

Does Gender Affect Rectal Temperature Cooling Rates? A Critically Appraised Topic

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Clinical Scenario: Exertional heat stroke (EHS) is a medical emergency characterized by body core temperatures $>40.5^{\circ}\text{C}$ and central nervous system dysfunction. An EHS diagnosis should be immediately followed by cold-water immersion (CWI). Ideally, EHS victims cool at a rate $>0.15^{\circ}\text{C}/\text{min}$ until their temperature reaches 38.9°C . While generally accepted, these EHS treatment recommendations often stem from research that examined only males. Since gender differences exist in anthropomorphics (eg, body surface area, lean body mass) and anthropomorphics impact CWI cooling rates, it is possible that CWI cooling rates may differ between genders. **Clinical Question:** Do CWI rectal temperature (T_{rec}) cooling rates differ between hyperthermic males and females? **Summary of Findings:** The average T_{rec} cooling rate across all examined studies for males and females was 0.18 (0.05) and 0.24 (0.03) $^{\circ}\text{C}/\text{min}$, respectively. Hyperthermic females cooled $\sim 33\%$ faster than males. **Clinical Bottom Line:** Hyperthermic females cooled faster than males, most likely because of higher body surface area to mass ratios and less lean body mass. Regardless of gender, CWI is highly effective at lowering T_{rec} . Clinicians must be able to treat all EHS victims, regardless of gender, with CWI, given its high survival rate when implemented appropriately. **Strength of Recommendation:** Moderate evidence (2 level 3 studies) suggests that females cool faster than males when treated with CWI following severe hyperthermia. Despite gender differences, cooling rates exceeded cooling rate recommendations for EHS victims (ie, $0.15^{\circ}\text{C}/\text{min}$).

Keywords: females, heat stroke, hyperthermia, males, sex

Focused Clinical Question

Do cold-water immersion (CWI) rectal temperature (T_{rec}) cooling rates differ between hyperthermic males and females?

recommendations for exertional heat stroke (EHS) victims (ie, $0.15^{\circ}\text{C}/\text{min}$).⁵

Summary of Search, “Best Evidence” Appraised, and Key Findings

- We searched for studies that used CWI (water temperature $<20^{\circ}\text{C}$), the gold standard treatment for exertional heat stroke,¹ to treat hyperthermic males and females (eg, $T_{\text{rec}} \geq 39.5^{\circ}\text{C}$).
- Nine studies met the search criteria; however, 6 studies were excluded because data were not separated by gender. Three studies²⁻⁴ met our predetermined inclusion and exclusion criteria for this critically appraised topic (CAT) study.
- Two studies^{2,3} observed clinically meaningful differences, with females having higher T_{rec} cooling rates. The third study⁴ observed no differences in T_{rec} cooling rates between males and females (Table 1). The average effect size for all studies analyzed in this CAT²⁻⁴ was 2.4 (ranged from 0 to 3.9).
- The average T_{rec} cooling rates across all examined studies²⁻⁴ were 0.18 (0.05) and 0.24 (0.03) $^{\circ}\text{C}/\text{min}$ for males and females, respectively. Although hyperthermic females cooled $\sim 33\%$ faster than males, both genders cooled faster than

Clinical Bottom Line

There is moderate evidence that hyperthermic females cool faster than males. In the studies analyzed,²⁻⁴ hyperthermic males typically needed to be immersed in cold water for 4.3 (3.0) minutes longer than hyperthermic females. Despite the apparent cooling differences between genders, CWI continues to be the gold standard treatment for all EHS patients, male or female.⁵

Terms Used to Guide Search Strategy

- Patient/Client group: Hyperthermic adults
- Intervention/Assessment: Gender (males), sex
- Comparison: Gender (females), sex
- Outcome: Rectal temperature cooling rate

Sources of Evidence Searched

- PubMed
- CINAHL
- SPORTSDiscus
- Cochrane Library
- ERIC
- Additional articles were obtained by review of reference lists

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Table 1 Characteristics of Included Studies

Authors	Armstrong et al ³	DeMartini et al ⁴	Lemire et al ²
Patients, n	8000 athletes. 21 (35 [3] y) were diagnosed with extreme hyperthermia and either heat exhaustion or EHS. 17 males (age = 36 [12] y); 4 females (age = 32 [7] y). *Subject anthropomorphics not reported.	180,000 athletes (~10,000 each year). 258 athletes had documented EHS signs and symptoms (179 EHS cases reported by gender). 110 males (age = 34 [13] y); 69 females (age = 36 [12] y). *Subject anthropomorphics not reported.	10 males (age = 25 [4] y, ht = 177.5 [5.8] m, mass = 73.6 [9.4] kg, body fat = 13.8% [2.9%], LBM = 63.4 [7.2] kg, BSA/M = 261 [16] cm ² /kg, BSA/LBM = 302 [15] cm ² /kg). 9 females (age = 24 [3] y, ht = 165.4 [6.8] m, mass = 64.2 [9.3] kg, body fat = 23.9% [6.1%], LBM = 48.4 [4.5] kg, BSA/M = 268 [19] cm ² /kg, BSA/LBM = 353 [17] cm ² /kg).
Experimental design and methods	Retrospective cohort study. – Subjects ran ~11 km in the Falmouth Road Race in August (24.4°C [0.8°C], 67% [4%] humidity). – $T_{rec} \geq 39.4^\circ\text{C}$ for all subjects prior to treatment.	Retrospective cohort study. – Subjects ran ~11 km in the Falmouth Road race in August (23.3°C [2.5°C], 70% [16%] humidity). – Race participants were included as subjects if $T_{rec} \geq 40^\circ\text{C}$ and an EHS diagnosis was documented.	Quasi-experimental study. – Subjects ran on a treadmill at 65% VO_2 max in heat (40.0°C, ~18% humidity) until T_{rec} reached 39.5°C.
Cooling intervention	13 males and 1 female were treated by IWI (1–3°C) until T_{rec} reached 39.0°C. – The subjects' torso and upper legs were completely immersed. – No mention of water circulation during treatment.	All subjects were treated by CWI (10°C) in a 50-gal tub until T_{rec} reached 38.8°C. No noted specifications on water circulation. – Subjects were immersed in a seated position. If arms or legs were not completely submersed, then wet ice towels were used to cover the arms, legs, neck, and head.	All subjects were immersed in a circulated water bath (2°C) until T_{rec} reached 37.5°C. – Subjects were immersed in a recumbent position (head and chest were not fully immersed).
Results	T_{rec} post exercise: female = 41.9°C; male = 41.6°C (0.6°C). Immersion duration: female = 11 min; male = 17 (8) min. T_{rec} cooling rate: female = 0.27°C/min; male = 0.20 (0.07)°C/min.	T_{rec} post exercise: female = 41.2°C (0.7°C); male = 41.4°C (0.7°C). Immersion duration: ^a female = 10.90 min; male = 10.45 min. T_{rec} cooling rate: female = 0.22 (0.10)°C/min; male = 0.22 (0.12)°C/min.	T_{rec} post exercise: female = 39.56°C (0.07°C); male = 39.57°C (0.06°C). Immersion duration: female = 10.89 (4.49) min; male = 18.13 (4.47) min. T_{rec} cooling rate: female = 0.22 (0.07)°C/min; male = 0.12 (0.03)°C/min.
Conclusions	The female with EHS cooled 35% faster than the males with EHS.	No differences were found for cooling rates between male and female athletes suffering from EHS.	Hyperthermic females cooled 83% faster than hyperthermic males.

Abbreviations: BSA/LBM, body surface area-to-lean body mass ratio; BSA/M, body surface area-to-mass ratio; CWI, cold-water immersion; EHS, exertional heat stroke; ht, height; IWI, ice water immersion; LBM, lean body mass; T_{rec} , rectal temperature; VO_2 max, maximum oxygen consumption. Note: All data are reported as mean (SD) with the exception of Armstrong et al³.

^aImmersion duration calculated using the following formula: (mean T_{rec} postexercise – 38.8°C)/mean cooling rate.

Predetermined Inclusion and Exclusion Criteria

Inclusion

- Following exercise, subjects were hyperthermic with a $T_{rec} \geq 39.5^\circ\text{C}$ (103.1°F).
- Studies used CWI ($\leq 20^\circ\text{C}$ [68°F]) to treat hyperthermia.
- Body core temperature was measured with T_{rec} since this is the only valid, clinically useful body temperature site for an exercising human.⁶
- Limited to studies published in English in the last 15 years (1993–2018).

- Limited to studies classified as Oxford Centre for Evidence-Based Medicine level 3 or higher.

Exclusion

- Studies that did not test both male and female subjects or differentiate cooling rates by gender.
- Studies that measured body core temperature by oral, axillary, esophageal, tympanic, or temporal thermometry.
- Studies that cooled hyperthermic subjects by other means (eg, cooling vests, passive cooling, ice towels).
- Studies that used precooling (ie, cooling during exercise) or precooling (ie, cooling before exercise).

Table 2 Summary of Study Designs of Articles Retrieved

Author	Study design	Level of evidence ^a
Lemire et al ²	Quasi-experimental	3
Armstrong et al ³	Retrospective cohort	3
Demartini et al ⁴	Retrospective cohort	3

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

Results of Search

Two retrospective cohort studies^{3,4} on EHS victims and 1 quasi-experimental laboratory study² met the predetermined inclusion and exclusion criteria. Each study was reviewed and independently categorized using the 2011 Oxford Centre for Evidence-Based Medicine (Table 2).

Best Evidence

The studies in Table 2 were identified as the best evidence and selected for inclusion in this CAT. These studies were included because they were considered level 3 evidence or higher and included data to allow comparison of gender differences in CWI T_{rec} cooling rates.

Implications for Practice, Education, and Future Research

Two main clinical observations can be derived from this CAT. First, hyperthermic male and female athletes do not have similar T_{rec} cooling rates. Hyperthermic females included in this CAT cooled ~33% faster than males. Males required CWI for 4.3 (3.0) minutes longer than females. Second, T_{rec} cooling rates for men and women were either acceptable (0.08–0.15°C/min) or ideal (>0.15°C/min).⁵ All 3 studies²⁻⁴ observed ideal cooling rates for females, whereas only 2 studies^{3,4} observed ideal cooling rates in males. In 1 study,² males cooled at only acceptable T_{rec} cooling rates. These results suggest that no additional precautions need to be taken based on gender; however, clinicians should be aware that males may cool slightly slower than females when being treated with CWI.

The primary reason for differences in T_{rec} cooling rates between genders is likely related to body surface area (BSA), lean body mass (LBM), and body surface area-to-lean body mass (BSA/LBM) ratios. Women, typically, have higher BSA than males.⁷ Thus, females may have a greater capacity to dissipate heat by nonevaporative mechanisms during CWI. Conversely, males are typically heavier and have more LBM than females,^{2,7} which would tend to favor higher metabolic activity and slower cooling rates during CWI. Collectively, this means BSA/LBM ratios tend to be higher in women than men. Several investigators^{2,8} have noted relationships between the BSA/LBM ratio and T_{rec} cooling rates of hyperthermic subjects. Friesen et al⁸ observed male subjects with a high BSA/LBM cooled 1.7 times faster than males with a low BSA/LBM. Similarly, Lemire et al² hypothesized that females cooled faster than males because of differences in BSA/LBM ratios, since the body surface area-to-mass (BSA/M) ratio and BSA were matched between genders. In fact, BSA/LBM was highly correlated with the CWI T_{rec} cooling rate ($r=.7$) when gender data was pooled.² Future research should confirm Friesen et al's⁸ observations in female subjects to provide greater evidence for the contribution of the BSA/LBM ratio to T_{rec} cooling rates.

Two other minor variables may explain why females cooled faster than males. First, females, in general, have higher adiposity than males.^{2,7,9} However, simply having more adipose tissue is an unlikely explanation for differences in cooling rate between genders. A difference of 10% adiposity did not affect T_{rec} cooling rates in hyperthermic men cooled in 8°C water (13% body fat = 0.23 [0.09]°C/min; 23% body fat = 0.20 [0.09]°C/min).¹⁰ However, individuals with more fat mass tend to shiver less during cold exposure, which may result in less metabolic activity in the lean tissue and may result in faster cooling rates.² The influence of adiposity on T_{rec} cooling rates in hyperthermic men and women with >25% body fat has not yet been tested. Second, increases in circulating plasma hormones, especially during the luteal phase of menses, may impact the sensitivity of the shivering response, skin vasoconstrictor response, and/or metabolic activity in women.¹¹ Experiments that attempt to control resting body core temperature typically test females during their follicular phase to decrease variability and these hormonal responses. Thus, T_{rec} cooling rates of women tested during the follicular phase are likely to be less impacted by menses than those of women tested in the luteal phase.

We acknowledge 2 main limitations of our CAT. First, only one of our studies² reported subjects' mass, body fat, BSA/M ratio, and BSA/LBM ratio. Therefore, it was not possible to compare the effects of anthropometric factors as they relate to gender between all 3 studies in our CAT. Because only 1 study² controlled for anthropometrics between genders, and these factors greatly influence T_{rec} cooling,^{8,7} we placed greater weight on the results of this study² for the final conclusion in our CAT. Second, while Armstrong et al³ had 4 females diagnosed with EHS in their study, only 1 was included in the CWI treatment group. Consequently, we were only able to compare the T_{rec} cooling rates of the lone female subject to the 13 male EHS victims who were also treated with CWI.

In conclusion, hyperthermic males and females (some with EHS) have different CWI T_{rec} cooling rates. Hyperthermic females cooled faster than males, which is likely attributed to their higher BSA/LBM ratio. However, future research may wish to answer the following questions: (1) Do females with different BSA/LBM ratios cool at different rates like their male counterparts?⁸ (2) When BSA/LBM ratios are matched between men and women, are T_{rec} cooling rates equivocal? (3) What is the effect of >25% body fat on T_{rec} cooling rates in men and women? Regardless of differences in T_{rec} cooling rates between genders, the cooling rates were either acceptable or ideal⁵ in all studies examined. The fact that 100% of the men and women who experienced EHS ($n = 295$) in both retrospective cohort studies^{3,4} survived without any noted complications attests to the life-saving capabilities of immediate CWI. Therefore, we conclude CWI is highly effective, regardless of gender, and must be the clinical gold standard for treating EHS victims. This CAT should be reviewed and revised upon the completion of additional studies as they relate to T_{rec} cooling rates between genders.

References

1. Casa DJ, DeMartini JK, Bergeron MF, et al. National athletic trainers' association position statement: exertional heat illnesses. *J Athl Train*. 2015;50:986–1000. PubMed ID: 26381473 doi:10.4085/1062-6050-50.9.07
2. Lemire BB, Gagnon D, Jay O, Kenny GP. Differences between sexes in rectal cooling rates after exercise-induced hyperthermia. *Med Sci Sports Exerc*. 2009;41:1633–1639. PubMed ID: 19568196 doi:10.1249/MSS.0b013e31819e010c

3. Armstrong L, Crago A, Adams R, Roberts W, Maresh C. Whole-body cooling of hyperthermic runners: comparison of two field therapies. *Am J Emerg Med.* 1996;14:355–358. PubMed ID: [8768154](#) doi:[10.1016/S0735-6757\(96\)90048-0](#)
4. DeMartini JK, Casa DJ, Stearns RL, et al. Effectiveness of CWI in the treatment of EHS at the Falmouth Road Race. *Med Sci Sports Exerc.* 2015;47:240–245. PubMed ID: [24983342](#) doi:[10.1249/MSS.0000000000000409](#)
5. McDermott BP, Casa DJ, Ganio MS, et al. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. *J Athl Train.* 2009;44:84–93. PubMed ID: [19180223](#) doi:[10.4085/1062-6050-44.1.84](#)
6. Casa DJ, Becker SM, Ganio MS, et al. Validity of devices that assess body temperature during outdoor exercise in the heat. *J Athl Train.* 2007;42:333–342. PubMed ID: [18059987](#)
7. Anderson GS, Ward R, Mekjavic IG. Gender differences in physiological reactions to thermal stress. *Eur J Appl Physiol.* 1995;71:95–101. doi:[10.1007/BF00854965](#)
8. Friesen BJ, Carter MR, Poirier MP, Kenny GP. Water immersion in the treatment of exertional hyperthermia: physical determinants. *Med Sci Sports Exerc.* 2014;46:1727–1735. PubMed ID: [24784433](#) doi:[10.1249/MSS.0000000000000292](#)
9. Tikuisis P, Jacobs I, Moroz D, Vallerand AL, Martineau L. Comparison of thermoregulatory responses between men and women immersed in cold water. *J Appl Physiol.* 2000;89:1403–1411. PubMed ID: [11007575](#) doi:[10.1152/jappl.2000.89.4.1403](#)
10. Lemire BB, Gagnon D, Jay O, Dorman L, Ducharme MB, Kenny GP. Influence of adiposity on cooling efficiency in hyperthermic individuals. *Eur J Appl Physiol.* 2008;104:67–74. PubMed ID: [18542989](#) doi:[10.1007/s00421-008-0780-0](#)
11. Castellani JW, Young AJ. Human physiological responses to cold exposure: acute responses and acclimitization to prolonged exposure. *Auto Neuro.* 2016;196:63–74. doi:[10.1016/j.autneu.2016.02.009](#)