Hand Cooling during Recovery from Exercise in the Heat: Cold Water Immersion *vs*. Dry Cold Negative Pressure

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INTRODUCTION

During exercise at high ambient temperatures, core temperature increases due to a rise in metabolic heat production.[1] An increase in core temperature coupled with an inability to dissipate body heat limits a person's ability to exercise and increases the risk of heat illness.[2] The body is equipped with specific areas that are devoid of hair that dissipate heat efficiently such as the palms of our hands or the soles of our feet.[3] A suggested method of cooling through these areas in order to effectively reduce core temperature is to immerse the hands in cold water. This method is criticized by its ability to trigger the reflex of cutaneous vasoconstriction in the body when exposed to cold temperatures.[2] This reflex of the body is said to bypass vasodilation due to heat exposure and thus limit the rate of heat loss to the environment.[2] An additional method has been introduced that uses negative pressure in order to enhance the effectiveness of the body's natural radiators by reducing vasoconstriction and helping to maintain a thermal gradient.[1] The effects of cold water immersion(10°C) and dry cold negative pressure (10°C) have not yet been directly compared in regards to a brief cooling period of 10 minutes.[4] Research that has been completed either performs cooling between exercise bouts[2,3] or after exercise bouts.[1,4] In addition, the time of the recovery period varied from 5 minutes[3] to 40 minutes[1], allowing room for varied results. Research with extended recovery periods showed that the cooling effect of the hand device had little effect in heat loss until after 35 minutes. [1] In addition, research is lacking for individuals of average fitness that are exposed to nonemergency practical situations such as a recovery after a standard workout bout when exposed to heat.[4] The use of negative pressure along with dry cooling is a novel technique and should be further reviewed in a more controlled environment.[1]

PURPOSE

The purpose of this study is to compare the effect of two different hand cooling modalities on core temperature when recovering from an exercise in a hot environment.

METHODS

IRB Approval. The study was approved by the Institutional Review Board (Human Subjects) at Texas A&M University-Kingsville.

Subjects. All subjects provided informed consent prior to testing. Twelve male subjects (N=12) were recruited from the student population at Texas A&M University-Kingsville.

Pre-participation Screening/Testing. All subjects underwent a health screening according to the American College of Sports Medicine's guidelines for exercise testing and prescription.[5] Only subjects classified as low risk for untoward events during exercise based on these guidelines were allowed to participate. Additionally, only those who were classified as physically active and had no prior history or heat illness/injury were allowed to participate in the study. Tests for body composition (mass, stature, percent body fat from air plethysmography) and peak oxygen consumption (via open circuit spirometry, modified Astrand[6] cycle protocol) were also conducted. Subjects were given instructions on how to report for each experimental trial, including specific pre-trial diet and hydration instructions.

Experimental Design. A balanced cross-over design was used. Each subject underwent three experimental trials using three different hand cooling methods [cold (10°C) water immersion (WTR), dry cold (10°C) negative pressure (NEG), and a control with no hand cooling (CON)] on separate days approximately one week apart. During the three trials, the subjects were required to exercise on a stationary rate independent cycle ergometer at an intensity equal to 65% of their peak oxygen consumption rate (i.e., low end of vigorous exercise) in the heat (approximately 35°C, 42% relative humidity). Subjects were asked to perform each exercise bout until their core temperature reached 38.33°C, their heart rate reached 95% of their age predicted maximum, or until they reached volitional maximum. After each trial, subjects were required to undergo one of the three cooling methods (WTR, NEG, or CON) for 10 min, during which time heart rate and core temperature were measured. For the WTR trials subjects had their preferred hand submerged in cold water, and for the NEG trials their hand was placed in sealed cold container (AVAcore CoreControl Pro, Ann Arbor, MI, Figure 1) [7] that provided negative pressure (approximately -47 mm Hg = -1 psi).

Measurements. During each experimental trial, the following measurements were made on the subjects:

Exercise Time (min) – Time to exercise termination (38.33°C, 95% of their age predicted heart rate maximum, volitional) was measured.

Exercise Rating of Perceived Exertion (6-20) – Subjects were asked to rate their perceived exertion (RPE) during the exercise bout using the Borg Scale[8] RPE was recorded after every minute of exercise and at the point of test termination.

METHODS, cont.

Measurements, cont.

Exercise/Recovery Core Body Temperature (°C) – Core body temperature was measured every minute throughout exercise and recovery using a rectal probe hard wired to a physiological data acquisition system (Biopac, Goleta, CA).

Exercise/Recovery Heart Rate (beat·min⁻¹) – Heart rate was measured every minute throughout exercise and recovery via telemetry (Polar, Lake Success, NY).

Statistical Analysis. One-way (cooling method) ANOVA with repeated measures was used to analyze for differences between trials (WTR, NEG, CON) in the exercise and recovery descriptors (Table 2). Two-way (cooling method x time) ANOVA with repeated measures was used to analyze for differences between trials (WTR, NEG, CON) across recovery time (pre-/post-) in: heart rate and core temperature. If needed, appropriate *post-hoc* tests were used to make all pairwise comparisons for specific differences across the three experimental trials or time points. The experimentwise error rate (α=0.05) was maintained throughout all *post-hoc* tests for specific differences.

Figure 1: Dry Cold Negative Pressure Device

RESULTS

Table 1: Subject Demographics

Variable	Mean	SD	Range
Age (yr)	21.3	2.5	18-27
Body Mass (kg)	83.9	15.0	63.5-113.6
Body Stature (cm)	174.5	6.4	166.4-188.0
Body Mass Index (kg·m²)	27.4	3.5	22.9-33.5
Body Fat (%)	19.3	4.8	10.1-27.5
VO_{2Peak} (ml·kg⁻¹·min⁻¹)	37.4	3.1	32.1-41.3

Table 2: Exercise and Recovery Descriptors

Variable	Water (WTR)	Negative Pressure (NEG)	Control (CON)
Exercise Ambient Temperature (°C)	35.2 ± 0.9	35.1 ± 1.2	35.0 ± 1.0
Exercise Relative Humidity (%)	42.3 ± 1.8	42.2 ± 2.5	42.9 ± 3.4
Exercise Time (min)	39.2 ± 8.9	40.0 ± 11.0	40.0 ± 12.4
Heart Rate at Exercise Termination (beat·min⁻¹)	175 ± 16	176 ± 11	176 ± 13
RPE at Exercise Termination (6-20)	19 ± 2	19 ± 2	19 ± 1
Rectal Temperature at Exercise Termination (°C)	37.7 ± 0.3	37.7 ± 0.3	37.7 ± 0.3
Recovery Ambient Temperature (°C)	21.5 ± 0.7	21.5 ± 0.6	21.7 ± 0.9
Recovery Relative Humidity (%)	58.4 ± 4.6	59.3 ± 5.0	58.5 ± 2.5

Mean ± SD, no significant differences were seen between cooling methods for all variables (p>0.05).

Table 3: Cooling Method Main Effect for Heart Rate, and Core Temperature

Variable	Water (WTR)	Negative Pressure (NEG)	Control (CON)
Heart Rate (beat·min⁻¹)	117 ± 12	113 ± 9	118 ± 13
Core Temperature (°C)	37.7 ± 0.3	37.8 ± 0.2	37.8 ± 0.3

When pooled across time, heart rate (p=0.1650) and core temperature (p=0.3560) during recovery did not differ significantly between the cooling methods.

RESULTS, cont.

Table 4: Time Main Effect for Heart Rate, and Core Temperature

Variable	Pre (Min 0)	Post (Min 10)
Heart Rate (beat·min⁻¹)	135 ± 13	97 ± 9*
Core Temperature (°C)	37.8 ± 0.2	37.6 ± 0.2**

When pooled across cooling methods, heart rate (*p=0.0001) and core temperature (**p=0.0040) during recovery were significantly lower after the 10 min recovery period.

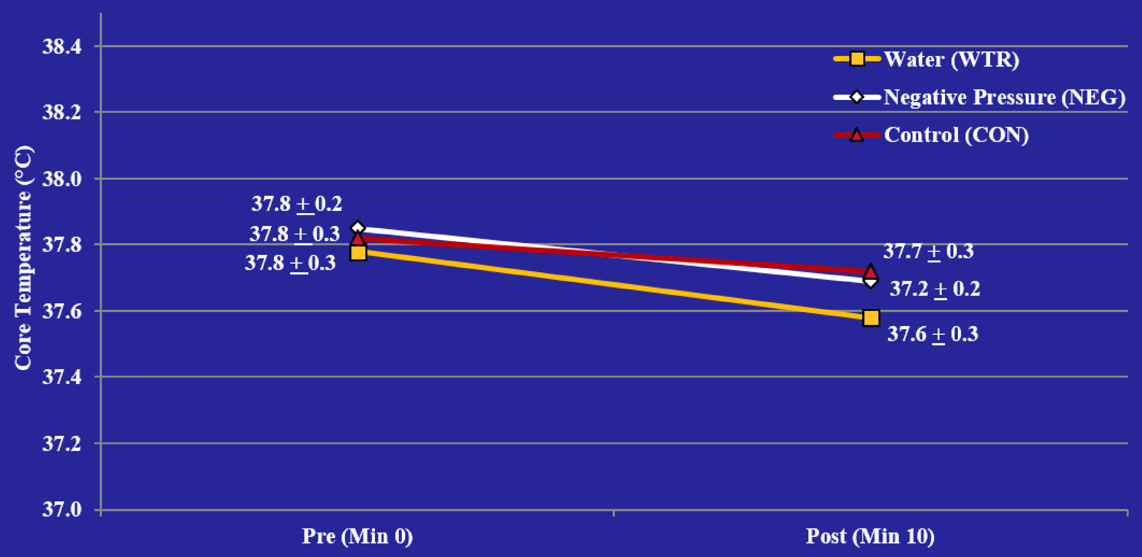

Figure 2: Cooling Method x Time Interaction for Core Temperature. The change in core temperature during recovery did not differ significantly between the cooling methods (p=0.4280).

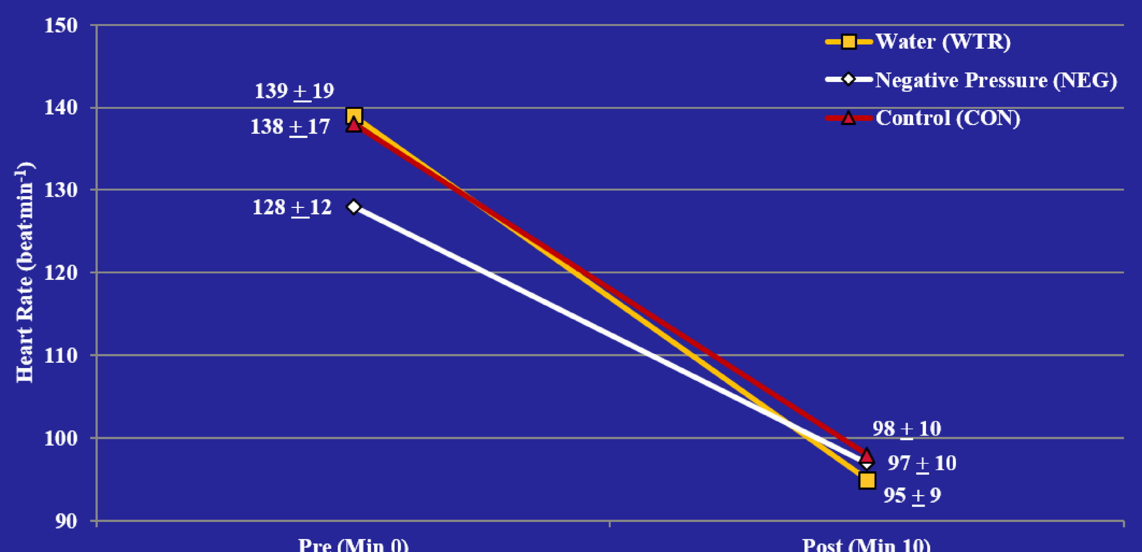

Figure 3: Cooling Method x Time Interaction for Heart Rate. The change in heart rate during recovery did differ between cooling methods (p=0.0320), where WTR heart rate appears to have declined at a slightly quicker rate than NEG and CON.

CONCLUSIONS

The results of this study suggest that overall, NEG didn't decrease core temperature more efficiently than WTR, and both treatments didn't decrease core temperature any more efficiently than CON. The results could suggest that there may be a potential time point in the recovery period where a cooling method does not necessarily yield a greater recovery rate in regards to core temperature. There was an cooling method x time interaction found in regards heart rate (p=0.0320). This slightly quicker reduction in WTR heart rate could provide the necessary data to agree with the construct that water acts as an extremely efficient dissipater of heat when compared to any other surface substance. This in turn, could suggest that the use of WTR, while not producing a significant greater reduction in core temperature, may advance the subject physiologically by decreasing the heart work necessary to cool down the body.

The findings may have been affected by the subjects' lack of ability to exercise for a longer period of time thus, not yielding a greater core temperature or heart rate during their exercise bouts. The data could have also been affected by the constraint of a 10 minute recovery period used to portray a practical setting. Regardless, the information is useful for subjects of average fitness who will tend to exercise for a shorter amount of time and cool down in a practical setting. It should be noted that most subjects terminated the work out bout prior to reaching the set core temperature. It should also be noted that our recovery time represented a practical rest period rather than an extended rest period. These two factors should be addressed in additional studies. Further investigation using larger sample sizes is warranted to examine the effects of cold water immersion and cold dry negative pressure on recovery post performance in the heat.

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