THE EFFECTS OF SPORT DRINK ICE SLURRY INGESTION DURING RECOVERY ON CYCLING PERFORMANCE & THERMOREGULATORY RESPONSES IN WARM-HUMID ENVIRONMENT AMONG KELANTAN STATE JUNIOR CYCLISTS

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Dissertation submitted in partial fulfillment of the requirements for the Degree of Bachelor of Health Science (Honours) (Exercise and Sports Science)

2020

CERTIFICATE

This is to certify that the dissertation entitled

THE EFFECTS OF SPORT DRINK ICE SLURRY INGESTION DURING RECOVERY ON CYCLING PERFORMANCE & THERMOREGULATORY RESPONSES IN WARM-HUMID ENVIRONMENT AMONG KELANTAN STATE JUNIOR CYCLISTS

Is the bona fide record of research work done by:

ZULKARNAIN RAZLAN

During the period from September 2019 to June 2020 under my supervision.

I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Health Science (Honours) (Exercise and Sports Science).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigation, except otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysisa the right to use the dissertation for teaching, research and promotional purposes.

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KESAN PENGAMBILAN BUBURAN AIS MINUMAN SUKAN SEMASA TEMPOH PEMULIHAN TERHADAP PRESTASI BERBASIKAL DAN TINDAK BALAS TERMOREGULASI DI PERSEKITARAN HANGAT-LEMBAP DALAM KALANGAN PELUMBA BASIKAL MUDA NEGERI KELANTAN

ABSTRAK

Tujuan: Kajian ini adalah untuk menyiasat kesan pengambilan buburan ais minuman sukan semasa pemulihan terhadap prestasi berbasikal dan respon thermoregulasi dalam persekitaran yang hangat dan lembap. **Kaedah:** Reka bentuk kajian rawak bersilang dengan dua lawatan kajian yang berasingan, 7 orang pelumba negeri Kelantan mengambil sebanyak 1.25 g/kg berat badan buburan ais minuman sukan (0.4°C) dan air biasa (27°C) semasa tempoh 30 minit pemulihan selepas kayuhan berintensiti tetap dan ujian masa (Senaman 1) sebelum menjalankan senaman seterusnya (Senaman 2) dalam persekitaran makmal hangat dan lembab (30.86 ± 0.14°C, 69.32 ± 0.72% RH dan 31.01 ± 0.21°C, 67.83 ± 1.29% RH). Kerja yang dilakukan, suhu rektum dan kulit, kadar denyutan jantung, tanggapan upaya penggunaan tenaga fizikal (RPE), sensasi termal dan ketidakselesaan haba diukur. **Keputusan:** Purata kerja yang diselesaikan dalam ujian masa 15 minit untuk buburan ais (146.9 ± 22.2 kJ) adalah lebih tinggi daripada kawalan (134.7 ± 28.6 kJ), namun perbezaannya tidak signifikan. Kadar denyutan jantung meningkat dengan buburan ais semasa Senaman 2 tetapi tidak terdapat perbezaan yang signifikan antara percubaan, p = 0.572. Tiada perbezaan suhu teras semasa kedua-dua latihan dijalankan di antara ujian, p = 0.512. Walau bagaimanapun, terdapat pengurangan suhu teras dalam buburan ais dalam Senaman 2. Semasa senaman, terdapat perbezaan yang signifikan dalam suhu kulit antara buburan ais dan kawalan, p = 0.02. Pengambilan buburan ais semasa pemulihan tidak secara nyata mengubah RPE (p = 0.543), ketidakselesaan haba (p = 0.972) dan sensasi haba (p = 0.732). **Kesimpulan:** Pengambilan buburan ais minuman sukan meningkatkan prestasi dalam senaman berikutnya berbanding dengan air biasa. Selain itu, buburan ais juga mengurangkan suhu kulit semasa senaman seterusnya dalam persekitaran yang panas dan lembap. Walau bagaimanapun, pengambilan buburan ais semasa pemulihan, tidak

merubah tindak balas terhadap suhu teras, kadar denyutan jantung dan RPE, ketidakselesaan haba dan sensasi haba semasa senaman berikutnya.

THE EFFECTS OF SPORT DRINK ICE SLURRY INGESTION DURING RECOVERY ON CYCLING PERFORMANCE AND THERMOREGULATORY RESPONSES IN WARM-HUMID ENVIRONMENT AMONG KELANTAN STATE JUNIOR CYCLISTS

ABSTRACT

Purpose: This study was to investigate the effect of sport drink ice slurry ingestion during recovery on cycling performance and thermoregulatory responses in a warm and humid environment. **Methods:** A randomised crossover study design with two separated visit of trials, 7 male Kelantan state cyclist ingested 1.25 g/kg body weight of sport drink ice slurry (0.4°C) and plain water (27°C) during 30-min recovery period after fixed-intensity cycling and time trial exercise bouts (Exercise 1) but before exercising the next subsequent exercise bouts (Exercise 2) in the warm and humid laboratory setting (30.86 ± 0.14°C, 69.32 ± 0.72% RH and 31.01 ± 0.21°C, 67.83 ± 1.29% RH). The average of work performed, rectal and skin temperature, heart rate (HR), rating of perceived exertion (RPE), thermal sensation and thermal discomfort ratings were measured. **Results:** The average work completed in the 15-min time trial for ice slurry (146.9 ± 22.2 kJ) was higher than control (134.7 ± 28.6 kJ) but it was not significantly different. The heart rate response in Exercise 2 ice slurry was elevated but there was no significant difference between trials, $p = 0.572$. There was no significant mean difference of core temperature during both exercise bouts between trials, $p = 0.512$. However, there was a reduction in core temperature with ice slurry in Exercise 2. During exercise, there was a significant difference in mean skin temperature between ice slurry and control trials, $p = 0.02$. Ice slurry ingestion during recovery did not significantly change RPE ($p = 0.543$), thermal discomfort ($p = 0.972$) and thermal sensation ($p = 0.732$). **Conclusion:** Ingestion of sport drink ice slurry improved cycling performance in subsequent exercise compared to plain water ingestion. In addition, ice slurry also attenuated the skin temperatures on the subsequent exercise in the warm and humid environment. However, ice

slurry ingestion during recovery did not affect core temperature, heart rate, RPE, thermal discomfort and thermal sensation in subsequent exercise.

CHAPTER 1: INTRODUCTION

1.0 BACKGROUND OF STUDY

Many sporting events take place during the hottest season, in warm to hot climates or at the hottest part of a day. During exercise in the heat, there are potentially several physiological and metabolic alteration contributing to fatigue. These include alteration in energy metabolism, cardiovascular function, fluid balance, central nervous system function and motor drive. However, a common element in fatigue during exercise in the heat appears to be a critically high core temperature (Hargreaves, 2008). In addition, when exercising in the heat, the rate of rising core temperature and heat storage were faster in higher humidity (Maughan, Otani, & Watson, 2012). The combination of heat and humidity in prolonged exercise can cause dehydration and hyperthermia, a condition of elevated body temperature due to failed thermoregulation when the body absorbs more heat than it dissipates.

The failure of the body to regulate rising temperature can also result in heat stress that can progress to life-threatening heat illness such as heatstroke. The recent 2016 El-Nino phenomenon in Malaysia has claimed two deaths as a result of heat stroke (Bernama, 2016). The El-Nino phenomenon reduce the rainfall during the dry season and can exacerbate the Malaysian climate (Suparta & Yatim, 2017). During the phenomenon, it was reported that there were 200 recorded cases of heat-related illnesses, of which 52 heat cramps, 126 heat exhaustion and 22 heatstroke (Bernama, 2016)

A cooling strategy to delay heat stress and fatigue in the prolonged exercise can be introduced to minimise the risk of heat-related illness and to optimise performance. There are various cooling methods, which can be applied either externally by direct application to the body or internally through ingestion as pre-cooling, per-cooling and/or post-cooling. Furthermore, many competitive situations are such that only a few hours separate the next bout of competitive effort. Hence, it is important that the cooling strategies are applied when exercising in the heat condition. Therefore, a novel aspect of this study is to introduce a practical cooling method to local (Malaysian) athletes as a strategy to attenuate high core temperature during training or competition in the hot and humid climatic conditions of Malaysia.

1.1 PROBLEM STATEMENT & STUDY RATIONALE

The environmental conditions in Malaysia are hot-humid with annual temperatures of 27-35°C and 70%-90% relative humidity (Che Jusoh, Stannard, & Mündel, 2016). Exercising in this heat stress condition could impair the athlete's performance and exposing them to the risk of heat-related illness such as hyperthermia. Tropical dwelling athletes are seemingly more robust as they are naturally acclimatised to the hot and humid conditions. However, the heat wave has caused heat illness that resulted in deaths were reported in Malaysian undergoing physical training (Bernama, 2016). There is still a lack of guidelines for optimum cooling and rehydration strategies for Malaysian exposed to this condition. The cooling strategy, specifically ice slurry ingestion is the most practical and less costly way that can be applied during exercise in thermally stressful condition. Information in this study will provide knowledge on the efficacy of ice slurry ingestion consumption during training or competition in the climatic conditions of Malaysia. The aim of this study is to examine the effect of sport drink ice slurry ingestion during recovery on endurance cycling performance and thermoregulatory responses in the warm-humid environment.

1.2 OBJECTIVE OF RESEARCH

1.2.1 General Objective

1. To investigate the effect of sport drink ice slurry ingestion during recovery on cycling performance and thermoregulatory responses in a warm and humid environment.

1.2.2 Specific Objectives

1. To compare cyclist's core temperature during subsequent cycling between sport drink ice slurry ingestion and control trial in a warm and humid environment.

2. To compare cyclist’s skin temperature during subsequent cycling between sport drink ice slurry ingestion and control trials in a warm and humid environment.
3. To identify the heart rate during cycling in the warm and humid environment.
4. To identify the rating of perceived exertion (RPE) and level of thermal comfort during cycling in the warm and humid environment.
5. To compare cyclist’s time-trial performance between sport drink ice slurry ingestion and control trials in a warm and humid environment.

1.3 RESEARCH QUESTIONS

1. Does sport drink ice slurry ingestion during recovery improve subsequent cycling performance in the warm-humid environment?
2. Does sport drink ice slurry ingestion during recovery reduce core and skin temperatures, heart rate, rating perceived exertion (RPE), level of thermal comfort and sensation scale during subsequent cycling in the warm-humid environment?

1.4 HYPOTHESES

H_{O1} = There is no significant difference in core temperature between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{A1} = There is a significant difference in core temperature between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O2} = There is no significant difference in skin temperature between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{A2} = There is a significant difference in skin temperature between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O3} = There is no significant difference in heart rate between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{A3} = There is a significant difference in heart rate between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O4} = There is no significant difference in RPE between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{A4} = There is a significant difference in RPE between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O5} = There is no significant difference in thermal comfort scale between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{A5} = There is a significant difference in thermal comfort and sensation scale between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O6} = There is no significant difference in thermal sensation scale between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O6} = There is a significant difference in thermal sensation scale between sport drink ice slurry ingestion and control trials in the warm-humid environment.

H_{O7} = There is no significant difference in time-trial performance between ice sport drink slurry ingestion and control trials in the warm-humid environment.

H_{A7} = There is a significant difference in time-trial performance between sport drink ice slurry ingestion and control trials in the warm-humid environment.

1.5 SIGNIFICANCE OF STUDY

There are many types of cooling strategies such as applying ice-cold towel on the head and neck, spraying cold-water to the face, wearing ice-cooling garments, immersing in cold water or cryotherapy and ingesting ice slurry. However, some of the strategies may not be practically applied during exercise or sports performance and some may be too expensive to be used. There are many previous studies that investigate the effectiveness of cooling strategies including all the possible strategies, but the application was only restricted to the laboratory setting. Thus, the use of ice slurry ingestion in this study offers a more practical, inexpensive and affordable method for the athletes in any sports institution to apply. In addition, the information from this study will give an appropriate guideline for athletes to sustain longer during exercise in the Malaysian climate.

CHAPTER 2: LITERATURE REVIEW

2.0 EXERCISE IN THE WARM AND HUMID ENVIRONMENT

Exercise in the warm challenges the body's ability to control its internal environment due to the high rates of metabolic heat production and heat gain by physical transfer from the environment. The rate of sweat secretion onto the skin is increased in an attempt to restrict the rise of core temperature. This may limit the rise of core temperature, but if the exercise is continued further, it will cause a loss of body water and electrolyte (Maughan & Shirreffs, 2004). Even at modest environmental temperatures, some reduction in exercise capacity is apparent, and the performance decrease becomes progressively greater as the environmental heat stress increases (Galloway & Maughan, 1997).

When exercising in the heat, the blood will flow to the muscle to meet energetic demand of muscular activity, and to the skin to meet the demand of temperature regulation. When blood flow is reduced to the muscle, it can limit the intensity and the duration of the exercise, and if the blood to the skin is reduced it will limit the disposal of heat which may cause the harmful effect of elevated internal temperature including that of the central nervous system (CNS). Exercise in the warm or heat cause the skin and muscle to compete for blood flow in addition to cutaneous vasoconstriction which compromises temperature regulation. The thermoregulatory demand cannot be met through cardiac output and blood flow redistribution to the active muscles causing increases in the circulatory strain. Hence, hyperthermia can significantly affect active muscle blood flow and performance negatively in a way which dehydration develops when prolonged exercise in a hot environment without fluid replenishment (González-Alonso, Crandall, & Johnson, 2008).

Humidity is also the related factor that causes a decrease in exercise performance as when the humidity of the environment is high, the rate at which sweat evaporates from the skin is lower compared to dry condition. This is likely to result in a marked rise in core temperature despite ongoing sweat losses (R. J. Maughan et al., 2012). A study demonstrated that as the environmental humidity rises, the exercise capacity in the warm/heat progressively reduced. Early fatigue in the higher humidity trials was accompanied by a faster rate of rising core temperature and a greater weighted mean skin temperature, with no differences in heart rate, skin blood flow or metabolic response to exercise (Ely, Cheuvront, Kenefick, & Sawka, 2010; R. J. Maughan et al., 2012). It has been reviewed that prolonged submaximal cycling performance is greatly decreased by dehydration and hyperthermia in the laboratory setting of 35°C, 70% RH (Hue, 2011).

2.1 COOLING STRATEGIES DURING EXERCISE IN WARM AND HUMID ENVIRONMENT

Individuals performing any physical activities in the tropical climate (a temperature of 32-35°C and humidity of 77-88%) are exposed to significantly higher heat stress due to physically demanding task, and/or non-porous personal protective equipment and clothing. Cooling interventions seek to increase body heat dissipation through evaporation, conduction, and convection and consequently prevent excess heat storage and the impairment of work performance (Yi, Zhao, Chan, & Lam, 2017). Cooling interventions could increase heat storage capacity (pre-cooling), attenuate the exercise-induced increase in human core body temperature (per-cooling) and accelerate recovery following intense exercise (post-cooling) (Bongers, Hopman, & Eijsvogels, 2017).

There are even intervention strategies for exercise in the heat to reduce the risk of hyperthermia and dehydration including whole-body precooling by increasing the margin for metabolic heat production and increasing the time to reach the critical limiting temperature (Wendt, Van Loon, & Lichtenbelt, 2007). Nowadays, there are many cooling strategies such as cooling vest, ice vest, cold water ingestion, ice slurry ingestion, menthol cooling, facial wind/water spray, cooling packs, cold water immersion and cryotherapy. Recently, there are modern cooling interventions available to prevent hyperthermia such as the hybrid personal cooling system (PCS) which is a jacket and a trouser that equipped with ventilation fans and phase change materials (PCMs) with frozen gels and ice packs to absorb body heat during melting (Song & Wang, 2016). However, some of them are less practical in the field of sports

(Bongers et al., 2017; Jay & Morris, 2018). The use of mid-cooling strategies can minimise the effect of heat stress on endurance exercise capacity and performance. It has been demonstrated by a range of effective and practical mid-cooling strategy on endurance sports but only a few comparisons exist between the timing and type of intervention (Christopher J Stevens, Taylor, & Dascombe, 2017).

2.2 ICE SLURRY INGESTION STRATEGY

Ice slurry ingestion introduces a new way of heat transfer (internal heat transfer) for an athlete exercising in the heat in addition to the four avenues of heat transfer at the skin surface (evaporation, convection, radiation and conduction) (Lee & Shirreffs, 2007; Morris, Coombs, & Jay, 2016; Siegel et al., 2010). Body heat storage with cold fluid ingestion is therefore determined by the cumulative difference between metabolic heat production and the combined heat loss from the skin surface and any internal heat transfer with an ingested fluid. If net heat dissipation from the skin remains unaltered with cold fluid ingestion, body heat storage will be lower and the athlete will likely be at the lower risk of heat-related illness (Jay & Morris, 2018).

A study by Byrne et al. (2011) demonstrated that pre-exercise ingestion of cold fluid is a simple, effective precooling method suitable for field-based application. They found that during rest, greater decrease in rectal temperature was observed with ingestion of cold fluid (2°C) than the control fluid (37°C) over 35 to 5 minutes before exercise. Distanced cycled was greater after ingestion of the cold fluid than after ingestion of control fluid but no difference were observed for pacing, mean skin temperature, heart rate, blood lactate, thermal comfort, perceived exertion and sweat loss (Byrne, Owen, Cosnefroy, & Lee, 2011). Meanwhile for cold fluid ingestion during exercise, a drink at 4°C during exercise in the heat enhances fluid consumption and improves endurance by acting as a heat sink, attenuating the rise of body temperature and therefore reducing the effects of heat stress (Mündel, King, Collacott, & Jones, 2006). As the ingestion of cold fluid post-exercise, this study compared an ice-slush beverage (ISB) at -0.8 ± 0.1 °C and cool liquid beverage (CLB) at 18.4 ± 0.5 °C on cycling performance, rectal temperature and stress response in hot and humid conditions (33.7 ± 0.8 °C, 60.3 ± 2.0% RH). The subjects consumed either ISB or CLB during recovery phase before performance trial. They found out that performance time was not significantly different after consuming ISB compared with CLB. The rectal temperature and physiological strain index were lower at the end of recovery and before performance trial after ingestion of ISB compared with CLB. Thus ingestion of ISB during recovery from exercise in hot and humid environment is practical and effective method for cooling athletes following exercise (Stanley, Leveritt, & Peake, 2010).

A recent study by Mejuto et al., (2018) demonstrated a significant decrease of rectal temperature in the combined cooling strategies of ice slurry ingestion and iced towel during pre-exercise then ingesting ice-slurry during steady-state cycling. In this study, seven well trained and unacclimated, male road cyclist warmed-up for 15 min and given the ice slurry (-1°C) as the pre-cooling intervention. Before cycling at steady state for 45 min at 70% of VO_2 max in 32°C, 50% RH climatic conditions, with ice slurry administered every 15 min as mid-cooling intervention. They conclude that the combined pre-cooling and mid-cooling did not enhance cycling performance, but it did reduce the core temperature compared to the exercise without pre- and mid-cooling intervention. Therefore, ice slurry ingestion could be a practical and effective way of reducing body temperature before and during the exercise (Mejuto, Chalmers, Gilbert, & Bentley, 2018).

2.3 BODY CORE TEMPERATURE

Exercise in heat can cause a lot of climatic injuries for example hyperthermia, hypothermia and heat stroke. By monitoring the body core temperature during exercise can give a huge impact on the performance and mainly the safety of the individual from the heat-related injury. There are a few clinically acceptable methods to measure the body core temperature which are through oral, rectal and oesophageal. To measure oral temperature, the thermometer was commonly used. According to Moran and Mendel (2002), rectal and oesophageal has been the most preferred measurement site that involved in the thermoregulatory experiment. However, the authors mentioned that oral temperature measurement is not accurate whereas oesophageal temperature measurement is difficult in inserting the thermistor which can cause irritation to nasal passages and discomfort. Rectal temperature is the most practical and accurate site for measuring the core temperature as being the most common site used in scientific exercise research. Rectal temperature is used for diagnosing heat exhaustion or stroke cases, especially in babies and small children (Moran & Mendal, 2002).

A validity study by Miller et al., (2017) showed the most valid depth for measuring rectal core temperature is 15 cm (6 in). However, they highlighted that the type of thermistors is crucial. It is better for the thermistor to be flexible to avoid damage to the surrounding tissue of rectum, and any infections (Miller, Hughes, Long, Adams, & Casa, 2017).

CHAPTER 3: RESEARCH METHODOLOGY

3.0 RESEARCH DESIGN

This is an intervention, randomised and crossover study design. The participants performed an intervention (cooling strategy) and control trials (no cooling), separated by 7 days. All participants visited the laboratory on four separate occasions: (1) Preliminary submaximal and maximal tests, (2) Experimental familiarisation, (3) Experimental trial and (4) Experimental trial. This study has no conflict of interest. Ethical approval for the experimental protocol was obtained from the Human Ethics Committee of USM *(USM/JEPeM/19020108)* and conducted in accordance with the latest *Declaration of Helsinki*.

A computerised randomiser generator (Dallal, 2008) was used to allocate the participants randomly to either firstly begin trial 1 (Ice slurry trial, 0.4 °C) or trial 2 (Control trial-plain water, 27°C). The randomisation was generated as follows:

Subject ID	**Trial**	
01	**1**	**2**
02	**2**	**1**
03	**2**	**1**
04	**1**	**2**
05	**2**	**1**
06	**2**	**1**
07	**1**	**2**

3.1 STUDY AREA

This study was conducted at the Exercise & Sport Science Laboratory, School of Health Sciences, Universiti Sains Malaysia, Kelantan.