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Optimizing Cold-Water Immersion for Exercise-Induced Hyperthermia: An Evidence-Based Paper

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Reference: Zhang Y, Davis JK, Casa DJ, Bishop PA. Optimizing cold water immersion for exercise-induced hyperthermia: a meta-analysis. *Med Sci Sports Exerc*. 2015;47(11):2464–2472.

Clinical Questions: Do optimal procedures exist for implementing cold-water immersion (CWI) that yields high cooling rates for hyperthermic individuals?

Data Sources: One reviewer performed a literature search using PubMed and Web of Science. Search phrases were *cold water immersion*, *forearm immersion*, *ice bath*, *ice water immersion*, *immersion*, AND *cooling*.

Study Selection: Studies were included based on the following criteria: (1) English language, (2) full-length articles published in peer-reviewed journals, (3) healthy adults subjected to exercise-induced hyperthermia, and (4) reporting of core temperature as 1 outcome measure. A total of 19 studies were analyzed.

Data Extraction: Pre-immersion core temperature, immersion water temperature, ambient temperature, immersion duration, and immersion level were coded a priori for extraction. Data originally reported in graphical form were digitally converted to numeric values. Mean differences comparing the cooling rates of CWI with passive recovery, standard deviation of change from baseline core temperature, and within-subjects r were extracted. Two independent reviewers used the Physiotherapy Evidence Database (PEDro) scale to assess the risk of bias.

Main Results: Cold-water immersion increased the cooling rate by 0.03°C/min (95% confidence interval [CI] = 0.03, 0.04°C/min) compared with passive recovery. Cooling rates were more effective when the pre-immersion core temperature was $\geq$38.6°C ($P = .023$), immersion water temperature was $\leq$10°C ($P = .036$), ambient temperature was $\geq$20°C ($P = .013$), or immersion duration was $\leq$10 minutes ($P < .001$). Cooling rates for torso and limb immersion (mean difference = 0.04°C/min, 95% CI = 0.03, 0.06°C/min) were higher ($P = .028$) than those for forearm and hand immersion (mean difference = 0.01°C/min, 95% CI = –0.01, 0.04°C/min).

Conclusions: Hyperthermic individuals were cooled twice as fast by CWI as by passive recovery. Therefore, the former method is the preferred choice when treating patients with exertional heat stroke. Water temperature should be <10°C, with the torso and limbs immersed. Insufficient published evidence supports CWI of the forearms and hands.

Key Words: ice-water immersion, ice bath, cooling rates, exertional heat stroke

COMMENTARY

The incidence of exertional heat stroke (EHS) was reported to be approximately 1 per 1000 participants over 18 years in a recreational road race.[1] Although the risk of EHS varies across sports and environmental conditions, it is a life-threatening condition that every athletic trainer should be prepared to manage. Clinicians must be aware of the treatment options for this condition, as the goal of EHS treatment is to lower core body temperature as quickly as possible. Extensive research has been conducted on various cooling mechanisms, including cold-water immersion (CWI; 1°C–15°C [33.8°F–59°F]), ice-water immersion (1°C–3°C [33.8°F–37.4°F]), ice sheets, ice packs, and passive recovery. Multiple authors[2,3] have validated CWI as the most effective cooling mechanism for the treatment of patients with EHS and deemed it the current gold standard accepted by multiple professional organizations. Cold-water immersion has a 100% survival rate, which cannot be overlooked when clinicians make decisions on cooling athletes with suspected EHS.[2] Researchers[2] have provided broad, practical guidelines, including preparation, body coverage, vital signs, circulation, duration, fluid consumption, and transportation recommendations. Although this literature has offered generic insights into guidelines for implementing CWI, specific evidence-based procedures have not been well established.

Investigation[3] suggests a direct relationship between the amount of time core body temperature is above the critical threshold (40°C) and the outcome of the treatment. Zhang et al[4] aimed to quantify specific factors that influence the effectiveness of CWI, including water temperature, air temperature, body surface contact, and severity of hyperthermia. Standard procedures to recognize and treat cases of EHS are provided to reduce fatalities in sport. The authors of this meta-analysis compared the effectiveness of CWI versus passive recovery, similar to situations involving a lack of medical personnel, inaccurate temperature measurement, misdiagnosis, or inappropriate emergency treatments (or a combination of these). Compared with passive rest, cooling rates were more effective when the pre-immersion core temperature (measured via rectal or telemetry pill thermometry) was ≥38.6°C ($P = .023$), immersion water temperature was ≤10°C ($P = .036$), ambient temperature was ≥20°C ($P = .013$), or immersion duration was ≤10 minutes ($P < .001$), demonstrating these best practices for treatment. The recommendations for ambient temperature are often uncontrollable in the field, but the spirit of the recommendation suggests that a larger *temperature gradient*, or the difference between the air and water temperatures, helps to cool the patient faster. If the ambient temperature does not exceed 20°C, ensuring that the water remains below 10°C is important to maintain the temperature gradient. Furthermore, the cooling rate of torso-plus-limb immersion (mean difference = 0.04°C/min, 95% confidence interval [CI] = 0.03, 0.06°C/min) was higher ($P = .028$) than that of forearms-plus-hands immersion (mean difference = 0.01°C/min, 95% CI = –0.01, 0.04°C/min).[4] The current literature, including this analysis and a recent systematic[2] review, has established consensus and provided overwhelming evidence for immersion of the largest portion of the body in cold water for effective cooling.[3]

With optimal guidelines for best practices, athletic trainers can act more systematically in life-threatening situations. Zhang et al[4] offered increased clarity and specificity about the effectiveness of CWI, which should guide emergency procedures. When the environmental temperature is ≥20°C, clinicians should have CWI readily available at athletic events. Although a water temperature of ≤5°C may not always be feasible in the field, water at 5°C to 10°C is effective in treating patients with severe cases of EHS. Previous researchers have investigated the cooling rate of various water temperatures to determine effectiveness. A greater cooling rate was found using the 2°C ice bath (0.35°C/min) compared with immersion at 8°C, 14°C, or 20°C (0.19°C, 0.15°C, and 0.19°C/min, respectively).[5] Yet to achieve such a temperature, a significant amount of ice is required, which may not always be readily available, and when applied to the water, may be uncomfortable and often intolerable for patients.[6] However, despite these limitations, CWI should be the treatment of choice. The recommendation of water temperature at 10°C, which requires less ice, has resulted in a 100% survival rate and should therefore not be disregarded.[7]

The authors made several recommendations stemming from the data, including the following: (1) be prepared to implement CWI when endurance events take place at ambient temperature of ≥20°C; (2) continuous exposure to cold water at approximately 10°C is a proven method, but be prepared to implement an even larger core-to-water temperature gradient for treating patients with severe EHS; (3) whole-body CWI can maximize conductive heat dissipation, but forearm-plus-hands CWI is insufficient for rapid cooling; and (4) although measuring core temperature is not commonly feasible in the field when a patient is thought to have EHS, CWI should be started at a core temperature of 41.5°C and can be stopped when it reaches 38.6°C, ideally within 20 minutes of immersion, so that active cooling and recovery are implemented before advanced emergency support services arrive.[4] Although the authors addressed the feasibility of measuring core temperature in the field, we remind readers to follow best-practice guidelines and the 2015 National Athletic Trainers' Association position statement on exertional heat illnesses[7] in performing rectal thermometry when a patient is believed to have EHS.

This meta-analysis and the position statement[7] summarize decades of research in environmental physiology and offer the best evidence to guide clinical practice in treating EHS. According to the position statement,[7] a cold-water or ice tub (1.7°C [35°F] to 15°C [59°F]) and ice towels should be available to immerse and soak the patient with suspected EHS up to the neck. The position statement supplements the conclusions of Zhang et al[4] by advising that the patient's equipment should be removed before he or she enters the cold tub or while the temperature is being assessed and the tub is being prepared.[7] Step-by-step guidelines for EHS recognition and return to play, as well as an algorithm for treatment, are provided. These detailed procedures, along with precise recommendations from Zhang et al,[4] should lead to improved recognition and optimal treatment of EHS. To reduce mortality, clinicians have the professional responsibility to rely on and properly implement these best evidence-based guidelines when a patient has suspected EHS.

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