



Literary review

## Alternating hot and cold water immersion for athlete recovery: a review

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### Abstract

**Objectives.** The aim of this review was to investigate whether alternating hot–cold water treatment is a legitimate training tool for enhancing athlete recovery. A number of mechanisms are discussed to justify its merits and future research directions are reported. Alternating hot–cold water treatment has been used in the clinical setting to assist in acute sporting injuries and rehabilitation purposes. However, there is overwhelming anecdotal evidence for its inclusion as a method for post exercise recovery. Many coaches, athletes and trainers are using alternating hot–cold water treatment as a means for post exercise recovery.

**Design.** A literature search was performed using SportDiscus, Medline and Web of Science using the key words recovery, muscle fatigue, cryotherapy, thermotherapy, hydrotherapy, contrast water immersion and training.

**Results.** The physiologic effects of hot–cold water contrast baths for injury treatment have been well documented, but its physiological rationale for enhancing recovery is less known. Most experimental evidence suggests that hot–cold water immersion helps to reduce injury in the acute stages of injury, through vasodilation and vasoconstriction thereby stimulating blood flow thus reducing swelling. This shunting action of the blood caused by vasodilation and vasoconstriction may be one of the mechanisms to removing metabolites, repairing the exercised muscle and slowing the metabolic process down.

**Conclusion.** To date there are very few studies that have focussed on the effectiveness of hot–cold water immersion for post exercise treatment. More research is needed before conclusions can be drawn on whether alternating hot–cold water immersion improves recuperation and influences the physiological changes that characterises post exercise recovery.

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**Keywords:** Recovery; Training; Post exercise; Hydrotherapy; Regeneration; Immersion

### 1. Introduction

Recovery is an important aspect of any physical conditioning programme however, many athletes train extremely hard without giving their body time to recover which can lead to over reaching, burnout or poor performances (Mackinnon and Hooper, 1991). Without the necessary recovery interventions it is very difficult for an athlete to maintain a high level of performance on a daily or weekly basis. As athletes look for the leading edge, rest is frequently overlooked for increases in overload, intensity and volume.

Recently a lot of emphasis has been placed on speeding up the recovery process so athletes can proceed to do successive bouts of training or competition without the associated fatigue or burn out effects. Numerous physical, psychological and nutritional methods have been used to

accelerate the recovery process (Calder, 1996). There has been an increase in the use of modalities such as massage, floatation, hyperbaric oxygenation therapy and acupuncture with little scientific evaluation of its use and effectiveness for exercise recovery. Alternating hot–cold water immersion is one technique that is very popular and is practised with increased frequency in aiding recovery after physical training and competition (Calder, 2001a). Anecdotal reports from coaches, medical personnel and athletes suggest that this method of water immersion has positive effects on subsequent performance.

The aim of this review was to source the literature and provide the scientific rationale and mechanisms of using alternating hot–cold water immersion for post exercise recovery.

### 2. Therapeutic modalities

Ice packs, whirlpools, baths, heat packs, infra-red lamps, paraffin wax and ice massage are various techniques of

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cryotherapy and thermotherapy that have been used in the sports medicine and rehabilitation fields for the treatment of acute injuries (Prentice, 1999). Additionally, contrast baths, warm and cold packs have also played a major role in injury management but increasingly these modalities are now used for post exercise recovery. Warm spas with cold plunge pools or contrast hot–cold baths and showers are common practises used by athletes after training or exercise. According to Calder (1996) the contrast hot–cold water technique is thought to speed recovery by increasing the peripheral circulation by removing metabolic wastes and stimulating the central nervous system. Calder (2001b) further claims that contrast hot–cold increases lactate clearance, reduces post exercise oedema and enhances blood flow to the fatigued muscle. Additionally, it is thought to slow down the metabolic rate and revitalise and energise the psychological state.

### 3. Physiology of cooling and heating

There is a general consensus that the application of cold ice or water immersion decreases skin, subcutaneous and muscle temperature (Enwemeka et al., 2002; Myrer et al., 1997; Hartvickson, 1962; Johnson et al., 1979; Lowden and Moore, 1975). The decrease in tissue temperature is thought to stimulate the cutaneous receptors causing the sympathetic fibres to vasoconstrict which decreases the swelling and inflammation by slowing the metabolism and production of metabolites thereby limiting the degree of the injury (Enwemeka et al., 2002).

Superficial tissues can remain cool up to four hours from ice packs or cold water immersion (Beltisky et al., 1987; Hocutt et al., 1982; McMaster et al., 1979). The mechanism of this process still remains unclear. Enwemeka et al. (2002) found that cold pack treatment up to 20 min significantly decreased superficial tissue temperature by dulling and reducing the sensation of pain. They concluded that cold pack treatment limits the amount of swelling in acute injuries by slowing the metabolic rate by shunting less blood to the cold superficial area. Earlier research has shown that metabolites are cleared by the blood exchange from superficial to deep tissue. Incoming warm blood is diverted to the deeper tissues thereby slowing down the cooling effect of the deep tissues (Pugh et al., 1960). A cooling effect also decreases nerve conduction velocity in superficial tissues by slowing the rate of firing of muscle spindle afferents and reflex responses thus decreasing muscle spasm and pain (Prentice, 1999; de Jesus et al., 1973).

Thermotherapy has shown to increase tissue temperature, increase local blood flow, increase muscle elasticity, cause local vasodilation, increase metabolite production and reduce muscle spasm (Prentice, 1999; Brukner and Khan, 2001; Zuluaga et al., 1995). Additionally, superficial heating decreases sympathetic nerve drive which causes vasodilation of local blood vessels and increases circulation.

The increased blood flow allows an increased supply of oxygen, antibodies and the ability to clear metabolites (Zuluaga et al., 1995).

Myrer et al. (1994) proposed that if contrast therapy is reported to produce physiologic effects (vasodilation and constriction of local blood vessels, changes in blood flow, reduction in swelling, inflammation and muscle spasm) significant fluctuations of muscle temperature must be produced by the alternating hot–cold contrast treatments. Participants immersed their right leg into a hot (40.6 °C) whirlpool for 4 min followed by a cold (15.6 °C) whirlpool for 1 min, and this was repeated four times (Myrer et al., 1994). This protocol did not produce any significant differences in intramuscular temperature 1 cm below the skin in the gastrocnemius muscle. In a subsequent study, Myrer et al. (1997) changed the modality of the contrast therapy to cold and hot packs. The exposure duration was extended to 5 min for both the hot–cold treatment. The rationale for using the packs was to give deeper penetration, greater heat transfer and elicit superior temperature fluctuations. The results verified their previous study that hot–cold contrast treatment does not produce the required physiologic effects required to induce intramuscular temperature changes. Wertz (1998) and Higgins and Kaminski (1998) have also reported similar results. Lehmann et al. (1974) suggested that for the physiologic effects to take place the muscle temperature must reach at least 40 °C, however, the above studies reported muscle temperatures below 40 °C. More research is required to investigate the required physiologic effects associated with using deep heat treatments in hot–cold contrast therapy.

### 4. Recovery

Recovery is defined as ‘the return of the muscle to its pre exercise state following exercise’ (Tomlin and Wenger, 2001). Aerobic metabolism remains elevated in the recovery phase after exercise. Known as excess post-exercise oxygen consumption (EPOC) it assists in replenishing the body stores (Bahr and Maehlum, 1986). EPOC consists of a fast and slow component (Gaesser and Brooks, 1984). The fast component restores 70% of ATP and PCr energy stores within 30 s (Hultman et al., 1967) and reloads plasma haemoglobin and muscle myoglobin (Bahr, 1992). The slow component is observed after strenuous exercise and has been associated with increased cardiac and respiratory functions, elevated core temperature and removal of metabolic waste products (Gaesser and Brooks, 1984; Sahlin, 1992). Dependent on the exercise intensity it may take up to 24 h for the slow component to return to its resting levels (Gaesser and Brooks, 1984). Phosphagen stores take 3–5 min to fully recover (Hultman et al., 1967) compared to an hour or more for the resting return of lactate and pH. The rise in lactate production and H<sup>+</sup> accumulation can disrupt the muscle contractile processes and the existing

transport and metabolic pathways can become less efficient (Tomlin and Wenger, 2001). The use of passive (no exercise, massage, contrast hydrotherapy) or active recovery (light exercise) for replenishing fuel stores and removal of metabolic wastes has implications for accelerating post exercise recovery rates.

#### 4.1. Metabolic removal in active and passive recovery

Lactate production is evident when training or competing, however, the amount produced is dependent on the duration and intensity of the exercise and the length of the recovery interval. The ability to clear lactate in the recovery phase relies on the working muscle to quickly remove, tolerate and/or buffer  $H^+$  (Sahlin and Henriksson, 1984). hot–cold immersion may have some merit in aiding recovery if waste products are cleared faster. However, the mechanism by which active recovery promotes lactate removal is not clearly understood. This process is complex as it depends on a range of factors for example, local blood flow, chemical buffering, movement of lactate from muscle to blood, lactate conversion to pyruvate in liver, muscle and heart (McArdle et al., 2001).

Research has shown that lactate removal is increased when active recovery periods are implemented compared to passive rest for continuous or repeated bouts of exercise (Hermansen and Stensvold, 1972; Weltman et al., 1979; Cortes et al., 1989). Dodd et al. (1984) found that a recovery period of moderate continuous intensity facilitated lactate removal faster than passive recovery. Additionally, a combination of high intensity (65%  $VO_2$  max) and low intensity (35%  $VO_2$  max) was no more beneficial than a recovery of low intensity (35%  $VO_2$  max) for 40 min.

There is conflicting evidence on the effect that active and passive recovery has on muscle glycogen synthesis. Choi et al. (1994) have shown active recovery delays glucose synthesis after high intensity (130%  $VO_2$  max) intermittent cycling in untrained males. However, Futre et al. (1987) found no statistical differences between passive and active recovery for muscle glycogen synthesis. Whatever the outcome there are implications to the type of recovery implemented in post training.

It appears that no further gains are elicited when performing the intensity of the recovery period above lactate threshold, as it may prolong the clearance of lactate by accumulating more (Dodd et al., 1984; Gladden, 1989). From isotope tracer studies, Brooks (2000) suggested that lactate produced in fast twitch muscle fibres can be transported to other fast twitch or slow muscle fibres for pyruvate conversion, which undergoes chemical reactions for aerobic energy metabolism. This shuttling allows for both production and removal of lactate. Signorile et al. (1993) claimed that during recovery from low intensity cycling, lactate clearance may be enhanced by active muscles causing a pumping action and adjacent muscles providing oxidative metabolism to removing metabolites.

Active recovery often requires additional energy that further depletes precious energy stores therefore, if passive recovery is proven to increase glycogen resynthesis contrast hydrotherapy may be justified as a post training tool. However, most athletes have the tendency to spend more time in the warm water immersion thus offsetting the purported benefits as dehydration and neural fatigue are accentuated.

Additionally, if competition is conducted at night recovery could be compromised if other engagements such as team debriefing, after match functions or press conferences take priority. Conducting hot–cold contrast training may not be any more beneficial than complete rest. Sanders (1996) used a contrast-temperature protocol involving hot–cold plunge pools to measure the recovery of lactate levels in elite women hockey players after a series of Wingate tests. A comparison of lactate clearances following passive rest, light exercising (active recovery) and the contrast immersion protocol was undertaken. Results indicated that lactate levels were recovered equally fast by using either the contrast water immersion or the active recovery protocol. However, the lactate recovery following passive rest was significantly slower. In sports medicine contrast baths have been used to treat subacute soft tissue and joint injuries by alternating hot–cold, thus promoting vasodilation/vasoconstriction causing a ‘pumping’ action to reduce swelling of the injured site (Rivenburgh, 1992; Prentice, 1999). This ‘pumping’ action may explain the possible anecdotal reports of reduced post exercise stiffness and the accelerated return to basal and metabolic resting levels. However, the removal of metabolites and reduced swelling from the mechanical force of alternating hot–cold immersion is unproven and contentious. Myrer et al. (1997) suggested that the significant skin temperature fluctuations from the hot–cold contrast packs caused vasoconstriction and vasodilation thereby initiating subcutaneous response and mechanical shunting. Conversely, they argue that the increase in local blood flow would not reduce oedema, as swelling reduction requires the removal of debris and fluid performed by the lymphatic system. Since the lymphatic system requires muscle contraction or gravity to move fluid contents, it is unlikely this mechanism can be substantiated, as lymph flow is independent of circulatory changes. Tomasik (1983) studied the effect of blood electrolytes and lactic acid levels in participants that underwent 30 min of hydromassage or control (no hydromassage) after 15 min of sub-maximal cycling. The investigation found that the hydromassage intervention was able to return haematocrit, plasma potassium and lactic acid levels to resting levels faster than those who received no hydromassage. However, the acquired effects of hypergravity and proprioception from the underwater jets to assist the clearance of waste products were not discussed. Unfortunately the studies of Tomasik (1983) and Sanders (1996) have relied on measurements of blood

lactate to reflect muscle lactate clearance, which may compromise conclusions on lactate removal (Tomlin and Wenger, 2001). Further research is needed to establish whether mechanical shunting from the hot–cold immersion elicits a possible mechanism for metabolite removal to accelerate post exercise recovery.

#### 4.2. Neural recovery

It is well established that during exercise there is a decrease in parasympathetic and increase in sympathetic activity. The sympathetic excitation causes a release of noradrenaline and adrenaline that increases myocardial contractility and accelerates heart rate (McArdle et al., 2001). Additionally, vasodilation occurs in skeletal and heart muscle, blood flow increases from vasoconstriction of other organs and the airways become dilated. Post exercise sympathetic activity remains high but with adequate recovery it returns to resting levels. However, if a high training load, volume or intensity is repeatedly performed without the necessary rest, sympathetic activity will become unceasingly high. This often leads to overtraining/overreaching when the signs and symptoms are not detected (Hahn, 1994).

Neurological recovery of the peripheral nervous system may be augmented by contrast hydrotherapy, massage and floatation by reducing the load of the sympathetic activity (Hahn, 1994; Calder, 1996). Athletes who perform hot–cold hydrotherapy after training or competition have reported lighter and less tight muscles with a feeling of mental freshness (Calder, 2001a). This may be associated to central nervous system relief. However, little is known on the effects that hot–cold water immersion has on the nervous system. Research conducted by Gieremek (1990) examined reaction time of simple reflex tasks, the tendon reflex (T reflex) of the Achilles tendon, Hoffman reflex (H reflex) of the soleus and conduction of the tibialis nerve before and after 30 min of jet pressured spa water immersion (34–36 °C) in judo fighters and healthy untrained males. He found that for both groups, the underwater jet spa improved the efficiency of both the central and peripheral nervous system. He supported his claim from the significant changes of simple reaction time, T and H reflexes. Gieremek stated that the underwater jets and lukewarm water activated the proprioceptors to increase the excitability to the brain, which stimulated the neuromuscular system. Additionally, he justified the periphery efficiency component from the significant increases in neural transmission and the induced M-response of the H reflex.

Gieremek claimed that the reflex and electrophysiological responses elicited from the underwater jet immersion may have improved the speed of the central spread of electrical activation in the nerve, neuromuscular synapses and the muscle thereby producing a positive post exercise recovery effect.

Viitasalo et al. (1995) investigated the effect of exposure and non-exposure of underwater jet massage (36–37 °C) on junior track and field athletes. The experiment used a cross over design where two groups of equal size under went a week of non-exposure and exposure of underwater jet massage. Three treatments of 20 min were performed over five days after power, speed and strength conditioning sessions. During the exposure week of underwater jet massage vertical jumping power declined slightly, continuous vertical jumping ground contact time increased, serum creatine kinase and myoglobin levels were elevated compared to no water jet treatment. The results indicated that the combination of intense speed, power and strength sessions with underwater jet massage increased blood markers to release more protein from the muscle to the blood thereby enhancing the neuromuscular system.

#### 4.3. Muscle recovery

It has been confirmed that eccentric, intensive and unfamiliar exercises are causes of muscle damage (Clarkson and Sayers, 1999; McHugh et al., 1999; Armstrong, 1984). Delayed onset of muscle soreness (DOMS) usually transpires 24–48 h post exercise with symptoms consisting of tender, stiff and sore muscles (Clarkson et al., 1992). Several theories have been presented to explain the physiological mechanism of DOMS but with little agreement. They include muscle fibre damage, breakdown of muscle proteins resulting in inflammation and cellular degradation (Armstrong, 1984; Smith, 1991; Friden and Lieber, 1992; Byrd, 1992; Clarkson and Sayers, 1999). McHugh et al. (1999) has argued for a combined neural, connective and cellular mechanism. Whatever the proposed mechanism causing DOMS the recovery process is important for regeneration. The symptoms of DOMS normally develop within 24 h and peak between 24–72 h (Cleak and Eston, 1992; Armstrong 1990).

The symptom of exercise-induced muscle damage (pain, spasm and inflammation) is similar to that of injured muscle therefore cryotherapy has been the primary treatment modality. Kuligowski et al. (1998) studied the effectiveness of warm, cold whirl pool and contrast therapy for treating delayed-onset muscle soreness 24, 48, and 72 h post exercise. The elbow flexors were eccentrically trained to elicit DOMS. Resting elbow flexion, active elbow flexion and extension, perceived soreness and maximal isometric contraction were the criteria used to assess what effect the different treatments had on DOMS. They found that perceived soreness and resting elbow flexion returned to baseline levels when cold whirlpool and contrast therapy were administered, propagating that these treatments were more effective than warm whirlpool and passive resting. Contrary, Miller (1992) found that a warm whirlpool was sufficient enough to decrease the perceived pain of DOMS in down hill treadmill running. However, the efficacy of control and warm whirlpool produced no significant

difference on quadriceps flexibility or strength. Likewise [Easton and Peters \(1999\)](#) concluded that following exhaustive eccentric exercise the cold-water immersion appeared to reduce muscle damage and stiffness but had no effect on the perception of muscle tenderness and strength loss.

It can be concluded that the research is contradictory to alleviating the symptoms of DOMS due to variations in the type, frequency and duration of treatments.

#### 4.4. Water temperature and ratio of cold to hot for hydrotherapy recovery

The common practised ratio of warm to cold bath duration for injury treatment is normally 3:1 or 4:1, with hot baths ranging from 37 to 43 °C alternating with cold baths temperature ranging from 12 to 15 °C ([Bell and Horton, 1987](#); [Myrer et al., 1994](#); [Brukner and Khan, 2001](#); [Halvorson, 1990](#)). The duration of the treatment is normally 20–30 min repeated twice daily ([Higgins and Kaminski, 1998](#)). It is also well documented that the treatment should finish on the cold treatment to encourage vasoconstriction for the injured athlete ([Bell and Horton, 1987](#); [Prentice, 1999](#); [Zuluaga et al., 1995](#); [Brukner and Khan, 2001](#)). [Calder \(1996\)](#) has documented guidelines (water temperature, repetitions and durations) for post exercise contrast water recovery that are similar to injury management. However, the duration for hot–cold shower (1–2 min hot, 10–30 s cold) differs to that of a spa/bath (3–4 min hot, 30–60 s cold) with little justification. [Higgins and Kaminski \(1998\)](#) and [Myrer et al. \(1997\)](#) found cold exposure of approximately 1 min was not sufficient enough to significantly decrease muscle temperature following warm water immersion, thus nullifying the required physiologic effects. There is a lack of evidence to support the post exercise recovery guidelines especially in the light of injury contrast treatment. Further research is required to investigate the different hot to cold time ratios. The appropriate mode of contrast treatment, the duration and the optimum water temperature need to be examined to verify its effectiveness as a recovery modality.

### 5. Holistic approach

Training and competition creates an overload to stress the body, which in turn produces fatigue followed by improved performance ([Calder, 1996](#)). Depending on the nature of the training or activities; nutritional, physiological, neurological and psychological components are stressed in different ways that result in fatigue. [Calder \(1995\)](#) devised a ranking system to help coaches identify which of the four fatigue components are the most stressed. For endurance training the ranking from the most to the least fatigued was nutritional, physiological, neurological, and psychological. However, for speed training the order was neurological, physiological,

nutritional and psychological fatigue. According to [Calder \(1995\)](#) the site of fatigue for the neurological component is the peripheral nervous system; physiological (muscle cell); nutritional (fluid and fuel stores); and psychological (central nervous system). From the ranking system the athlete and coach can then identify the appropriate recovery techniques needed to accelerate the recovery, which are rehydration and carbohydrate intake for fluid and fuel stores; hydrotherapy, ‘warm down’ and massage for increasing blood flow to fatigued muscles; visualisation, progressive muscular relaxation, meditation, flotation and massage for psychological fatigue; passive rest, massage, hydrotherapy, and ‘warm down’ for neurological fatigue. The holistic approach for recovery training may give better responses rather than using isolated recovery techniques. [Flanagan et al. \(1998\)](#) simulated a soccer tournament to examine the effects of recovery strategies on young male soccer players. They found those in the recovery group did not show any significant decline in 10 and 20 m speed times until the sixth day of competition compared to the control group. However, there was no change in vertical jump for both groups during the tournament. The recovery techniques that were employed included; massage, active pool sessions, hot–cold showers, stretching, hydration and nutritional plans. The consequences of the combined recovery techniques prevented physical drop off, lowered the occurrence of influenza symptoms and produced a higher rating of overall wellness.

### 6. Conclusion

Despite the popularity of hot–cold water immersion as a recovery modality, little research has been conducted. hot–cold contrast therapy for acute injuries has been used to explain the purported physiologic effects for post exercise recovery. However, the conflict of literature makes it difficult to give a conclusive mechanism. Additionally, the guidelines of the duration spent in each water condition, the repetitions, temperature, the use of underwater jets, the learning and training effect of the body adapting to the hot–cold contrast therapy all need to be vigorously investigated before it can be claimed as an accelerant for aiding recovery.

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