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Effect of Ice Cooling Jacket on Cardiovascular Responses to Treadmill Exercise in Untrained Adults

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Abstract

Hyperthermia has been shown to be a limiting factor to endurance exercise performance while pre-cooling combats the debilitating effect of heat stress induced fatigue. Most studies demonstrated attenuated heart rate response during endurance exercise after pre-cooling, none of these examined blood pressure changes. Therefore, the objective of this study is to recognize, quantify, and compare changes that may occur in blood pressures and heart rate after pre-cooling (wearing of ice jacket) following treadmill exercise. Twelve (n=12) healthy nonathletic young male adults volunteered after obtaining written consent. Mean ± S.E.M age, weight, height and B.M.I were 22.0±0.8 years, 60±3.0 kg, 1.7±0.2 m, and 21.0±1.0 kg/m^2. Day 1, participants performed treadmill exercise to exhaustion (Bruce protocol). Two readings of blood pressures and heart rates were taken before, at exhaustion and five minutes into recovery. Day 2, participants wore ice jackets for about 30 minutes before the exercise. There was a significant reduction ($p<0.05$) in the heart rate at exhaustion from 101.3 ± 6.5 to 98.1 ± 5.7 and during recovery from 95.3 ± 5.0 to 79.4 ± 3.6 with no significant change in the blood pressures after pre-cooling. Findings are in support of

previous studies and may suggest that wearing of ice-cooling jacket attenuates heart rate with no significant change in the blood pressures following isotonic treadmill exercise in untrained young male adults.

Keywords: Pre-cooling, ice cooling jacket, heart rate, blood pressure, treadmill exercise

Introduction

Hyperthermia which is caused by increased body heat load in excess of heat dissipation has been shown to be a limiting factor to endurance exercise performance (Booth *et al.,* 1997 and Marsh and Sleivert, 1999). Increased body heat may be due to endogenous or exogenous factors. Human endurance to high heat load has been studied both at rest and during exercise with a demonstration of narrow body heat storage directly linked to exercise intensity, body size, and metabolic heat production (Marino, 2002). Hyperthermia during exercise attenuates cardiovascular responses, reduces maximal oxygen uptake ($\dot{V}o_{2\ max}$), and increases relative metabolic strain (Arngrimsson *et al.,* 2004), thus affecting the central nervous system (Nybo *et al.,* 2002). Rowell (1986), a renowned cardiovascular physiologist stated that ‘‘Perhaps the greatest stress ever imposed on the human cardiovascular system (except for severe hemorrhage) is the combination of exercise and hyperthermia” (Gonzalez-Alonso *et al.*, 1999).

Pre-cooling is an approach used to combat the debilitating effect of heat stress induced fatigue. The efficacy of pre-cooling before prolonged submaximal exercise is demonstrated with a variety of pre-cooling modalities amongst which are cold air/cool water immersion (Lee and Haymes, 1995 and Booth *et al.,* 1997), and wearing of ice vest/jacket (Barr *et al.,* 2011). Pre-cooling studies confirm that increase in body heat is one of the limiting factors to exercise (Marino, 2004). Hence, the aim of various modalities of pre-cooling strategy is to lower body temperature before exercise, thereby increasing the margin for metabolic heat production and the time to reach the critical limiting temperature when a given exercise intensity can no longer be maintained (Nielsen *et al.,* 1993). Studies have demonstrated the advantages of pre-cooling over preheating or control under

low ambient conditions (5°C; 40% rh) with a rise in the body heat storage during exercise (Booth *et al.,* 1997 and Lee and Haymes, 1995). The major challenge in evaluating the effectiveness of pre-cooling on exercise performance is the type of exercise protocol used. Thus, various exercise protocols have been explored to determine the effectiveness of pre-cooling on exercise performance.

The heart rate response following exercise after precooling is well established. A reduction in body temperature rise and skin blood flow increases the volume of blood in central circulation thereby increasing stroke volume and reducing heart rate responses (Marino, 2002 and Gonzalez-Alonso *et al.,* 1999). Most studies demonstrated an attenuated heart rate response (Booth *et al.,* 1997 and Lee and Haymes, 1995) under steady conditions during submaximal endurance exercise after pre-cooling (Selkirk *et al.,* 2004 and Cheung and Robinson, 2004) with few demonstrating no significant difference (Duffield *et al.,* 2003). None of these studies revealed blood pressure changes that may occur following exercise after pre-cooling. Therefore, we sought to recognize, quantify, and compare changes that may occur in blood pressure and heart rate responses after wearing ice cooling jackets, following isotonic treadmill exercise in untrained young male human adults. These may have implication in designing an effective approach in combating heat stress and fatigue during exercise thus increasing exercise performance. We hypothesized that pre-cooling would bring about a reduction in heart rate and an increase in blood pressure.

Materials and Methods

Participants

Twelve (n=12) healthy non-athletic young male adults volunteered and were recruited randomly to participate in this study after obtaining written consent. The Mean ± S.E.M age, weight, height and B.M.I were 22.0±0.8 years, 60±3.0 kg, 1.7±0.2 m, and 21.0±1.0 kg/m2 respectively. Participants were undergraduate students of the Faculty of Basic Medical Sciences,

College of Health Sciences, University of Ilorin, Ilorin, Nigeria. They had no apparent physical or neurological deficits that might preclude exercise performance on a treadmill. Participants were non-smokers and had no history of cardiovascular and respiratory disorders. They were informed to abstain from caffeine, caffeine containing products or alcohol 48 hours prior to the study. The procedures of this study agree with the ethical guidelines of the local ethics committee of University of Ilorin. Written and verbal consents were taken from all the participants in the Physiology Laboratory of the College of Health Sciences, University of Ilorin.

Equipment

Heart rate monitor (Puma, U.S.A) which is made up of a polar watch worn on the wrist and a chest belt attached to the chest at the Xiphisternum was used to record the heart rates. Automated blood pressure monitor (KD-595, Japan) was used to measure the blood pressures. Cooling was achieved with an ice cooling jacket (FLEXI ICE JACKET, China). The cooling jacket was constructed from neoprene and shaped in the form of a vest, with an elastic button on the front, allowing easy application and removal. Multiple pockets allowed the placement and removal of cold substances (ice/ice packs) to cool the trunk region. The cooling jacket was worn over the exercise attire (light jersey white material). The icepacks were within the jacket and needed to be frozen before use with 12 pockets of icepacks (400-500 ml): 3 on the chest, 3 over the shoulder blades, 3 on the upper abdomen, and 3 on the lower back. The jacket was worn for about 40 minutes and then removed before the exercise. The treadmill machine (AFG3.1AT, China) was used as a form of isotonic endurance exercise. In addition, Stadiometer was used for height measurement, weighing balance (SECA, North America) for weight measurement, dry bulb thermometer (LIEBA, Mumbai) for axillary temperature measurement, and stop clock for timing the experiment.

Protocol

Before the experimental days (two-time visit), participants were taken to the experimental room (Physiology Laboratory of the College of Health Sciences, University of Ilorin), protocol was explained and they were

allowed to familiarise themselves with the procedures and the use of the equipment (treadmill). They were told to abstain from food 2 hours before the experiment, to avoid caffeine or caffeine containing products, and alcohol 48 hours before the experiment. We pleaded with the participants not to participate in any competitive sports or strenuous exercise other than normal daily activities during the experimental period. All participants filled the pre-test health questionnaire (to record personal health details and behaviours) and the Physical Activity Readiness Questionnaire (PARQ) to exclude respiratory or cardiovascular disorders. They were told to read the information sheet which is an outline of the experimental procedures, equipment to be used, and complications that may arise from the procedure. Subjects were prepared in an aerated/well ventilated room of 20-25 ºC dry bulb temperature. The experiments were conducted before noon.

On the first day of the experiment, the room was prepared (quiet, neat, and temperature controlled), equipment were checked, assembled, and calibrated appropriately. Start time of the experiment and room temperature were noted. The weights of the participants with light clothes on were taken while their heights, without shoes on, were measured. Participants were seated for 20 minutes during which two- readings of blood pressures and heart rates were taken. The average was calculated and taken as the control. Afterwards, the participants performed treadmill exercise to exhaustion using the Bruce Protocol. The two readings of blood pressures and heart rates were taken at exhaustion/peak of exercise and five minutes after the exercise (recovery period).

On the second day of the experiment, the refrigerated frozen ice packs were placed in the jacket and worn by the participants for about 30 minutes[5] in sitting position, and then the jackets were taken-off. Subsequently, subjects mounted the treadmill to repeat the exercise to exhaustion. The two readings of blood pressures and heart rates were taken before the start of the treadmill exercise, at exhaustion/peak of the exercise and during recovery period (five minutes). Thereafter, the pulse pressure (PP) and the mean arterial blood

pressure (MABP) were figured out from the systolic blood pressure (SBP) and diastolic blood pressure (DBP) respectively.

Statistical Analysis

The data obtained was analysed using Graph Pad Prizm 5 software. Using the descriptive statistics, unpaired t- test was used to compare the SBP and H.R responses to exercise between the two groups (with/ without pre-cooling jacket). Significance was set at 95% confidence interval ($p< 0.05$).

Results

Baseline anthropometric data

The mean values of the physical characteristics of the participants are presented in Table 1. The mean height, weight, and body mass index falls within the normal range for age and sex of the participants.

Cardiovascular responses to treadmill exercise without the use of ice jacket

Table 2 shows the cardiovascular changes that occurred at rest, at the peak of treadmill exercise and during recovery without the use of ice jacket. There was a significant increase ($p<0.05$) in SBP from the control of 111.6 ± 2.8 mmHg to 145.7 ± 1.1 mmHg and 115.5 ± 2.2 mmHg at the peak of exercise and during recovery respectively. The DBP increased significantly ($p<0.05$) from control of 72.6 ± 2.4 mmHg to 77.4 ± 1.8 mmHg at the peak of exercise and reduced significantly ($p<0.05$) to 67.5 ± 2.5 mmHg during recovery. The PP increased significantly ($p<0.05$) from control of 43.3 ± 4.5 mmHg to 59.1 ± 3.6 mmHg and 48.0 ± 3.3 mmHg at the peak of exercise and during recovery. The MABP increased significantly ($p<0.05$) from control of 85.6 ± 2.4 mmHg to 98.0± 2.2 mmHg at the peak of exercise and reduced significantly ($p<0.05$) to 83.5 ± 1.8 mmHg during recovery. The HR increased significantly ($p<0.05$) from control of 82.4 ± 3.3 mmHg to 101.3 ± 6.5 mmHg at the peak of exercise and to 95.3 ± 5.0 mmHg during recovery.

Cardiovascular responses to treadmill exercise after wearing ice jacket

Table 3 shows the cardiovascular responses to treadmill exercise after the putting on of the ice jackets. There was a significant increase ($p<0.05$) in SBP from control of 118.7 ± 3.4 mmHg to 128.3 ± 3.1 mmHg and 114.1 ±2.1 mmHg at the peak of exercise and during recovery. The DBP increased insignificantly from control of 73.1 ±2.5 mmHg to 78.2 ± 2.4 mmHg at the peak of exercise and later reduced to 72.6 ± 2.5 mmHg during recovery. The PP increased insignificantly from control of 45.7 ± 3.0 mmHg to 50.2 ± 3.9 mmHg at the peak of exercise and reduced insignificantly to 41.6 ± 1.8 mmHg during recovery. The MABP increased significantly ($p<0.05$) from control of 88.3 ± 2.5 mmHg to 94.8 ± 1.9 ($p=0.046$) and 86.3 ± 2.2 mmHg at the peak of exercise and during recovery. The HR increased insignificantly from control of 89.8 ± 6.0 mmHg to 98.1 ± 5.7 mmHg at the peak of exercise and reduced significantly ($p<0.05$) to 79.4 ± 3.6 mmHg during recovery.

Cardiovascular responses to treadmill exercise without ice jacket (*NP)* vs after wearing ice jacket *(P)*

Figures 1-5 compare the cardiovascular responses (to treadmill exercise) that may occur without, and after, the wearing of the ice jackets. There was no significant difference in SBP in control (, peak of exercise, and recovery of ***NP*** and ***P*** (Fig.1). The DBP shows no significant difference in the exercise conditions (Fig.2). The PP of the ***P*** increased insignificantly ($p<0.05$) in the control and decreased insignificantly at the peak and recovery when compared to the ***NP*** (Fig.3). There was an insignificant difference in the MABP of the control, peak of exercise, and recovery of ***P*** and ***NP*** (Fig.4). The heart rate response shows no significant difference in the control with a significant reduction ($p<0.05$) at the peak and recovery in the ***P*** when compared to ***NP***. (Fig.5).

Discussion

The main objective of this study was to examine the possible influence of wearing ice cooling jackets on blood pressure and heart rate responses before, during, and after a treadmill exercise in healthy young untrained male adults. The effect of ice cooling jacket on heart rate is controversial, and this effect has not been previously investigated on blood pressure. The objective of this study was to recognize, quantify, and compare changes that may occur in blood pressures and heart rates after pre-cooling (wearing of ice jacket) following a treadmill exercise. The results of this study indicate a significant reduction in the heart rate ($p<0.05$) from 101.3 ± 6.5 to 98.1 ± 5.7 (bpm) at the peak of exercise, and during recovery ($p<0.05$) from 95.3 ± 5.0 to 79.4 ± 3.6 (bpm) with no significant changes in the blood pressures before exercise, at the peak of exercise, and during recovery between pre-cooling and non pre-cooling. Therefore, our findings suggest that blood pressure (not heart rate) is unaffected following isotonic treadmill exercise and after wearing ice cooling jackets in healthy untrained young male adults. Thus, findings in this study are in support of previous studies (Marino, 2002; Booth *et al.,* 1997; Lee and Haymes, 1995; and Walters *et al.,* 2000).

Prolonged exercise requires sympathetically-mediated increase and redistribution of cardiac output to meet up with the increased demand for skin perfusion and the active muscle. Earlier studies comparing exercise in hyperthermic (36–44°C) against normothermic environments (25-26ºC) and exercise with hyperthermic against hypothermic environments demonstrated cardiac output to be increased (Nielsen *et al.,* 1993; Gonzalez-Alonso *et al.,* 1999), unchanged (Rowell, 1986), or reduced (Rowell, 1986). Cardiac output is an expression of the product of heart rate and stroke volume. The decrease in cardiac output during exercise in a hyperthermic condition has been attributed to a larger decline in stroke volume with the mechanism not being directly elucidated. The assumption is that increased skin blood flow increases heart rate and reduces stroke volume (SV) by reducing ventricular filling as a result of displacement of blood from the central circulation to

peripheral skin veins as core temperature increases (Gonzalez-Alonso, 1999) which is reversed on cooling of the whole body. In contrast, studies by Duffield *et al.* (2003) showed no significant difference in heart rates between cooling and non-cooling prior and after prolonged repeated sprint exercises with the average heart rate ranging from 145 to 157 beats / min. In the study of Duffield *et al.* (2003), the influence of cooling was investigated before, during, and after intermittent repeated sprint exercise bouts. In this study, exercise was acute and continuous - with the effect of cooling examined before, at the peak of, and after (5 minutes) of a treadmill exercise.

Lower physiological and metabolic strain experienced during endurance exercise after pre-cooling has been shown to cause a significant improvement in exercise performance (Lee and Haymes, 1995; Booth *et al.*, 1997; Gonzalez-Alonso *et al.*, 1999). The extent of the improvement may depend on several factors, amongst which are the type and extent of body cooling method; model, duration, and intensity of exercise; mode and intensity of the environment, and training status of the individual. For example, studies by Booth *et al.*(1997) reported an increase in work output by 4%, Hessemer *et al.*(1984) by 7%; Lee and Haymes (1995) recorded an increase in the time of exhaustion by 21%, and Olschewski and Bruck (1988) by 12% in athletes exercising in compensable heat stress and by 37% in uncompensable heat stress conditions (Gonzalez-Alonso *et al.*, 1999). Five minutes cooling of the body with ice-packs after a warm-up exercise caused reductions in the average HR during a 6 minute rowing trial associated with a significant improvement of 1% in the distance rowed (Myler *et al.*, 1989). However, studies of Duffield *et al.* (2003) found no performance benefit for a simulated partial triathlon, even though their participants swam for the initial 15min of exercise after pre-cooling.

The drawback of using the ice cooling jacket as a means of pre-cooling is that it is to some extent heavy (~4.5 kg with the ice packs) and may interfere with running or stretching and thereby increase the energy dissipated in running. We counteracted this effect by wearing the cooling

jacket for 30 minutes before the start of the exercise (Duffield *et al.,* 2003). Six of the participants when asked responded that they liked the jacket on and perceived they sweated less. Two reported the jacket made them feel better overall. Three complained of cold and skin irritation. Most of the participants performed better after wearing the ice cooling jacket. This is in support of previous studies (Walters *et al.,* 2000; Nybo *et al.,* 2002; Marsh and Sleivert, 1999; Gonzalez-Alonso *et al.,* 1999; Booth *et al.,* 1997; and Arngrimsson *et al.,* 2004) who proposed the use of ice cooling jacket or other pre-cooling modalities as a measure of improving exercise performance. Even though the mechanism by which pre-cooling improves exercise performance in comfortable and hot ambient conditions is not known, it is considered that reduction in body heat content before exercise, lowers the cardiovascular strain, and more work can be performed before a critical level of hyperthermia associated with fatigue, is reached (Marino, 2002). Significant studies on the human subject (Nielson *et al.,* 1993; and Gonzalez-Alonso *et al.,* 1999) and animals (Fuller *et al.,* 1998 and Kruk *et al.,* 1985) indicate that there is a critical temperature of ∼40°C that usually results in fatigue.

The uniqueness of this study is that no previous study examined the influence of pre-cooling modalities on blood pressures and on heart rates in untrained participants. Most studies explored pre-cooling effect on exercise performance in trained sportsmen. On searching the literature, none of these studies investigated and/or compared the usefulness of a treadmill exercise as a model of submaximal aerobic form of endurance exercise. However, in the course of this study and in interpreting the data, certain limitations may have to be well thought-of. Our findings may not be generalized to individuals with cardiovascular disorders and future findings from a similar study in older people may be dissimilar. Gender disparity and diurnal variation should also be considered. Considering these limitations, more studies of this kind are recommended in hypertensive people or individuals with cardiovascular diseases, healthy females and older people. Furthermore, more studies with the large sample size of this kind are necessary to validate the findings of this study.

In conclusion, exercising in the heat causes alterations in cardiovascular, metabolic, neuromuscular, and thermoregulatory functions. Strategies such as pre-exercise cooling amongst which include the use of ice cooling jacket has been shown to cause attenuated physiological and psychophysical strain during exercise. Pre-cooling lessens the thermal, cardiovascular, and metabolic strain experienced during an endurance exercise in hot and temperate environments. Therefore, findings of this study may suggest the usefulness of wearing an ice-cooling jacket to reduce heart rate without any change in the blood pressure during a treadmill exercise.

Tables and Figures:

Table.1. Baseline anthropometric data of subjects

Physical characteristics (n=12)	Values
Age (yrs)	**22.0 ± 0.8**
Weight (kg)	**60.0 ± 3.0**
Height (m)	**1.7 ± 0.2**
Body mass index (kg/m2)	**21.0 ± 1.0**

Values expressed as Mean ± SEM

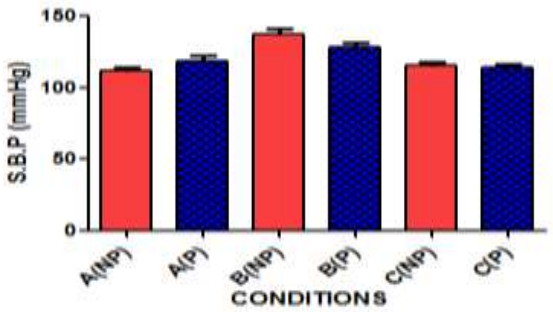
Table.2. Subject's cardiovascular responses at different conditions before wearing ice jacket

	A	B	C
S.B.P (mmHg)	**111.6 ± 2.8**	**145.7 ± 1.1*****	**115.5 ± 2.2*****
D.B.P (mmHg)	**72.6 ± 2.4**	**77.4 ± 1.8***	**67.5 ± 2.5****
P.P (mmHg)	**43.3 ± 4.5**	**59.1 ± 3.6***	**48.0 ± 3.3***
M.A.B.P (mmHg)	**85.6 ± 2.4**	**98.0± 2.2*****	**83.5 ± 1.8*****
Heart rate (bpm)	**82.4 ± 3.3**	**101.3 ± 6.5*****	**95.3 ± 5.0****

Table.3. Subject's cardiovascular responses at different conditions after wearing ice jacket.

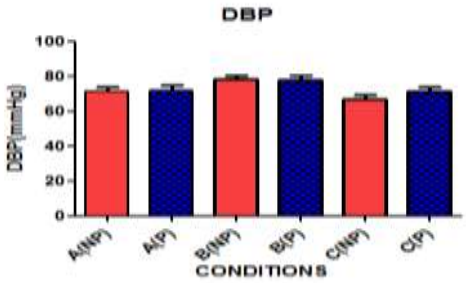
	A	B	C
S.B.P (mmHg)	**118.7 ± 3.4**	**128.3 ± 3.1***	**114.1 ±2.1*****
D.B.P (mmHg)	**73.1 ±2.5**	**78.2 ± 2.4**	**72.6 ± 2.5**
P.P (mmHg)	**45.7 ± 3.0**	**50.2 ± 3.9**	**41.6 ± 1.8**
M.A.B.P (mmHg)	**88.3 ± 2.5**	**94.8 ± 1.9***	**86.3 ± 2.2****
Heart rate (bpm)	**89.8 ± 6.0**	**98.1 ± 5.7**	**79.4 ± 3.6 ***

A= Before exercise/control, B= Peak of exercise, C= Recovery (5 minutes); Values expressed as Mean ± SEM; n=12, *p<0.05, ** p<0.01, *** p<0.001



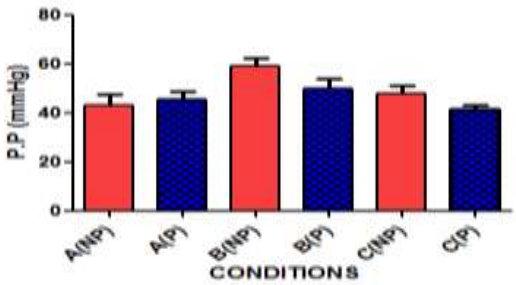
A= Before exercise, B= Peak of exercise, C= Recovery (5 minutes), NP= No pre-cooling, P= Pre-cooling; Values expressed as Mean ± SEM; n=12

Fig.1. Changes in Systolic Blood Pressure (SBP) without, and after wearing, ice jacket at different conditions



A= Before exercise, B= Peak of exercise, C= Recovery (5 minutes), NP= No pre-cooling, P= Pre-cooling.); Values expressed as Mean ± SEM; n=12

Fig.2. Changes in Diastolic Blood Pressure without, and after wearing, ice jacket at different conditions



A= Before exercise, B= Peak of exercise, C= Recovery (5 minutes), NP= No pre-cooling, P= Pre-cooling.); Values expressed as Mean ± SEM; n=12

Fig.3. Changes in Pulse Pressure (PP) without, and after wearing, ice jacket at different conditions

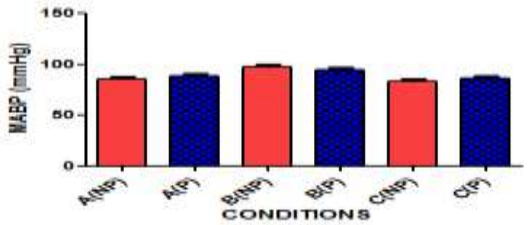
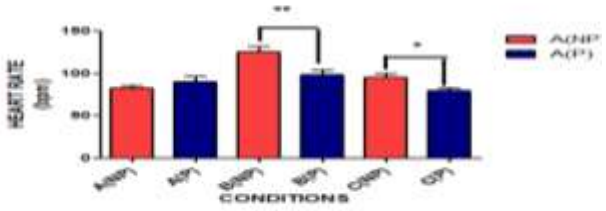


Fig.4. Changes in Mean Arterial Blood Pressure (MABP) without, and after, wearing, ice jacket at different conditions



A= Before exercise, B= Peak of exercise, C= Recovery (5 minutes), NP= No pre-cooling, P= Pre-cooling.); Values expressed as Mean ± SEM; n=12; * $p<0.05$, ** $p<0.01$

Fig.5 Changes in the eart rate without, and after wearing, ice jacket at different conditions; Values expressed as Mean ± SEM; n=12

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