Effectiveness of wearing a cooling vest on exercise performance and thermoregulatory responses during a 5-km time trial in highly trained athletes

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6 July 2012

Radboud Universiteit Nijmegen

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Abstract

Background: Exercise is strongly related with an increased core body temperature (CBT) and therefore hyperthermia (CBT >40.0°C) may develop, which could lead to clinical symptoms and/or decreased performance levels. Therefore, we examined the effects of wearing a cooling vest during a 5-km treadmill run on the exercise performance of highly trained athletes.

Methods: Ten male athletes performed a 5-km time trial on a treadmill in a climate chamber (25°C, 55% relative humidity) with and without cooling vest. During the tests half kilometer split times and finish times were measured. Additionally, CBT, skin temperature and heart rate were measured continuously throughout the test.

Results: No differences in exercise performance were found between the cooling and control condition (1246±96 seconds and 1254±98 seconds, respectively $p=0.85$). Additionally, the increase in CBT (1.5±0.4°C for control and 1.4±0.4°C for cooling condition) and heart rate (86±8 bpm for control and 86±13 bpm for cooling condition) during the 5-km time trial were comparable across conditions (all p-values >0.05). Trunk skin temperature and thermal sensation score were comparable at baseline, but were lower in cooling compared to control condition during the 5-km time trial. ($p<0.001$ and $p=0.013$ respectively).

Conclusion: Wearing a cooling vest during exercise did not improve exercise performance, whilst also CBT and HR responses were comparable across conditions. Trunk skin temperature and thermal sensation score were significantly lower when wearing a cooling vest. Therefore, wearing a cooling vest may be useful to stay cool and comfortable during practice, despite it does not enhance performance in competitive settings.

Keywords: Treadmill running, time trial, cooling, thermoregulation, achievement levels

Word count abstract: 251

Introduction

Approximately 70 - 80% of the produced energy during exercise appears as thermal energy. (1-3) The increased metabolic heat production usually exceeds the maximal capacity of heat dissipation(4), which results in a rise of core body temperature (CBT). Accordingly, hyperthermia (CBT > 40.0°C) may develop (4, 5), which could lead to clinical symptoms (6) and/or decreased performance levels due to fatigue. (7, 8) As CBT becomes elevated, exercise will be terminated once critically high internal temperatures are attained, which is a safeguard that limits the potential development of dangerous heat illness. (9, 10) Furthermore, the rate of heat gain is detected by our body, which could anticipatorily adjusts the work rate to ensure that the exercise task can be completed within the homeostatic limits of the body. (9, 11) Consequently, any attempt to delay the rise in core body temperature during exercise may enhance exercise performance levels, which could be the difference between the first and the second place during competition. (12-14)

Recently, many cooling techniques were evaluated in athletes, with particular attention on pre-cooling strategies. The general principals of pre-cooling are to increase the heat storage capacity of the body and perform more work prior to reaching a limiting core body temperature, thus delaying fatigue due to hyperthermia. (12) Pre-cooling with cold air, cold water immersion, cooling vests, and ice slurry ingestion effectively reduced CBT, and increased athlete performance levels in previous studies (6, 9, 10, 12, 15, 16). However, these cooling strategies may be impractical for use in competitive settings due to the need of specialized equipment, poor transportability to a field setting, athlete discomfort and costs. (9, 15)

Alternatively, cooling during exercise may be even more practical and efficient in improving exercise performance. Previous studies indicated that local cooling of the hand or neck during exercise improved performance of the athlete with 6 to 13,5%. (17-19) Accordingly, cooling a larger part of body may result in a further increase of exercise performance levels. Cooling vests are an easy way to cool a large part of the body. Whilst previous cooling vests were not comfortable and too heavy for athletes (6, 16), recent developments resulted in a new light-weight cooling vest (HyperKewl™ vest, TechNiche International, Vista, California, USA) which is suitable for cooling during exercise. It is, however, unknown to what extend this new cooling vest may improve exercise performance levels.

Therefore, the purpose of this study was to determine the effects of wearing a cooling vest during a 5-km treadmill time trial on the exercise performance levels of highly trained athletes. We hypothesized that wearing a cooling a vest during exercise is effective in limiting or delaying the increase in CBT, and thus improves the time to finish the 5 km running trial.

Methods

Subjects

A total of 10 highly trained male athletes (19-52 years) volunteered to participate in this study (Table 1). Subjects of 18 years and older and a personal record on the 5 kilometers (5 km) under 20 minutes were eligible for inclusion. Exclusion criteria were based on the use of the temperature pill: a body weight lower than 36,5 kg, use of an implanted electro medical device, an obstructive disease of the gastrointestinal tract or gastro intestinal surgery, and a MRI scan during the period that the telemetry pill was in the body. Subjects were recruited from athletic teams and all subjects gave written informed consent prior participation in the study. The study was approved by the Medical Ethical Committee of the Radboud University Nijmegen Medical Centre, and was conducted in accordance with the Declaration of Helsinki.

Table 1. Subject characteristics (mean ± SD)

Variable	Subjects (n=10)
Age (years)	42 ± 10
Height (cm)	182 ± 5
Mass (kg)	73.6 ± 6.5
BMI (kg/m²)	22.2 ± 1.4
Personal record 5-km (min)	18:10 ± 00:54

Design

A cross over design was used in this study. Prior to inclusion, subjects were medically screened at the Radboud University Nijmegen Medical Centre to determine whether the subject met the in-and exclusion criteria. After medical screening, all subjects performed the first time trial. In this habituation session subjects performed the entire test to get used to the protocol and to run on a treadmill in a climate chamber (25 °C, 55% relative humidity and wind velocity of 3 m/s). After the first session, two sessions, one intervention and one control session, were performed at random, with at least 5 days of recovery in between. In the intervention session the subject ran the 5-km time trial while wearing the cooling vest.

To remove any bias, subjects were informed that the study investigated whether running in a cooling vest improved performances because of cooling, or decreased performances because of the added weight of the vest. (12) All subjects were tested at the same time of the day to minimize the effects of the circadian rhythm on the CBT and heart rate. (6, 20)

Protocol

After arrival at the Sport Medical Centre Papendal, body weight and lactate level were measured, followed by 5 minutes of bed rest, in which the heart rate, CBT and skin temperature were measured to establish baseline. The treadmill was set at a grade of 1%, to extrapolate physiological assessment of trained runners to conditions of outdoor road running. (21) Thereafter, subjects performed a standardized warm up, which consisted of a 12 minutes running phase, in which the speed was increased with 2 km/h every two minutes with a starting velocity of 6 km/h. After 8 minutes of warm up the speed was decreased to 10 km/h and thereafter to 6 km/h, followed by 5 minutes of stretching. In the intervention condition, the same protocol was followed and the cooling vest was put on in the last minute of stretching.

Once the 5-km time trial was started, the speed was controlled by the subjects. To assist in pacing, completed distance was continuously displayed and the runners were encouraged at every 500 meter milestone. During the tests subjects did not receive information about running speed and split times, and they were not provided with their finishing times until completion of the study.

After finishing the 5-km time trial, there was a cooling down of 2 minutes at 6 km/h. Followed by a recovery phase of 15 minutes of bed rest without wearing a cooling vest. Lactate level was measured two minutes after finishing the 5-km time trial and directly after the recovery phase. Rates of perceived exertion (RPE) and thermal sensation were measured every kilometer during the 5 km run and every 2 minutes during the warm up and recovery phase.

During all sessions, subjects were instructed to wear the same clothes, which consisted of a short and a dry-fit running shirt. Subjects were allowed to eat and drink *ad libitum* before exercise, whilst they registered all fluid intake in a diary 24-h before measurement. Furthermore, the subjects were instructed to take the same diet before each session to minimize the effect of nutrition. This diet should be equally as prior to competitive exercise. In preparation for all sessions, subjects were not allowed to perform strenuous exercise, or ingest alcohol or caffeine 24 hours before testing.

Cooling vest

The cooling vest (HyperKewl™ vest, TechNiche International, Vista, California, USA) was developed by TechNiche International for supporting humans in thermal uncomfortable conditions. The vest is a sleeveless shirt, which covered the major part of the trunk and consisted of a fabric layer. The fabric layer absorbed and stored water, which could be released through evaporation. This evaporation during exercise could cause the suggested cooling effect of the vest.

Before each measurement, the cooling vest was activated in a standardized way. Firstly, the vest was soaked in tap water for two minutes. Thereafter, the excess water was squeezed out very carefully, followed by a drying period of two hours. After these two hours, the vest was placed in a refrigerator (6.0°C ± 0.5°C) for at least 10 hours. Afterwards the cooling vest was ready to use.

Measurements

Core body temperature (CBT). The CBT was determined by using a portable telemetry system (CorTemp™ system, HQ Inc., Palmetto, Florida, USA), which is safe and reliable. (22, 23) Subjects ingested an individually calibrated telemetric temperature sensor at least five hours preceding the experiment, to avoid any interaction with fluid ingestion. (24) Before start of the measurement, the CBT of an individual was measured with an external recorder. Subsequently, the CBT was measured every 20 seconds during the whole protocol. The highest value of these measurements was presented as maximum core body temperature. Baseline CBT was calculated as the average of all measurements during the five minutes of bed rest before the start.

Heart rate. The heart rate was measured every 15 seconds, using a 2-channel ECG chest band system (Polar RS 400, Polar Electro Oy, Kempele, Finland). The mean heart rate was defined as the average heart rate during the exercise period. Exercise intensity was calculated by dividing the mean heart rate during exercise by the maximal predicted heart rate according the formula of Tanaka *et al.* (208 – 0.7 * age). (25) The highest value of the heart rate measurements was presented as the maximum heart rate.

Skin temperature. The skin temperature was measured every 20 seconds at 8 sites of the body (head, chest, scapula, 2x upper-arm, hand, thigh and calf) with iButtons (type DS1922L, Maxim/Dallas Semiconductor Corp, USA). These were small (16 x 6 mm^2) systems that measured the skin temperature wirelessly. (26) In the 8-point model that was used to calculate the mean total body skin temperature, every iButton had his own weight factor, which was based on the

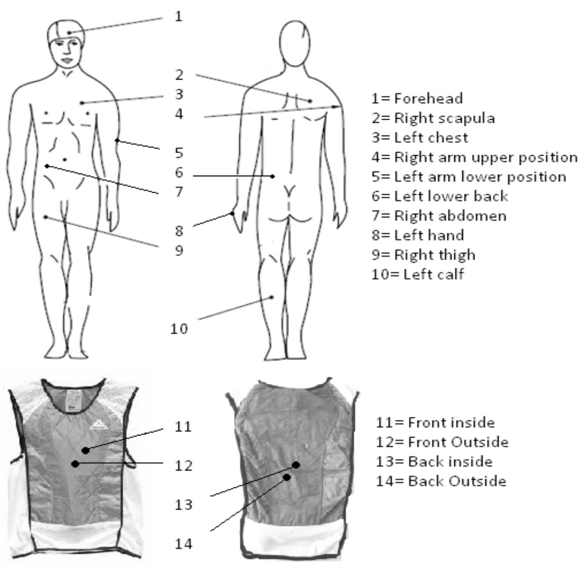

Figure 1. Placement of iButtons on the body

relative surface of the body that was represented by the iButton. (27) The mean skin temperature was the enumeration of all separate values. Additional to the 8-point model, two extra iButtons were placed on the trunk (abdomen and lower back) to calculate the trunk skin temperature more precisely. The trunk skin temperature was calculated by taking the average of the four iButtons on the trunk (scapula, chest, abdomen and lower back). The ambient temperature was measured with a separate iButton.

Vest temperature. The vest temperature was measured every 20 seconds at 4 sites of the vest with iButtons, which were equally distributed between the in and outside of the cooling vest. The difference between skin and vest temperature was measured and called the skin to vest temperature gradient.

Blood lactate level. Blood lactate levels were measured with an Accutrend Plus lactate-glucose analyzer (Accutrend plus GCT Cobas, Roche Diagnostics Limited, West Sussex, England). The blood lactate level was measured 3 times, baseline (prior to warm up), directly after 5 km and 15 minutes after finishing 5-km time trial respectively.

Rate of perceived exertion (RPE). The RPE was measured by the BORG 10-point category scale, in which 0 was corresponding to rest and 10 to maximal exertion. (28) The RPE was asked every kilometer during the 5-km time trial and every 2 minutes during the warm up and recovery phase.

Thermal sensation. The thermal sensation was measured on a 7-point category scale, in which -3 was corresponding with very cold and +3 was very hot. (29) Thermal sensation scores were asked at the same time as the RPE.

Data analysis

The primary outcome in this study was the finishing time on the 5-km time trial performance. This finishing time was defined as the time between start and finish of the 5-km. All values were presented as mean +/- standard deviation, unless indicated otherwise. Statistical analysis were performed using SPSS 16.0 (SPSS, Chicago, USA) and the level of significance was set at $p<0.05$. To assess differences in exercise characteristics between control and cooling condition, a one-way analysis of variance (ANOVA) was applied. Two-way repeated measures ANOVA was used to assess differences over distance in time, CBT, skin temperature, Heart rate, RPE and thermal comfort score. The between subject factor was the exercise condition.

Results

Exercise characteristics

All subjects successfully completed the 5 km time trials. There was no difference in temperature of the climate chamber between the cooling (25.5 ± 0.2°C) and the control (25.3 ± 0.2°C) condition ($p=0.19$). Also relative humidity did not differ across conditions ($p=0.32$). The mean temperature of the cooling vest at the start of the 5-km time trial was 9.7 ± 2.3 °C.

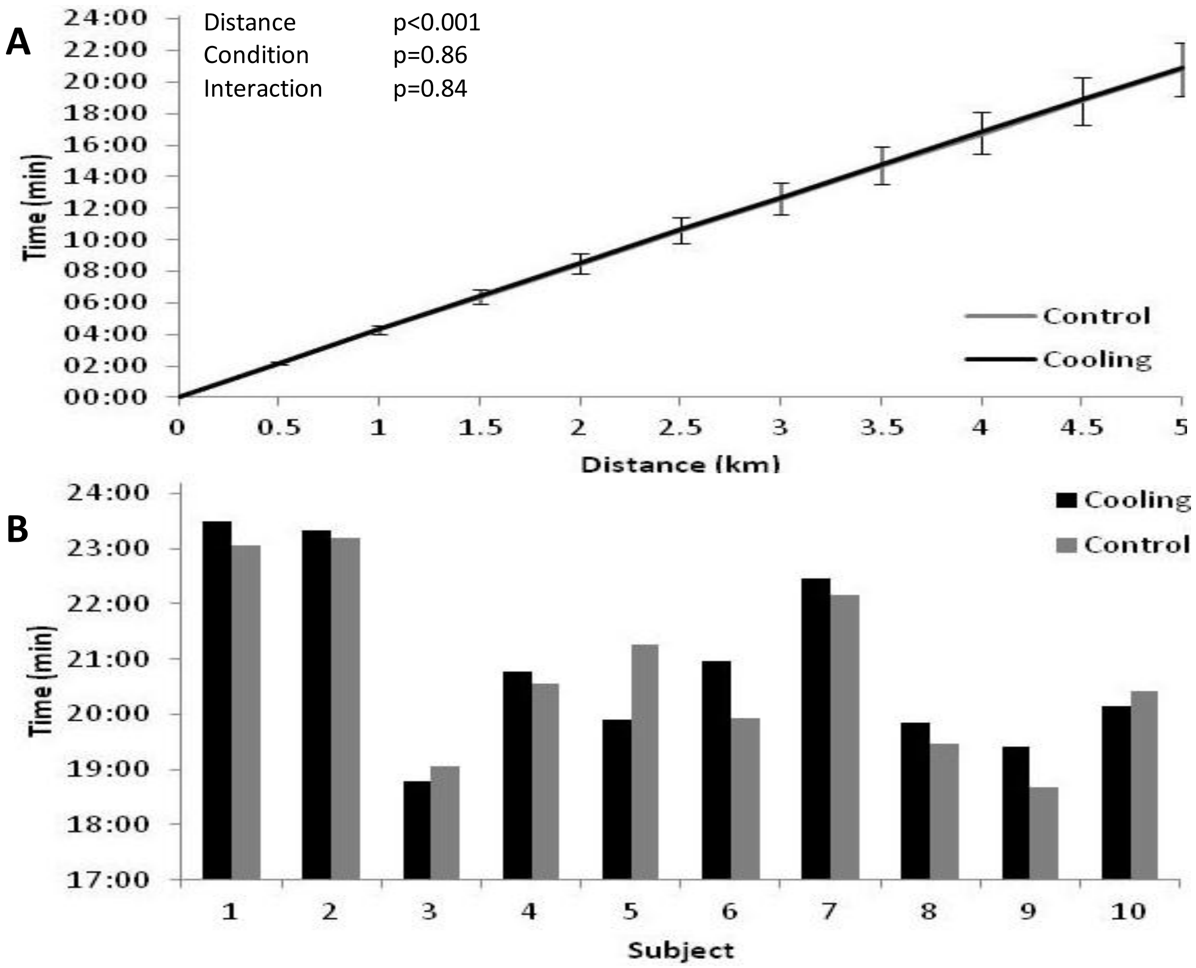

Figure 2. (A) Running time during the 5-km time trial for the control (grey line) and the cooling condition (black line). Error bars represented the SD. (B) Individual finishing times in the 5-km time trial in response to the control (grey bars) and the cooling condition (black bars).

5-km time trial running performance

The 5-km finish times were 1246 ± 96 seconds (20 minutes and 46 seconds) for the control condition and 1254 ± 98 seconds (20 minutes and 54 sec) for the cooling condition and did not statistically differ (p=0.86) (Figure 2A). Furthermore, all 500 meter split times were comparable across conditions (*distance * condition,* F(1,10)=0.044, p=0.84). Individual comparisons in 5-km time trials for both conditions are showed in Figure 2B.

Core body temperature

The baseline CBT was 37.2 ± 0.3 °C during the control condition and 37.0 ± 0.2 °C during the cooling condition, and did not differ (p=0.18). The CBT was not different between conditions (p=0.41). During the 5-km time trial a comparable increase in CBT was observed between the control (1.5 ± 0.4 °C) and cooling condition (1.4 ± 0.4 °C) (*distance * condition,* F(1,10)=0.071, p=0.84) Finally, maximum CBT did not differ between conditions (p=0.54). (Table 2)

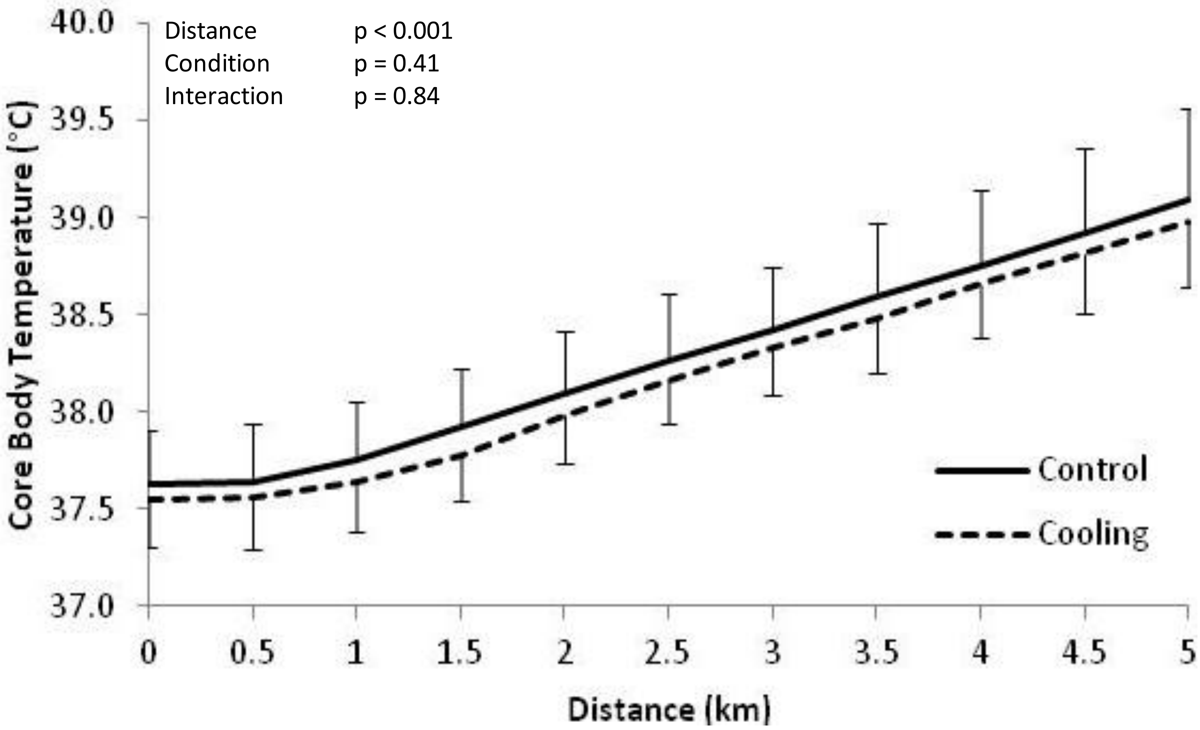

Figure 3. Mean core body temperature responses during the 5-km time trial for the cooling (dotted line) and the control (continuous line) condition. The error bars represented the SD.

Skin Temperature

The baseline skin temperature of the trunk was 34.2 ± 0.4°C and 34.4 ± 0.7°C in the cooling and control condition respectively ($p=0.46$). Trunk skin temperature during the race decreased significantly more during the cooling (2.1 ± 0.6 °C) compared to the control condition (0.5 ± 1.1 °C, *distance * condition,* $F(1,10)= 11.059$, $p<0.001$). Accordingly, minimum trunk skin temperature was lower in the cooling condition ($p<0.001$) and it was continuously lower throughout the time trial ($p<0.001$). (Figure 4A) In parallel, the mean core to trunk skin temperature gradient was higher in the cooling (5.1 ± 0.8 °C) compared to the control condition (3.9 ± 0.7 °C) ($p=0.001$). (Figure 5) In addition, the temperature gradient significantly increased during the race (*distance*, $F(1,10)=34.477$, $p<0.001$), whilst this increase in gradient during the race was not comparable between conditions (*distance * condition,* $F(1,10)= 12.137$, $p<0.001$). Finally, the trunk skin to vest temperature gradient decreased during the 5-km time trial (*distance,* $F(1,10)=163.526$, $p<0.001$). (Figure 6)

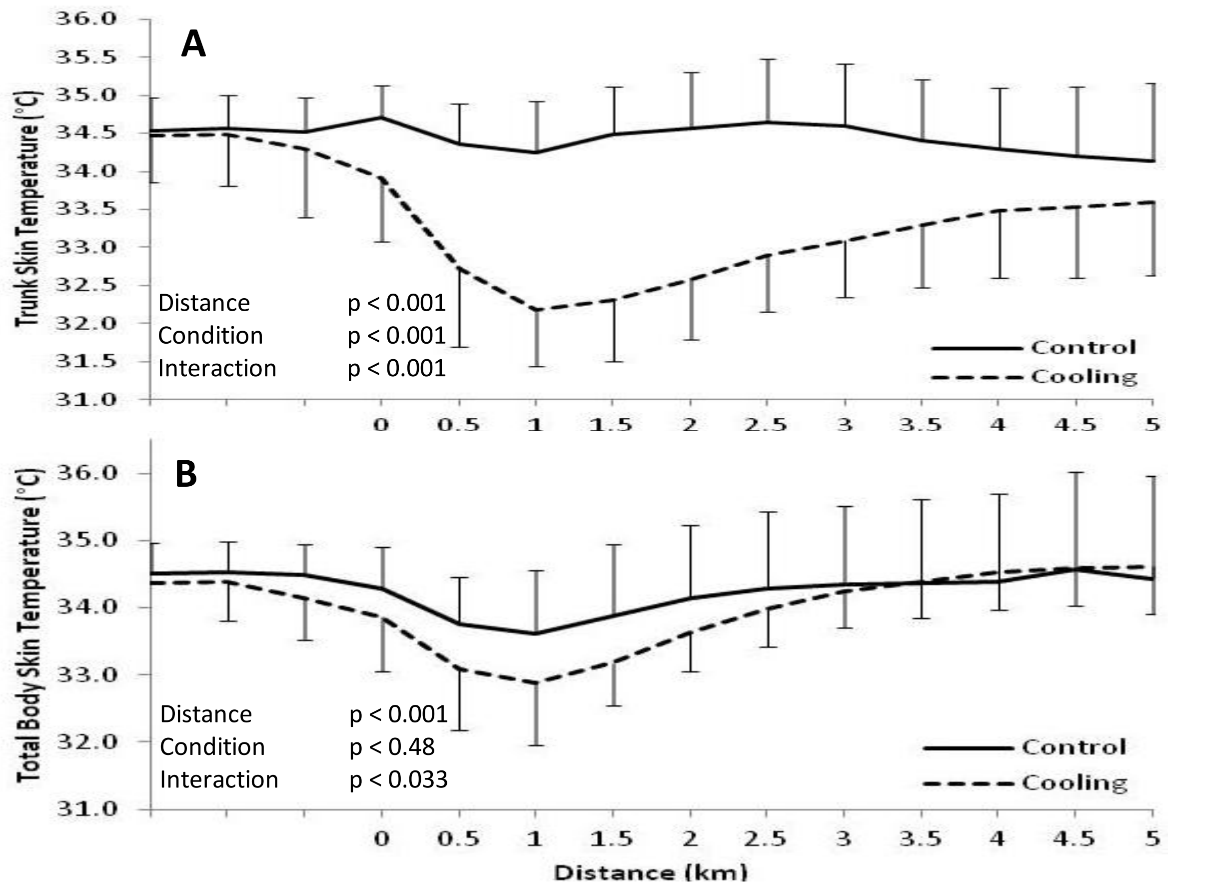

Figure 4. (A) Trunk skin temperature during 5-km time trial for the control (continuous line) and the cooling (dotted line) condition. (B) Time course of total body skin temperature during the 5-km time trial for the control (continuous line) and cooling (dotted line) condition. The first three points of both graphs consisted of the three minutes prior to 5-km time trial. The error bars represented the SD.

Besides the trunk skin temperature, we also examined the total body skin temperature. The total body skin temperature during the 5-km time trial did not differ between conditions (p=0.48).) The total body skin temperature in the first part of the 5-km time trial is lower in the cooling condition, due to the decline in skin temperature after the cooling vest was placed around the trunk. However, at finish line the total body skin temperature is comparable across conditions (*distance * condition,* F(1,10)=3.616, p=0.033). (Figure 4B)

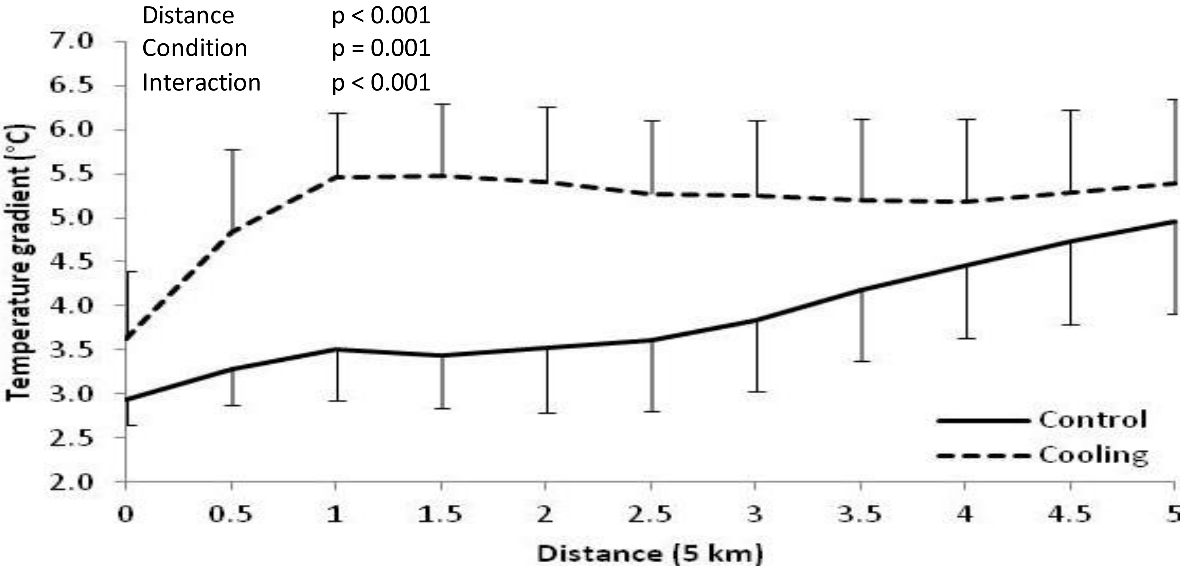

Figure 5. Core to skin temperature gradient (defined as the CBT subtracted by the skin temperature of the trunk) during the 5-km time trial for the cooling (continuous line) and the control (dotted line) condition. Error bars represented the SD.

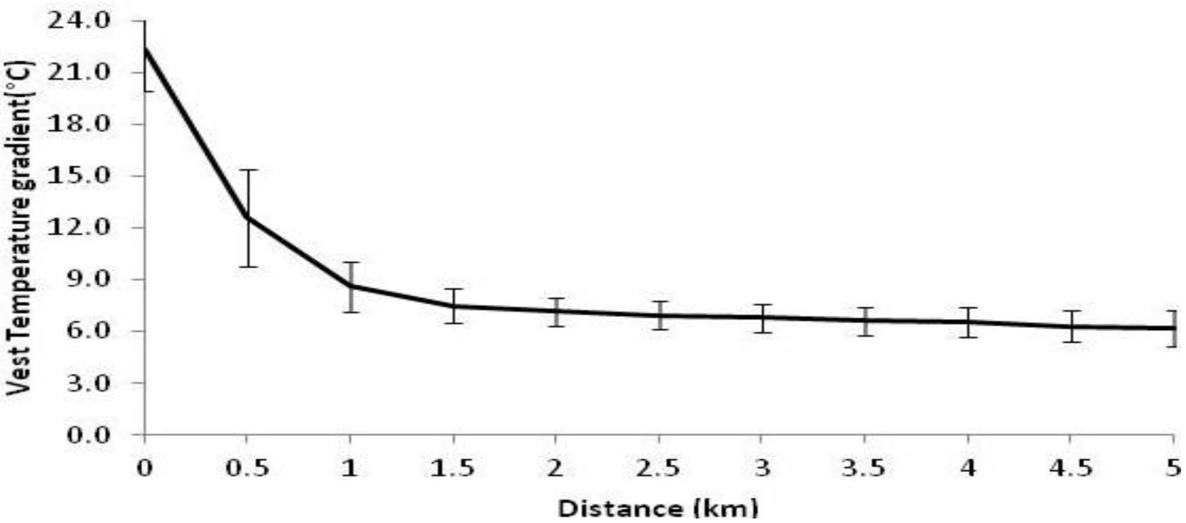

Figure 6. Skin to vest temperature gradient (defined as the skin temperature of the trunk subtracted by the vest temperature) during the 5-km time trial.

Heart rate

Baseline heart rate did not different between conditions (p=0.96). The heart rate during the 5-km time trial was comparable between the control and cooling condition (p=0.68). The heart rate raised during the first 2 km of the 5-km time trial and reached a plateau thereafter. The change in heart rate during the time trial did not differ across conditions (*distance * condition*, F(1,10)=1.645, p=0.21). Maximum heart rate was 178 ± 16 beats per minute(exercise intensity of 99.9 ± 8.9%) in the control condition and 175 ± 13 beats per minute (exercise intensity of 97.9 ± 7.3%) in the cooling condition and did not statistically differ (p=0.67).

Rate of perceived exertion

No significant difference in RPE was found between conditions (p=0.64), but throughout each 5-km time trial the RPE significantly increased during the race (*distance*, F(1,5)=93.410, p<0.001). Nevertheless, the increase in RPE was not different between conditions. (*distance * condition,* F(1,5)=1.000, p=0.39). (Figure 7)

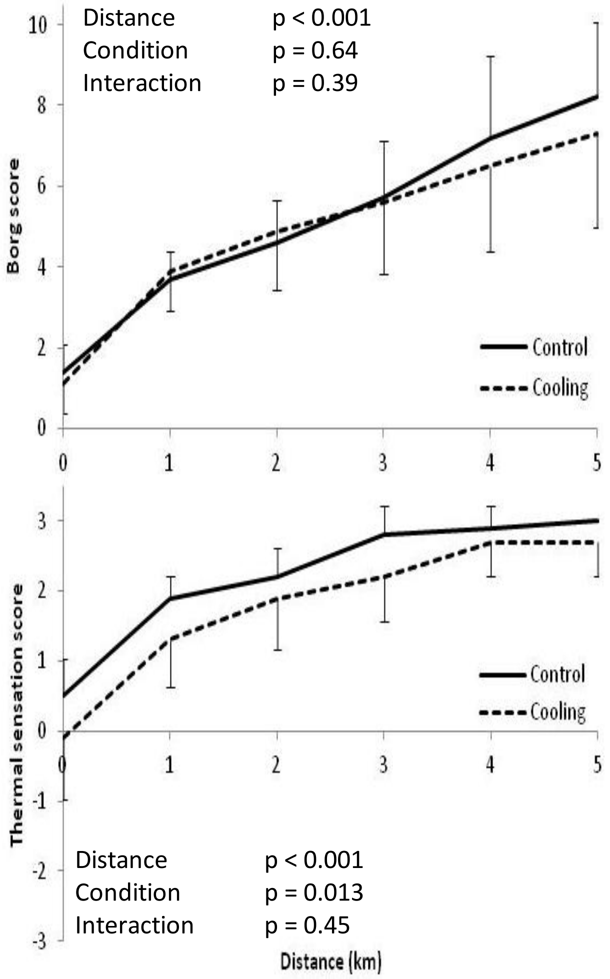

Figure 7. Responses of RPE and thermal comfort score during the 5-km time trial for the control (continuous line) and cooling (dotted line) condition.

Thermal sensation score

The thermal comfort score was significantly lower in the cooling condition (1.8 ± 0.4) compared to the control condition (2.2 ± 0.2)(p=0.013). Furthermore, the thermal sensation score increased significantly during the race (*distance*, F(1,5)=101.237, p=<0.001), whilst this was comparable across conditions (*distance * condition,* F(1,5)=.875, p=0.45). (Figure 7)

Body mass loss and blood lactate level

The relative body mass loss during the 5-km time trial trials was 1.4 ± 0.3% for the control condition and 1.3 ± 0.3% for the cooling condition, with no significant difference between conditions (p=0.75). The blood lactate level after finishing the 5-km time trial was 9.2 ± 2.4 mmol/L in the control condition and 8.5 ± 1.9 mmol/L in the cooling condition, but did not differ (p=0.47).

Table 2. Outcome parameters during the 5-km time trial in both conditions (mean ± SD).

Core body temperature (°C)	**Control**	**Cooling**	**p-value**
Baseline CBT *	37.2 ± 0.3 °C	37.0 ± 0.2	0.18
Δ CBT	1.9 ± 0.5	2.0 ± 0.5	0.93
Maximum CBT	39.1 ± 0.5	39.0 ± 0.3	0.54
Total body skin temperature (°C)			
Baseline Tskin *	33.7 ± 0.5	33.5 ± 0.5	0.39
Δ Tskin	0.2 ± 1.1	0.7 ± 0.4	0.18
Minimum Tskin	33.5 ± 1.0	32.8 ± 0.6	0.08
Trunk skin temperature (°C)			
Baseline Tskin *	34.4 ±0.7	34.2 ± 0.4	0.46
Δ Tskin	0.5 ± 1.1	2.1 ± 0.6	**0.001**
Minimum Tskin	33.9 ± 0.8	32.1 ± 0.7	**<0.001**
Heart rate (bpm)			
Baseline HR *	58 ± 10	58 ± 11	0.96
Δ HR	120 ± 12	117 ± 13	0.61
Maximum HR	178 ± 16	175 ± 13	0.68
Blood lactate level (mmol/L)			
Baseline	2.2 ± 0.6	2.2 ± 0.5	0.90
After 5-km	9.2 ± 2.4	8.5 ± 1.9	0.47
After recovery	4.1 ± 1.5	4.2 ± 2.0	0.86
Body mass (kg)			
Baseline	73.6 ± 6.6	73.7 ± 6.8	0.97
After recovery	72.6 ± 6.4	72.7 ± 6.6	0.97
Environmental conditions			
Ambient temperature(°C)	25.5 ± 0.2	25.3 ± 0.2	0.19
Humidity (%)	60.2 ± 2.0	59.2 ± 2.4	0.32

P- value refers to one-way ANOVA T test * P-value refers to a 2-way repeated measures ANOVA.

Discussion

The aim of our study was to determine the effects of wearing a cooling vest during a 5-km time trial on the exercise performance levels and thermoregulatory responses in highly trained athletes. Although we hypothesized that wearing a cooling vest during exercise may limit the increase in CBT and subsequently may enhance exercise performance, our results could not confirmed that. Wearing a cooling vest during exercise did not result in a faster finish time, lower core body temperature or lower heart rate. However, the trunk skin temperature was significantly lower in the cooling condition, and subjects had a lower thermal sensation score while wearing the cooling vest. These results suggest that use of a cooling vest did not improve exercise performance, however it may be useful to stay cool and comfortable during exercise.

The absence of any improvement in 5-km time trial performance is in contradiction with previous studies, which examined the influence of a cooling vest on running ability. A previous study demonstrated that the 5-km time trial time was significantly reduced with 13 seconds (1.1%) when wearing a cooling vest during active warm-up. (6) In parallel, two other studies concluded that the exercise time until exhaustion was increased with 2.2% and 7.8 minutes respectively, after pre-cooling with an ice-vest. (30) On the other hand, a study by Stannard et al. (12) was in accordance with our results. They showed that wearing a cooling vest during a warm-up does not improve 10-km performance. (12) An important factor that may impact these findings is the type of cooling. While the above-mentioned studies were related to pre-cooling methods, we applied the cooling vest during exercise. Pre-cooling provided athletes to begin exercise with a cooler CBT and have an increased heat storage capacity, thus delayed fatigue associated with hyperthermia. (9) Probably, cooling during exercise is not able to limit the increase in core body temperature sufficiently. In competitive settings, the cooling effect of the vest may be largely neglected by the high amount of heat production during the 5-km time trial. It could be possible that the cooling capacity of the vest is not sufficient to compensate for this rapid increase in CBT during exercise. Thus, the cooling vest, used during exercise, was unable to compete against the extreme heat production during the 5-km time trial.

An alternative explanation for the lack of improvement in 5-km time trial performance may relate to the trunk to vest temperature gradient of the vest. The use of our evaporative cooling vest during the 5-km time trial did not affect the core body temperature. Indeed Figure 6 clearly shows that the trunk to vest temperature gradient decreased very fast, which means that the cooling capacity of the vest was already limited within the first km. After 1-km the trunk to vest temperature gradient approached a steady state of 7.0 ± 0.4°C, which may have been inadequate to improve time trial performance. However, the effective trunk to vest temperature gradient is not known from literature, because this is the first study that examine the cooling vest temperature during exercise. Nevertheless, previous studies with positive cooling effects used an ice-vest. (6, 13, 30-32) In general, the mean vest temperature of an ice-vest is lower compared to the temperature of an evaporative vest (13), and thus the trunk to vest temperature gradient is higher. For example, Luomala et al. used an ice-vest (-20°C) and found a 21.5% improvement of performance. (31) Unlike another study, where they used an evaporative vest, and thus a lower trunk to vest temperature gradient, the 10-km time trial performance was not improved. (12) In a recent study both types of vests were used. (13) They demonstrated an improvement in time until exhaustion in both conditions, however in the ice-vest condition the improvement was larger (7.8 minutes versus 5.1 minutes) compared to the control condition. (13) Therefore, our trunk to vest temperature gradient may be inadequate to improve performance.

In contrast with the core body temperature, the trunk skin temperature was significantly lower in the cooling condition. This could be explained by wearing a cooling vest during the 5-km time trial. However, literature demonstrated that cooling the neck region may have more influence on skin temperature and exercise performance. (8, 18) Furthermore, a previous study concluded that cooling the head and neck region is more efficient than cooling elsewhere, possibly due to the neck's close proximity to the thermoregulatory centre. (33) Subsequently, cooling the head and neck region was more efficient than cooling the trunk in the attenuation of heat strain during exposure to high ambient temperatures. (34) This attenuation in heat strain may be responsible for the improved exercise performance. Hence, the use of a cooling vest is effective in lowering the trunk skin temperature, though this effect on the skin temperature could be increased by using neck cooling.

Another factor, that could explain the lack of improvement of the 5-km time trial, may be the maximal CBT. The maximal CBT achieved during our experiment was 39.1°C, which is considerably less than the critical core temperature of 40°C which was previously related with limiting exercise performance. (9, 10) A reason for the relatively low CBT may have been the moderate ambient temperature of the climate chamber (25°C). Indeed, previous studies that found a positive effect of a cooling vest on running performance were observed when the ambient temperature was higher than 30°C. (6, 30-32) Additionally, cycling performance was enhanced in environmental temperatures of approximately 30°C, but not in 25°C conditions. (13, 31, 35) These results emphasized the idea that a cooling vest is predominantly effective in high ambient temperatures. Therefore, the ambient conditions of our study may be inadequate to trigger heat stress and thus limit performance, resulting in comparable responses during the cooling and control condition.

In accordance with most other studies, we found a significant lower thermal sensation score during the 5-km time trial in the cooling condition. (12, 13) Despite subjects experienced less thermal stress and have a lower trunk skin temperature in the cooling condition, still no differences in CBT, heart rate and finishing time across conditions were found. Additionally, there was a trunk to vest temperature gradient throughout the whole trial, and thus subjects felt more cool and comfortable during running.

Strengths and limitations

The strengths of this study are the randomized cross over design with an appropriate recovery period of 5 consecutive days. The continuous measurement of the CBT, skin temperature and heart rate are also a strong point of the study. Furthermore, we used a 5-km time trial to mimic performance during competition as good as possible, but were still permit to measure physiological factors that provide insight into the mechanism of performance alteration.

Still, some limitations should also be taken into account. Firstly, human beings have a thermal cycle over the day, which could influence thermoregulatory responses during exercise. (20) However, we have anticipated to that by scheduling the two 5-km time trials at the same time of the day. Secondly, an inherent problem with cooling studies is the inability to blind the subjects for the intervention, which could lead to placebo effects. However, to remove bias, we told prior to participation that the cooling vest could have either positive (cooling) or negative (more weight) effect on the 5-km time trial performance.

Conclusion

The results of this study indicate that wearing a cooling vest during exercise is not effective in improving simulated 5-km time trial performance in a moderate ambient condition in male competitive runners. Additionally, wearing a cooling vest does not decrease core temperature or heart rate during exercise. Trunk skin temperature and thermal sensation scores were significantly lower in the cooling condition. Therefore, wearing a cooling vest may be useful to stay cool and comfortable during practice, despite it does not enhance performance. As previous studies demonstrated that a cooling vest improved performance in hot ambient conditions, future research should focus on the magnitude of cooling necessary to enhance performance of different durations and under different conditions.

Acknowledgements

I want to thank dr. Thijs Eijsvogels and prof. dr. Maria Hopman for their guidance and support during the study. Furthermore, I want to thank Maarten Moen, Arjan Kokshoorn, Diederik Oei, Tjeerd de Vries and Peter van Beek for being medical back up during the tests. I also want to thank NOC*NSF and in particular Albert Smit for the opportunity to use the climate chamber. Finally, I want to thank all subjects for their cooperation, involvement and persistence throughout the study.

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