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A Comparison of 2 Practical Cooling Methods on Cycling Capacity in the Heat

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Context: Cooling the torso and neck can improve exercise performance and capacity in a hot environment; however, the proposed mechanisms for the improvements often differ.

Objective: To directly compare the effects of cooling the neck and torso region using commercially available devices on exercise capacity in a hot environment (temperature = 35°C ± 0.1°C, relative humidity = 50.1% ± 0.7%).

Design: Crossover study.

Setting: Laboratory.

Patients or Other Participants: Eight recreationally active, nonheat-acclimated men (age = 24 ± 4 years, height = 1.82 ± 0.10 m, mass = 80.3 ± 9.7 kg, maximal power output = 240 ± 25 W).

Intervention(s): Three cycling capacity tests at 60% maximal power output to volitional exhaustion: 1 with no cooling (NC), 1 with vest cooling (VC), and 1 with a neck cooling collar (CC).

Main Outcome Measure(s): Time to volitional exhaustion, rectal temperature, mean skin temperature, torso and neck skin temperature, body mass, heart rate, rating of perceived exertion, thermal sensation, and feeling scale were measured.

Results: Participants cycled longer with VC (32.2 ± 9.5 minutes) than NC (27. 6 ± 7.6 minutes; $P = .03$; d = 0.54) or CC (30.0 ± 8.8 minutes; $P = .02$; d = 0.24). We observed no difference between NC and CC ($P = .12$; d = 0.31). Neck and torso temperature and perceived thermal sensation were reduced with the use of cooling modalities ($P < .001$), but no other variables were affected.

Conclusions: Cycling capacity in the heat improved when participants used a commercially available cooling vest, but we observed no benefit from wearing a commercially available CC. The vest and the collar did not alter the heart rate, rectal temperature, skin temperature, or sweat-loss responses to the cycling bout.

Key Words: thermoregulation, cooling during exercise, exhaustion, thermal sensation, torso, collar

Key Points

- In hot conditions, commercially available cooling vests provided sufficient cooling to improve exercise capacity.
- Exercise capacity was not different between the neck-cooling and no-cooling conditions.
- Vest cooling did not provide physiologic alterations.
- Physiologic alterations were not required to improve exercise performance and capacity in the heat, but thermal perceptions were distorted by cooling.

The impaired ability to exercise in hot compared with moderate ambient temperatures has been well reported[1,2]; however, the exact mechanisms are not fully understood. The impairment is often associated with the development of hyperthermia.[3] Therefore, researchers have investigated ways to attenuate the rise in internal body temperature or dampen the perceived level of thermal strain experienced during exercise. These strategies have included hydration interventions, acclimation and acclimatization, and cooling.[3–5] Investigators have studied the effectiveness of precooling in hot conditions[6–8] and, more recently, cooling during exercise.[9–12] The recent interest in cooling during exercise is, in part, due to improvements in the practicality of cooling devices, such as cooling vests and collars that can be applied quickly, efficiently, and without causing much disruption to the athlete before, during, or after competition.[3]

Precooling using cooling vests can lower internal body temperature, improve perceptions of thermal strain, and improve subsequent running performance (assessed using tests with a fixed endpoint [eg, time or distance]) and capacity (assessed using tests with no fixed endpoint),[6,13,14] but the benefits of such precooling are often lost during exercise.[3] Given the transient time course of precooling-induced physiologic alterations, cooling applied during exercise may be beneficial, and the results of a recent meta-analysis[3] support this suggestion. Data on vest cooling (VC) during exercise are limited, but such garments can attenuate internal body temperature increases and improve exercise capacity during uncompensable heat exposure.[9] Cooling vests tend to be used because they cool a relatively large surface area, potentially allowing for greater heat exchange than cooling smaller surface areas elsewhere; however, performance and capacity benefits have often been observed in cooling studies without physiologic alterations when thermal perceptions are altered.[3] Different regions of the body have different levels of thermal sensitivity,[15] and given that the head and neck region is an area of high thermal sensitivity, researchers have suggested that cooling this region may have a disproportional benefit. Shvartz[16] reported that cooling the neck region alleviated heat strain more efficiently than cooling the torso, and more recently, investigators[10–12] have demonstrated that exercise performance and capacity in the heat can be improved by cooling the neck region using a modified, commercially available cooling collar (CC). Whereas researchers have suggested that cooling the neck region can alleviate heat strain,[16,17] most authors[10–12,17,18] have reported that cooling this region during exercise has no effect on internal body temperatures. In the absence of physiologic alterations, investigators have proposed that neck cooling may enhance performance and capacity due to an alteration in thermal sensation and a dampening of the thermal information relayed to the brain. Tyler and Sunderland[12] reported a 13.5% improvement in exercise capacity with the use of a CC and observed that, although participants voluntarily terminated exercise at higher internal body temperatures and heart rates (HRs) when using the CC, their perceived levels of thermal and exertional strain were identical at termination.

Data on cooling during exercise are limited; however, they suggest that both cooling vests and CCs may offer benefits to exercise performance and capacity when worn during exercise in the heat.[3] To our knowledge, the only direct comparison of neck and torso cooling was conducted by Shvartz,[16] who cooled the neck and chest during bench stepping in the heat using a water-perfused cooling system. In recent years, the commercial availability of a range of inexpensive, practical cooling garments has increased, but their effectiveness is largely unknown. Identifying optimal cooling interventions would provide users with an important competitive edge. Therefore, the purpose of our study was to compare the effects of practical torso and neck cooling on exercise capacity in a hot environment.

METHODS

Participants

Eight recreationally active, nonheat-acclimated men (age = 24 ± 4 years, height = 1.82 ± 0.10 m, mass = 80.3 ± 9.7 kg, maximal power output [W_{max}] = 240 ± 25 W) volunteered to participate in our study. *Recreationally active* was defined as participating in up to 150 minutes of physical activity each week. We calculated that a sample size of 8 would provide sufficient statistical power (0.8; β = .2) based on an effect size (Cohen d) of 0.45[3] and an α level of .05 to detect meaningful changes in exercise capacity. Before each laboratory visit, participants completed a health screen questionnaire,[19] which we scrutinized to ensure their health status had not changed. All participants provided written informed consent, and the study was approved by the Ethical Advisory Committee of the University of Roehampton.

Experimental Procedures

Before the familiarization and 3 experimental trials, participants completed an incremental cycle ergometer (model 874E; Monark Exercise AB, Vansbro, Sweden) test to determine W_{max} using a modified version of the protocol of Kuipers et al.[20] In ambient conditions (temperature = 21.8°C ± 0.6°C, relative humidity = 54.7% ± 3.1%), participants cycled for 5 minutes at 100 W, after which the workload was increased by 50 W every 2.5 minutes until HR reached 160 beats/min. When HR reached 160 beats/min, the workload was increased by 21 W every 2.5 minutes until volitional exhaustion. The maximum workload was calculated using the equation of Kuipers et al[20]: $W_{max} = W_{com} + ([t/150] \times \Delta W)$, where W_{com} is the last workload completed; t is the duration in seconds of the final, uncompleted stage; and ΔW is the final load increment (typically 21 W).[20]

After preliminary testing, participants visited the laboratory on 4 occasions (familiarization followed by 3 experimental trials) at the same time of day (±30 minutes) 7 to 10 days apart. They abstained from alcohol, strenuous exercise, and caffeine 24 hours before all trials and completed a food record for the 24-hour period before the initial trial. This 24-hour diet and abstinence from alcohol, strenuous exercise, and caffeine was repeated for the 24 hours before each subsequent visit. Approximately 30 minutes before the trial started, participants arrived at the laboratory in a hydrated state (approximately 1.5 hours after drinking 500 mL of water) and at least 3 hours postprandial. Adherence to these requirements was verified orally before all trials, and no violations were reported. Participants were allowed to drink water ad libitum during all trials.

All trials were conducted in a walk-in environmental chamber (Procema Environmental, Middlesex, United Kingdom) set to hot ambient conditions (temperature = 35.0°C ± 0.1°C, relative humidity = 50.1% ± 0.7%). During all 4 visits, participants cycled to volitional exhaustion on a mechanically braked cycle ergometer (Monark 874E) at a workload calculated to elicit 60% of W_{max} (144 ± 15 W). The first trial served as a familiarization session and was followed by 3 experimental trials. During these 3 experimental trials, participants cycled to volitional exhaustion with no cooling (NC), VC using a commercially available cooling vest (Arctic Heat PTY Ltd, Burleigh Heads, Australia), or CC using a commercially available neck CC (Black Ice LLC, Memphis, TN). Time to exhaustion was recorded in all trials. We provided no feedback other than cadence during each trial. The order of the 3 experimental trials was randomized and counterbalanced.

Physiologic and Perceptual Variables

On arrival at the laboratory, each participant's nude body mass was recorded. A rectal temperature probe (model 401; DigiTec Corporation, Lancaster, United Kingdom) was self-inserted approximately 10 cm past the anal sphincter, and an HR monitor (model S625X; Polar Electro OY, Kempele, Finland) was attached before participants entered the walk-in environmental chamber for each trial. During the 3 experimental trials, 8 skin thermistors (model THERM 37904; Viamed Ltd, West Yorkshire, United Kingdom) were attached to participants using a transparent dressing (Tegaderm; 3M Health Care, St Paul, MN) and waterproof tape (Transpore; 3M Health Care). We calculated weighted mean skin temperature (T_{sk}) at 4 skin thermistor sites (sternal notch, forearm, thigh, and calf) using the equation of Ramanathan.[21] We measured mean neck temperature (T_{neck}) using 2 thermistors attached to the posterior aspect of the neck and mean torso temperature (T_{torso}) using 1 thermistor attached to the pectoralis major and 1 attached to the scapula. Rectal temperature (T_{rectal}), T_{sk}, T_{neck}, T_{torso}, HR, rating of perceived exertion (RPE; 6 [*no exertion*] to 20 [*maximal exertion*]),[22] thermal sensation, and feeling scale (FS) score[23] were recorded at 5-minute intervals and at exercise termination. Thermal sensation was rated using a 9-point scale that ranged from 0 (*unbearably cold*) to 8 (*unbearably hot*), with 4 (*neutral*) as comfortable. Participants were instructed to differentiate between thermal sensation of the body (TS_{body}) and neck (TS_{neck}).[24] The FS was recorded as a measure of affect during exercise and assessed levels of pleasure and displeasure using an 11-point scale that ranged from –5 (*very bad*) to 5 (*very good*), with 0 (*neutral*) as the midpoint. After completing each trial, participants towel dried and recorded postexercise nude body mass from which sweat loss and percentage of body mass loss were calculated.

Vest-Cooling Trials. Before the VC trials, the vest was activated according to the manufacturer's guidelines by immersing it in water for approximately 10 minutes and was then frozen for at least 120 minutes in a domestic freezer (–24°C). Participants applied the vest immediately on removal from the freezer and wore it under their clothing. The vest covered 23.4% ± 2.1% of estimated body surface area (BSA); however, the activated cooling strips covered only 5.0% ± 0.4% of the estimated BSA. We calculated the BSA cooled by the vest for each participant using the equation of Mosteller.[25]

Cooling-Collar Trials. The cooling section of the collar was made from a thin plastic casing consisting of 5 compartments filled with cooling reagent (Black Ice LLC). The cooling section of the collar was 375-mm long, 60-mm wide, and 15-mm deep and weighed 155 g at room temperature. It was held in place by a 600-mm neoprene wrap secured with hook-and-loop fastenings at the anterior aspect of the neck. Before the CC trials, the collar was placed in a freezer (–24°C) for 45 to 60 minutes according to the manufacturer's guidelines. The collar was applied immediately to the neck on removal from the freezer. The estimated BSA that the collar cooled was 1.1% ± 0.1%.

Statistical Analysis

Data are presented as mean ± SDs unless stated. Data for time to volitional exhaustion, sweat loss, and fluid consumption in the VC, CC, and NC trials were analyzed using 1-way analysis of variance (ANOVA) with repeated measures. Two-way ANOVAs with repeated measures were conducted for the HR and temperature data. Given that capacity times were different in each experimental trial, several comparisons were made. All participants completed at least 20 minutes; however, because of equipment problems, complete sets of data were available only until the 15-minute reading, so HR and temperature data from 0, 5, 10, and 15 minutes were compared using an ANOVA. We compared the data at volitional exhaustion using 1-way ANOVA with repeated measures. When an interaction was observed, simple main-effect analyses were conducted. When we observed a main effect, we calculated Bonferroni post hoc tests to identify pairwise differences. Torso and neck BSA data were compared using a paired-samples *t* test. Friedman ANOVA and Wilcoxon signed-rank tests were used for the perceptual data collected at the time points 0 to 15 minutes and at exhaustion. Effect sizes were calculated for parametric data using the Cohen d[26] with the following thresholds indicating the likelihood that the true value of the effect represented a worthwhile change: *trivial effect* (<0.2), *small effect* (0.2–0.5), *moderate effect* (0.5–0.8), and *large effect* (>0.8).[27] The α level was set at .05. We used SPSS (version 21; IBM Corporation, Armonk, NY) to analyze the data.

RESULTS

Time to Volitional Exhaustion

Time to exhaustion was longer in the VC (32.2 ± 9.5 minutes) than the NC (mean difference = 4.7 minutes; 95% confidence interval [CI] = 2.8, 6.6; $P = .03$; d = 0.54) or CC (mean difference = 2.2 minutes; 95% CI = 1.4, 3.0; $P = .02$; d = 0.24) condition, but we did not observe a difference between NC and CC (mean difference = 2.5 minutes; 95% CI = 1.1, 3.9; $P = .12$; d = 0.31). The time to volitional exhaustion improved in 7 of the 8 participants during both the VC and CC trials compared with the NC trial (Figure 1).

Neck Skin Temperature

The mean T_{neck} was lower in the CC than the NC ($P <$ .001) or VC ($P < .001$) condition at 5, 10, and 15 minutes and volitional exhaustion (Figure 2). No difference existed between VC and NC at any time point ($P > .99$).

Torso Skin Temperature

The mean T_{torso} was lower in the VC than the NC ($P <$ .001) or CC ($P < .001$) trial at 5, 10, and 15 minutes and volitional exhaustion (Figure 3). We observed that T_{torso} was cooler with VC than NC ($P = .001$; d = 1.62). No difference existed between NC and CC at any time point ($P > .99$, d = 0.32).

Rectal Temperature, Mean Skin Temperature, and Heart Rate

Temperature responses are shown in Table 1. Both T_{rectal} ($F_{3,21} = 33.7$, $P < .001$) and T_{sk} ($F_{1.4,9.8} = 24.1$, $P < .001$) increased over time during the exercise bout, but the response did not differ among trials. Similarly, HR increased over time, and we noted main effects for trial ($F_{2,14} = 4.4$, $P = .03$) and time ($F_{3,21} = 171.4$, $P < .001$); however, we did not observe an interaction effect ($F_{6,42} = 0.9$, $P = .50$).

Perceptual Data

Thermal-sensation responses were different among trials and over time for TS_{neck} ($\chi^2_2 = 40$, $P < .001$ and $\chi^2_4 = 37$, $P < .001$, respectively) and TS_{body} ($\chi^2_2 = 52$, $P < .001$ and $\chi^2_4 = 75$, $P < .001$, respectively). Site-specific thermal sensation was similar at baseline but lower at subsequent comparative time points. The cooling intervention did not

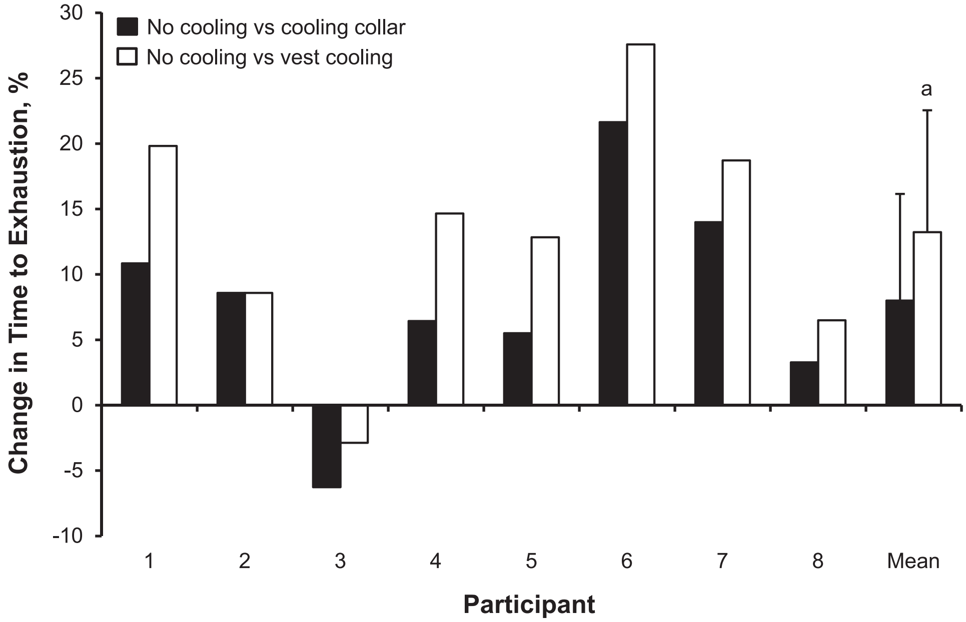

Figure 1. Percentage change in cycling capacity with each cooling intervention compared with the no-cooling condition. Values reflect individual responses (mean ± SD). A positive percentage indicates an increase in time to exhaustion. A negative percentage indicates a decrease in time to exhaustion. [a] Indicates greater percentage improvement than with the cooling collar ($P < .001$).

affect RPE ($\chi^2_2 = 0.2$, $P = .89$) or FS ($\chi^2_2 = 1.8$, $P = .40$). However, over time, RPE increased ($\chi^2_4 = 0.94$, $P < .001$) and FS decreased ($\chi^2_4 = 0.90$, $P < .001$). We did not observe differences among trials at volitional exhaustion for RPE ($\chi^2_2 = 2.5$, $P = .29$) or FS ($\chi^2_2 = 0.9$, $P = .63$; Table 2).

Body Fluid Balance

We did not observe differences in body fluid loss among the NC (1.3% ± 0.6%), CC (1.3% ± 0.4%), and VC (1.4% ± 1%; $F_{2,14} = 0.02$, $P = .94$) conditions.

DISCUSSION

We are the first, to our knowledge, to directly compare the effect of cooling the neck or torso using commercially available cooling-vest and neck-cooling devices on exercise capacity in the heat. Despite low levels of thermal strain (final T_{rectal} = approximately 38.2°C), exercise capacity was greater for the VC than the NC (17.2% ± 13.5%) trial but not different between the CC and NC (9.4% ± 9.8%) trials. Site-specific skin temperatures and perceived levels of thermal sensation were reduced with use of the cooling

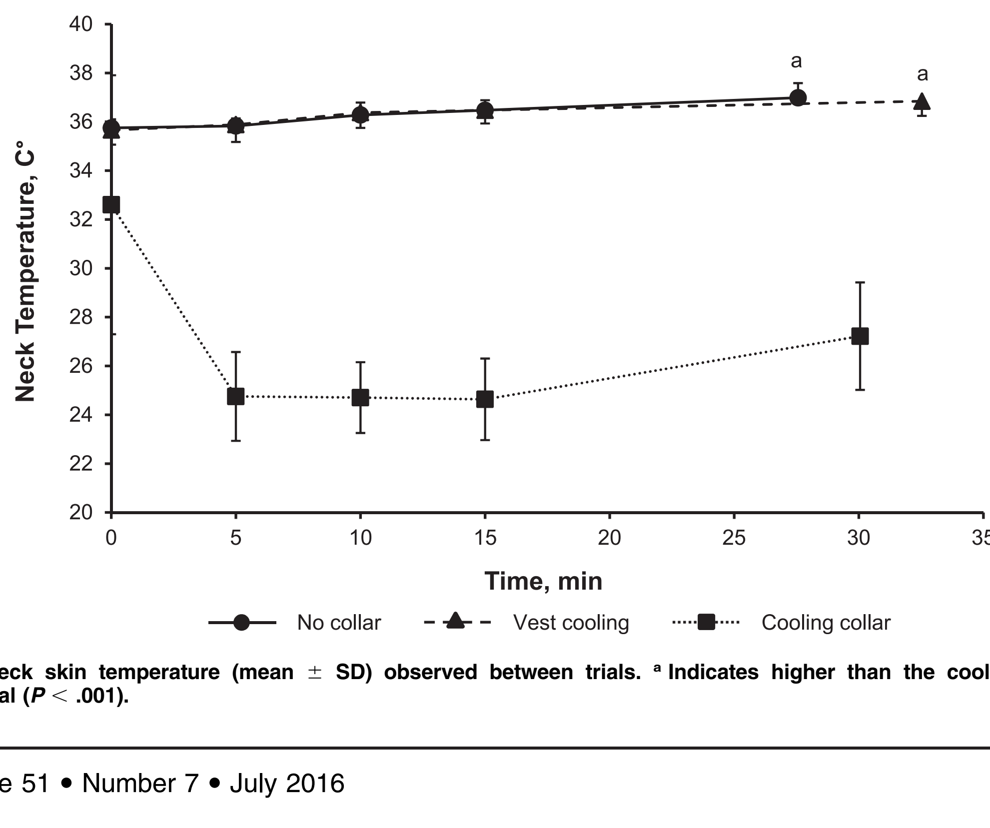

Figure 2. The neck skin temperature (mean ± SD) observed between trials. [a] Indicates higher than the cooling-collar condition throughout the trial ($P < .001$).

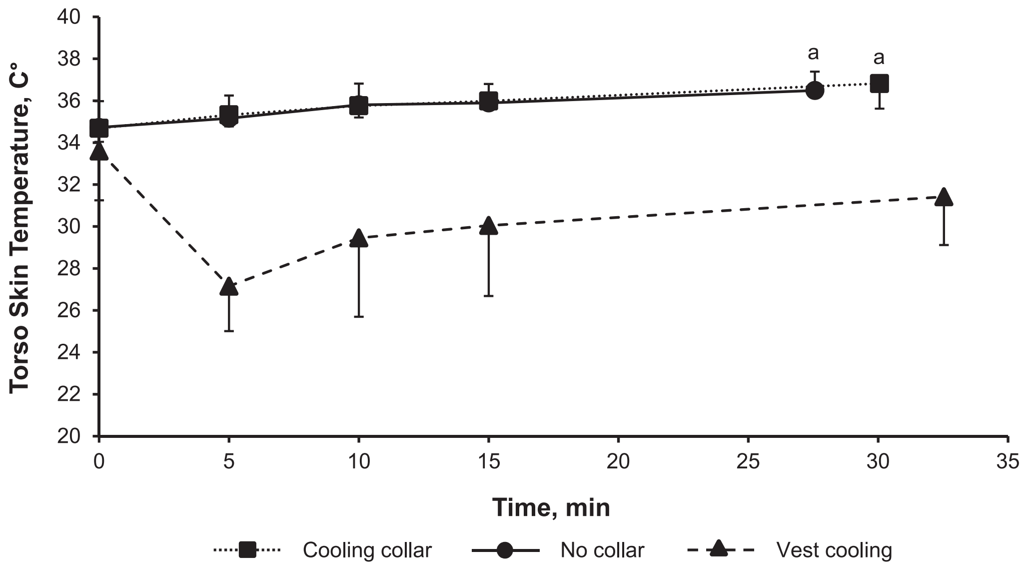

Figure 3. The torso skin temperature (mean ± SD) observed between trials. [a] Indicates higher than the vest-cooling condition throughout the trial ($P < .001$).

modalities, but neither intervention affected any other physiologic or perceptual variable measured.

Whereas several researchers have investigated the effect of cooling before exercise, few authors have studied the effect of cooling during exercise on performance or capacity. In a recent meta-analysis, Tyler et al[3] reported a moderate positive effect of cooling during exercise performance and capacity (mean improvement = approximately 7%) and a larger beneficial effect of cooling the torso on exercise performance and capacity in uncompensable heat stress[9] than cooling the head and neck region during exercise performed in compensable heat stress. These data were calculated from only 6 studies, none of which directly compared different heat-stress environments or cooling sites.

The effect size of cooling the torso during uncompensable heat stress in the study by Kenny et al[9] (d = 2.26) was greater than that of cooling the torso during compensable heat stress in our study (d = 0.54). Kenny et al[9] investigated the use of a cooling vest in participants who wore nuclear, biological, and chemical protective clothing while walking: the vest effectively decreased the thermal strain experienced, reducing both internal body and skin temperatures. The greater effect size that they[9] reported was likely due to the greater thermal strain caused by the uncompensable heat stress. The effectiveness of cooling vests for lowering internal body and skin temperatures when they are worn before exercise (precooling) in the heat is mixed, with some researchers noting reductions and others not observing changes[6,28,29] (see table 1 in Tyler et al[3] for a comprehensive review). In our study, the cooling interventions reduced site-specific skin temperature (ie, VC lowered T_{torso}, CC lowered T_{neck}) without affecting any other physiologic variable measured. The lack of physiologic alteration in the CC trials is in line with the research published to date,[10–12] and we and the authors of this research propose that such cooling has little to no effect on physiologic variables due to the relatively small BSA cooled.

Table 1. Thermoregulatory and Heart-Rate Data During the Cycling Test to Volitional Exhaustion (Mean ± SD)

	Time				
Variable	0 min	5 min	10 min	15 min	Volitional Exhaustion
Mean skin temperature, °C					
No cooling	34.4 ± 0.5	34.7 ± 0.5	35.2 ± 0.5	35.4 ± 0.6	36.1 ± 0.5[a]
Cooling collar	34.2 ± 0.5	34.7 ± 0.4	35.2 ± 0.6	35.5 ± 0.5	36.0 ± 0.5[a]
Vest cooling	34.3 ± 0.5	34.5 ± 0.3	35.0 ± 0.5	35.1 ± 0.9	35.5 ± 0.6[a]
Heart rate, beats/min					
No cooling	83 ± 10	140 ± 14	154 ± 13	165 ± 7	178 ± 5[a,b]
Cooling collar	73 ± 8	126 ± 13	145 ± 11	152 ± 13	174 ± 8[a,b]
Vest cooling	81 ± 7	131 ± 17	147 ± 14	155 ± 12	176 ± 12[a,b]
Rectal temperature, °C					
No cooling	37.5 ± 0.4	37.5 ± 0.3	37.7 ± 0.3	37.8 ± 0.3	38.4 ± 0.3[a]
Cooling collar	37.2 ± 0.2	37.2 ± 0.1	37.4 ± 0.1	37.6 ± 0.1	38.2 ± 0.5[a]
Vest cooling	37.2 ± 0.2	37.4 ± 0.2	37.6 ± 0.5	37.6 ± 0.2	38.1 ± 0.3[a]

[a] Indicates difference over time ($P \leq .05$).
[b] Indicates main effect for trial ($P < .05$).

Table 2. Perceptual Data During the Cycling Test to Volitional Exhaustion (Median [25th to 75th Interquartile Range])

Variable	Time				
	0 min	5 min	10 min	15 min	Volitional Exhaustion
Rating of perceived exertion[a]					
No cooling	NA	11.0 (9.3–12.0)	12.5 (11.3–13.8)	14.0 (13.0–15.8)	19.0 (17.0–20.0)[d]
Cooling collar	NA	11.0 (9.3–12.0)	13.0 (12.0–13.0)	14.0 (12.3–14.8)	19.0 (18.0–19.8)[d]
Vest cooling	NA	9.5 (7.3–12.0)	11.5 (9.3–13.8)	13.0 (11.3–16.5)	19.5 (18.3–20.0)[d]
Thermal sensation of body[b]					
No cooling	4.8 (4.0–5.0)	6.0 (5.0–6.4)	6.5 (5.5–7.3)	6.5 (6.1–7.0)	8.0 (7.5–8.0)[d]
Cooling collar	4.8 (4.0–5.5)	5.5 (4.6–6.4)	6.0 (5.0–6.5)	6.5 (5.1–6.9)	8.0 (7.1–8.0)[d]
Vest cooling	4.0 (3.0–5.0)	3.5 (2.0–4.6)[e]	4.0 (2.5–5.5)[e]	4.3 (3.0–6.0)[e]	6.3 (5.0–7.0)[d,e]
Thermal sensation of neck[b]					
No cooling	4.5 (4.0–5.0)	5.0 (4.6–5.3)	5.8 (4.8–6.4)	6.3 (5.6–7.0)	7.8 (7.1–8.0)[d]
Cooling collar	5.3 (2.9–5.9)	2.3 (1.6–4.5)[e]	3.0 (2.3–4.9)[e]	3.8 (2.3–5.1)[e]	5.5 (4.5–6.9)[d,e]
Vest cooling	5.3 (4.0–5.9)	5.3 (4.3–6.0)	6.0 (5.0–6.5)	6.5 (5.6–7.0)	7.3 (7.0–7.9)[d]
Feeling scale[c]					
No cooling	3.0 (2.3–4.5)	1.0 (1.0–3.3)	0.0 (0.0–1.5)	−1.0 (−1.8 to −1.0)	−4.0 (−4.0 to −2.3)[d]
Cooling collar	3.0 (3.0–3.0)	1.0 (1.0–2.0)	0.0 (0.0–0.8)	−1.0 (−2.0 to −0.3)	−4.0 (−4.8 to −3.3)[d]
Vest cooling	3.0 (2.3–4.0)	2.0 (0.0–3.5)	0.0 (−1.0–2.0)	−1.0 (−3.0–1.0)	−4.0 (−5.0 to −1.3)[d]

Abbreviation: NA, not applicable.

[a] Rated on the Borg[22] scale (range, 6 = *no exertion* to 20 = *maximum exertion*).
[b] Rated on a 9-point scale (0 = *unbearably cold*, 4 = *neutral*, 8 = *unbearably hot*).
[c] Rated on an 11-point scale (–5 = *very bad*, 0 = *neutral*, 5 = *very good*).
[d] Indicates different over time ($P < .001$).
[e] Indicates lower than the other 2 trials ($P < .05$).

The effectiveness of a cooling intervention appears to depend on the magnitude of thermal strain experienced and the magnitude of cooling presented.[27,30] The purpose of our study was to compare 2 commercially available cooling devices, without attempting to match the surface area cooled; therefore, approximately 5 times more BSA was cooled with VC than with CC. Despite the difference in surface areas cooled, neither cooling intervention altered the physiologic variables measured; however, exercise capacity was improved in the VC trial. The relatively low internal body temperatures observed at termination (highest mean = 38.4°C, highest individual = 39.3°C) suggest that internal body temperature was unlikely to be the main determinant of exercise capacity for most participants.

Skin temperature and the perceived level of thermal comfort are both strong mediators of exercise capacity,[31] and whereas T_{sk} did not differ between trials, site-specific temperatures were lowered, resulting in a lower T_{torso} with the VC and a lower T_{neck} with the CC condition. Previous improvements in exercise capacity after skin-temperature reductions have been attributed to redirection of blood flow from the skin to the working muscles and decreased perception of thermal strain.[32] The reduction in T_{torso} with VC resulted in a lower TS_{body} than the CC and NC trials, and the difference in thermal sensation may help explain the increase in time to exhaustion due to the volitional nature of exercise termination. Similar site-specific reductions in T_{neck} and TS_{neck} were observed with the CC condition, but capacity did not improve despite data suggesting that the head and neck are more sensitive to cooling during exposure to a hot environment.[15] Our study showed that the VC trial had a moderate beneficial effect on improving exercise capacity in the heat (+4.7 minutes), whereas the CC trial had a small beneficial effect (+2.5 minutes). Shvartz[16] suggested that cooling the neck more effectively alleviated heat strain than cooling the same surface area of the trunk. Other researchers[10–12] have shown that neck cooling can improve running performance and capacity by approximately 6% and 13%, respectively, due to a dampening of the perceived thermal load.

Previous investigators[10–12] have used a modified CC that was cooled using a –80°C freezer, whereas we used an unmodified CC that was cooled using a conventional (–24°C) freezer. The differences in methods meant that the lowest mean T_{neck} in our study (approximately 25°C) was markedly warmer than the 17°C to 19°C reported in the previous investigations.[10–12] Given the proposed relationship between the magnitude of thermal load experienced and the cooling provided,[3] it is possible that the lower magnitude of cooling offered by the unmodified commercially available collar or the lower heat load of cycling exercise compared with treadmill running was insufficient to elicit a substantial benefit. Interestingly, despite differences in thermal sensation, we observed no differences in RPE or FS among trials at any comparative time point, offering tentative support that thermal sensation is a primary perceptual mediator for exercise in the heat.

Limitations and Future Directions

Our study augments the existing literature on cooling during exercise and contributes to the limited data comparing cooling sites; however, as with most cooling studies, we did not blind the participants to the intervention. They were blinded to the hypotheses and their data until all trials were completed to minimize the effect of knowing such data on their responses. The purpose of our study was to compare 2 commercially available garments, so we did not match or attempt to match the BSA cooled by the devices. Researchers should investigate the effect of matched cooling at different sites on exercise performance and capacity in the heat and on the physiologic and perceptual responses to the exercise. Investigators should also study the effects of such cooling in individuals with higher internal body temperatures, as previous data have suggested that the benefit might be greater in such populations.

CONCLUSIONS

Effective cooling strategies are highly sought by athletes and coaches. Our results suggested that, in hot conditions, commercially available cooling vests were beneficial to exercise, but they may offer insufficient cooling to improve capacity. Improvements in capacity without physiologic alterations were observed with the VC trial, further supporting the suggestion that such alterations are not required to improve performance and capacity in the heat as long as thermal perceptions are distorted by cooling.

Practical Applications

Athletes and members of their support teams desire effective, practical strategies to improve exercise performance and capacity in hot environments, and our study showed that commercially available devices offered small to moderate beneficial effects. Previous cooling data have suggested that cooling devices worn during exercise might place participants at risk of developing high internal body temperatures due to their negligible effect on reducing thermal strain; however, in our study, neither device resulted in the participants reaching such temperatures. In more highly motivated individuals, such temperatures could possibly be reached and exceeded, so effective monitoring and briefing procedures may be required to ensure participant safety during exercise performed in a hot environment when using such cooling devices. These procedures should be adopted and followed by the potential user (eg, athlete), and care providers (eg, coach, athletic trainer, health professional) need to be cognizant of these concerns.

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