The impact of cold-water-immersion on athletes' muscle function and aerobic capacity: studies from thin to thick

L'impact de l'immersion en eau froide sur la fonction musculaire et l'aptitude aérobie des athlètes : brève analyse critique de certaines études

Helmi Ben Saad

University of Sousse, Farhat HACHED Hospital, Heart Failure (LR12SP09) Research Laboratory, Sousse, Tunisia.

RÉSUMÉ

Les études analysant l'impact de l'immersion en eau froide (IEF) sur les performances des athlètes sont intéressantes et devraient être encouragées. L'IEF attire actuellement l'attention du monde du sport en tant que technique de récupération et elle est souvent recommandée dans les sports où le contact se répète tout au long de l'entraînement et des compétitions. Cependant, si certaines études rapportaient l'efficacité de l'IEF en tant qu'analgésique contre les aspects traumatiques ou immunitaires, actuellement il n'y a pas d'unanimité sur son utilisation comme méthode d'amélioration des performances. Les chercheurs ont entrepris d'observer les effets de l'IEF sur la restauration de nombreux indicateurs de performance, caractérisant à la fois les voies énergétiques aérobies et anaérobies, mais aussi les différentes modalités de contraction musculaire. Cependant, peu de données semblent disponibles sur les effets de l'IEF sur la performance et la capacité de récupération. Les résultats concernant l'impact de l'IEF sur la performance sont contradictoires avec quelques études suggérant des effets bénéfiques et d'autres indiquant des effets négligeables. Les deux principaux objectifs de cet article sont d'exposer brièvement les données de la littérature relatives aux effets de l'IEF sur la fonction musculaire et la capacité aérobie des athlètes, et de clarifier l'origine des divergences entre les résultats des différentes études.

Mots clés. Immersion, Athlètes, Fonction musculaire, Capacité aérobie, Tunisie

SUMMARY

Studies treating the impact of cold-water-immersion (CWI) on athletes' performance are very interesting and should be encouraged. The CWI is currently attracting the attention of the sports world as a recovery technique and it is often recommended in sports where contact is repeated throughout training and competitions. However, if some studies reported the efficacy of CWI as an analgesic against traumatic or immune aspects, currently there is not consistent unanimity of its use as a method of improving performance. The researchers set out to observe the effects of CWI on the restoration of numerous performance indicators, characterizing both the aerobic and anaerobic energy pathways, but also the different modalities of muscle contraction. However, few data appear to be available on the effects of CWI on performance and recovery capacity and very few studies have observed results in the same direction. Results regarding the impact of CWI on performance are conflicting, with a few studies suggesting beneficial effects and others indicating negligible effects. The two main aims of the present paper are to briefly expose the literature data related to the effects of CWI on muscle function and aerobic capacity of athletes, and to clarify the origin of discrepancies between studies' findings.

Key-words. CWI, Athletes, Muscle function, Aerobic capacity, Tunisia

Correspondance
Helmi Ben saad
Laboratoire de Physiologie / Université de Sousse/Faculté de Médecine de Sousse
Email : helmi.bensaad@rns.tn

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A study of Babak et al. (1) aiming to explore the effects of four weeks of cold water habituation on the effectiveness of cold water immersion (CWI) recovery technique on muscle damage and function indices of young football players (n=20) was recently published in “La Tunisie Médicale”. The authors reported that CWI had no significant effect on serum levels of muscle damage biomarkers (ie, aspartate aminotransferase (AAT) and lactate dehydrogenase (LDH)) (1). Furthermore, there was no significant difference in power output and percent of decrease of repeated sprint ability (RSA) (1). The authors have recommended that football coaches and athletes should think more about using CWI as a recovery method (1). The findings of Babak et al. (1) are opposite to those reported by a Tunisian team in a recent experimental study published in Tunis Med [20 men aged 17 to 20 years divided into two groups matched for anthropometric data (CWI (n = 10) and no-CWI (n=10) groups] (2). The authors reported that at the end of the experimental protocol [Eight CWI sessions, CWI until the hip in a standing position (10 min; temperature: 11-12 °C)], compared to the non-CWI group, the CWI group had a better run time (3.27±0.07 vs. 3.15±0.04 min, respectively), had a lower heart-rate at rest (34±1 vs. 36±1%), had a better chronotropic response at the end of the 1000-m race (44±2 vs. 57±2%); had better hemoglobin oxygen saturation at the end of the race (98±0 vs. 95±1%), included a statistically lower number of desaturators during exercise (0 vs.90%), and had a significantly higher strength for all muscles tested (2). Contrarily to Babak et al. (1), Boujezza et al. (2) concluded that CWI improves the aerobic capacity and muscle strength of young footballers.

The two main aims of the present paper are to briefly expose the literature data related to the effects of CWI on muscle function and aerobic capacity of athletes, and to clarify the origin of discrepancies between studies' findings.

Studies treating the impact of CWI on athletes' performance are very interesting and should be encouraged. The CWI is currently attracting the attention of the sports world as a recovery technique and it is often recommended in sports where contact is repeated throughout training and competitions (eg, football) (2-5). However, if some studies (6, 7) reported the efficacy of CWI as an analgesic against traumatic or immune aspects, currently there is not consistent unanimity of its use as a method of improving performance (1, 2, 8). The researchers set out to observe the effects of CWI on the restoration of numerous performance indicators, characterizing both the aerobic and anaerobic energy pathways, but also the different modalities of muscle contraction (1, 2, 9-33). However, few data appear to be available on the effects of CWI on performance and recovery capacity (1, 2, 4, 15, 17, 30, 33) and very few studies have observed results in the same direction (9-16, 19, 32, 34-39). Results regarding the impact of CWI on performance are conflicting, with a few studies suggesting beneficial effects (2, 9, 32, 37) and others indicating negligible effects (1, 14, 35, 38, 39). The following paragraphs aimed to briefly report the impact of CWI on muscle function and aerobic capacity.

Impact of CWI on muscle function

Some studies have shown a positive impact of CWI on the recovery of force production capacity (2, 9, 17, 30). Thus, Bailey et al. (9) have shown a decrease in the loss of isometric force of knee flexion after use of CWI. Peiffer et al. (30) noted a decrease in strength loss after recovery by immersion (5 minutes at 14° C) after a 90-minutes cycling exercise followed by a 16.1 km time trial. Ingram et al. (17) demonstrated a decrease in isometric loss of strength, both extensor and flexor of the knee, after exercise simulating a team sport followed by immersion (twice 5-minutes at 10° C). The explanatory hypotheses are based on a reduction in muscle edema associated with a reduction in the inflammatory response, but not linked to water temperature or the duration of exposure to cold (3, 5). Several other studies (1, 9, 13, 23, 26, 29, 31) have observed that CWI does not attenuate loss of strength after strenuous exercise. Thus, Howatson et al. (23) showed that 96-h after exercise, the non-CWI and the CWI groups were, respectively, able to reproduce only 96 and 93% of their initial isometric force-producing capacity of the knee extensors. Likewise, Bailey et al. (9) have observed that the recovery of isometric maximum voluntary force of the knee extensors was not affected by the recovery modality employed after 90 minutes' exercise followed by CWI (10 minutes at 10° C). The explanatory hypotheses for the absence of positive results are linked to the inability to contain the inflammatory response and to the decrease in nerve conduction by cold (3, 5). This would prevent the athlete for a time from producing maximum power (31) and maximum voluntary or stimulated force (13). Indeed, some studies have shown that there is a correlation between the decrease in muscle temperature and the electromyography signal (26). Finally, a study on reflexes has concluded that cold induces a decrease in performance via an increase in the excitability of the motor neuron pool (27).

Impact of CWI on aerobic capacity

Some previous studies (1, 2, 9, 15, 22, 24, 30) have focused on the impact of CWI, as a recovery method, on the reproduction of a performance lasting longer than one minute. Only a few authors (15, 30) have attempted to measure the impact of recovery by immersion on the repetition of a time trial on a bicycle of 4 km (30) and 9 min (15). Peiffer et al. (30) have observed a smaller decrease in the mean output power for the CWI group compared to the non-CWI group, leading to better performance for the first group. Vaile et al. (16) have shown that the performance can be maintained through recovery by CWI. The explanatory hypotheses classically advanced have been the reduction in the perception of pain and/or fatigue (3, 5). Thus, CWI would reduce, via vasoconstriction, the permeability of vessels to immune cells, thereby reducing edema and the inflammatory process, which would reduce the perception of pain (9). Moreover, a decrease in nervous activity would have a positive impact because it would allow a significant reduction in the perception of fatigue after immersion (24) and, therefore, would increase the subjects' ability to maintain an impact for longer or to travel a distance faster. Finally, Heyman et al. (22) have demonstrated that 15 minutes of CWI (3 x 5 minutes) made it possible to preserve the performance linked to climbing routes for a female population. It is recognized that maintaining core temperature has a greater metabolic cost because it increases the respiratory rate and oxygen consumption (VO_2) (3, 5). In addition, vasoconstrictions associated with a decrease in heart-rate can be deleterious or even dangerous for health (3, 5). In addition, it has been noted that the mediation of heart-rate by β2-adrenergics is reduced after cold treatment (25). A Tunisian study had confirmed the above-mentioned data by showing a lower heart-rate at rest or at end of the race in the CWI group (2). The Tunisian study had identified the beneficial effects of CWI, performed after 20 minutes of a passive recovery (2). This goes against the idea that CWI technique does not seem to provide any benefit when applied more than 20 minutes after exercise or between sets of short sprints (3, 5, 18).

3. Physio-pathological mechanisms

Recovery by CWI is based on two mechanisms: the impacts of cold and hydrostatic pressure (2, 3, 5). The first mechanism is linked to the temperature of the water (usually located between 4 and 16° C (14, 16, 32, 37) and would reduce the core temperature, generate local vasoconstriction, alter nerve transmission, or to minimize the inflammatory response (2, 3, 5). The second mechanism is induced by the use of water which would allow the effects of hydrostatic pressure on the body submerged to be combined with the cold (2, 3, 5). The pressure of water exerts a pressure greater than that of air on the body, causing the movement of gases, substances, and fluids (2, 3, 5). This quality would particularly reduce the size of the edema caused by exercise, but also reduce the nerve impulse by compression of muscles and nerves (2, 3, 5).

Origin of the reported findings' discrepancies

The discrepancies between the results could be explained by different factors related to the characteristics of the CWI (points 1 to 5), the applied exercise protocols, and/or the applied performance tests (points 6 to 9), and the characteristics of the included subjects (points 10 to 12):

Point 1. CWI duration (minutes): 3 (14),10 (2, 9, 32, 40), 14 (15, 16), 15 (1, 19, 34, 37), 20 (39), 24 (36);

Point 2. Applied temperature (°C): 5 (14), 6 (41), 8 (32), 10 (9, 19, 39), 11-12 (2), 15 (1, 15, 16, 37, 40), 24 (14);

Point 3. Depth of the body subject to the CWI: up to the hip in a standing position (2, 9, 19, 32), chest height (1), entire body up to the neck in a standing position (15, 16), iliac crest in a sitting position (14);

Point 4. Delays between the end of the training session and the CWI session: passive recovery of 20 minutes (2, 18, 21), CWI immediately after the end of the training session (1, 19, 28, 41) or immediately after a slight active recovery (20);

Point 5. Number of CWI sessions: 4 (1), 8 (2), undetermined (9, 13-15, 19, 32, 34-39);

Point 6. Exercise protocols: treadmill running (19), team games (34), eccentric limb exercise (15), simulated football test (1);

Point 7. Applied performance tests: races (400-m (19), 1000 m (2, 19), 5000 m (19)), shuttle test (1, 9, 19), handgrip (39), vertical jump (9, 15, 34), eccentric quadriceps exercises (14, 15), static muscle contractions of the lower limbs (32), eccentric contractions and concentric elbow (32), 6-s bicycle sprint (34), muscular exercise test with increasing load (39), 3 repetitions of 20 m jogging, one 20 m running, 4 seconds rest, 3 repetitions of 20 m jogging with 55% VO_{2max} and 3 repetitions of 20 m sprinting with 95% VO_{2max} (1), Sargent vertical jump test (1), RSA (1);

Point 8. Exercise intensity: 6 seconds sprint on a bicycle (34), muscular exercise test with increasing load (39);

Point 9. Applied methods to explore muscle activities: direct ["muscle testing" (2), isometric maximum force (14, 32), muscle power (34), isokinetic muscle function (9), isokinetic flexion and extension (35), dynamometer or an isocynistism device (9, 14, 32, 34, 35)] and indirect [biomarkers of muscle damage (eg, AAT (1, 40), creatine phosphokinase (40), LDH (1, 40, 41))] methods;

Point 10. Physical activity status of included subjects: sedentary subjects (14, 36, 39) or subjects involved in various sports (1, 2, 9, 15, 19, 34, 35);

Point 11. Sports disciplines: multisport athletes (19), basketball (35), endurance sport (15), football (1, 2, 34), Jujitsu (41), rugby (40);

Point 12. Sex of the included subjects: only men (1, 2, 9, 40, 41) or both men and women (22, 32).

This difference in CWI procedures could alter physiological adaptations (3, 5). First, the different delays between the end of the training session and the CWI session can modify lactate elimination and therefore performance (18). Secondly, Farhi and Linnarsson (33) by modulating the depth of CWI at constant water temperature have observed very large variations in heart-rate. This difference in CWI procedures could generate more or less pressure on the body, thereby altering physiological adaptations (3, 5). Thirdly, the impacts of CWI are sex-dependent (32): the effect of CWI on isometric strength is more pronounced in men compared to women.

In conclusion, the present Letter to the Editor is a call for additional future studies treating the impacts of CWI on athletes' physical performance.

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