

Does Precooling With Whole-Body Immersion Affect Thermal Sensation or Perceived Exertion? A Critically Appraised Topic

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Clinical Scenario: Exertional heat stroke (EHS) is a potentially deadly heat illness and poses a significant health risk to athletes; EHS survival rates are near 100% if properly recognized and treated. Whole-body cold water immersion (CWI) is the most effective method for lowering body core temperature. Precooling (PC) with CWI before exercise may prevent severe hyperthermia or EHS by increasing the body's overall heat storage capacity. However, PC may also alter athletes' perception of how hot they feel or how hard they are exercising. Consequently, they may be unable to accurately perceive their body core temperature or how hard they are working, which may predispose them to severe hyperthermia or EHS. **Clinical Question:** Does PC with whole-body CWI affect thermal sensation (TS) or rating of perceived exertion (RPE) during exercise in the heat? **Summary of Key Findings:** In 4 studies, RPE during exercise ranged from 12 (2.0) to 20 (3.0), with no clinically meaningful differences between PC and control trials. TS scores ranged from 2 (1.0) to 8 (0.5) in control trials and from 2 (1.0) to 7.5 (0.5) during PC trials. **Clinical Bottom Line:** PC did not cause clinically meaningful differences in RPE or TS during exercise. It is unlikely that PC would predispose athletes to EHS by altering perceptions of exercise intensity or body core temperature. **Strength of Recommendation:** None of the reviewed studies (all level-2 studies with Physiotherapy Evidence Database scores ≥ 5) suggest that PC with CWI influences RPE or TS in exercising males.

Keywords: exercise, heat stroke, hyperthermia, prevention

Focused Clinical Question

Does precooling (PC) with whole-body cold water immersion (CWI) affect thermal sensation (TS) or rating of perceived exertion (RPE) during exercise in the heat?

Summary of Search, "Best Evidence" Appraised, and Key Findings

- We searched for studies that compared subjects' TS and RPE during exercise in the heat after they underwent CWI to responses from the same subjects who were not precooled. To be included, studies must have been of level-2 evidence or higher (Oxford Centre for Evidence-based Medicine [CEBM])¹ and have Physiotherapy Evidence Database (PEDro) scores ≥ 5 .
- Four studies²⁻⁵ met our predetermined inclusion and exclusion criteria.
- None of the reviewed studies²⁻⁵ reported clinically meaningful differences in RPE or TS between PC and control conditions.

Clinical Bottom Line

There is minimal evidence to suggest that CWI before exercise would impair perception of exercise intensity or TS during exercise in the heat. Clinicians can use PC with CWI with minimal concern for predisposing athletes to exertional heat stroke (EHS) or other

exertional heat illnesses because of alterations in these 2 perceptual variables.

Terms Used to Guide the Search Strategy

- Patient/Client group: Exercising humans
- Intervention/Assessment: PC with whole-body CWI
- Comparator: Exercising humans who were not precooled before exercise
- Outcome: TS, RPE, or perceived effort during exercise

Sources of Evidence Searched

- PubMed
- CINAHL
- Cochrane
- SportDiscus
- PEDro
- Additional articles obtained through review of reference lists

Predetermined Inclusion and Exclusion Criteria

Inclusion

- Studies with subjects who were euthermic before exercise
- Studies in which subjects exercised in a hot and humid environment (ambient temperature $>30^{\circ}\text{C}$, with relative humidity $>30\%$)
- Studies with exercise duration lasting ≥ 30 minutes
- Studies that used whole-body CWI to precool their subjects before exercise

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- Studies that measured TS and RPE during exercise
- English-language studies published between 2002 and 2017
- Studies classified as Oxford Centre for Evidence-based Medicine (CEBM)¹ level-2 evidence or higher, with PEDro scores ≥ 5

Exclusion

- Studies that used passive heating techniques rather than exercise to induce hyperthermia
- Studies that cooled subjects during exercise (ie, percooling)
- Studies that cooled subjects between exercise bouts

Results of Search

We found 4 studies²⁻⁵ that met our predetermined inclusion and exclusion criteria. Each study was independently categorized and scored by both authors using the 2011 CEBM criteria¹ and separate PEDro checklists (Table 1). If discrepancies in scores existed between authors, studies were re-reviewed and discussed until consensus was reached.

Best Evidence

The 4 studies²⁻⁵ in Table 1 were the best evidence and selected for inclusion in this Critically Appraised Topic (CAT). These studies were included because they were considered to be level-2 evidence or higher, had PEDro scores ≥ 5 , and compared TS and perceived exertion during exercise in the heat with or without PC.

Implications for Practice, Education, and Future Research

Our results demonstrate that PC with CWI has minimal impact on how hot subjects feel or their perceived exercise intensity in the heat. These results remove 2 of the main concerns with using PC as a prophylactic for severe hyperthermia and EHS. Although PC does not appear to alter subjects' RPE or TS, it does increase the body's heat storage capacity,⁶ which may prevent the onset of severe hyperthermia and improve exercise tolerance in hot and humid conditions. Consequently, athletes may be able to exercise at higher exercise intensities or for longer durations before they become severely hyperthermic.^{2,5} For example, Siegal et al⁵ reported that PC increased time to exhaustion by approximately 10 minutes (PC = 56.8 [5.6] min vs control = 46.7 [7.2] min). However, clinicians must still monitor their athletes for exertional heat illnesses even if PC is used prior to exercise because its effects on TS and RPE are small and transient.

Rating of perceived exertion provides a means of quantifying how hard an individual feels they are exercising. Environmental conditions, exercise intensity, age, and psychologic factors can influence RPE.⁷ Based on our results (Table 2), there was no evidence to suggest that PC before exercise caused clinically meaningful differences in RPE during exercise compared with the control condition. This could be the result of our selected studies²⁻⁶ designs. All the studies in our CAT used crossover designs that would have minimized age and psyche as factors contributing to differences in RPE. Moreover, all subjects completed the same exercise protocol under similar environmental conditions on the PC day as the control day. Thus, the workload for each subject would have been consistent regardless of the cooling condition performed and likely contributed to the lack of differences in RPE between studies.

TS is a subjective measurement of how hot an individual feels in an environment. Our results showed that PC with CWI produced no differences in TS during exercise compared with the control condition. The lack of differences in TS between conditions is likely for 3 reasons. First, TS stabilizes relatively quickly (within 4–8 min) when humans move from cool to warmer environments.¹² Second, in warm environments, whole-body TS is influenced more by how warm the head feels.¹³ None of our studies cooled the head during PC; therefore, TS scores were comparable between conditions. Finally, TS is primarily affected by skin temperature and rate of skin temperature change.¹⁴ In our CAT's studies, the effects of PC on skin temperature were temporary and lessened as exercise progressed. For example, Clarke et al⁴ observed that skin temperatures following PC were comparable with control skin temperatures after just 10 min of exercise.

We acknowledge 2 limitations of our CAT. First, all the studies we reviewed measured the effects of PC in healthy males between 20 and 33 years of age. PC effects on females, youth, or elderly athletes is worthy of future research given that thermoregulatory capabilities differ between genders¹⁵ and change over the life span.¹⁶ Second, the exercise durations of the studies we reviewed ranged from 47 to 90 minutes. To compare results between studies, we divided each study's exercise duration into thirds (ie, start, middle, and end of exercise). Consequently, the TS and RPE data from each study in our CAT were demonstrative of similar but not the exact same times during exercise.

PC with CWI may be a safe strategy to prevent severe hyperthermia or EHS in athletes exercising in hot and humid environments. PC did not cause meaningful differences in perceptions of environmental conditions or exercise intensity between trials. Therefore, clinicians can consider using whole-body PC to improve body heat storage capacity without affecting athletes' perceptions of how hot they feel or how hard they work during exercise.

Table 1 Summary of Study Designs of Articles Retrieved

| Author | Study design | Level of evidence ^a | PEDro score |
|---------------------------|---|--------------------------------|-------------|
| Skein et al ² | Randomized, counterbalanced crossover trial | 2 | 6 of 10 |
| Ross et al ³ | Randomized, crossover trial | 2 | 6 of 10 |
| Clarke et al ⁴ | Randomized, counterbalanced crossover trial | 2 | 6 of 10 |
| Siegel et al ⁵ | Randomized, crossover trial | 2 | 6 of 10 |

^aLevel of evidence assessed using the Oxford Centre for Evidence-based Medicine 2011 criteria.¹

Table 2 Characteristics of Included Studies

| Authors | Skein et al ² | Siegel et al ⁵ | Clarke et al ⁴ | Foss et al ³ |
|---|---|---|---|---|
| Patients, n | 10 males (age = 20 [1] y, ht = 182 [6] cm, mass = 84 [11] kg, BSA ^a = 2.05 m ² , BSA/mass = 0.024 m ² /kg) | 8 males (age = 26 [4] y, ht = 179.9 [6.7] cm, mass = 78.1 [5.9] kg, BSA ^a = 1.98 m ² , BSA/mass = 0.025 m ² /kg) | 8 males (age = 28 [6] y, ht = 176 [8] cm, mass = 72.6 [12.5] kg, BSA ^a = 1.89 m ² , BSA/mass = 0.026 m ² /kg) | 12 males (age = 33 [5.1] y, ht = N/A, mass = 72.1 [5.5] kg, BSA ^a = N/A, BSA/mass = N/A) |
| Experimental design | Randomized, counterbalanced, crossover study | Randomized crossover study | Randomized, counterbalanced, crossover study | Randomized, crossover study |
| Precooling intervention before exercise | Subjects immersed up to the suprasternal notch for 15 min in 10°C (1°C) water. Ice towels (5°C [2°C]) then placed on shoulders for ≤6 min | Subjects immersed to the midsternum for 30 min in water that gradually lowered from 24.8°C (0.8°C) to 23.4°C (0.7°C) | Subjects immersed up to the neck for 60 min in 20.3°C (0.8°C) water | Subjects immersed to the midsternum for 10 min in 10°C water. Subjects then wore a cooling vest for 20 min |
| Control intervention before exercise | Subjects sat in a thermoneutral environment (19°C [2°C]; 24% [6%] RH) for 15 min | Subjects ingested 7.5 g/kg body mass of warm carbohydrate drink (37°C) | Subjects sat in a thermoneutral environment (20.2°C [1.7°C]; 60.2% [2.5%] RH) for 60 min | Subjects sat in a hot environment (32°C – 35°C; 50%–60% RH) for 30 min |
| Exercise protocol | Subjects completed a 50-min self-paced, intermittent sprint protocol in a hot environment (31°C [1°C]; 33% [5%] RH) | Subjects ran to exhaustion (~47–57 min) at ventilatory threshold in a hot environment (34°C [0.1°C]; 52% [3%] RH) | Subjects completed a 90-min run at 65% VO ₂ max on a treadmill in a hot environment (32.4°C [0.9°C]; 46.8% [6.4%] RH) | Subjects completed a 46.4-km cycling time trial (~80 min) at an average power output of ~280 W in a hot environment (32°C–35°C; 50%–60% RH) |
| Results | <p>RPE start^g CON = 14 (1) PC = 14 (1)</p> <p>RPE mid^h CON = 17 (1) PC = 17 (2)</p> <p>RPE endⁱ CON = 19 (1) PC = 19 (1)</p> <p>TS start^g CON = 6 (0.5) PC = 5.5 (1)</p> <p>TS mid^h CON = 7.0 (1) PC = 7 (0.5)</p> <p>TS endⁱ CON = 7.5 (1) PC = 7.5 (0.5)</p> <p>T_{core} start^g CON = 37.6°C (n/a) PC = 36.9°C (0.3°C)</p> <p>T_{core} mid^h CON = 38.5°C (n/a) PC = 38.0°C (0.4°C)</p> <p>T_{core} endⁱ CON = 38.8°C (n/a) PC = 38.6°C (0.6°C)</p> | <p>RPE start^g CON = 14 (3) PC = 13 (3)</p> <p>RPE mid^h CON = 17 (3) PC = 16 (2)</p> <p>RPE endⁱ CON = 20 (3) PC = 19 (2)</p> <p>TS start^g CON = 6 (0.5) PC = 5 (0.5)</p> <p>TS mid^h CON = 7 (0.5) PC = 6 (0.5)</p> <p>TS endⁱ CON = 8 (0.5) PC = 7 (0.5)</p> <p>T_{core} start^g CON = 37.4°C (0.2°C) PC = 36.8°C (0.3°C)</p> <p>T_{core} mid^h CON = 38.1°C (0.3°C) PC = 37.6°C (0.2°C)</p> <p>T_{core} endⁱ CON = 38.8°C (0.3°C) PC = 38.3°C (0.3°C)</p> | <p>RPE start^g CON = 12 (2) PC = 12 (2)</p> <p>RPE mid^h CON = 14 (2) PC = 14 (2)</p> <p>RPE endⁱ CON = 16 (3) PC = 16 (3)</p> <p>TS start^g CON = 2 (1) PC = 2 (1)</p> <p>TS mid^h CON = 3 (1) PC = 3 (1)</p> <p>TS endⁱ CON = 3 (1) PC = 3 (1)</p> <p>T_{core} start^g CON = 37.8°C (0.3°C) PC = 37.1°C (0.3°C)</p> <p>T_{core} mid^h CON = 38.5°C (0.3°C) PC = 38.4°C (0.3°C)</p> <p>T_{core} endⁱ CON = 38.8°C (0.4°C) PC = 38.8°C (0.4°C)</p> | <p>Rating of effort start^g CON = N/A PC = N/A</p> <p>Rating of effort mid^h CON = N/A C = N/A</p> <p>Rating of effort endⁱ CON = 98% (6%) PC = 98% (3%)</p> <p>TS start^g CON: 6 (0.5) PC = 5.5 (0.5)</p> <p>TS mid^h CON = 6.5 (0.5) PC = 6 (1)</p> <p>TS endⁱ CON = 7 (0.5) PC = 6 (1)</p> <p>Raw T_{core} data are not reported</p> |

(continued)

Table 2 (continued)

| Authors | Skein et al ² | Siegal et al ⁵ | Clarke et al ⁴ | Ross et al ³ |
|-------------|--|--|--|---|
| | <p>$T_{skin_start}^g$ CON = 26.2°C (n/a) PC = 24.5°C (0.5°C)</p> <p>$T_{skin_mid}^h$ CON = 32.5°C (n/a) PC = 32.5°C (0.5°C)</p> <p>$T_{skin_end}^i$ CON = 32.0°C (n/a) PC = 33.0°C (0.5°C)</p> | <p>$T_{skin_start}^g$ CON = 35.5°C (0.5°C) PC = 33.0°C (0.5°C)</p> <p>$T_{skin_mid}^h$ CON = 35.5°C (0.5°C) PC = 34.5°C (0.5°C)</p> <p>$T_{skin_end}^i$ CON = 35.5°C (1.5°C) PC = 35.0°C (1.0°C)</p> | <p>$T_{skin_start}^g$ CON = 35.0°C (0.1°C) PC = 33.1°C (3.5°C)</p> <p>$T_{skin_mid}^h$ CON = 35.0°C (1.0°C) PC = 35.0°C (1.0°C)</p> <p>$T_{skin_end}^i$ CON = 35.0°C (1.2°C) PC = 35.0°C (1.0°C)</p> | <p>T_{skin} was not measured</p> |
| Conclusions | No clinically significant differences were seen in RPE and TS scores between conditions | No clinically significant differences were seen in RPE and TS scores between conditions | No clinically significant differences were seen in RPE and TS scores between conditions | No clinically significant differences were seen in RPE and TS scores between conditions |

Abbreviations: BSA, body surface area; CON, control; ht = height; N/A, not available; PC, precooling; RH, relative humidity; RPE, rating of perceived exertion; T_{core} , body core temperature; T_{skin} , skin temperature; TS, thermal sensation. Note: All data are reported as mean (SD); data were rounded to the nearest 0.5 integer for TS and nearest full integer for RPE because of the reporting accuracy of these scales.

^aBSA estimated using the Du Bois⁹ formula: weight (kg)^{0.425} × height (cm)^{0.725} × 0.007184.

^bRPE measured using Borg's 6 (least effort) to 20 (maximum effort) scale.⁹

^cThermal stress measured using a 10-point Likert scale ranging from 1 (unbearably cold) to 10 (unbearably hot).¹⁰

^dThermal sensation measured using a 9-point Likert scale ranging from 0 (unbearably cold) to 8 (unbearably hot).¹¹

^eThermal sensation measured using ASHRAE-standard 55-2004 thermal environmental conditions for human occupancy.

^fRating of effort given measured using modified Borg scale,⁹ where effort was recorded between 0% and 100%.

^gStart = first third of exercise.

^hMid = middle third of exercise.

ⁱEnd = final third of exercise.

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