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Effect of providing cooling techniques (pre-cooling & per-cooling) on cognitive function

Efecto de proporcionar técnicas de enfriamiento (preenfriamiento y perenfriamiento) sobre el aumento de la función cognitiva

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Abstract. The implementation of cooling techniques plays a crucial role in minimizing exercise-induced hyperthermia, thereby enhancing performance and preserving cognitive function during training. However, studies on the effect of cooling techniques on cognitive function have yielded mixed results due to inconsistent methodologies, unclear implementation guidelines, variations in cooling protocols, types of exercise, different environmental temperature, and variations in subject fitness levels. Therefore, this study compared the effectiveness of different cooling techniques in improving cognitive function during high-intensity exercise. Eleven young, healthy adult men, aged 18 to 28 years, with a Body Mass Index (BMI) ranging from 18.5 to 24.9 kg/m², normal blood pressure, and a resting heart rate (RHR) between 60 and 100 bpm, were recruited for this study. This research employed a crossover design. The subjects received three types of interventions in a random order: 1) pre-cooling using an ice vest for 30 minutes before training; 2) pre-cooling by consuming an ice slushy at a dosage of 7 g/kg of body weight over 30 minutes; and 3) a combination of both methods. The washout period between interventions was 72 hours. The results indicate a significant decrease in cognitive performance in the pre-cooling and per-cooling groups, with p-values of <0.001 (pre-cooling) and 0.014 (per-cooling). In contrast, cognitive performance in the group receiving the combination of the two methods was maintained ($p = 0.641$). The combination of pre-cooling with an ice vest and per-cooling with an ice slushy can help maintain cognitive function after high-intensity exercise compared to using either method alone.
Keywords: Pre-cooling, Per-cooling, Hyperthermia, High-Intensity Exercise.

Resumen. La implementación de una técnica de enfriamiento tiene un papel importante en la minimización de la hipertermia durante el ejercicio. Mantener la temperatura corporal central en condiciones normales es importante como factor que apoya el rendimiento. Sin embargo, la metodología inconsistente, las pautas de implementación poco claras, las variaciones en los protocolos de enfriamiento, el tipo de ejercicio, las diferencias en la temperatura ambiental y el nivel de condición física del sujeto pueden conducir a diferentes efectos. Por lo tanto, este estudio tiene como objetivo analizar la efectividad de las técnicas de enfriamiento para mejorar la función cognitiva durante el ejercicio de alta intensidad. La investigación se llevará a cabo con un diseño de preprueba-postprueba de un grupo utilizando un grupo de hombres adultos jóvenes en Surabaya con 11 sujetos que cumplieron con los siguientes criterios de inclusión, de 18 a 28 años, índice de masa corporal (IMC) 18,5-24,9 kg/m², presión arterial normal, frecuencia cardíaca en reposo (FCR) 60-100 latidos por minuto (lpm), haciendo ejercicio físico activamente 150 minutos/semana y saludable. Para ver el impacto a través de las etapas de prueba de prerrequisitos de normalidad, homogeneidad y diferencias, el proceso de análisis de datos fue asistido con SPSS versión 25. Los resultados de este estudio son que la aplicación de una combinación de técnicas de enfriamiento entre el enfriamiento previo con chalecos de hielo y el enfriamiento previo con hielo raspado puede mantener la función cognitiva después de la prueba posterior. Por lo tanto, las investigaciones futuras deberían buscar explorar más a fondo las relaciones multifactoriales entre el enfriamiento y los resultados fisiológicos, de rendimiento y perceptivos, al tiempo que se considera el momento de la aplicación del enfriamiento.
Palabras clave: Preenfriamiento, Preenfriamiento, Hipertermia, Ejercicio de alta intensidad.

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Introduction

Exercise in high environmental temperatures can lead to an increase in core body temperature and result in hyperthermia (Douzi et al., 2020). It is a condition in which the body is unable to regulate its core temperature effectively, resulting in a core body temperature that exceeds 40°C (Bouchama, 2016; Wasserman, Creech, & Healy, 2017). The rise in core temperature occurs when the thermoregulatory system fails to counteract the effects of metabolic heat production and environmental heat exposure (Bradley et al., 2019). This condition can lead to fatigue and decreased performance in athletes, impaired cognitive function, and potentially fatal consequences if not treated promptly. Specifically, it can result in compromised function of the heart, brain, and liver, and may even lead to heatstroke and death (Leon & Helwig, 2023; Epstein & Roberts, 2011). Therefore, it is crucial to maintain core body temperature within normal ranges as a key factor supporting optimal performance.

The implementation of cooling strategies plays a crucial role in minimizing heat stress during exercise. Various cooling techniques can be employed both before (pre-cooling) and during exercise (per-cooling), yielding positive benefits for performance. A literature review and meta-analysis conducted by Wegmann et al. (2012) revealed that pre-cooling methods, such as consuming cold beverages, using cold packs, maintaining cold room temperatures, and wearing ice vest, resulted in a significant improvement in sports performance. The findings indicated that consuming a cold drink before exercise led to the highest performance increase of 15%, while the use of an ice vest produced the least effect at 4% (Wegmann et al., 2012). However, according to Bongers et al. (2017), the positive effects of pre-cooling strategies may diminish during exercise. Furthermore, pre-cooling techniques did not demonstrate significant improvements in performance times for high-intensity exercises, such as sprinting (Bongers et al., 2017). Therefore, alternative methods are necessary to enhance the effectiveness of cooling techniques in high-intensity exercise.

Another cooling method, known as per-cooling (during exercise), is often neglected due to several considerations such as sports regulations and the size of cooling equipment (Taylor et al., 2015). Numerous studies have investigated cool-down strategies in exercise, yielding mixed results. Research by Mazalan, (2021) indicated that head cooling during high-intensity exercise in high temperatures can lower forehead temperature; however, it does not significantly impact core body temperature or cognitive performance. Conversely, when head cooling is combined with ice consumption, it significantly reduces both core body temperature and head temperature, as well as enhances cognitive performance during exercise (Mazalan et al., 2022). Additionally, interventions such as applying cold packs to the head (Racinais, Gaoua, & Grantham, 2008) and neck (Sunderland et al., 2015) can significantly preserve memory capacity during training. A combination of pre-cooling and per-cooling has also shown similar benefits. Consuming ice slushies at -1˚C, or combining them with cold air, is effective in improving performance (Ziemann, Grzywacz, & Sportu, 2011).

However, inconsistent methodologies, variations in cooling techniques, different ambient conditions, and subject characteristics can lead to various effects. Therefore, this research aims to compare the effect of pre-cooling, post-cooling, and combining both methods on cognitive function during high-intensity exercise.

Methods

Participants

Eleven young, healthy adult men were recruited for this study. The inclusion criteria were ages 18 to 28 years, a Body Mass Index (BMI) ranging from 18.5 to 24.9 kg/m², normal blood pressure, a resting heart rate (RHR) between 60 and 100 beats per minute (bpm), engagement in exercise for at least 150 minutes per week, and overall good health. Exclusion criteria included any illness occurring during the study and the inability to continue participation. The sample size was calculated using G*Power software version 3.1, with an effect size of 1.42 based on the findings of Mazalan et al. (2022), with α set at 0.05 and β at 0.9. Random sampling was employed to determine the interventions provided. The study received approval from the Human Research Ethics Committee of the Faculty of Medicine at Airlangga University (Reference number 43/EC/KEPK/FKUA/2024) and was conducted in accordance with established ethical guidelines.

Procedure

This research employs a crossover design. The subjects received three types of interventions in a random order: 1) pre-cooling using an ice vest (Veemoon, United States) for 30 minutes before training; 2) pre-cooling by consuming an ice slushy at a dosage of 7 g/kg of body weight over 30 minutes; and 3) a combination of both methods. The washout period between interventions was 72 hours (Bleakley et al., 2012). High-intensity training was conducted using a monark ergocycle (Ergomedic 828e, Monark, Varberg, Sweden) at an intensity of 90% of HRmax until volitional fatigue, in a controlled room temperature of 20-26°C. Cognitive performance was assessed using the OSPAN test (OSPAN; Unsworth et al, 2005) 15 minutes before and immediately after completing the exercise protocol. Body temperature was continuously monitored every 5 minutes using a tympanic thermometer.

Data Analysis

The data analysis utilized the Statistical Package for the Social Sciences (SPSS) software version 25 (Chicago, IL, USA). The analysis was conducted in several stages to address the hypothesis. These stages include: 1) a normality test using the Shapiro-Wilk test; 2) a homogeneity test using the Levene test; and 3) a paired sample t-test with control group as a pre-test comparison.

Results

Subject characteristic

The characteristics of the respondents are normally distributed among the subjects. The average age of the participants was 21.09 years. The participants' heart rate, height, weight, and body mass index before the exercise did not show significant differences (Table 1).

Table 1.
Subject characteristics.

Variables	Baseline (n=11)	Pre-cooling (n=11)	Per-cooling (n=11)	Combination (n=11)	*p*-Value
Heart rate (bpm)	64 ± 11.0	66 ± 10.2	63 ± 8.4	66 ± 8.9	0.705
Height (cm)	171.6 ± 6.5	171.6 ± 6.5	171.6 ± 6.5	171.6 ± 6.5	0.868
Weight (kg)	68.1 ± 8.4	68.1 ± 8.4	68.1 ± 8.4	68.1 ± 8.4	0.980
BMI (kg/m^2)	23.0 ± 1.8	23.0 ± 1.8	23.0 ± 1.8	23.0 ± 1.8	0.173

Effect of cooling technique on cognitive function

Table 2 shows the difference in mean scores of cognitive performance between groups before and after the high-intensity exercise. Paired sample t-test analysis shows that there was a significant decrease in cognitive performance in the pre-cooling and per cooling group with a p-value of <0.001 (pre-cooling) and 0.014 (per-cooling). Whereas, the cognitive performance in the combination group was maintained (p= 0.641).

Table 2.
The comparison of cognitive performance, before and after intervention

Group	Cognitive performance		Mean Difference	95% CI		T-value	P value
	Pre	Post		Lower	Upper		
Pre-cooling	66.54 (6.23)	65.28 (5.24)	1.28 (2.83)	-0.63	3.18	1.491	<0.001
Per-cooling	66.64 (3.35)	64.36 (4.84)	2.28 (3.41)	-0.02	4.56	2.211	0.014
Combination	67.54 (3.8)	65.73 (4.73)	1.82 (5.58)	-1.93	5.57	1.080	0.641

Note: CI: Confidence interval

Discussion

This study aimed to compare the effects of cooling techniques on cognitive function during high-intensity exercise. The main findings indicate that pre-cooling with an ice vest and per-cooling with an ice slushy intervention were not effective in preventing the reduction of cognitive performance after high-intensity exercise. However, when these techniques are combined, cognitive performance is maintained.

Cognition refers to the processes by which the mind operates, encompassing information processing, decision-making, and problem-solving (Purves, 2008). To achieve success in sports, it is essential for cognitive functions such as perception, attention, and working memory to operate effectively. However, a progressive increase in core body temperature during exercise can diminish cognitive capacity. Cognitive function begins to decline when body temperature reaches 38.5°C (Saldaris et al., 2020; Racinais et al., 2008). The mechanisms underlying the decline in cognitive function due to hyperthermia are not yet fully understood. As core body temperature (Tc) rises during heat exposure and/or exercise, the temperature of the blood flowing to the brain also increases (Nybo et al, 2002). This rise in temperature is associated with reduced cerebral blood flow, which can hinder the delivery of oxygen and glucose to the brain, potentially compromising brain function (Nybo et al, 2002). Additionally, loss of body fluids can exacerbate hyperthermia, leading to brain dysfunction and decreased cognitive performance (Walter and Carraretto, 2016; Masento et al., 2014; Nuccio et al., 2017). Research by Qian et al. (2020) indicates that hyperthermia can inhibit cognitive neural networks in specific brain regions, such as the caudate, putamen, insula, and posterior cingulate, by impairing metabolic processes.

A decline in cognitive function occurs when body temperature reaches 38.5°C (Choo et al., 2018). The findings of this study indicate that combining pre-cooling with an ice vest and per-cooling with an ice slushy intervention can help maintain cognitive function during high-intensity exercise. However, when these interventions were applied individually, the effects were not significant. The pre-cooling technique aims to remove heat from the body immediately prior to exercise. It is a popular strategy used to combat the debilitating effects of heat-stress-induced fatigue and to enhance exercise performance. The use of an ice vest can significantly reduce the thermal stress levels during activities in hot environments. This is because applying an ice vest to the torso can create a cooling sensation in the chest and back (Douzi et al., 2019). This technique is recommended before exercise because, as it can suppress core temperature (Tc), thermal sensation (Ts) and skin temperature (Tsk) (Arngrïmsson et al., 2004; Price et al., 2009; Chaen et al., 2019; Clarke et al, 2011).

The application of pre-cooling or per-cooling alone in our study did not demonstrate an improvement in cognitive function. The findings regarding the per-cooling technique using ice slushy are different from the results of Saldaris et al. (2020) study, which demonstrated that consuming ice slushy during exercise for 30 minutes (at -0.1°C; 7g/kg body weight) can reduce body temperature by -0.8°C. Additionally, a study by Choo et al. (2018) revealed that consuming ice slushy during repeated sprint exercises in hot weather can help maintain cognitive performance, as measured by the S7 and OSPAN tests. Other studies indicated that the use of an ice vest can significantly reduce the level of thermal stress during activities in hot environments (Kenny et al., 2011; Luomala et al., 2012). This is because using an ice vest on the torso of the body can cause a cold feeling in the chest and back (Douzi et al., 2019). This technique is recommended before exercice, because it can suppress core temperature (Tc), thermal sensation (TS) and skin temperature (Tsk) (Arngrïmsson et al., 2004; Price et al., 2009; Chaen et al., 2019; Clarke et al, 2011). Pre-cooling using an ice vest has been shown to reduce skin blood flow during exercise in hot weather (Price and Maley, 2015). Skin temperature is a key factor that influences our perception of temperature in indoor environments, which typically falls within the thermoneutral zone (TNZ) where our body regulates heat (Vellei et al., 2021). In these settings, the body adjusts skin blood flow through processes such as vasoconstriction and vasodilation. Sweating is minimal or may not occur at all, making skin temperature more significant than factors like skin wetness (Vellei et al., 2021). A recent review indicated that the effectiveness of cooling under moderate hyperthermia on cognitive performance yielded mixed results; therefore, further studies should be directed toward exploring which methods are efficient and effective in improving cognitive performance (Donnan et al., 2023).

Despite the findings, this study has some limitations. First, the room temperature of 20 to 26 °C was used in this study; however, the room was not tightly air-sealed. Therefore, the actual temperature may have fluctuated, potentially being lower or higher. Second, the objective of the exercise protocol was to induce exertional hyperthermia; however, a specific target core body temperature was not established. Therefore, it may result in the variability in core body temperature before the cognitive performance test.

Conclusion

The combination of pre-cooling with an ice vest and per-cooling with an ice slushy can help maintain cognitive function after high-intensity exercise. Future research should further investigate the multifactorial relationships between cooling methods and their physiological, performance, and perceptual outcomes, while also considering the timing of cooling application.

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