University of Arkansas
Human Performance Laboratory

Effect of the Core Cooler device on physiological, perceptual and performance during and after cycling in the heat

Investigation: We evaluated the Core Cooler device in an environmental chamber with environmental conditions set to 87.8°F (31.0°C) and 55% relative humidity. Participants cycled at steady state resistance (about 55% of max) for 75 minutes. Immediately following, they entered a performance ride of 5-kilometer distance at a 6% grade. Once the performance ride was complete, they cooled down for a maximum of 10 minutes and then rested for 5 minutes before trials ceased. Participants completed 3 separate exercise trials:

1. Control condition: breathing from the Core Cooler device for 1 minute on, and 4 minutes off of the bottle. In this condition, the device had no ice in it.
2. Low intermittent: breathing from the Core Cooler device for 1 minute on, and 4 minutes off of the bottle. The bottle was filled with crushed ice.
3. High intermittent: breathing from the Core Cooler device for 2.5 minutes on, and 2.5 minutes off of the bottle. The bottle was filled with crushed ice.

During all trials, participants used the device only during the initial 75 minutes and during the 15 minute cool down time period. We had 12 well-trained cyclists volunteer and complete the entire study.

Summary of Findings: The Core Cooler device cooled inspired air by about 20°F (11.1°C) on average. Core temperature, heart rate, systolic blood pressure, thirst and thermal sensation were improved when participants completed their high intermittent trial compared to the control condition. Participants felt as though they were not working as hard (perceived exertion) but performed 3.5% faster during their 5-kilometer climb with the low intermittent trial compared to their control trial (52 seconds faster). Further, participants finished 3.9% faster than control during their high intermittent trial (58 seconds faster).

Conclusions: The simple and portable Core Cooler device is a feasible and effective bottle to be used during exercise in the heat. Physiologically, we found small, but consistent beneficial results when using the Core Cooler compared to when the same subjects did not use the device. Further, performance was enhanced by 3.9% when participants used the device. There are physiological and perceptual benefits in terms of safety and performance. The Core Cooler helps in the prevention of heat related illnesses.

Charged with evaluating the effect of the Core Cooler device on a host of physiological and performance variables, we embarked on an intensive investigation. We recruited 12 trained male cyclists to participate in our study. These cyclists needed a VO_2max above 40mL/Kg/min (above average) to be included in our trial. Cyclists then underwent a stationary bike steady state (~55% VO_2max) ride for 75 minutes prior to completing a 5-kilometer 6% grade climb for performance outcomes. All exercise and cool down was completed in an environmental chamber. Following exercise, the cyclists used the device as prescribed in their trial for 15 min as a cool down. Subjects underwent the trials in one of three conditions. During the trial they were instructed to inhale through the Core Cooler device continuously for a number of minutes throughout the first 75 minutes.

In the control (CN) trial, there was no ice or water in the device and subjects breathed through the device continuously for 1 minute, followed by a 4 minute span off the device. This pattern was continued for the first 75 minutes. For the low intermittent (LI) trial, the 1 to 4 ratio was the same as the CN trial, though this time the Core Cooler device contained crushed ice that was refreshed every 5 minutes. Crushed ice was determined to provide the coldest air available for inhalation when connected to a vacuum compared to solid and cubed ice. For the high intermittent (HI) trial, we used a 2.5 minute to 2.5 minute ratio and the Core Cooler device contained crushed ice that was refreshed every 5 minutes.

Results:

Subject Demographics

Subject demographics data is presented for all subjects in table 1.

Table 1.

Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation
Age	22	33	26.5	3.6
Height (cm)	170.0	186.7	180.5	4.9
VO2max (mL/Kg/min)	44.5	67.2	57.6	7.9
Percent Body Fat	5.1	28.9	13.7	7.0
Pre-Exercise body mass (Kg)	62.1	84.0	72.2	7.5

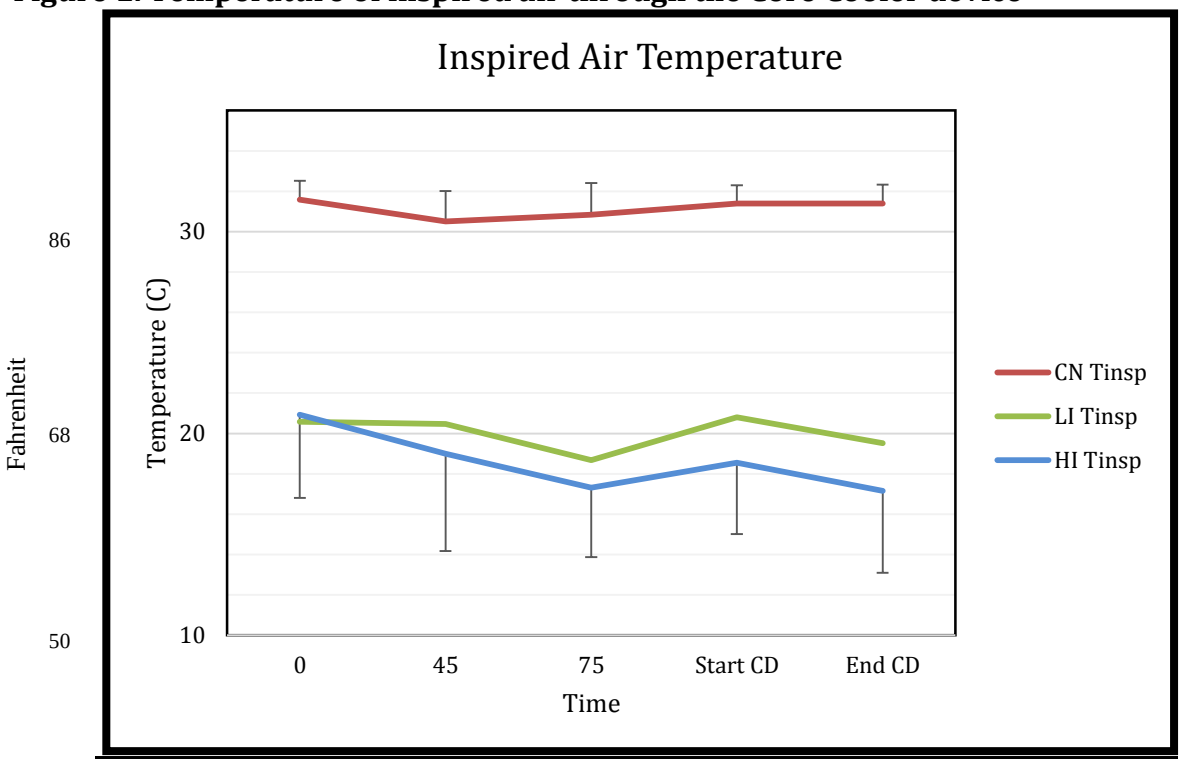
Environmental Data

The ambient temperature of the environmental chamber was maintained at 88.3 ± 0.29°F (31.30 ± .16°C). The relative humidity of the environmental chamber was 56.15 ± 1.0%. We used a new environmental chamber to maintain a consistent heat stress throughout trials. We chose a moderate humidity level to minimize normal sweat evaporation and a temperature to provide adequate, but compensable heat stress. It was hot enough, but not hot enough to induce heat illness given our exercise regimen.

Inspired Air Temperature

The average temperature of air inspired through the Core Cooler device for each trial is displayed in Figure 1. There was a significant difference in inspired air temperature between the control and intermittent trials. The Core Cooler device lowered the temperature of the air inspired by an average of 20.0°F (11.1°C). Inspired air temperature of the control trial was 88°F (31°C), while during HI was 68°F (20°C).

Figure 1. Temperature of inspired air through the Core Cooler device



Core Temperature

Core temperature measurements were obtained via an ingestible pill. Participants ingested the sensors at least 5 hours prior to their trials to assure it has passed their stomach and entered their intestines. Average core temperature across all trials is displayed in Figure 2. There was a significant increase in temperature over time in all trials ($p<.001$). Although no difference between trials, the lowest body temperature was recorded during the HI trial, when subjects used the device the most.

Figure 2. Average core temperature of subjects across all trials

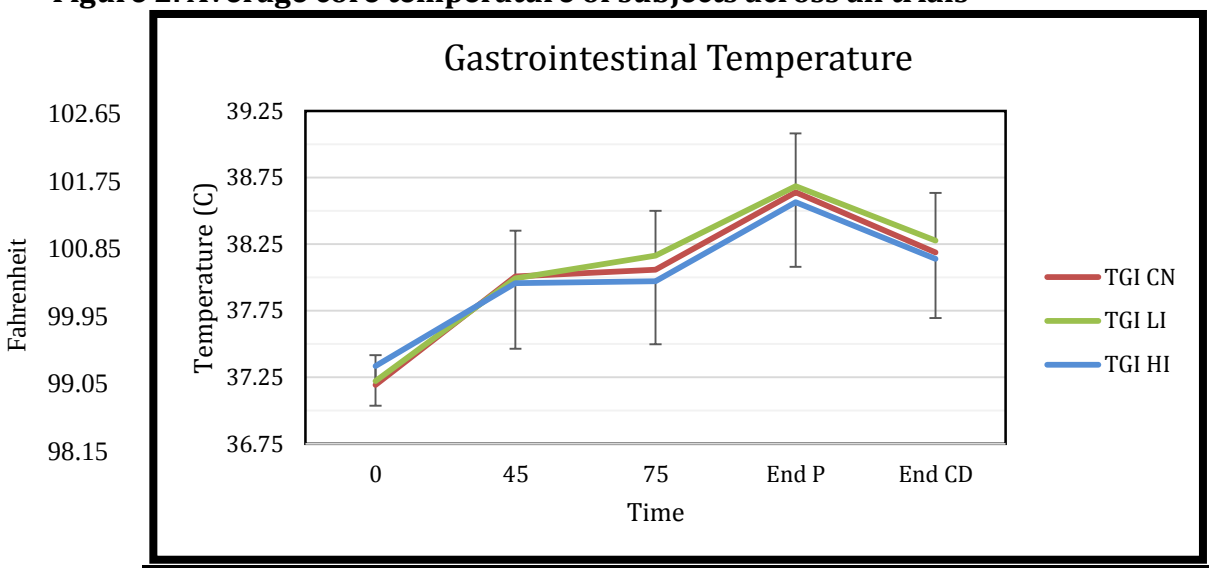
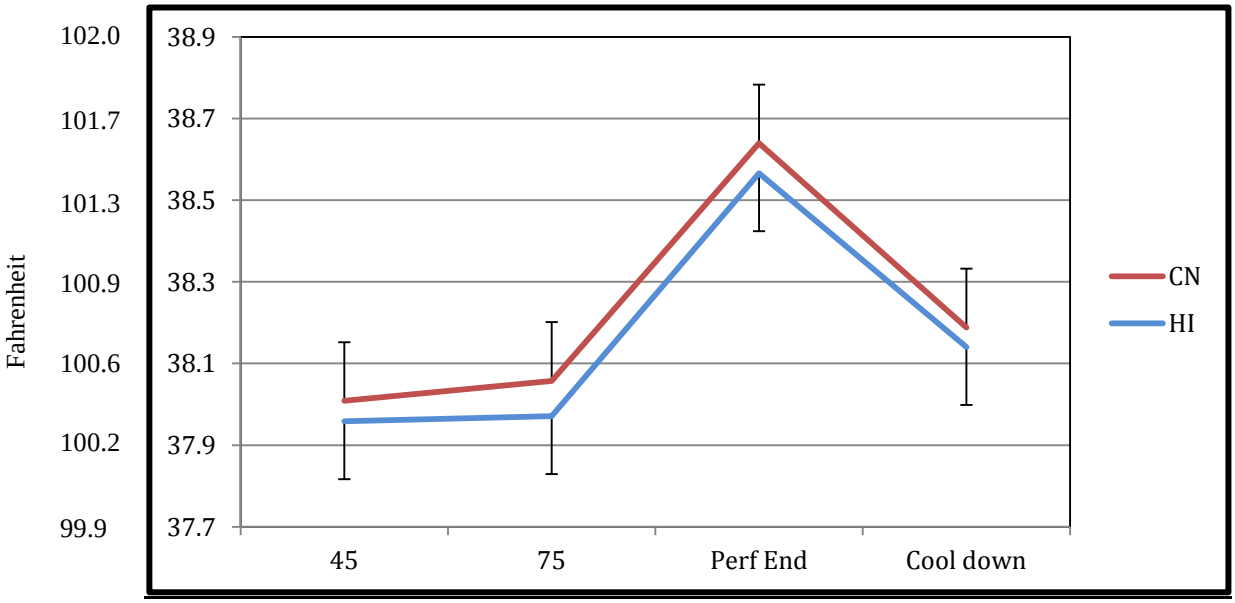


Figure 2a. Core Temperature

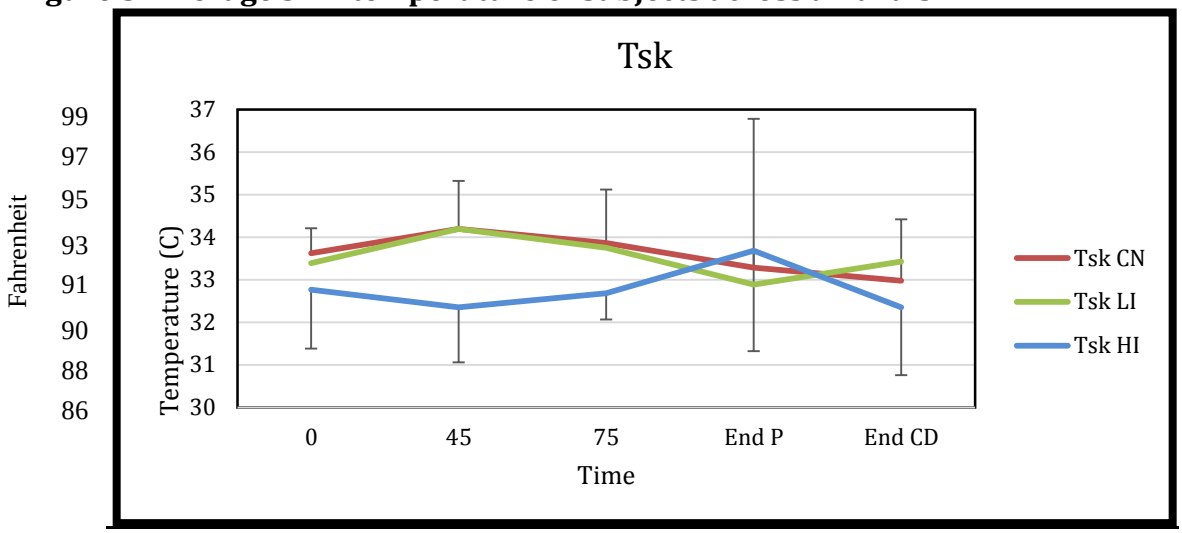


Gastrointestinal Temperature – Another way to represent our data with core temperature during trials.

Skin Temperature

We obtained skin temperature by attaching skin temperature thermistors at 4 sites on the participants. That data was entered into a reputable 4-site equation for mean skin temperature measures. Mean skin temperatures across all trials are displayed in Figure 3. Reliable measurements from all trials were obtained from 5 subjects. Interestingly, skin temperature was decreased when subjects used the device the most, during the HI trial.

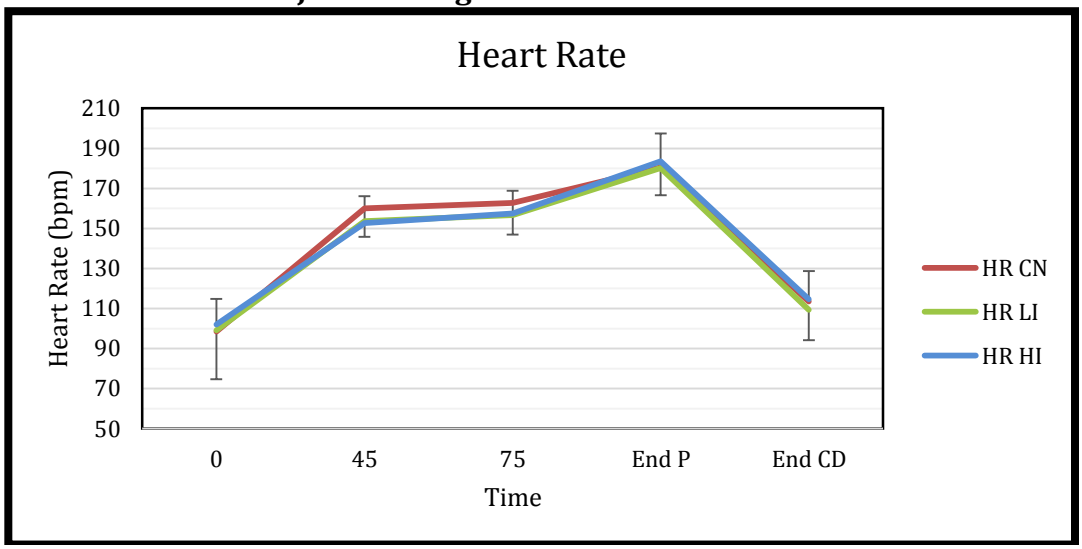
Figure 3. Average skin temperature of subjects across all trials



Heart Rate

Figure 4 displays the heart rate for all trials. There is a significant increase over time throughout the exercise trials ($p<.001$). Although no significant differences were identified between trials, heart rate was less in both the LI and HI trials. At the 45 minute mark, HR was 7 beats per minute less in both LI and HI compared to CN. This points to a clinical benefit, with less cardiovascular strain when using the device during steady state exercise.

Figure 4. Heart rate of subjects throughout trials



Blood Pressure

Figures 5 and 6 show the systolic and diastolic blood pressures, respectively, throughout all trials. Systolic blood pressure was significantly higher in the high intermittent trial than the other two trials, on average. This reflects the physiological response that more blood was available during the HI trials, reducing cardiovascular strain for subjects during trials. There were no significant differences between trials for diastolic blood pressure during trials.

Figure 5. Systolic blood pressure throughout all trials

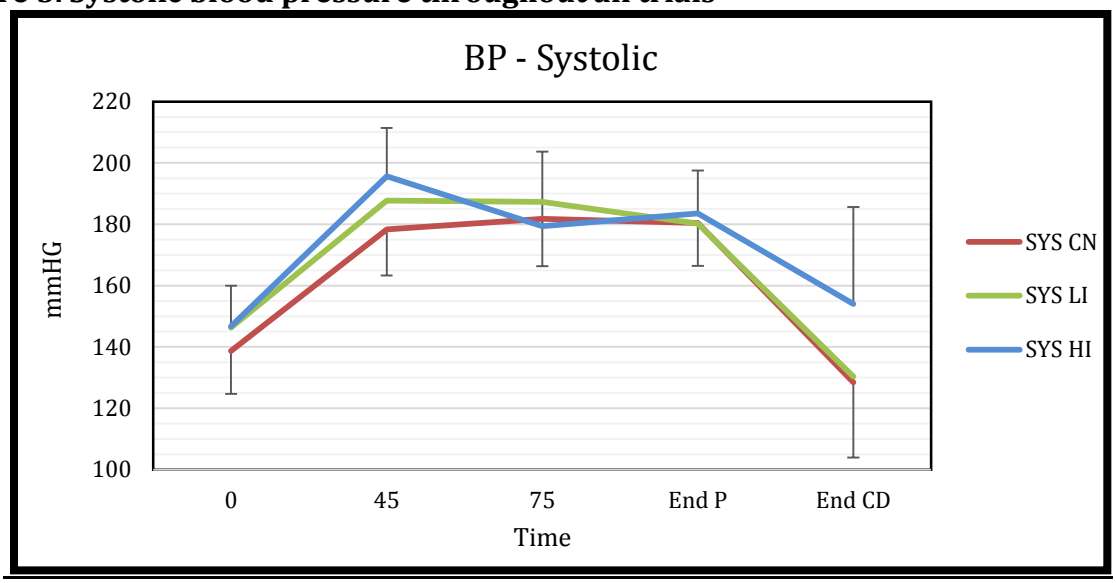
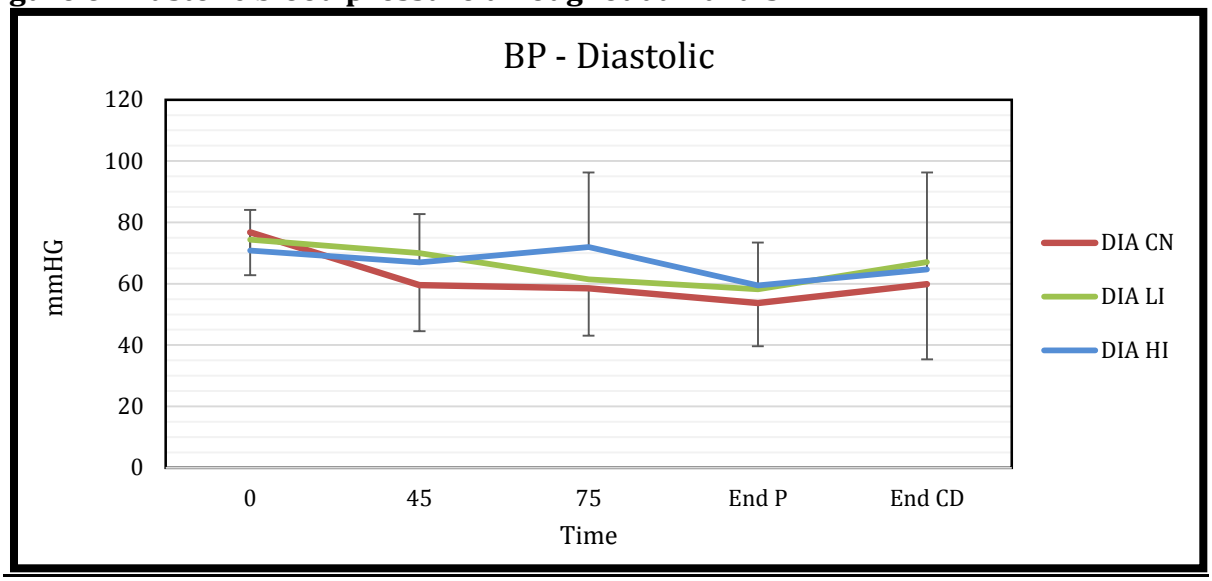


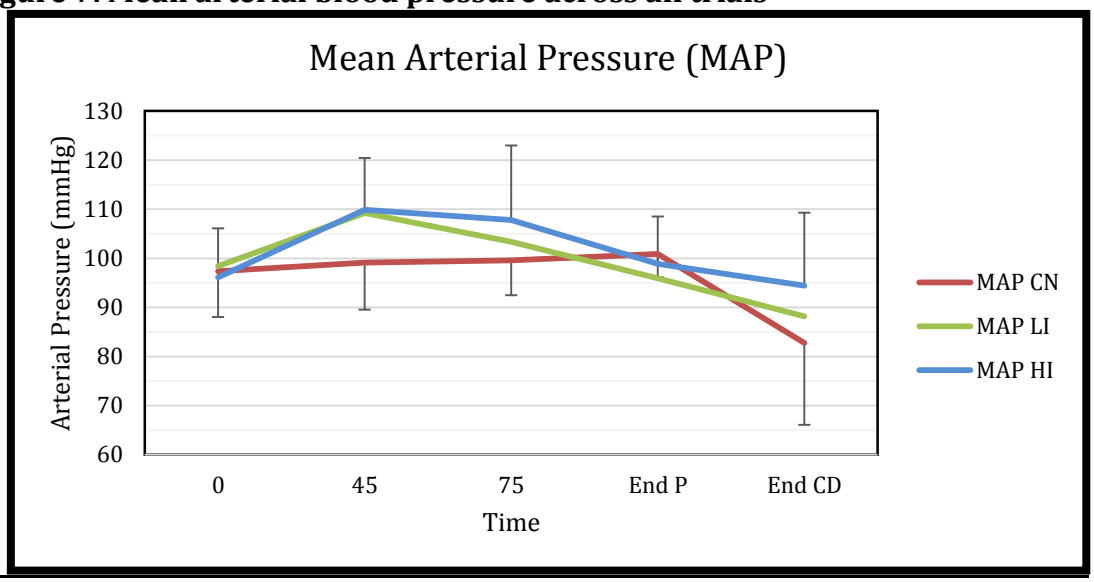
Figure 6. Diastolic blood pressure throughout all trials



Mean Arterial Pressure

Blood pressure seemed to be maintained better during steady state exercise and during cool down with the Core Cooler device.

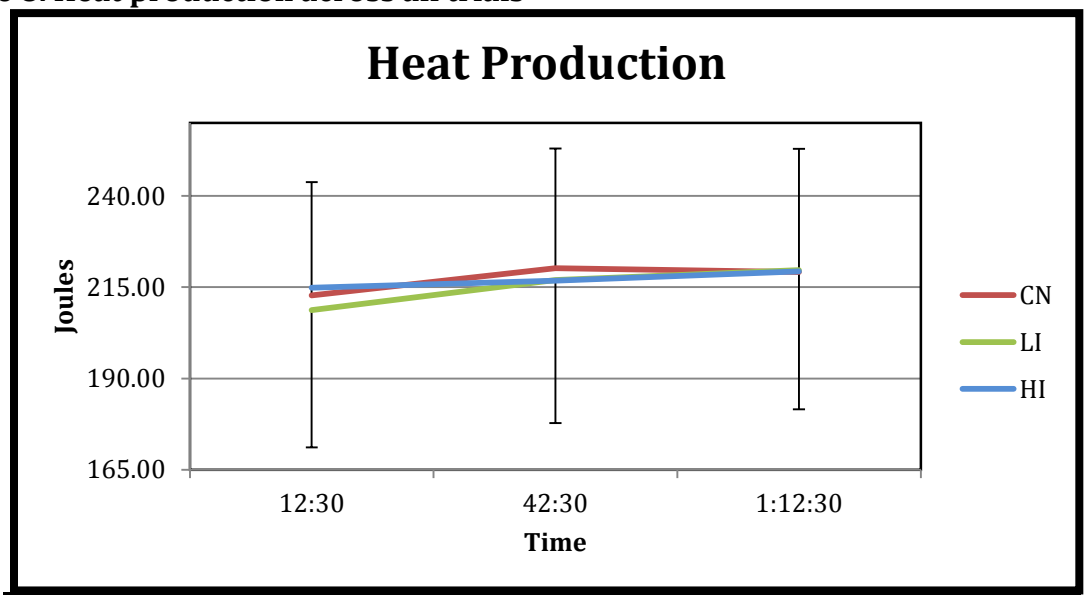
Figure 7. Mean arterial blood pressure across all trials



Heat Production

There was no significant change in heat production over time. There was also no difference between trials. This was expected given that heat production is dependent only on the amount of work subjects completed. Therefore, we successfully matched exercise work output during our 75 minute exercise protocol prior to their performance in the 5 kilometer climb.

Figure 8. Heat production across all trials



Perceptual Measures

Every 15 minutes subjects were asked to self-report perceived measures of thirst, heat, and exertion. Despite no significant thirst differences, Figure 9 reflects that using the Core Cooler device decreased thirst in comparison to CN. Thirst rating was more than 1 greater during CN than during LI and HI at the conclusion of the performance ride as well as cool down.

Figure 9. Thirst sensation across all trials

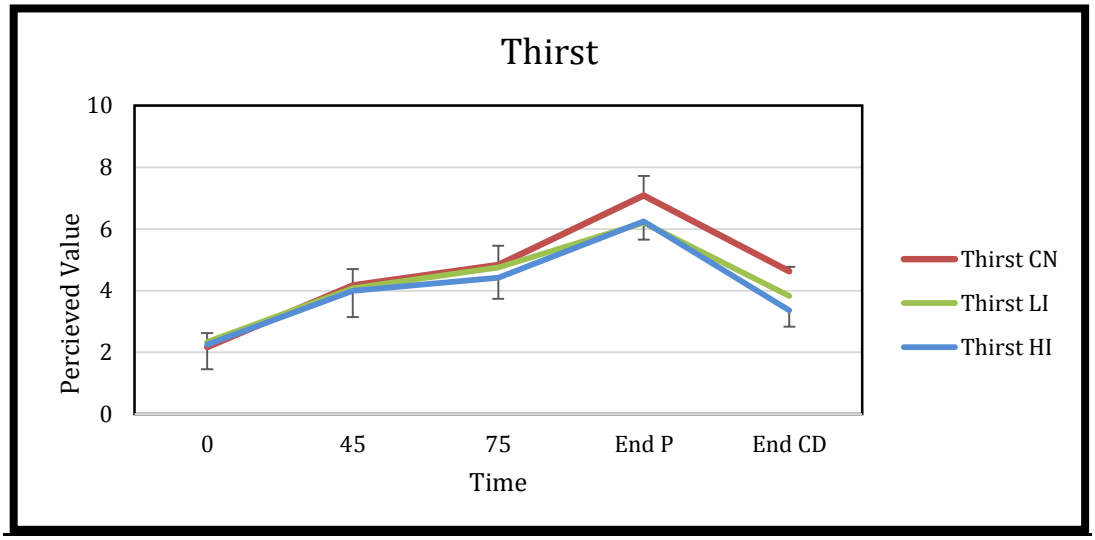
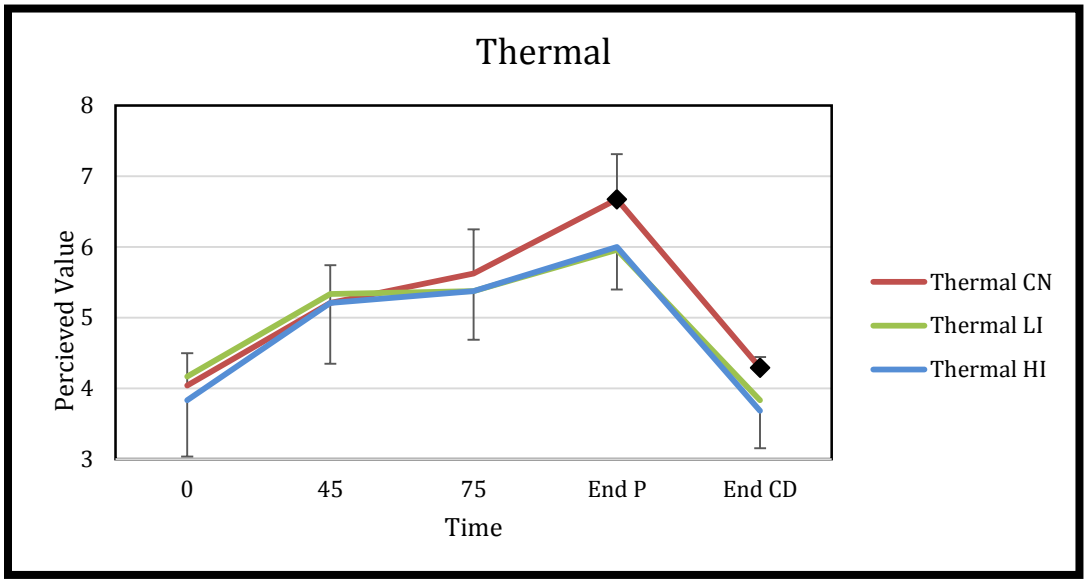


Figure 10. Thermal sensation across all trials

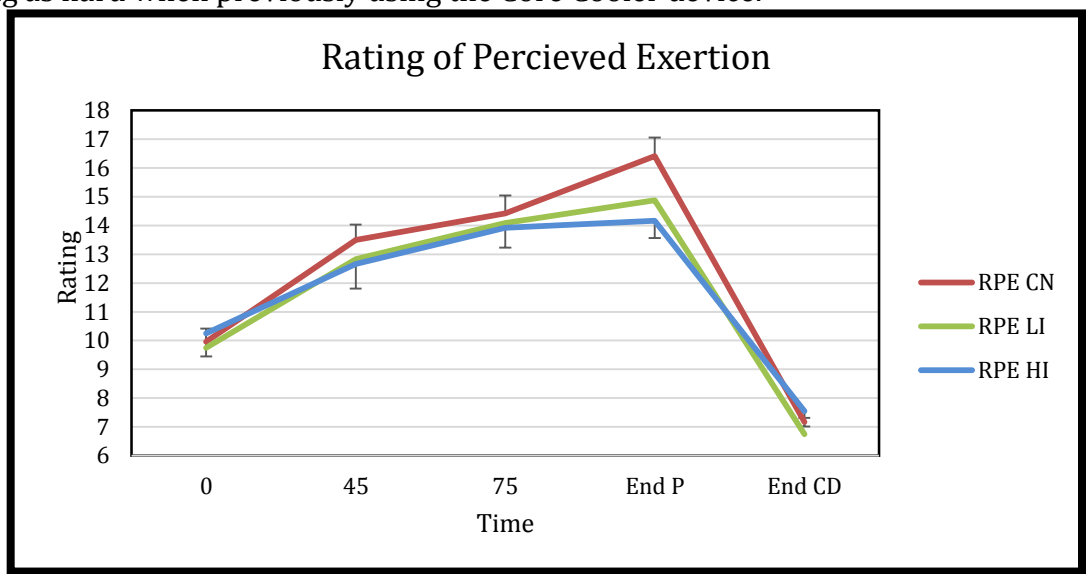
There was a significant increase across all trials up to the end of performance and then a decrease during the cool down. The control trial was significantly higher than the other two trials at the indicated time points. Subjects felt cooler when breathing cold air than when they were breathing warm air.



◆- Control values found to be significantly greater at marked time points

Figure 11. Rating of perceived exertion across all trials

Participants were repeatedly asked how hard they felt they were working. Despite no statistical differences, at most time points average measures demonstrate that subjects felt as though they were not working as hard when exposed to cold air breathing. Interestingly, during performance, subjects finished faster, but felt like they weren't working as hard when previously using the Core Cooler device.



Performance Measures

Subjects performed a 5 kilometer time trial at a 6% incline after a 75 minute exercise trial of different treatments (CN, LI, or HI). Figure 12 displays the time in seconds it took subjects to complete the time trial. Statistically, there was no difference in times, but subjects finished 58 seconds faster (HI) after using the Core Cooler device. This represents a 3.9% increase in performance! Interestingly, subjects had a 3.5% performance increase with LI as well.

Figure 12. Time to complete 5 kilometer performance trial

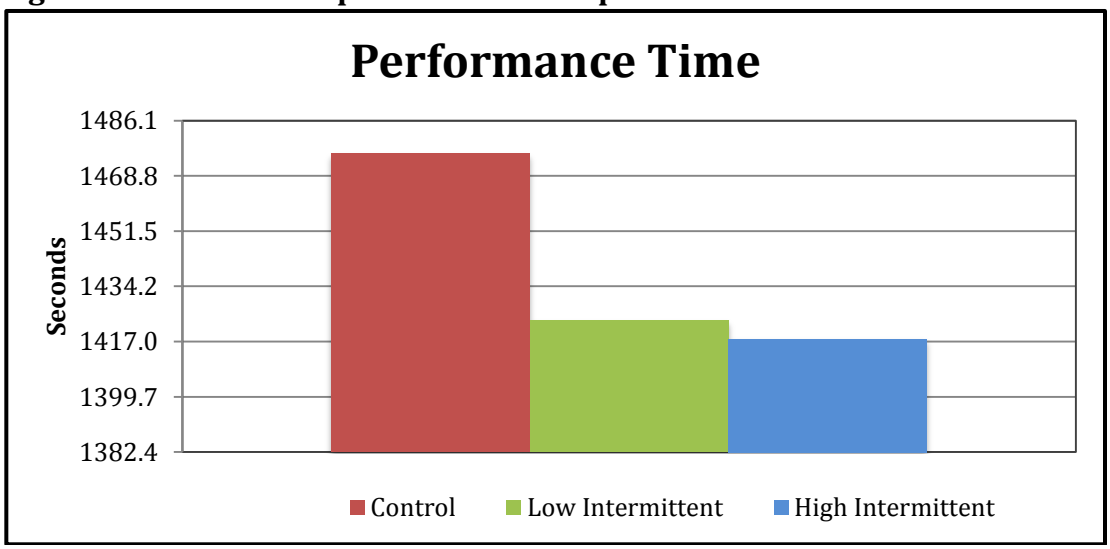
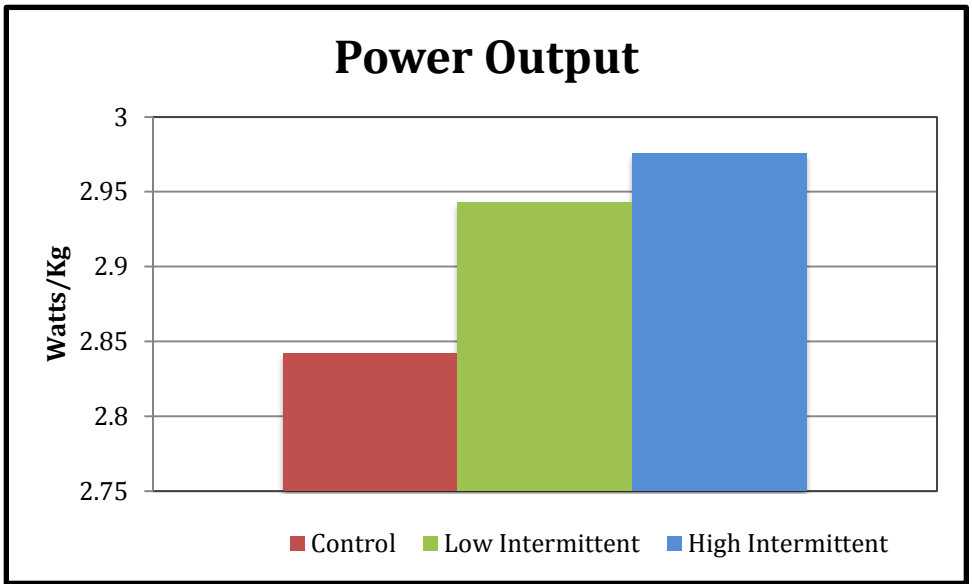


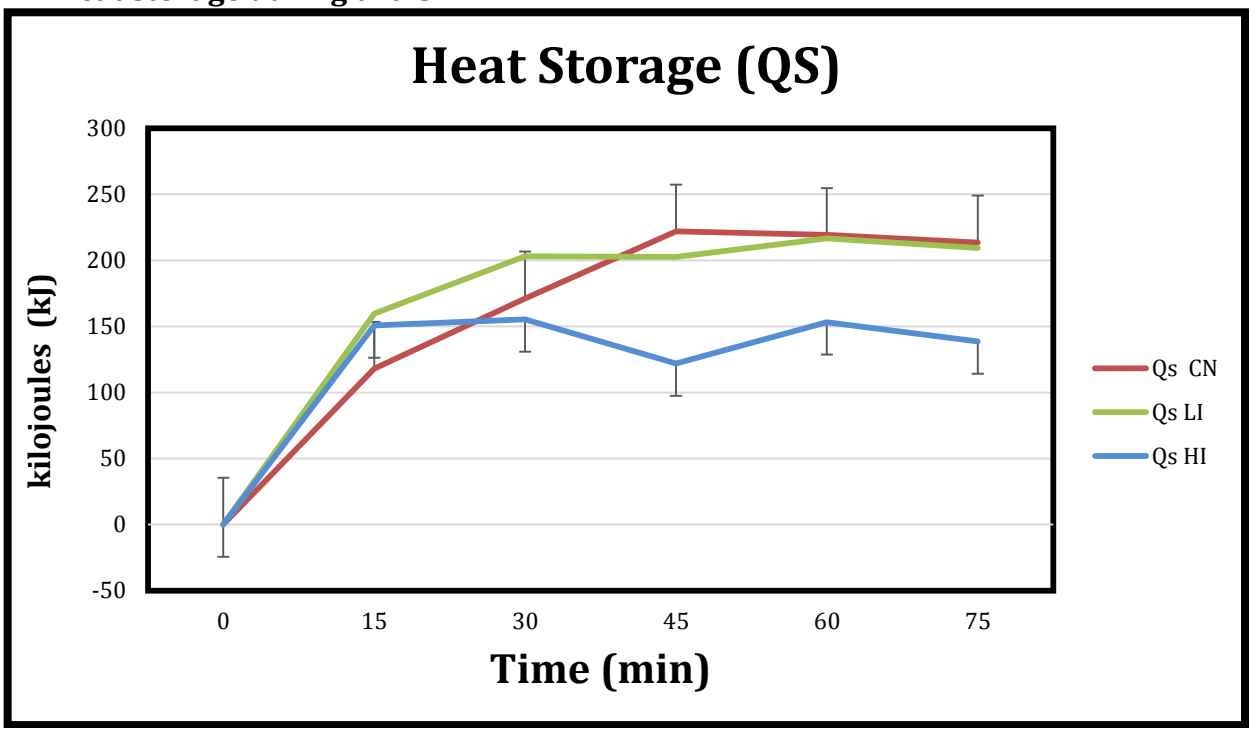
Figure 13. Normalized performance power output



Heat Storage

Our data suggests that subjects were storing roughly 30% less heat from 45-75min of steady state exercise, on average. This suggests greater heat dissipation via respiratory heat exchange while using the Core Cooler during our HI trial.

Figure 14. Heat storage during trials



Conclusion. Overall, there are physiological and perceptual differences when exercising in the heat and using the Core Cooler device. We observed benefits in core temperature, heart rate, blood pressure and thermal sensation during steady state exercise in the heat. Further, using the Core Cooler during steady state exercise increased performance by more than 3% for low and high usage of the device. It appears that breathing cold air during exercise in the heat allows greater blood flow in the heart, which allows for heat exchange in the airway and more blood flow to working muscles during exercise. This has the potential to maximize performance and perception, while also allowing maintenance of body temperature during exercise in the heat. There are physiological and perceptual benefits in terms of safety and performance. The Core Cooler helps in the prevention of heat related illnesses.