE – rating of perceived exertion, DOMS – delayed onset muscle soreness; MS – muscle strength; MVIC – maximum voluntary isometric contraction

that CWT is incapable of producing any significant physiological effect on the temperature of intramuscular tissue 1 cm below the skin and subcutaneous tissue.

Versey et al. [50] applied alternating 1 min hot (38°C) and 1 min cold (15°C) baths in a sitting position (excluding head and neck immersion) for 6 (CWT6), 12 (CWT12), or 18 min (CWT18), 10 minutes post--exercise, observing significantly lower subjective measures of thermal sensation and muscle soreness after each CWT intervention. Same authors demonstrated elsewhere, significantly improved time-trial and sprint performance with 6-minute CWT, and significantly improved sprint total work and peak power with 12-minute CWT [51]. Vaile et al. [49] used whole-body CWT (except for the head and neck) directly after each testing session, and once a day for 72 h post-exercise. In their study, squat jump performance and isometric force recovery were significantly enhanced at 24, 48 and 72 h post-exercise following CWT as compared to passive recovery intervention.

Hot water immersion HWI

The first HWI treatments and their measurable effects were reported in 1966 by Craig and Dvorak [8]. The most common treatments involve immersion up to the head and neck level [37, 48, 49, 54], to the clavicle level [10] or partial body shower [10]. Although the boundary between the concept of hot and thermoneutral water has not been defined, it is assumed in most studies that HWI uses water approximately 34-36°C.

HWI is currently the least often used method of hydrotherapy armamentarium as a recovery intervention after intense physical exercise. Its efficacy has not been clearly established and effects reported about post-exercise recovery in sportsmen [48, 52, 54] vary significantly [48, 52, 54]. Research articles on HWI often recommend supplementing this recovery intervention with other treatments, e.g. massage of selected muscles using high pressure jets of water and/or air [27].

Vasodilatation (smooth muscle relaxation in vascular walls) and the resulting increased blood flow are the typical effects of HWI. It usually causes very low decrease in core body temperature during recovery, although there also were cases of increased core body temperature [49]. The available studies assessed the effect of HWI on the biochemical blood markers and other factors, e.g. heart rate (HR), rectal temperature, rating of perceived exertion (RPE), creatine kinase (CK), myoglobin and DOMS (Table 3).

A study by Zurawlew et al. [54] was carried out in physically active participants, who completed two or more hours of endurance exercise per week. They found significant differences occurring fairly late, on day 3.-6. (rectal temperature) or day 4.-6. (sweating). Beneficial effects of HWI (at 38-40°C) demonstrated in this study suggest that hot water therapy may be

Table 3. Sample research on the possible use of the HWI for promoting recovery in athletes

Study (author, year)	Type of hydrotherapy	No. of tests/ level of engagement in sport/ mean age/ type of exercise	Type of treatment/ water temperature/ treatment duration (minutes) vs. CONTROLS: type, parameters	Assessed parameters and time of measurement (hours)	Conclusions
Cuesta-Vargas et al. 2013 [10]	partial shower – on the sides of the torso and abdomen (avoiding the gall bladder area as much as possible) whirlpool baths (whole body) – up to the clavicle level	34/ recreational sportspeople/ mean age of 29.4 ± 8.4 years/ aerobic exercise: 3.1 ± 1.9 hours/week; strength exercise: 1.2 ± 1.4 hour/week	3 cycles of Vichy shower followed by whirlpool bath over 30-minute period; shower 90-120 seconds long at 36-38°C alternating with a 10 minutes whirlpool bath at 33.5-35.5°C (aromatherapy application using lavender and chamomile oils was used in all hydrotherapy sessions) vs. rest in a bed (PR)	blood pressure HR handgrip strength vertical jump RPE body temperature	hydrotherapy after aerobic exercise facilitate cardiovascular recovery and perceived fatigue, but not strength
Vaile et al. 2008 [49]	subjects immersed their entire body (excluding head and neck)	38 (12 – CWI, 15 – CWT, 11 – HWI)/ active: high intensity cycling/ ND/ high intensity cycling professional athletes	CWI at 15ºC for 14 minutes vs. PR CWT – 7 cycles: 1 minute at 15ºC followed by 1 minute at 38ºC vs. PR HWI at 38ºC for 14 minutes vs. PR	DOMS: 0, 24, 48, 72 CK: 0, 24, 48, 72 LDH: 0, 24, 48, 72 Mb: 0, 24 IL-6: 0, 24 MS: 0, 24, 48, 72 MVIC for squats	CWI and CWT are effective in restoring muscle strength and reducing physiological and functional DOMS-related deficits HWI is only effective in muscle strength recovery
Zurawlew et al. 2016 [54]	water bath – up to the neck level	17/ physically active males (yet not athletes), non-heat-acclimatized/ mean age of 23 ± 3 years/ 6-day intervention involving a daily treadmill run for 40 minutes	HWI at 40ºC for 40 minutes vs. TWI at 34ºC for 40 minutes	HR body temperature (rectal and skin) sweat rate physiological strain hemoglobin hematocrit	HWI presents a simple, practical, and effective heat acclimatization strategy to improve endurance performance in the heat

Note: CWI – cold water immersion; CWT – contrast water therapy; HWI – hot water immersion; TWI – thermoneutral water immersion; PR – passive recovery; CK – keratin kinase; HR – heart rate; La – lactates; LDH – lactate dehydrogenase; Mb – myoglobin; RPE – rating of perceived exertion; DOMS – delayed onset muscle soreness; MS – muscle strength; MVIC – maximum voluntary isometric contraction indicated for facilitating adaptation to exercise in hot climate conditions, rather than for promoting recovery in athletes.

The authors who observed beneficial effects of HWI used very discrepant treatment methods. Cuesta-Vargas et al. [10] used a very specific protocol, not encountered in any previous research. They have applied 3 cycles of Vichy showers and whirlpool baths over a 30-minute period. As first sedative Vichy shower at 36-38°C was used for 1.5-2 minutes on the sides of the torso and abdomen (avoiding the gallbladder area). A shower was followed by a short, partial jet spray. As a third cycle, a whirlpool bath up to the clavicle level was administered at 33.5-35.5°C for 10 min. Lavender and chamomile oil-based aromatherapy was additionally used for all sessions. They demonstrated statistically significant differences in the levels of heart rate, diastolic pressure, and fatigue.

Vaile et al. [49] assessed the effect of HWI on DOMS and the level of creatine kinase (CK). It seems that due to the beneficial effect of HWI on accelerating the blood flow through the vasodilatation phenomenon, CK can be an important indicator of its efficacy in eliminating fatigue after physical exercise in athletes. The authors found significant differences in isometric muscle strength after 24, 48, 72 hours, and in CK levels after 48 hours.

The small number of published research articles, as well as significant discrepancy in research methods and contradictory results indicates the necessity of further research in order to unequivocally determine the benefits of HWI as a part of comprehensive recovery intervention in athletes.

Conclusions

Despite the commonly held conviction as to the efficacy of hydrotherapy in restoring a good psychophysical condition after physical exercise, positive reviews of athletes, and some published research, the actual efficacy of hydrotherapy still remains debatable [5, 9, 16, 24, 25, 26, 39, 40, 43, 47].

Literature reviews based on specific criteria are useful in the assessing of potential efficacy of hydrotherapeutic treatments. So far, none of them has provided an unequivocal answer which of hydrotherapy treatments is the most efficient, although the results indicate the potential utility of water treatments in promoting recovery in athletes [3, 17, 33, 40, 52]. The presented results comparing the efficacy of individual treatments at different temperatures on restoring general wellbeing and post-exercise fitness in athletes seem to indicate higher superiority of CWI or CWT over HWI [37, 49, 50].

The comparison of CWI and CWT effectiveness indicates that CWI is more effective facilitating post--exercise recovery in some aspects – this was confirmed by the meta-analyses conducted by Sánchez-Ureña et al. [40] and Higgins et al. [22]. Yet, both research teams point out the need of more research evaluating hydrotherapy for sport recovery, including different sport disciplines, competitions and workouts, covering 48 post-exercise hours.

Bleakley et al. [3] evidenced that compared with passive interventions involving rest or no intervention the use of cold water after exercise reduces DOMS. Similarly, Leeder et al. [30] described the efficacy of CWI in DOMS reduction. In contrast, in latest meta-analysis of Dupuy et al. [13], which compared the impact of recovery techniques (i.e. water immersion) after physical exercise, the authors showed that massage seems to be the most effective method for reducing DOMS and perceived fatigue.

Although a number of papers including several meta--analyses, about the efficacy of different temperatures hydrotherapy for promoting recovery in athletes this have yet been published subject still remains debatable. The most commonly indicated limitations include the lack of high-quality studies. The research is not well reported and carried out in small samples [3, 4], discrepant methods are used [47, 52]. Hence, as pointed out fairly often, there is a need for establishing model protocol, including all hydrotherapeutic treatments to optimize an athlete's recovery [47]. There is a need to include more variables in well-designed studies [22, 40]. It must also be taken into account that there are individual differences in the response to hydrotherapy [42]. Therefore, although some practical recommendations are now available [22, 52], it is necessary to take up further research, which would include the above remarks.

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