EDINBURGH NAPIER UNIVERSITY

School of Life Sciences

HONOURS PROJECT

Does Wearing a Cooling Vest During an Active Warm Up Improve 10km Cycling in Heat?

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In partial fulfilment of the requirements for the degree of Bachelor of Science in Sport and Exercise Science

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Consent Statement

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Abstract

The aim of this study was to investigate the effects that wearing a cooling vest during a 10-minute active warm-up had on the 10km time trial cycling performance of recreationally active males in a hot environment. The null hypothesis was that there would be no difference in performance between the cooling vests trials and the control.

Nine recreationally active, healthy male participants (Mean ± S.D; Age = 25.2 ± 3.3 years, Height = 178.1 ± 4.1cm , Body Mass = 77.9 ± 7.1Kg) took part three trials; an identical familiarisation and control session with participants wearing a t-shirt on their torso for the warm up and an experimental session with participants wearing a cooling vest for the warm-up. A randomized repeated–measures experimental design was used where-in participants served as their own control. Each session consisted of 10-minute warm up followed by a 10Km time trial cycle in an environmental chamber set to 30°C and 60% relative humidity. Measurements were taken at every two kilometer mark. Blood lactate was measured pre warm-up and post 10Km cycle.

Results from the study showed no significant difference in performance, heart rate, tympanic temperature, RPE and thermal discomfort. Blood lactate concentration was 12% higher in the intervention than in the control. These findings suggest that wearing a cooling vest during an active warm up has no effect on 10Km time trial cycling performance in heat. Further research should apply the cooling vest for a longer duration to maximise the effect of pre-cooling.

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1.0 Introduction

Up to 80% of energy generated during exercise appears as thermal energy (González-Alonso *et al.,* 1999). During exercise, the increased metabolic rate in the body leads to the heat dissipation capacity being exceeded and subsequently the core body temperature (CBT) of the body increases (Kenefick *et al.,* 2007). This rise in body temperature often increases the risk of an individual developing hyperthermia (CBT between 37.5 – 39.5°C) and possibly hyperpyrexia (CBT > 40°C) which could be fatal (Castle *et al.*, 2004; Epstein and Moran, 2006). Furthermore, exercising in warm or hot environment will only increase the rate in which these conditions develop which inevitably puts an individual at greater risk (Nielson *et al.,* 1993; Tucker *et al.,* 2004). Increased body temperature has an inverse relationship with the levels in which an individual can exercise, consequently, any means in which this increase in temperature can be delayed will greatly benefit an athlete's performance.

In recent years, cooling the body before a bout of exercise has became more popular as it has proven to effectively improve performance, this method is known as pre-cooling (Bogerd *et al.,* 2010). Pre-cooling attempts to lower the core body temperature of an individual, in turn this is expected to increase the heat storage capacity of the body and allow an athlete to perform for longer or at a higher intensity before reaching a limiting CBT (Stannard *et al., 2011;* Wegmann *et al.,* 2012). Multiple methods of pre-cooling have been shown to effectively improve performance, such as; ice slurry ingestion, cold air exposure; cold water immersion and cooling vests (Quod *et al.,* 2006).

Although some of these methods have shown greater improvements in performance than others, the equipment, time, cost and practicality to perform some of these methods often renders them useless to athletes and sports organisations (Marino, 2002).

Cooling vests are often seen as the cost efficient and practical method of pre-cooling due to their ease of use and ability to be transported with ease (Ross *et al.,* 2013). Cooling vests have been shown to reduce CBT and improve performance in past studies, verbal feedback has shown them to often be heavy and uncomfortable which is not beneficial for the individual wearing it (Webster *et al.,* 2005). This feedback has been taken on board by many cooling vest companies and recently, lightweight cooling vests have been produced. However, it is unknown to what extent these light weight cooling vests can reduce CBT and improve exercise performance.

1.1 Aim

This study will aim to look at the effects of wearing a cooling vest during an active warm up on the 10km time trial cycling performance of active males in heat. The factors being measured will be; performance, blood lactate concentration, thermal discomfort, rate of perceived exertion and tympanic temperature.

2.0 Literature Review

Sports scientists worldwide are constantly looking for effective ways to improve an athlete's performance (Wegmann *et al. ,*2012). This is especially difficult in warm, humid environments where the added heat influences performance, causing fatigue to occur at an increased rate (Almudehki *et al.,* 2012; Galloway and Maughan, 1997; Morris et al. 1998). It is widely accepted that acclimatising to exercise in heat involves a complicated set of physiological adjustments that are in place to minimise the risk of injury (Armstrong and Maresh, 1993). Due to the increased risk of hyperthermia and even hyperpyrexia that can occur whilst exercising in heat, researchers in sports science have investigated multiple safety methods in an attempt to minimise or prolong these potentially critical conditions (Castle *et al.*, 2004; Epstein and Moran, 2006). Such methods include pre-cooling of the body. Pre-cooling attempts to lower the core body temperature of an individual before they partake in an exercise protocol (Wegmann *et al.,* 2012). As a result of the lowered initial core body temperature, it is often predicted that an athlete will have improved performance as it will take longer to reach the temperature in which the body begins to fatigue at an increased rate (Hasegawa *et al*., 2005). There are multiple methods of pre-cooling that have shown significant improvements in performance, such as; ice slurry ingestion, cold water immersion and cold air exposure (Tyler and Sunderland, 2011). However, it is often suggested that the cooling vest is the most practical method as it requires little time to set-up and can be used very easily in a number of environments (Ross *et al.,* 2013).

2.1 Training in Heat

Within a wide variety of environmental conditions, exercise increases core body temperature, until a steady state is reached when heat production equals heat loss (*Kay et al.,* 1999; Nielsen and Nielsen, 1962). The increased heat production during exercise (which is 15-20 time greater than at rest), and simultaneous increase in metabolic rate, places a great strain upon the human thermoregulatory system. With the combined heat from the environment and the heat generated by exercising, changes in cardiovascular function and thermoregulatory failure may also affect exercise capacity in a hot environment, placing great physiological risks on the body. In order for exercise to continue, the body must compensate for the production of excess heat, thus the heat must be transferred out of the body into the environment to ensure a critical core body temperature does not occur (Nielson *et al.,* 1993). The body has four main methods of heat dissipation; conduction, convection, evaporation and radiation. When an individual is exercising in a warm humid environment, the contributions of conduction, convection, and radiation become progressively inconsequential in the body's ability to alleviate heat. Although the body's ability to dissipate heat through sweating is greatly reduced in warm, humid environments, evaporation may account for up to 98% of the bodies alleviated heat. (Nielson, 1996; Armstrong and Maresh, 1993; Werner, 1993).

In a study by Castle *et al.* (2004), sprint cycling performance by eight male games players was seen to significantly reduce when the athletes were performing in a heated environment (37.1 ± 1.4°C, 74 ± 2.4% relative humidity, RH) when compared to the more temperate environment (21.4 ± 0.3°C, 62.2 ± 2.0% RH). The results of this study showed that the heat strain (thermal sensation) of the athletes had a negative correlation with peak power output recorded during the protocol. Similarly, sprint running performance was also reduced in three separate studies all performed in a similar climate (Maxwell *et al.,* 1999; Morris *et al.,* 1998; Morris *et al.,* 2000). It is therefore apparent that heat strain can negatively correlate with sprint performances in varied areas of sport. Morris *et al*. (1998) and Morris *et al.* (2000) both reported sprint running performance levels being reduced in a hot climate (~30°C) when compared with a moderate climate (~16-20°C), however no difference was noted between the blood lactate or rate of perceived exertion (RPE) of the participants when comparing both climates. The only areas that showed a significant difference with the reduced performance were core temperature and heart rate.

Likewise, the same detrimental effect can also be seen when aerobic activities are performed in hot, humid environments (Galloway and Maughan, 1997; González-Alonso *et al.,* 1999; Nielson *et al*., 1993). Galloway and Maughan (1997) looked at the effects of cycling to exhaustion in different environmental conditions. It was evident over the different temperatures they controlled for that the hottest temperature (30.5±0.2°C, RH 70±2%) had the most significant adverse effects on the athlete's performances. As well as performance, significant effects were also found with heart rate, RPE and core body temperature. Furthermore, González-Alonso *et al.,* (1999) found a similar significant inverse relationship; when the ambient temperature increased, the time to exhaustion of the participants decreased. González-Alonso *et al.,* (1999) also saw the parallel increase in heart rate with core body temperature that was shown in the study by Galloway and Maughan (1997). From this literature it is evident that both aerobic and anaerobic activities have shown an inverse relationship between exercising in heat and the adverse effect it has on performance (Tyler *et al*., 2015).

2.2 Physiological Measures

It has been well documented and widely accepted that endurance based activities can be impaired in hot, compared with temperate climates and that time to exhaustion is directly influenced by changes in the initial core body temperature (Galloway and Maughan, 1997; González-Alonso *et al.,* 1999). The conversion of metabolic energy into mechanical and thermal energy creates heat within the majority of cells within the human body (Edwards *et al.,* 1975; González-Alonso *et al.,* 2000). This process is extremely inefficient as between 30–70% of the energy released during muscle contractions is released as thermal energy, thus resulting in little production of mechanical energy (Bangsbo *et al.,* 2001; Krustrup and Bangsbo*.,* 2001; Krustrup *et al.,* 2003). During the 1990s and early 2000s, health and safety boards worldwide were emphasising the importance of protection, by means of; sunscreen, hydration and pre-cooling, for anyone who trained in hot, humid climates as heat-related disorders were appearing more and more frequently (Webster *et al*., 2005). It has been proposed that the body's inability to rid itself of heat is the underlying reason behind the majority of heat related illnesses (Duffield *et* *al*., 2003). Nielson *et al*. (2001) and González-Alonso *et al*. (2001) suggest that the rate of hyperthermia (the elevation of core body temperature caused by a thermoregulatory failure) appears at the same rate in a hot environment as that in a cooler environment and that the duration of the exercise has no significant effect on the rise in core body temperature. These studies both proposed that the difference between the initial core body temperature and the temperature recorded at the end of the exercise bout, were very similar when comparing a hot to a temperate environment. These results contradict the findings of multiple other studies that have proposed that the rate in which core body temperature increases at, is significantly greater when athletes perform in a warm, humid environment when compared to a cooler, more temperate environment (Galloway and Maughan, 1997; Nielson *et al.,* 1993; Nybo and Neilson, 2001). When comparing the methodology of these studies, there are no substantial differences that would suggest a reason for the opposing results. The five studies mentioned each look at high level athletes that are not accustomed to exercising in heat and have relatively similar exercise/exhaustion protocols and temperatures/environments in which the protocols are performed. Therefore, no clear suggestions can be made as to why all five studies have not found a similar relationship between the rate of hyperthermia when comparing the two opposing environments.

González-Alonso *et al.* (1999) proposes the progression of hyperthermia during exercise is the reasoning behind a number of pre-cooling strategies being investigated (Eijsvogels *et al.,* 2014; Tyler and Sunderland, 2011). These pre-cooling strategies are designed in an attempt to counter the physiological strains associated with the hot, humid environments (Duffield and Marino, 2007).

2.3 Perceptual Measures

Thermal stress has always been an important factor when athletes are performing in heat. There have been several studies over the past century attempting to create a central method to effectively measure thermal stress within athletes (Schlader *et al*., 2010). Thermal comfort is one variance of thermal stress and is commonly described as, the condition of mind which expresses satisfaction with the thermal environment (Epstein and Moran, 2006). Thermal sensation scales, often called thermal comfort/discomfort scales, are commonly used in studies to measure participant's contentment with their perceived body temperature (Huizenga *et al*., 2001; Zheng *et al*., 2006). Most thermal sensation scales have derived from a commonly used and cited study by Gagge *et al*., (1967). The original thermal discomfort scale by Gagge et al., (1967) (Appendix A) is the most frequently used thermal perception scale, and is usually used in conjunction with physiological measures, such as; core body temperature, heart rate and skin temperature, as a means of comparing participant's actual physical output and body temperature to their perception of their body temperature (Belluye, 2006; Fournet *et al*., 2013; Nielson and Neilson, 1984; Young *et al*., 1987).

Studies by Duffield and Marino, (2007) and Minett *et al*. (2011) investigating pre-cooling in heated environments on male team-sport athletes, both used similar thermal perception scales to that of Gagge *et al.* (1967) as well as other physiological factors including; core temperature and heart rate. The results of both these studies showed significantly reduced readings in thermal perception and core temperature when the participants underwent pre-cooling before the exercise protocol. The results from these two studies suggest the athlete's perceptual temperature was accurate to that of their recorded core body temperature. A significant improvement in performance was found in the results of the studies and it is proposed that the pre-cooling reduced heat stress and allowed the participants to maintain a higher level of performance before fatiguing. However, a study by Arngrïmsson *et al.,* (2004) on seventeen competitive runners (9 male, 8 female), only found an improvement in thermal discomfort during the early stages of the 5km run and little or no differences were seen in the latter stages. Ultimately, no performance improvement was not found in this study. Participants in all three studies (Arngrïmsson *et al.,* 2004; Duffield and Marino, 2007; Minett *et al.,* 2011) were elite level runners. However, differences occur when you look at the exercise protocols. In the studies by Duffield and Marino, (2007) and Minett *et al*., (2011) participants were asked to complete intermittent sprint runs, and in the study by Arngrïmsson *et al.,* (2004) participants are asked to perform a 5km run. A possible reason for this difference in thermal comfort results is the rest time available for the participants, as the intermittent run protocol provided breaks where as the 5km run was a constant protocol.

Another perceptual measure frequently used in many exercise studies is RPE. RPE is commonly defined as a scale to measure perception of effort during an exercise (Scherr *et al.,* 2013). The Borg Scale (Borg, 1982) (Appendix B) is the most commonly used method of collecting a participants RPE. The Borg Scale asks participants to rate their exertion levels between 6-20 (6 – No exertion at all, 20 – Maximal exertion). RPE frequently shows a strong correlation with heart rate as both factors will generally increase as the intensity of an exercise progresses (Scherr *et al.,* 2013).

Two of the studies previously mentioned (Duffield *et al.,* 2003; Duffield and Marino, 2007) also asked their participants to give a rating of RPE at the same intervals as thermal comfort. Results from both of these studies displayed no significant differences between the ratings for RPE in the pre-cooling session when compared to the control session (no pre-cooling). On the contrary, Cotter *et al.* (2001) reported significantly lower ratings of RPE in habitually active males throughout the full duration of the protocol when comparing the pre-cooling sessions to that of the control with no pre-cooling. Duffield *et al.* (2003) and Duffield and Marino (2007) both looked at the effects of pre-cooling via the use of a cooling vest during intermittent sprint running performances, whereas Cotter *et al.* (2001) looked at the effects of pre-cooling using a cooling vest on a 35-minute cycling performance. These results suggest that RPE can be significantly reduced in prolonged performances, such as long duration cycles, when pre-cooling is used but is not effective on reducing RPE in sprint performances (Cotter et al., 2001; Duffield *et al.,* 2003; Duffield and Marino, 2007). Despite the contradictive findings, using RPE to measure the perceived intensity of an exercise during performance is still used in the majority of studies and regardless of exercise protocol.

2.4 Pre-cooling Modalities

The development of hyperthermia and hyperpyrexia is fundamental to the many proposed theories of pre-cooling (Hasegawa *et al*., 2005). The general rationale for all pre-cooling modalities is to reduce core body temperature prior to a bout of exercise and the consequent reduction of the rate at which hyperthermia develops in an effort to improve performance (Wegmann *et al.,* 2012). Many studies have presented results suggesting that lowering core body temperature before exercise increases the heat storage possible within the body before a critical temperature is reached that would limit performance (Arngrimsson *et al.,* 2004; Booth *et al.,* 1997; González-Alonso *et al.,* 1999; Lee and Haymes, 1995). During exercise, a small volume of the blood available is directed to peripherals of the body as a means of dispersing excess heat (Marsh and Sleivert, 1999). Blood supply to the periphery (skin) is increased as exercise duration and/or intensity increases until a point where the blood supply to the muscles is equal to the blood supply to the skin (Booth *et al.,* 1997). The application of a pre-cooling modality may cause vasoconstriction around the peripherals resulting in an increase in available blood for the working muscles (Marsh and Sleivert, 1999). An increase in central blood volume may consequently increase the oxygen delivered to the working muscles and simultaneously increase the rate in which metabolic byproducts are removed, which hypothetically could be very beneficial to an athlete's performance (Booth *et al.,* 1997; Marsh and Sleivert, 1999). If the extent of the pre-cooling is not sufficient enough to have physiological effects of an athlete, performance improvements are often seen due to athletes perceived thermal strain being reduced by the pre-cooling (Tyler and

Sunderland, 2011). Researchers have investigated many different methods of pre-cooling (Tyler and Sunderland, 2011). Cold water immersion, cool air exposure, ingestion of cold water, cooling garments and often a combination of two of these techniques are the most common pre-cooling modalities used in studies (Wegmann *et al.* ,2012). When many of the pre-cooling techniques mentioned have been tested, they have shown not only improvements in the endurance based exercise being tested, but also many key physiological aspects related to the performance, such as; RPE, heart rate and core body temperature (Arngrimsson *et al.,* 2004; Booth *et al.,* 1997; Lee and Haymes, 1995; Webster *et al.,* 2005).

Some original studies investigating pre-cooling by Schmidt and Brück (1981) and Lee and Haymes (1995) looked at the effects of using cold air exposure. Schmidt and Brück (1981) had their participants endure two periods of cold air exposure at near 0°C before beginning a cycling protocol to exhaustion. Exercise endurance and was found to improve after the cold bouts of pre-cooling in this study. Likewise, the study by Lee and Haymes (1995) also reports an improved performance in cycling to exhaustion following a bout of cold air exposure at 5°C. In addition to cold air exposure, whole body cold water immersion is often looked at as a method of pre-cooling (Marino, 2002). Participants in a study by González-Alonso *et al,* (1999) induced 30 minutes of cold water immersion before performing a cycling protocol at 60% VO2 max to exhaustion. The findings from this study displayed a significant increase in performance time which is similar findings to the studies by Schmidt and Brück (1981) and Lee and Haymes (1995) investigating cold air exposure.

Despite cold water immersion and cool air exposure consistently displaying very significant improvements in performance, they are becoming less frequently used. Many athletes and athletics facilities do not have the required equipment to perform these methods, and in some cases, the time it takes to perform these modalities is not feasible (Kay et al., 1999). As a result of these limitations, many athletes have resorted to using cooling vests as a quick and practical alternative (Ross *et al.,* 2013).

2.5 Cooling Vest

Cooling vests have been suggested as a time efficient and practical alternative to many other techniques of pre-cooling, such as full body ice bath immersion (Ross *et al.,* 2013). Although used in many international sporting events, and by successful athletes, research into the effectiveness of cooling vests is fairly limited (Arngrïmsson *et al*., 2004; Duffield and Marino, 2007; Martin *et al*., 1998; Webster *et al.*, 2005). A study by Arngrïmsson *et al*. (2004) on experienced runners showed that when an active warm up was performed with a cooling vest on, the 5km running times significantly improved and the thermal discomfort and RPE of the participants was reduced. In this study participants performed a 5km run in 32°C, 50% relative humidity following a 38-minute active warm up wearing either wearing a cooling vest or a t-shirt. Similarly, Webster *et al.* (2005) also found an improvement in 30-minute time trial running performance and reduced core temperature and RPE score, at 37°C, 50% relative humidity, when the experienced participants wore a cooling vest during the warm up periods of the test.

However, in a study by Duffield and Marino (2007), looking at the effects of wearing a cooling vest for 15-minutes prior to an intermittent sprint protocol, no significant change in performance or core body temperature was observed, only a significant difference in thermal discomfort and heart rate. These findings are similar to another study by Duffield and colleagues, (Duffield *et al*., 2003), that also looked at pre-cooling on intermittent sprint performance. Duffield *et al*. (2003) had participants wear a cooling vest for 5-minutes prior to an intermittent sprint protocol and found no improvement in performance, heart rate or core body temperature. The climate of these two studies was slightly different, (32 ± 1°C with 30 ± 3% relative humidity and 30°C with 60% relative humidity). Regardless of this small difference, neither study found any significant improvement in performance or reduction in core body temperature in either of their protocols.

The literature suggests that the use of a cooling vest as a replacement for ice-water immersion or cold air exposure is effective in improving performance, primarily in prolonged activities. No improvements in performance or reduction in core body temperature was found in either study by Duffield and colleagues (Duffield and Marino, 2007; Duffield *et al*., 2003) looking at the effects of wearing a cooling vest during a warm up on intermittent sprint performance in heat.

2.6 Summary of Relative Literature

It is evident from the literature that exercising in hot, humid environments carries many physiological and psychological health risks, such as hyperthermia and heat stress (Galloway and Maughan, 1997). Exercising in heat has shown to have a detrimental effect on performance in sport (Galloway and Maughan, 1997; González-Alonso *et al.,* 1999; Nielson *et al*., 1993). Due to these reports of impaired performance, many techniques have been investigated as a means of counter-balancing the physiological complications that come with exercising in heat (Hasegawa *et al*., 2005). Pre-cooling modalities such as cold water immersion and cold air exposure have shown to reduce core body temperature, thermal discomfort and as a result improve performance in a heated environment (Schmidt and Brück, 1981; Marino, 2002). However, these methods are often too time and cost consuming and not feasible for many athletes (Kay et al., 1999). As a result of this, many athletes and sports science researchers have investigated the cooling vest as an efficient alternative. The cooling vest has shown to be effective in long duration exercise, improving performance and effectively reducing RPE scores in many running studies (Arngrïmsson *et al*., 2004; Webster *et al*., 2005). Thermal discomfort ratings and core body temperature were also both significantly reduced in prolonged running exercises when the cooling vest was worn during the warm up (Arngrïmsson *et al*., 2004; Webster *et al*., 2005). Despite the results showing the positive effects of a cooling vests as a pre-cooling modality, research into the cooling vest is still relatively limited (Martin et al., 1998; Duffield and Marino, 2007). Most studies investigating the cooling vest have looked its effectiveness during a warm up prior to a running performance. There is limited literature that has looked at the effectiveness during an active warm up on prolonged cycling performance. It is also evident that the majority of literature has used elite level athletes as participants. As a result of this, if performance improvements were reported, they were often very minute as the athletes were at the peak of their ability. There is little literature on amateur athletes in this area. Perhaps if the participants in these studies were of a lower level, the improvements in performance may have been greater.

2.7 Research Question & Hypothesis

The researcher is posing the question: Does wearing a cooling vest during an active warm up improve a recreationally active individual's 10km cycling performance in heat? The hypothesis of the study is that the application of the cooling vest will improve performance. The null hypothesis of the study is that no difference in; performance, blood lactate, thermal discomfort, RPE, tympanic temperature and heart rate, will be seen when comparing the results from the control and intervention testing sessions.

3.0 Methodology

3.1 Participants

Nine recreationally active, healthy male participants were recruited for this study (Mean ± S.D; Age = 25.2 ± 3.3 years, Height = 178.1 ± 4.1cm , Body Mass = 77.9 ± 7.1Kg). This sample size was based around costing limitations, time constraints and the availability of the environmental chamber in the Edinburgh Napier University laboratories. Recruitment of the participants was done via posters in Edinburgh Napier University and posts on three social media websites (Facebook, Twitter and Instagram). All participants were informed of the procedure they would be performing during the three visits to Edinburgh Napier University Sighthill Campus, the reasoning behind it and the possible risks that may have occurred during the study, prior to giving their written consent for their participation. All participants were also given multiple opportunities to ask about any queries they may have had. A health questionnaire was handed to every willing participant to ensure they were suitable for taking part in the study. Participants read the information sheet provided and were then asked to read and sign the consent form.

3.2 Inclusion Criteria

Participants for this study had to meet strict requirements outlined in the inclusion criteria and health questionnaire. All participants must have been male and aged between 18 and 30 years. It was also stated in the inclusion criteria that participants must take part in exercise at least two to three times per week. The specific age range and exercise requirements were put in place in an attempt to make the participant sample more similar. In order to standardise the factor of sex, only males were used for the study. All participants were asked to abstain from drinking alcohol for 48 hours prior to each session of the study and to avoid consuming any caffeinated beverage 12 hours prior to each testing session. Finally, every participant had to be fully consenting to taking part in the study and physically capable of completing all three sessions of the study without unnecessary and excessive discomfort.

3.3 Exclusion Criteria

The exclusion criteria worked in conjunction with the inclusion criteria, if a potential participant met any part of the exclusion criteria, they were not allowed to partake in the study. Smokers and potential participants who were on medication, specifically medication that may affect the participant's health or effect the reliability of the results were excluded from the study. Anyone who had sustained a serious injury within the 12 months prior to testing and anyone currently suffering from an illness or infection were not permitted to volunteer for the study.

3.4 Participant Welfare

Prior to the familiarisation session, all participants were given an information sheet detailing the outline of the study and informed they can ask about any queries before, during and after the testing. Upon arrival at Edinburgh Napier University, all participants were asked to read and sign a consent form. The consent form detailed the participant’s right to relieve themselves from the study at anytime, with or without reason, and participants were informed that all data collected would be kept confidential and destroyed upon completion of the study.

The participant details and data collected from the testing sessions were kept on a password locked computer and USB memory stick. For data protection purposes all participants were made anonymous by the use of participant numbers being allocated. Only the researcher and project supervisor had access to the data collected from the study, in accordance with Edinburgh University Data protection guidelines.

Upon completion of each session, participants were supplied with a debrief sheet. The debrief sheet consisted of information regarding the well-being and aftercare of the participant. If any issues or health related problems occurred following testing, contact details of the researcher and research supervisor were provided at the foot of the debrief sheet.

3.5 Ethics and Risk Assessment

Prior to any data being collected, the procedure received ethical approval from the Edinburgh Napier University ethics committee. A risk assessment form was also approved prior to testing.

3.6 Experimental Design

A repeated –measures experimental design was used where-in participants served as their own control (Arngrimsson *et al.,* 2004). Each participant completed three 10-km cycles, 5-7 days apart, on a cycle ergometer in the environmental chamber within the Sport & Exercise laboratories at Edinburgh Napier University, Sighthill Campus. The 5-7 day period between testing was to eliminate any effect that fatigue and delayed onset muscle soreness (DOMS) may have had on the participant's performance. Each of the three sessions was conducted around the same time of day to minimize the effect of circadian rhythm (Arngrimsson *et al.,* 2004). The environmental chamber was set to 30°C and 60% relative humidity (Duffield *et al.*, 2003; Castle *et al*., 2006). Every participant underwent a familiarisation session before partaking in the two experimental sessions. The two experimental sessions that took place were: 1) the investigational condition where the participant wore a cooling vest (6201 KewlShirt, TechNiche International, Vista, California, USA) (V) during the warm up, and 2) the control condition where the participant wore a T-shirt during the warm-up (C). The two tests were performed in random order for all participants.

3.7 Baseline Procedures

Upon arrival at the lab on each of the three sessions, participants had their semi-nude body mass recorded (only wearing shorts) and on the familiarisation session, which was identical to the control session, they also had their height measured. Prior to the warm up commencing, participants had their chest's lightly lubricated with water and fitted with a heart rate monitor (Polar, FS1, Finland). Resting measures of heart rate, tympanic temperature, rate of perceived exertion and thermal discomfort were only recorded once both participant and researcher has entered the environmental chamber.

3.8 Test Procedures

Participants were asked to arrive at the laboratory on the days of testing after only consuming a light meal (200-300 calories), 2 hours prior to testing. It was asked that all the food and drink consumed 24 hours prior to the first trial was recorded and replicated as best as possible before the second testing session. As participants were training in heat, it was very important they stayed well hydrated. Water was consumed ad libitum during the warm up, the amount of water ingested was recorded and participants were asked to drink the same amount during the warm up of the second session (Arngrïmsson *et al*., 2004). Participants were also asked to abstain from ingestion of alcohol (48 hours prior to testing), caffeine (12 hours prior to testing), and non-prescription medication and dehydrating behaviors (sauna, diuretics, sweat suits, etc.) 48 hours prior to each test, to ensure neither of these factors could influence the results of the study in anyway (Lopez *et al.,* 2008).

Each participants primary visit was a familiarisation session. Participants partook in the 10km cycle whilst experiencing all the methods of data collection that were to be used in the main experiments. During the familiarisation session participants were given the opportunity to ask any questions. The environmental chamber was set to 30°C and 60% humidity, as used in similar studies by Duffield *et al.* (2003) and Castle *et al*. (2006) who both replicated climates typical to a north American summer. The environmental chamber conditions were kept the same for both the familiarisation session and the testing sessions. The primary focus of the familiarisation session was to allow the participants to experience the climate they would be performing the exercise protocol in. The protocol of the familiarisation session was identical to that of the control, thus the participant will not be wearing the cooling vest during this trial. Participants were not inside the environmental chamber for longer than 45 minutes in each of the three sessions.

It was during the warm up phase of the protocol that the intervention took place. The warm up consisted of a 10-minute cycle at 40-50% of the participant's predicted maximum heart rate. This is a similar set up to a study by Marsh and Sleivert (1999) but with the intensity reduced as the participant's in this study were recreationally fit and not professional level athletes. Predicted maximum heart-rate was calculated using '220-age' (Tanaka *et al*., 2001). The warm up was controlled by the heart rate monitor attached to the participant's chest and the watch on their wrist displaying their heart rate. The warm up protocol remained the same for the familiarisation session and the control session, where the participant was wearing only a t-shirt on their torso. When the participant was undertaking the experimental protocol, the same 10-minute warm up at 40-50% of predicted maximum heart rate was used, however, the participant was wearing the cooling vest instead of a t-shirt.

Upon completion of the baseline procedures, the cooling vest or t-shirt was applied and the participant was asked to enter the environmental chamber. The cooling vest was placed in a basin of tap water and ice was added to the bucket to make it reach the desired temperature (6°C ± 0.5°C). The temperature of the water was controlled by a LASER THERMOMETER REFRENCE. The vest was soaked for 2 minutes, rinsed thoroughly and patted dry with a towel before being applied to the participants (Eijsvogels *et al.,* 2014). Upon entering the chamber, the participant adjusted the saddle and handlebar height, mounted the bike and the primary measurements of blood lactate and heart rate were taken and recorded. Blood lactate was taken from the ear using a single use safety lancet (Owen Mumford, Unistik 3 Extra, England). The blood sample was absorbed by a Lactate pro 2 test strip (Arkray, Japan) and placed into a Lactate pro 2 monitor (Arkray, LT-1730, Japan) for readings. At this time, the participants were also asked to give their pre-warmup readings for thermal discomfort and rate of perceived exertion (Arngrïmsson *et al*., 2004). Participants were then asked to start the warm up cycle in the chamber. After the warm up was completed the participant was asked to remove the cooling vest or T-shirt. The 10km time trial began after the post warm up measurements were recorded. Participants were reminded prior to beginning the cycle that they were to perform the trial as fast as possible without undue or excessive discomfort. CBT and heart rate were measured throughout the duration of the trial (measurements recorded at every 2Km interval) to ensure participants were not reaching cut-off measures put in place for their safety. Participants were in control of the resistance they were cycling at, and to assist with pacing, participants were able to view the distance they had covered throughout the full protocol (Eijsvogels *et al.,* 2014). Participants only found out their performance times after all three cycles had been completed, this was to ensure they were not aiming to improve their performance in each session. Perception of thermal discomfort was measured using a 5-point scale (Gagge et al., 1967) (see appendix A). Participants will be allowed to drink water ad libitum during the warm ups in all three sessions but will be asked to refrain from drinking water during the 10Km cycle unless feeling faint. Immediately following the completion of the cycle, the final blood lactate measure was taken. Participants were asked to perform a cool down cycle for 2 minutes at their own pace upon completion of the trial.

3.9 Tympanic Temperature

The first measure of tympanic temperature was taken immediately before the 10km cycle began and there after at 2,4,6,8 and 10 kilometers. Temperature was taken using a tympanic thermometer (Braun, IRT 4520 ExacTemp Type 6022 Germany). Critical CBT is ~40°C, as tympanic temperature is not the most accurate reading of CBT, a cut off point of 38°C was put in place for the participant's safety. If a participant's tympanic temperature was above 38°C before they had completed the protocol, they were asked to stop the trial.

3.8 Heart Rate

The chest and chest strap of the heart rate monitor were lightly lubricated with water before being attached firmly to the participant's chest. The watch was attached to the participant's wrist and heart rate was recorded at every 2 kilometer interval beginning when the 10km cycle commences. The heart rate monitor was also used to ensure the participant was exercising between 40-50% of their predicted maximum heart rate during the warm up and to ensure they were not exceeding their predicted maximum heart rate during the 10Km protocol. If a participant's heart rate reached that of their predicted maximum, the protocol was ended. This cut off point was put in place for the participant's health and safety.

3.9 Blood Lactate

Due to costing limitations, blood lactate levels were only taken immediately prior to the warm up beginning and directly after the participant finishes the testing. Firstly, the participants ear was cleansed using an alcohol wipe. Blood was then taken using a single using a safety lancet (~5µl) from the ear. The blood sample was absorbed by a Lactate pro 2 test strip and placed into a Lactate pro 2 monitor to produce a reading of blood lactate in millimoles per litre (mmol/L). The alcohol wipes, lancets, lactate strips and tissues used to wipe any excess blood were safely disposed of immediately after the protocol in a biohazard bin.

3.10 Thermal Discomfort

Thermal Discomfort was measured using 5-point scale (see appendix A) designed by Gagge *et al.* (1967). The participant was asked "How comfortable do you feel with the temperature of your whole body?" at every 2 kilometer interval beginning at 0km mark of the test. If a participant reported a reading of '5 - Extremely Uncomfortable' before the protocol was complete, the testing was ended as this was putting the participant's health at risk.

3.11 Rate of Perceived Exertion

Rate of perceived exertion was measured using the Borg scale (Borg, 1982) (see appendix B). Participants were asked to give a reading off the scale at the 0,2,4,6,8 and 10km points through the 10km time trial. Similar to the Thermal Discomfort scale, for safety reasons, if participants gave a score of '20 - Maximal Exertion' before the 10km cycle was finished, the testing was terminated.

3.12 Data Analysis

Data was analysed using Statistical Package for the Social Sciences (SPSS), (Version 18, IBM, New York, USA). Paired Samples T-tests were used to assess the data for Performance (time) and blood lactate levels. All other data (heart rate, tympanic temperature, RPE and thermal discomfort) were analysed using two-factor (trial; control vs. cooling vest) repeated measures (distance) analysis of variance (ANOVA). All data is presented as Mean ± Standard Deviation (SD) and has been checked for normality. Significance was set at the 95th percentile ($p \leq 0.05$).

4.0 Results

Overall, the results were calculated from 9 participants whom completed the familiarisation session and both trials. One participant's results were not included as they only completed the familiarisation session and one trial due to personal commitments.

4.1 10Km Time Trial Cycling Performance

No significant effect was found between trials (see Figure 1), ($t(8)=2.221$, $p>0.05$). However, the mean time to complete the protocol was 1.2% faster in the cooling vest condition (18.3 ± 1.04) than in the control (18.5 ± 1.09).

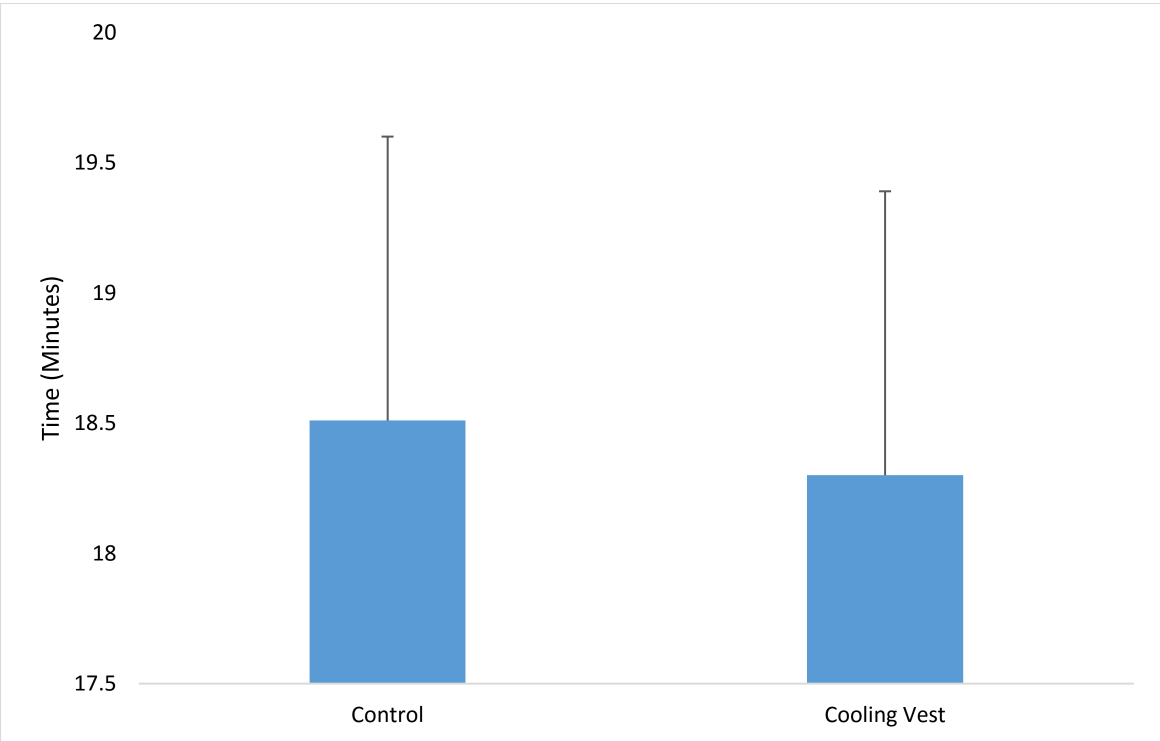

Figure 1: Means and SD of time for both conditions. This contains no significant data (p>0.05).

4.2 Blood Lactate

A significant difference was found between blood lactate concentrations post protocol. This indicated a significant increase of 12% in the cooling vest trial blood lactate concentration (9.4±1.7) when compared to blood lactate concentration in the control trial (8.4±2.5) post protocol ($p<0.05$). Significance was also found between both control results (1.3±0.2, 8.4±2.5) and both cooling vests results (1.5±0.2, 9.42±1.7).

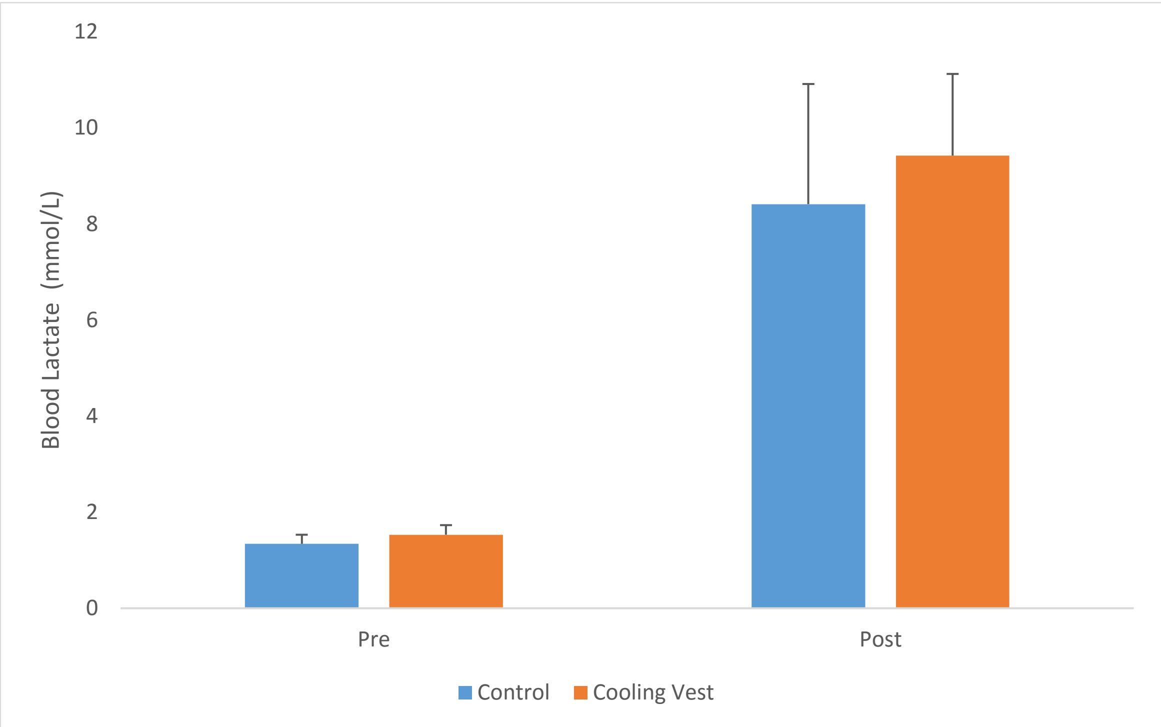

Figure 1: Means and SD of blood lactate concentration pre and post protocol for the control and the cooling vest trials. (*) denotes significance between blood lactate concentrations post control and post cooling vest (p<0.05). (~) denotes a significant increase in blood lactate concentrations over the duration of the trial.

<u>4.3 Heart Rate</u>

Figure 3 displays the heart rate data over the set distance points where measurements were taken. The repeated measures ANOVA returned no significant data found between the trials and hence no further tests were performed (p>0.05).

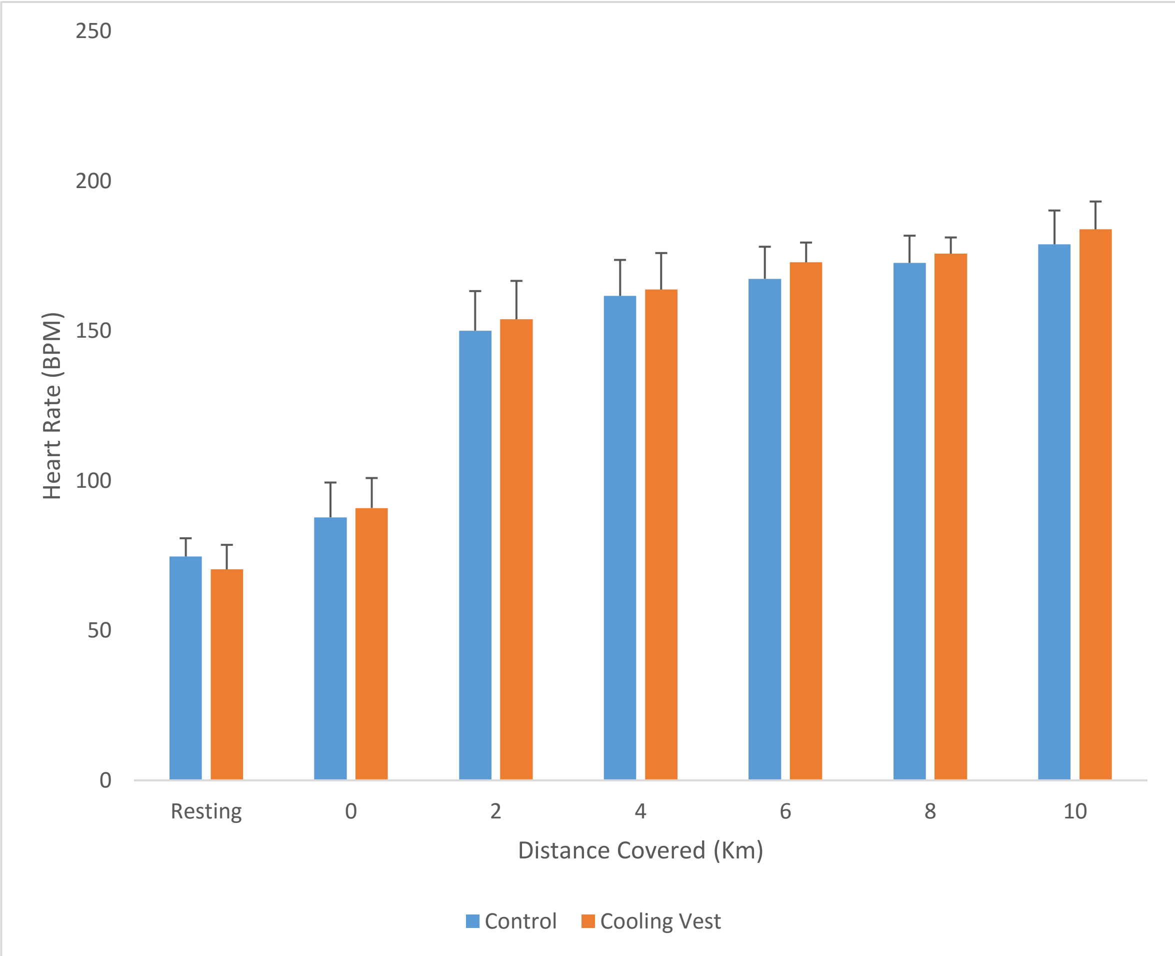

Figure 3: Means and SD of heart rate at each set distance point. No significant data were found between control and cooling vest.

4.4 Tympanic Temperature

The data in Figure 4 displays the Mean ± SD tympanic temperatures over the set distance points where measurements were taken. No significant data were found between any of the distances ($p>0.05$). No more statistical tests were performed.

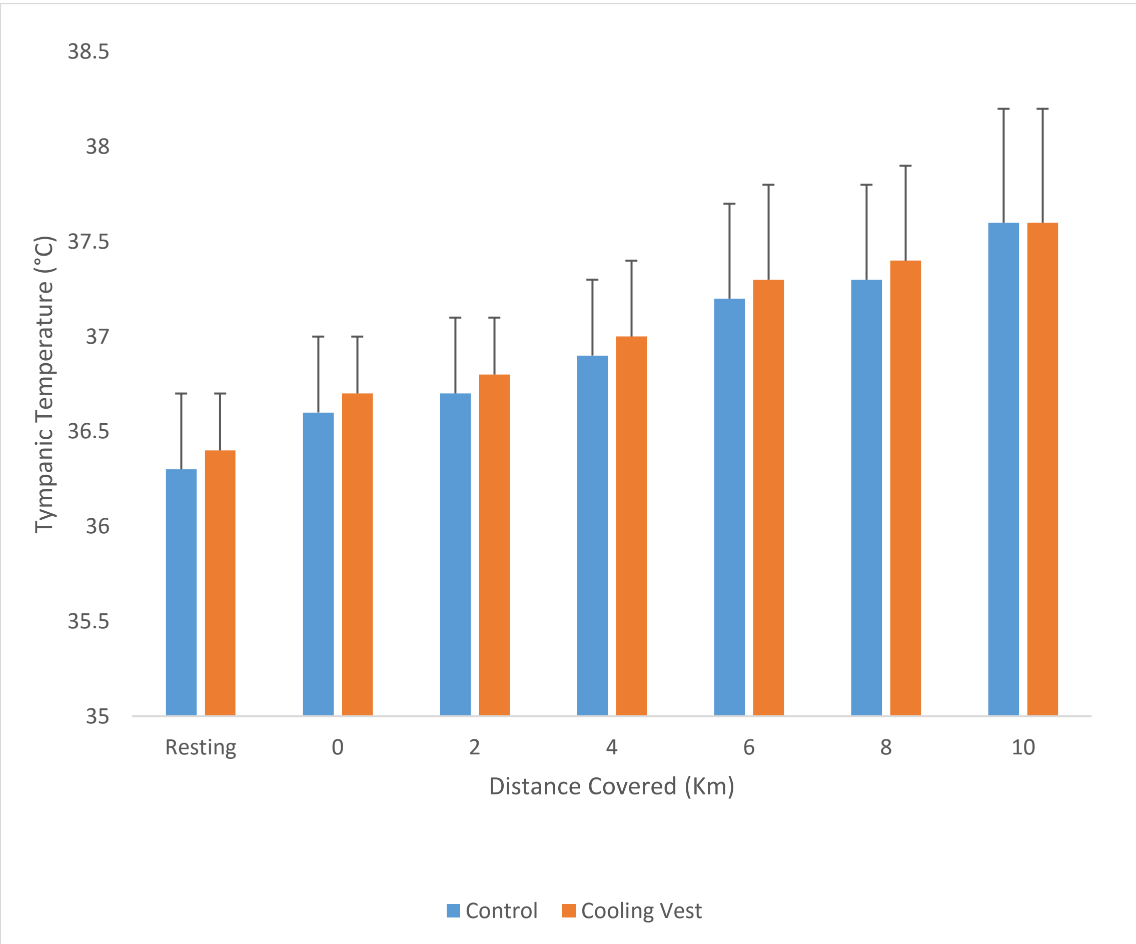

Figure 4: Means and SD of tympanic temperature at each set distance point. No significant data were found between control and cooling vest.

4.5 Rate of Perceived Exertion

Table 1 presents rate of perceived exertion scores for both trials throughout the duration of the 10Km cycles. Although lower results were recorded in the cooling vest trial at 0, 2, 4, 6 and 10Kms, no significant data was collected between the trials ($p>0.05$).

Table 1: Mean and SD of RPE (Borg Scale) at each set distance point. No significant data were found between control and cooling vest.

	Rest	0Km	2Km	4Km	6Km	8Km	10Km
Control	6 ± 0	7.9 ± 1.7	11.1 ± 2.5	13 ± 1.7	14.3 ± 1.7	15.6 ± 1.1	18.1 ± 1.6
Cooling Vest	6 ± 0	7.4 ± 0.5	10.2 ± 0.8	12.4 ± 0.7	14.1 ± 0.7	15.8 ± 0.6	17.9 ± 0.5

4.6 Thermal Discomfort

Figure 5 displays the thermal discomfort data for the control and cooling vest trials. Although thermal discomfort scores were repeatedly lower in the cooling vest trial than the control trial, no significant data were found between the trials ($p>0.05$).

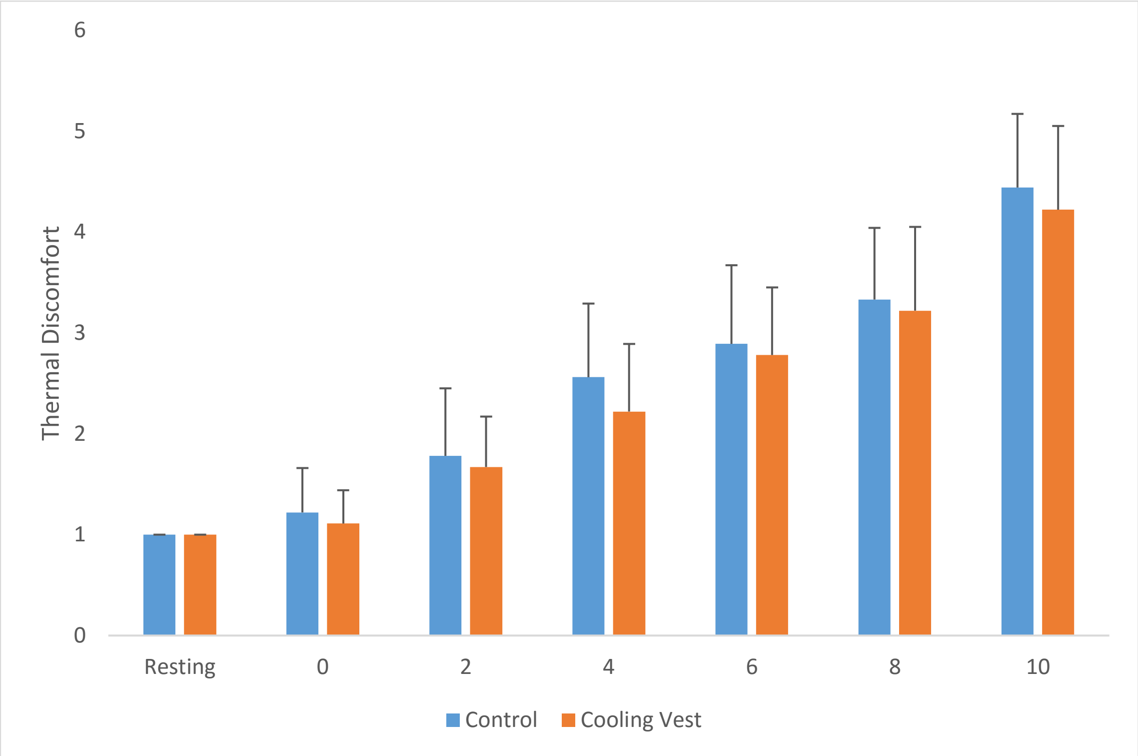

Figure 5: Mean and SD of thermal discomfort scores at each set distance point. No significant data were found between control and cooling vest.

5.0 Discussion

The author observed the effect that wearing a cooling vest during an active warm up had on recreational athletes 10Km time trial cycling performance in heat. The null hypothesis of the study was that the application of a cooling vest during the active warm up would have no effect on the physiological measurements (performance, blood lactate, heart rate and tympanic temperature) or the perceptual measurements (rate of perceived exertion and thermal discomfort) when compared to the control trial. The null hypothesis can be accepted for all measurements except blood lactate concentration which saw a 12% increase in the cooling vest trial when compared to the control. This discussion will debate how the intervention (cooling vest) affected the physiological and perceptual results of the sample and the possible reasons to why more significant differences were not found within the study.

5.1 Physiological Findings

5.1.1 Performance

Although the data analysis returned no significant results suggesting that the use of cooling vest improved performance, on average performance was seen to be 1.2% faster in the cooling vest trial (18.3 ± 1.04) when compared to the the control (18.5 ± 1.09). The absence of a significant improvement in 10Km cycling performance in this study opposes findings from previous studies investigating the effects of pre-cooling via the use of a cooling vest on prolonged endurance based activities. A study by Webster *et al.*, (2005) investigating the effects of wearing a cooling vest during an active warm up (30 minutes of running at 70% [Vdot]O_2max) on running time to exhaustion at 95% [Vdot]O_2max saw a significant increase in time to exhaustion in the cooling vest trial when compared to the trial with no cooling vest. This same pattern was seen by Arngrïmsson *et al*. (2004) who used experience runners, performing a 5Km run, in 32°C, 50% relative humidity following a 38-minute active warm up. Their results showed that when the active warm up was performed with a cooling vest on, the 5km running times improved by 1.1%.

A possible reason for the lack of improvement in 10Km cycling performance may be that the cooling vest was not applied for long enough to make a reduction in core body temperature. The application of a cooling vest during an active warm up saw a mean drop of 0.21°C in rectal temperature in the study by Arngrïmsson *et al*. (2004). Participants in the study performed a 38 minute active warm up which is 280% longer in duration than the 10 minute warm up performed in the current study. The increased duration in which participants wore the cooling vest in the study by Arngrïmsson *et al*. (2004) could possibly be an explanation to why an improvement in performance was not seen within participants during the 10Km cycle in the present study. As the cooling vest was applied for longer, the cooling effect had more time to reach the deep tissue within the body as opposed to potentially only cooling the skin. The data for tympanic temperature in this study reports a 0.1°C difference in both control (36.3°C) and cooling vest (36.4°C) temperature from the measurements taken pre warm up. Post warm temperatures were recorded 0.3°C warmer than pre warm up temperatures (control: 36.6°C; cooling vest:

36.7°C). As the difference between the two trials is still 0.1°C at post warm up (0Km) this suggests the cooling vest had no effect reducing core body temperature. From this analysis it is apparent that the application of a cooling vest during a 10-minute active warm up does not prove physiologically sufficient enough to provide any benefit to 10Km cycling performance. Future studies may wish to replicate the protocol of the study but increase the duration the cooling vest is applied for.

Another possible explanation for the absence of an improvement in performance may be due to the cooling vest being worn during the warm up as opposed to during the trial itself. In a recent study by Luomala *et al.* (2012), they applied the cooling vest 30 minutes into a cycling to exhaustion protocol. Seven trained cyclists performed continuous 10-minute cycles, consisting of nine minutes at 60% of their [Vdot]O_2max immediately followed by a one-minute sprint at 80% [Vdot]O_2max. This protocol was repeated until participants reached exhaustion. The control for this study was cycling with a t-shirt for the duration of the protocol and the intervention was applying the cooling vest 30-minutes into the protocol. In the study by Luomala *et al.* (2012), time to exhaustion was seen to improve 21.5%, from 61 minutes and 29 seconds in the control to 74 minutes and 14 seconds when the cooling vest was applied. Although the protocols between both studies were different, it is evident that applying the cooling vest during the performance had a hugely significant effect on the performances of these trained cyclists. In the present study, only a 1.2% increase was seen. A reason for this may be due to the body being cooled during the latter and more difficult stages of the study in the experiment by Luomala *et al.* (2012), whereas in the present study participants were only receiving the benefits of the pre-cooling for 10 minutes prior to the 10Km cycle.

5.1.2 Tympanic Temperature

Similar to performance, no significant differences were returned from the data analysis for tympanic temperature between the control and the cooling vest. Again, this agrees with the null hypothesis of the study, no difference will be seen between the tympanic temperature when comparing the control and the cooling vest trial. As previously mentioned, a potential reason for no reduction in tympanic temperature may have been due to the cooling vest not being applied for long enough to effect the core temperature of the body. However, another possible reason for this may be the degree of the pre-cooling. A temperature increase of 0.8% was seen between the pre and post warm up temperatures in both the control and the cooling vest trials, thus suggesting the cooling vest had no effect on reducing tympanic temperature during the warm up. The cooling vest in the present study was submerged in water at 6°C ± 0.5°C for 2 minutes before being rinsed out and patted dry before being applied to the participant who then entered the environmental chamber (30°C, 60% relative humidity). From the moment the cooling vest was removed from the water it would have started to increase in temperature, this means that towards the end of the 10-minute warm up, the vest is likely to have been considerably warmer than when it was first applied to the participant (Eijsvogels *et al.,* 2014). Although this process was unavoidable, it may have been influential on the degree of cooling provided by the vest. Although previous studies have shown a reduction in core temperature with the use of a cooling vest, the reductions are often very minimal (Arngrïmsson *et al*., 2004; Stannard *et al.,* 2011; Webster *et al.,* 2005). A recent study by Stannard *et al*., (2011) had a similar protocol to the current study and also found no difference between performance time between the two trials. Stannard *et al*., (2011) investigated the effects that wearing a cooling vest during a 30 minute active warm up had on 10km running performance in experienced male runners. Although no improvements in performance were seen, core body temperature was reduced by 0.4°C when comparing the cooling vest trial to the control. Literature suggests improvements in performance are more evident when core body temperature has decreased by a more substantial amount. In a study by Booth *et al.* (1997) pre-cooling by means of whole body cold water immersion (23-24°C) resulted in a 4% increase in distance ran in 30-minutes. There was a reduction of 0.7°C in body temperature when comparing pre-cooling to the control (no pre-cooling) in the study by Booth *et al.* (1997) which is likely linked to the improvement in performance reported. It is widely accepted that cold water immersion is more effective than a cooling vest at reducing core body temperature, but cooling vests are still used frequently as they are more practical and cost efficient (Kay et al., 1999). However, Ückert and Joch, (2007) found a 2.2-minute improvement in running time to exhaustion in heat when a cooling vest worn during an active warm up resulted in tympanic temperature being reduced by 0.6°C. In the study by Ückert and Joch, (2007) the cooling vest was soaked in water at 0-5°C. This lower temperature of water could be a reason why this study found a performance improvement and a lowered tympanic temperature where as the present study did not. With body temperature being reduced so significantly in these two studies (Booth *et al.,* 1997; Ückert and Joch, 2007) (0.7°C and 0.6°C) this allowed for participants to exercise for a longer duration before reaching a core temperature that would have negatively influenced performance (hyperthermia). Collectively these results suggest that the degree of pre-cooling in the present study may not have been sufficient enough to cause a significant reduction in tympanic temperature. Further studies could submerge the same cooling vest in a lower temperature of water (0-5°C similar to that of Ückert and Joch, (2007)) and then repeat the protocol and check for a significant reduction in tympanic temperature.

5.1.3 Blood Lactate Concentration

Blood lactate analysis is one of the most frequently used procedures in clinical exercise testing as well as during performance testing to measure anaerobic threshold (Crickmore, 2002). Although a high blood lactate concentration may be indicator of hypoxemia, it is also a “normal” physiological response evident with exertion (Goodwin *et al*., 2007). Duffield *et al*. (2003) predicted that the use of a cooling vest may result in a greater aerobic energy supply and consequently lower blood lactate concentrations when compared to the control with no cooling vest. The reasoning behind this was the cooling vest would lower skin temperature, and potentially core temperature, resulting in a delay in the redirection of blood flow to the skin to dissipate heat. This delay would allow a greater volume of blood to be directed to the muscles for a longer duration and allow them to work aerobically for longer. In the present study a significant time effect was found in both trials as well as a significant difference noted between the blood lactate concentrations post control (8.4±2.5) and post cooling vest (9.4±1.7). This indicated a significant increase of 12% in the cooling vest trial blood lactate concentration when compared to blood lactate concentration of the control trial post protocol. The higher blood lactate concentration in the cooling vest trial contradicts the prediction by Duffield *et al*. (2003). The higher lactate concentration in the experimental session may suggest that the cooling vest enabled participants to perform at a higher lactate threshold in the latter stages of the 10Km cycle than in the control trial. Although performance results were not significant, the higher blood lactate concentration in the cooling vest results could explain the lower time reported in the cooling vest performance trials. As participants were approaching the final two kilometers of the protocol, despite their actual tympanic temperature being 0.1°C higher in the experimental trial compared to the control (37.4 ± 0.5°C vs 37.3 ± 0.5°C) their mean reported thermal discomfort was 3.4% lower in the cooling vest trial than in the control. This may suggest that participants felt less thermal strain approaching the final two kilometers of the protocol, and therefore could finish with a more powerful sprint in the last ~100m in the cooling vest trial than in the control. A more powerful sprint or a sprint over a longer distance would have likely resulted in a higher blood lactate concentration (Lee and Haymes, 1995).

This trend can also be seen in a study by Arngrïmsson *et al.,* (2004). Participants in this study performed two 5Km time trial runs in a warm environment (32°C, 50% relative humidity) after performing a 38-minute active warm up either wearing a cooling vest on their torso (V) or a t-shirt (C). Arngrïmsson *et al.,* (2004) reported mean lactate concentration to be 7% higher in the final reading (immediately post 5Km run) of the experimental protocol (6.1 ± 1.9) than in the control (5.7 ± 1.4). Similarly, in this protocol, the penultimate readings of thermal discomfort show scores 2.6% lower in the cooling vest trial (3.9 ± 0.7) when compared to the control (4.0 ± 0.7).

The results from the two mentioned aerobic performances suggest that blood lactate concentration is increased with the use of a cooling vest during exercise in heat. As previously mentioned, if the participants perceived their body temperature to be lower then they were more likely to finish their protocol with a more powerful sprint and consequently increasing blood lactate concentration (Lee and Haymes, 1995).

5.1.4 Heart Rate

Heart rate is often used as a measure of exertion; as exertion levels increase, heart rate also increases (Borg *et al.,* 1987). Physiological indicators of exertion are important as they accurately reflect the physiological strains on the body which is important when ensuring the safety of an athlete (Borg, 1982).

Similar to performance and tympanic temperature, no significant differences were seen between the two conditions for heart rate. Although not significant, the results from heart rate were unexpected. In the cooling vest trial, heart rate appeared higher than the control at all 6 distances measured (excluding resting). Immediately post warm up heart rate in the investigational trial (90.9 ± 10 bpm) was 3.5% higher than in the control (87.8 ± 11.6 bpm). Final readings of heart rate after the 10Km time trial showed heart was 2.8% higher in the cooling vest trial (183.9 ± 9.3 bpm) than in the control (178.9 ± 11.3 bpm).

Comparably, no significant difference in heart rate between was also found in the study by Stannard *et al*., (2011) who as previously mentioned, found no improvement in performance during the 5km running time trial. Stannard *et al*., (2011) reports heart rate (bpm) lower in the cooling vest trial immediately post warm up when compared against the control, but similar to the present study, displays higher heart rate readings post exercise in the cooling vest trial. Arngrimsson *et al.,* (2004) found a reduction in heart rate post warm up and in the early stages of the 5km run but no differences were seen for the final third of the protocol (3.6Km onwards). These results suggest that heart rate can be effectively reduced in the early periods post pre-cooling but the cooling effect has no influence on reducing heart rate towards the end of a prolonged period of aerobic exercise.

As previously stated, the intensity of the pre-cooling, duration in which the pre-cooling was applied for and the method of pre-cooling could all be possible explanations as to why heart rate was not reduced in this protocol. Past literature by Schmidt and Brück (1981) showed a significant difference in heart rate for the duration of their cycling to exhaustion protocol after participants had endured two periods of near 0°C cold air exposure. It was also reported by Schmidt and Brück (1981) that core body temperature was up to 1°C lower post pre-cooling than post control which could explain this difference in heart rate. It is widely accepted that whilst exercising in hot environments, the body's heat dissipating processes compete with the active muscles for blood flow. When an effective pre-cooling modality is used, it is expected that both skin and core temperature will reduce, resulting in less blood being directed to the skin for heat dissipation. In turn, this would lead to an increased central blood volume, increased stroke volume and a consequent reduction in heart rate during exercise.

In the study by Schmidt and Brück (1981), heart rate and core body temperature were both lower during the cycling protocol following the bouts of cold air exposure which suggests that cold air exposure is more effective at lowering core body temperature and stunting heart rate than pre-cooling via the use of a cooling vest.

5.2 Perceptual Measures

5.2.1 Rate of Perceived Exertion

RPE is commonly defined as a scale to measure perception of effort during an exercise (Scherr *et al.,* 2013). RPE is important as it is an indicator of an individual's perceived level of physical strain (psychophysical strain) (Borg *et al.,* 1987). Similar to heart rate, RPE is expected to increase as the intensity and/or duration of an exercise increases (Borg *et al.,* 1987). As these factors generally show the same pattern of results; perceptual measure of effort is often used in conjunction with physiological measures of exertion (Borg and Dahlström, 1959; Scherr *et al.,* 2013).

The results from this study accept the null hypothesis as there were no significant differences in the RPE scores between both trials. Although no significant results were found, it should be noted that RPE scores in the cooling vest results were on average 2.8% lower across the cooling vest trial than in the control. RPE scores immediately post warm up were 6.8% lower in the intervention protocol (7.4 ± 0.5) than in the control (7.9 ± 1.7). The final readings of RPE after participants had completed the 10Km cycling time trial were on average 1.1% lower in the experimental trial (17.9 ± 0.5) than in the control trial (18.1 ± 1.6).

These results do not reflect the findings of Cotter *et al.* (2001) who looked at the effects of pre-cooling via the use of a cooling vest on a 35-minute cycling performances of habitually active males. Cotter *et al.* (2001) reported RPE scores significantly lower throughout the full duration of the cycle when participants had pre-cooled using a cooling vest during as opposed to no pre-cooling. In the intervention trial, participants were pre-cooled for 45 minutes before participating in a 6-minute active warm up followed by a 35-minute cycle (20 min at a fixed external work rate of ~65% [Vdot]O_2max, then a 15-min self-paced, maximal-performance trial). This period of pre-cooling was 3.5x longer than the pre-cooling in the present study, and the cooling vest was applied before the warm up was performed, where as the the current study had the the cooling vest worn during the warm up. These differences in duration of pre-cooling and when the cooling vest was applied may explain why Cotter *et al.* (2001) found differences in the RPE between the two trials. Due to the relationship between heart rate and RPE, comparisons between the studies can be made using both measurements. Heart rate was seen to be considerably lower (~14 bpm) at the beginning of the 35-minute cycling protocol after participants had worn the cooling vest. This is reflected in the RPE where the initial scores post warm up were 'Somewhat hard' in the experimental protocol and 'hard' in the control. In the present study, no difference in heart rate was seen at any point in the study between the two trials, which suggests the cooling vest had no effect on stunting heart rate. Again, this may be why no difference was seen in RPE scores in the current study.

5.2.2 Thermal Discomfort

Thermal discomfort is one variance of thermal stress and is commonly described as, the condition of mind which expresses dissatisfaction with the thermal environment (Epstein and Moran, 2006). As the name suggests, thermal discomfort in frequently measured in correspondence with core body temperature. In this study, neither thermal discomfort nor tympanic temperature saw any significant difference between the two trials. Thermal discomfort appeared lowered throughout the duration of the study in the cooling vest trial. Immediately post warm up, thermal discomfort was 9.9%

higher in the control trial (1.22 ± 0.44) when compared with the intervention (1.11 ± 0.33). Post time trial, participants reported marginally lower scores in the cooling vest trial (4.22 ± 0.83) than in the control (4.33 ± 0.73).

Although thermal discomfort was reported to be higher in the control sessions than in the cooling vest trials, the lack of significant results may be due the exercise protocol used. In studies by Duffield and Marino, (2007) and Duffield *et al*. (2003) thermal discomfort was seen to be reduced by the use of a cooling vest. Both these studies investigated the effects of pre-cooling on intermittent sprint performances in heat (32°C and 30% RH; 30°C and 60% RH). Each of these studies had participants perform intermittent sprint sessions, 2 x 30-minute running (Duffield and Marino, 2007) and 4 x 15-minute cycling (Duffield *et al*., 2003), with the cooling vest also being worn during the breaks in between sessions. Eliminating the fact that the cooling vest was re-applied, from the primary sessions of sprinting it is still evident that thermal discomfort levels were lower in the intervention studies than in the control. A possible explanation for these results may be due to the recovery periods present in the protocols. The 10km cycling time trial in the current study had participants continuously exercise for the full duration of the protocol knowing they were attempting to perform the 10Km as fast as they could. This protocol had no breaks or periods of reduced effort, thus body temperature was constantly increasing at a greater rate due to the constant physical stress that comes with exercising. In both studies by Duffield and colleagues, (Duffield and Marino, 2007; Duffield *et al*., 2003) participants had active rests in between their maximal exertion sprints. These short breaks of sub maximal exercise could allow for participant’s heart rates to lower and exertion levels to fall, consequently leaving the participant feeling less effected by the heat. These results suggest that pre-cooling via a cooling vest is more effective in reducing thermal discomfort levels intermittent sprint protocols and has little/no effect on prolonged constant exercise in heat.

5.3 Limitations

Time constraints of the study lead to multiple inevitable limitations, such as the small subject group that limited the power behind the statistics. Furthermore, it was essential to allow participants 5-7 days in between trials to eliminate any effects that fatigue or DOMS may have had on performance. However, this time period may have allowed for a variation in the motivational level and mood of the participants (Minett *et al.,* 2011). Optimistically, each of the three sessions of the study were performed at the same day and time each week and in an attempt to avoid change in mood and motivation levels, however this was not always possible. There is only one environmental chamber in the Edinburgh Napier University laboratories which occasionally meant the desired slots for participants and the researcher were already booked out for other research. Ultimately this lead the researcher only testing on nine participants despite originally stating there would be ten. Finally, an inevitable issue with pre-cooling studies is the inability to blind the participants for the intervention, which could lead to placebo effects (Eijsvogels *et al.,* 2014).

5.4 Future Research

The findings of this study contradict the findings of similar studies investigating the effects of pre-cooling via the use of a cooling vest before a prolonged bout of aerobic exercise (Arngrimsson et al., 2004; Hasegawa et al., 2005; Webster et al., 2005). The majority of pre-cooling studies investigate the effects of running performances, both prolonged distance and intermittent sprint protocol. Further research should continue to look into the effects on cycling performance as research is very limited in this area. Future trials should maintain the warm up and exercise protocols similar to what athletes would be experiencing but apply the cooling vest for a longer duration to extend the benefits of the cooling. Finally, more cooling garments that can be worn during exercise without interfering with the individual's performance should be investigated, e.g. cooling vests with hoods and cooling leggings, as it is these would assist with greater body cooling.

5.5 Conclusion

To conclude, the results of this study indicate that the use of a cooling vest during an active warm up is not effective in improving the 10km time trial cycling performances of recreationally active individuals in a hot environment. Furthermore, no differences were found between trials in; heart rate, tympanic temperature, RPE and thermal discomfort. A significant increase in blood lactate concentration was seen in the cooling vest trial when compared to the control, suggesting the cooling vest allowed for more powerful sprint in the final stages of the 10km cycle. The null hypothesis can be accepted for all measurements, except blood lactate concentration, as no significant differences were seen between the results of the control and the intervention. As previous studies have proven that cooling vests can significantly improve performance in hot environments, future studies should investigate longer durations in which the cooling vest is applied for and perhaps applying cooling garments to other areas of the body.

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7.0 Appendices

Appendix A. Thermal Discomfort Scale by Gagge et al., (1967)

Thermal Discomfort How comfortable do you feel with the temperature of your whole body (or skin) region? 1 Comfortable 2 Slightly Uncomfortable 3 Uncomfortable 4 Very Uncomfortable 5 Extremely Uncomfortable

Appendix B. The Borg Rating of Perceived Exertion

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Appendix C. Blank Copy of Consent Form

School of Life, Sport and Social Sciences
Research Ethics and Governance Committee

Consent Form for Participation in Honours Project

The effects of wearing a cooling vest during an active warm up on a 10 Kilometre cycle

You are invited to participate in an honours project study conducted by Jack Rennison from Edinburgh Napier University. I hope to learn about the effects that wearing a cooling vest during an active warm up has on 10km cycling performance in heat.

You have been previously briefed on the full protocol and heard the risks that this project may encounter. You have also had had the opportunity to ask any questions you may have.
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Participant identities will be kept confidential by only saving their data on one memory stick.

Your participation is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty. If you do decide to withdraw from the study, all personal information collected up to this point will be destroyed.

If you have any further questions about the study, please feel free to contact me at 40056677@live.napier.ac.uk.

You will be offered a copy of this form to keep.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, and that you will receive a copy of this form.

Name of participant: ______________________________________

Signature of participant: ______________________________________

Signature of researcher: ___________________________________

Date: __________________