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Cardiff School of Sport
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Student name:	Rosie Tregear	***Student ID:***	St20018679
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Dissertation title:	The Effect of Cool (19ºC) and Neutral (24ºC) Room Recovery Temperature on Blood Pressure after Interval Exercise		
Supervisor:	Mike Hughes		

Comments	**Section**
	Title and Abstract (5%) Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review (25%) To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
	Methods and Research Design (15%) To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
	Results and Analysis (15%) [2] To include: description and justification of data treatment/ data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.
	Discussion and Conclusions (30%) [2] To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.
	Presentation (10%) To include: academic writing style; depth, scope and accuracy of referencing in the text and final reference list; clarity in organisation, formatting and visual presentation

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[2] There is scope within qualitative dissertations for the RESULTS and DISCUSSION sections to be presented as a combined section followed by an appropriate CONCLUSION. The mark distribution and criteria across these two sections should be aggregated in those circumstances.

CARDIFF METROPOLITAN UNIVERSITY

Prifysgol Fetropolitan Caerdydd

CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT AND EXERCISE SCIENCE

2014-5

The Effect of Cool (19ºC) and Neutral (24ºC) Room Recovery Temperature on Blood Pressure after Interval Exercise

(Dissertation submitted under the Physiology & Health area)

Rosie Tregear

St20018679

THE EFFECT OF COOL (19ºC) AND NEUTRAL (24ºC) ROOM RECOVERY TEMPERATURE ON BLOOD PRESSURE AFTER INTERVAL EXERCISE

Cardiff Metropolitan University

Prifysgol Fetropolitan Caerdydd

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Notes:

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ABSTRACT

The purpose of the present study was to examine whether blood pressure was influenced by a cool (19ºC) or a neutral (24ºC) recovery temperature after a bout of interval exercise. Participants were ten healthy active Cardiff Metropolitan University students (5 male) aged between 18 – 21 years. After a preliminary VO_2 max test participants completed 4 bouts of 4 minutes of exercise at 85% VO_2 max and 3 minutes at 50% VO_2 max after which participants, in a randomised order, sat in a temperature controlled laboratory for one of the two temperature conditions (19°C and 24°C) for a recovery period of 60 minutes.

Measurements of blood pressure, heart rate and body temperature were taken during recovery at ten minute intervals. Systolic blood pressure was found to decrease over the recovery time from baseline values with the cool condition showing larger differences, baseline 113.7 mmHg (± 10.4) to 109.05 (± 9.50) at 50 minutes, ($p = 0.74$). Diastolic blood pressure was significantly affected by temperature ($p \leq 0.02$) as the cool condition had lower values from baseline and also over the 50 minute recovery period, with the largest difference at 10 minutes (6.1 mmHg). Heart rate was shown to decline over the 50 minute recovery period for both temperature conditions (cool: 99.2 (± 14.3) to 77.3 (± 11.4) beats/min, neutral: 97.1 (± 15.0) to 84.9 (± 11.2) beats/min. Further analysis showed heart rate at the fifty minute measurement in the cool condition was significantly lower ($p \leq 0.02$) for both time and temperature. Body temperature measurements were higher than baseline but decreased over the recovery period, while time caused significant difference of ($p \leq 0.02$). These results indicate that recovery in a cool temperature would likely to have beneficial effects on blood pressure, however, this results appears to contradict previous research.

CHAPTER 1

INTRODUCTION

Cardiovascular disease (CVD) is the generic term for all diseases of the heart and circulatory system such as coronary heart disease, congenital heart disease, heart failure and strokes. It is known that these particular diseases have been increasing throughout the population over the years. The British Heart Foundation (2014) stated that in the United Kingdom in 2011 160,000 people died from CVD, while the predicted number of deaths caused by cardiovascular disease worldwide will have reached up to 23.3 million deaths by 2030 (Lanzinger *et al*., 2014; World Health Organisation, 2013). Of the many risk factors associated with CVD some are lifestyle dependent, such as smoking, obesity, physical inactivity, harmful use of alcohol and high cholesterol, while others are predetermined such as family history, age and ethnicity.

Lifestyle dependent factors are important to consider when regarding the risk of CVD, as they can be altered by the individual to lower the chances and possibility of developing the disease. The one treatable factor of CVD which focused on is hypertension, which is also known as high or raised blood pressure (BP), generally defined as ≥ 140/90 mmHg (Pescatello, Franklin, Fagard, Farquhar, Kelley & Ray 2004).

Blood pressure is spilt into systolic and diastolic pressures, where systolic is the first number and generally the higher of the two numbers, it measures the pressure in the arteries when the heart muscle contracts. Diastolic, on the other hand, measures the pressure in the arteries between heartbeats, when the heart muscle is at rest between beats and refilling. It is important to understand the fact that the higher the pressure in the heart and blood vessels, the harder it is for the heart to pump and oxygenate the body (World Health Organisation [WHO], 2014).

The relationship between CVD risk and BP is always present although the risk is less prevalent when BP is low. Therefore, due to the increasing number of people suffering with hypertension, it is important to achieve a decrease in hypertension in society. According to Semlitsch *et al*., (2013) BP and the occurrence of hypertension are lower in those who are physically active. Hence, this suggests that physical activity has a role in the reduction of hypertension and so to reduce hypertension it is beneficial to increase an individual's physical actively.

Due to the fact that lifestyle interventions, in this case increasing physical activity levels, have negligible side effects, minimal cost, and interact positively with other CVD risk factors, they have been recommended by the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (1997) and the European Society of Hypertension (2003). Whelton *et al*., (2002) stated that lifestyle interventions are more likely to succeed, and the absolute reduced risk of hypertension is greater, when those who are targeted are older and have a higher risk of developing hypertension. Whelton *et al*., (2002) also indicated that strategies to reduce the incidence of hypertension should be adopted early in life.

Researchers (Burns, Oo & Tran, 2012) have provided evidence that exercise does have an effect on lowering BP, therefore, supporting Semlitsch's *et al*., (2013) statement that by increasing hypertensive patients' physical activity or exercise levels can have significant benefits. Burns *et al*., (2012) found that acute bouts of exercise caused changes in BP up to 24 hours post intervention, which suggested that exercise can produce acute alterations in BP. This fact has also been reported by Lubkowska and Suska (2011) who found that after physical activity on a cycle ergometer a significant increase in systolic BP occurred in every participant (average of 70 mmHg). While diastolic BP showed variation in results with only an average of 6 mmHg.

Furthermore, research has progressed into investigating different types of exercise and it has typically been found that interval exercise, which incorporates an exercise period as well as a set time of recovery between exercise bouts, can produce similar physiological effects in both healthy and diseased populations to those caused by endurance training, particularly when interval exercise sessions are matched for work done (Gibala, Little, MacDonald & Hawley, 2012). For example, Burns *et al*., (2012) found systolic BP was significantly lower compared to a rested control group at 90 minutes post-exercise.

While considering which type, mode or intensity of exercise is most suitable for the treatment of hypertension consideration needs to be taken into account of an environmental factor which can have implications and effects on BP. This environmental factor is temperature. Brook, Weder and Rajagopalan, (2011) found short term variations in air temperature were linked to cardiovascular events where an increase in risk of cardiovascular problems was reported at both high and low temperatures. Correspondingly, not only does temperature have an effect on cardiovascular events but also BP responses. It is possible that high temperatures can cause a lower BP in individuals and several studies have reported an inverse effect between temperature of the environment and BP, in that a decrease in temperature causes an increase in BP (Halonen, Zanobetti, Sparrow, Vokonas & Schwartz, 2010; Madsen & Nafstad, 2006). This is an important consideration as practitioners, who are suggesting increasing the amount of physical activity as a treatment for hypertension, need to understand the impact and the effects that environment temperature has on their patients. Critically, exercising in high or low temperatures could have serious consequences for hypertensive patients particularly given their already high BP.

The increasing numbers of people suffering from hypertension and the health implications which accompany this condition needs to be addressed and practitioners need to be aware of the temperature of the environment on those undertaking physical activity as it has adverse effects on BP. Therefore, it is important to undertake further research on the effect of temperature has on BP.

Consequently, the objective of this study is to examine the effects of the recovery environment temperature on BP after interval exercise. The study will limit the research to recovery environments at room temperature and low temperatures due to the findings of Halonen *et al*., (2010) and Madsen and Nafstad (2006). However, from the research of Kenney and Seals (1993) which found that there are reductions in BP in both normotensive and hypertensive participants, this study will only use healthy participants to provide a starting point for identifying the potential benefits to hypertensive patients without the risk of causing harm to such patients should the research produce dramatic results.

CHAPTER 2

LITERATURE REVIEW

1.1 Hypertension

Hypertension is one risk factor which can be altered by lifestyle modifications to decrease the risk of developing the heart condition known as CVD. CVD is of increasing concern as the number of deaths from CVD is growing. The WHO (2013) stated that more individuals die yearly from CVD causing it to be the most common reason of death. There are several groups of diseases of the heart and blood vessels which fall under the name of CVD, these include: coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis and pulmonary embolism. These diseases have a number of risk factors which can be spilt into predetermined and behavioural risk factors. The most prominent behavioural risk factors of CVD include; physical inactivity, an unhealthy diet, tobacco use and harmful use of alcohol (NHS, 2014). It has been stated that these lifestyle behaviours account for 80% of CVDs (WHO, 2013). Another risk factor of CVD, which is linked with an increased occurrence of all types of CVD and CVD mortality, is high blood pressure, known as hypertension (Pestcatello *et al*., 2004).

Hypertension has been defined by WHO (2014) as continually high or raised BP above 140/90 mmHg, causing the blood vessels to be continuously under high pressure. Blood vessels carry blood from the heart to every body part and BP is produced due to the force of the blood pushing against the walls of the blood vessels. With high or raised BP there is always a potential of risk of CVD.

The NHS (2014) emphasises that the likelihood of an individual developing hypertension increases as they become older, which is supported by Pescatello *et al*., (2004) as these researchers suggested that an individual aged fifty five with normal BP had a 90% lifetime risk of developing hypertension. Although there is no clear single cause of high BP the chances are greater if the individual is overweight, smokes, is African or of Caribbean descent, has a family history of high blood pressure, poor diet of too much salt, not enough fruit and vegetables, high caffeine intake, drinks too much alcohol and is inactive (NHS, 2014).

In addition, the term pre-hypertension has been identified, defined as when systolic BP is between 120-139 mmHg and diastolic is in the range of 80-89 mmHg. The introduction of pre-hypertension is to emphasise the importance of lowering the general population's BP and so reduce the risk of hypertension, as worldwide 9.4 million (16.5%) deaths each year can be accredited to high BP (Pescatello *et al*., 2004; WHO, 2013). Even a small reduction of just 2 mmHg in diastolic BP has been linked to decrease of 17% in the occurrence of hypertension in the general population (Moreira, Lima, Silva and Simões, 2014). When BP is continuously over pre-hypertension levels the type of treatment that is considered is dependent on blood pressure level and the risk of developing CVD. For instance, a patient may be offered medication and/or advice on changing lifestyle habits such as, lowering the amount of salt intake, stopping smoking or increasing the amount of physical activity.

1.2 Post-Exercise Hypotension

Alterations to lifestyle behaviours are encouraged for the prevention, treatment and control of hypertension and increased exercise is a fundamental part of these recommendations (Pescatello *et al*., 2004). The use of exercise as a lifestyle intervention has been shown to be an effective form of treatment as there are minimal costs, there are minor negative side effects and correspondingly has positive interactions with other CVD risk factors, therefore making it an appropriate choice for reducing BP. Another significant consideration of the use of exercise is that several researchers (Burns *et al*., 2012; De Morais *et al*., 2014; Franklin, Green & Cable, 1993; Lubkowska & Suska, 2011; Pescatello *et al*., 2004) have found that after a bout of exercise BP was reduced further than pre-exercise levels. This is known as 'post-exercise hypotension' (PEH).

PEH can be defined as the occurrence of reduced BP to below pre-exercise levels and it occurs in both hypertensive and normotensive individuals (De Morais *et al*., 2014; Franklin *et al*, 1993; Pescatello *et al*, 2004). The precise mechanisms of the phenomenon PEH are unknown, although it has been suggested that there are neurohumoral, vascular and structural adaptations which could result in the occurrence of PEH (Pescatello *et al*., 2004). Other events which occur that could explain the reduction in BP after exercise is in terms of arterial BP being a function of the product of cardiac output and total peripheral resistance, so PEH could be the result of both or one of these factors decreasing (Kenney & Seals, 1993; McArdle, Katch & Katch, 2010). Another event causing a lowering of BP could be linked to the need of the body to dissipate the heat that is accumulated while exercising (Franklin *et al*., 1993).

Regardless of the mechanisms behind the cause of PEH it has been stated that BP reductions after exercise are greater for hypertensive individuals rather than normotensive individuals. Pescatello *et al*., (2004) found those with hypertension who participated in endurance exercise decreased their BP by in the region of 5-7 mmHg after either an isolated session of exercise (acute) or exercise training (chronic). It has also been found that the occurrence of PEH after a single bout of exercise has been reported to persist for up to 24 hours while long term exercise programmes have caused long term reductions in BP (Hecksteden, Grütters, & Meyer, 2013). This would suggest that PEH should be considered as a strategy to help control resting BP (Hecksteden *et al*., 2013; Sun *et al*., 2014). However, the acute responses of PEH are dependent on the intensity of the exercise an individual undertakes (Arazi, Asadi, Rahimzadeh & Moradkhani, 2013).

Therefore, the optimum training frequency, intensity, duration and type of activity needs to be investigated further to establish the most suitable exercise to achieve a decrease in BP, particularly for children, women, older adults and certain ethnic groups as there is little research (Pescatello, *et al*., 2004). As suggested by Fagard (2005), the most suitable way of identifying the optimum for a particular individual may be to use longitudinal studies to assess the interactions between the effects of physical activity and BP. One reason behind this is that Fagard (2005) found that alumni of a college who did not engage in vigorous after college sports were at a 35% increased risk of hypertension suggesting that a lack of strenuous exercise leads to a greater risk of hypertension.

2.1 Exercise Modes to Reduce Blood Pressure

The potential for exercise to be an effective treatment for hypertension has been considered in several populations. However, there is little information available on how the level and duration of PEH varies and the factors which affect it, such as; type of exercise, duration, intensity, initial BP and posture during recovery (Cléroux, Kouamé, Nadeau, Coulombe & Lacourciere, 1992; Coats, Conway, Isea, Pannarale, Sleight & Somers, 1989; Kenney & Seals, 1993; Sun *et al*., 2014). Despite this, there are a variety of exercise modes which are deemed to have the most beneficial effect of lowering BP. For example, Sun *et al*., (2014) suggested moderate intensity aerobic exercise promoted greater and longer reductions in BP than resistance exercise. Kenney and Seals (1993) also indicated that PEH was observed in several types of large-muscle dynamic exercise and also in submaximal intensities between 40% and 70% of maximal oxygen consumption. Whereas, Arazi, *et al.,* (2013) stated that resistance and endurance exercise were equally effective when compared to aerobic to alter resting arterial BP in hypertensive patients.

Nevertheless, the use of higher intensity aerobic exercise, including interval exercise needs to be examined in more detail.

2.2 Aerobic Exercise

The use of aerobic and interval exercise in relation to PEH have been examined throughout the literature with diverse findings. Aerobic exercise can be defined in terms of training which is used to enhance the aerobic contribution during exercise (McArdle *et al*., 2010). It has been suggested that exercise in general, as an intervention, is best for those patients in need of greater reductions in BP. As researchers (including Bhammer, Angadi & Gaesser, 2012; Franklin *et al*., 1993; Halliwill, Minson & Joyner, 2000; Kenney & Seals, 1993) have indicated, aerobic training and exercise with durations of between 3 to 10 minutes and up to as long as 170 minutes have led to reductions in BP for a period of several hours, which could, in part, be due to PEH, although the majority of exercise durations are between 20 – 60 minutes. For example, Pescatello, Fargo, Leach, and Scherzer, (1991) reported that light to moderate intensity aerobic exercise between 40-70% VO_2 max, which had a duration of 20 - 30 minutes, was adequate to produce PEH which persisted for up to 12.7 hours post exercise. Other research has stated that BP reductions can occur with exercise duration as little as 3 minutes and intensity as low as 40% VO_2 max and found reductions in BP of up to 22 hours after an endurance exercise bout (Pescatello *et al*., 2004). Many studies have found evidence that peak reductions after exercise have been systolic BP of between 18 to 20 mmHg and diastolic BP between 7 to 9 mmHg in hypertensive subjects while in normotensive subjects systolic in the range of 8 to 10 mmHg and diastolic 3 to 5 mmHg have been found (Cléroux *et al.,* 1992; Coats *et al.,* 1989; Kenney & Seals, 1993; Pescatello *et al*., 1991).

In contrast, according to several researchers (Kaufman, Hughson & Schaman, 1987; Kenney & Seals, 1993; Pescatello *et al*., 1991) there were no significant changes in BP in normotensive humans after a single bout of exercise. There have also been differences in post-exercise reductions between systolic but not diastolic BP in borderline hypertensive subjects (Kenney & Seals, 1993). These variations in findings between studies are most likely due to methodology differences such as duration of exercise, intensity being worked at, baseline levels of BP and the sample of population used. For example, the findings of Sun *et al*., (2014) support the evidence that different populations vary in BP responses and also that PEH is greater in those with an initial higher BP. Measurements were taken from Chinese and Caucasian participants at 30 and 60 minutes after 45 minutes of treadmill exercise at 70% of heart rate reserve (HRR) and it was found that significant reductions in systolic BP in both populations occurred after acute exercise, although reductions were more pronounced in the Caucasian group who had a higher baseline at the start. Even though BP was higher at baseline in the Caucasian participants Sun *et al*., (2014) stated that the elements of BP, that is, cardiac output and peripheral resistance, were not statistically different, which they suggested could be due to the higher changes in those variables compared to BP. Findings also showed that heart rate (HR) was elevated during recovery after exercise when compared to pre-exercise levels.

Interestingly, Malfatti and Ferreria (2010) found reductions in diastolic BP and also systolic during recovery phase after exercise of 75% HR max in both healthy and non-healthy male participants. The findings from this study again support the notion that variances in methodology between studies will cause differences in results, the use of which can make analysing the data across studies difficult, thus making it hard to understand which regime is best for lowering BP. For example, in the Malfatti and Ferreria (2010) only male participants were studied, suggesting the results can only be applied to males in those age ranges and with that particular disease in relation to the unhealthy population.

2.3 Interval Exercise

The type of exercise also appears to have a significant impact on the extent and duration of PEH as researchers have shown that continuous aerobic exercise can cause reductions in BP as well as interval exercise. Interval exercise can be defined in terms of repeated bouts of exercise with a brief recovery period which can differ from a few seconds to several minutes depending on the training outcome (McArdle *et al*., 2010). This recovery period can be either active, where the participant exercises at a lower intensity, or passive where no exercise occurs. Participants then repeat the high intensity exercise and the recovery period for a set duration of time. For example, in the Burns *et al*., (2012) study their subjects performed two 30 second high intensity sprint exercises which were separated by 4 minutes of recovery. Interval exercise has been reported to be more enjoyable than prolonged low intensity exercise (Gibala *et al*., 2012), and with this type of exercise there have been benefits of increased cardiorespiratory fitness in a range of populations including those with diseases such as CVDs, coronary heart disease, congestive heart failure and obese individuals (Warburton *et al*., 2005; Wisløff *et al*., 2007).

Interval exercise has also shown alterations in different components of resting BP (Rognmo Hetland, Helgerud, Hoff & Slørdahl, 2004; Schjereve *et al*., 2008; Whyte, Gill & Cathcart, 2010). The use of low volume interval exercise can be seen as a time efficient method of training for producing central cardiovascular and peripheral skeletal muscle variations which are associated with enhanced health outcomes (Gibala *et al*., 2012).

In the Burns *et al*., (2012) study the researchers examined the effect of sprint interval exercise on several physiological functions including; post-exercise oxygen consumption, respiratory exchange ratio (RER), substrate oxidation and blood pressure in their population sample of adolescents. The results found that systolic BP was significantly lower than the resting control group at 90 minutes post-exercise. However, Burns *et al*., (2012) noted that sprint interval exercise was able to produce short-lived BP changes and these results may also be seen in those who are considered to have optimum BP levels. Positives in terms of methodology from this experiment include that the researchers used a randomised procedure for the two groups and also had a control group, although the study lacked ecological validity as it was completed in a laboratory and only used two sprints which are not realistic in terms of exercising as the number of sprints was low.

During the recovery period within an interval exercise, and likewise once exercise has been completed, BP responses can be influenced by the exercise intensity. Arazi *et al*., (2013) stated there is a possibility that different exercise intensities can have contrasting effects on PEH. Various forms of interval exercise have also been found to produce similar results by reducing BP. For instance, Bhammar *et al*., (2012) conducted a study to examine the effects of both fractionised (three 10 minute exercise sessions) and continuous (one 30-minutes session) aerobic exercise on 24 hour BP. The main findings were that only fractionised exercise, which was performed as three sessions throughout the day, reduced 24 hour systolic BP and that either fractionised or continuous exercise have an effect on diastolic BP. These findings support a similar earlier study by Angadi *et al*., (2010) who established that fractionised exercise was more beneficial than continuous exercise in relation to PEH in normotensive individuals and therefore suggested that short exercise sessions could be a more suitable strategy for those individuals with high BP or even to help control pre-hypertension. However, a limitation of this study was that it was confined to a clinical research centre and therefore would not be applicable to free living conditions with individuals who have high BP. Hence these findings propose an alternative and effective form of exercise to the more traditional continuous and endurance based exercises. The literature has also examined the effect of other training methods such as resistance exercise (Neto, Sousa, Costa, Salles, Navaes & Novaes, 2014), circuit sessions (Moreira *et al*., 2014) and plyometric exercises (Arazi *et al*., 2013) on BP and found that all three training methods produced PEH.

3.1 Temperature Effects on Blood Pressure

It is clear that various types of exercise can cause reductions in BP and produce PEH in individuals. Nevertheless, another consideration which needs to be addressed by health care providers is the need to be aware of the significant effect of the environment, (i.e. high and low temperatures), on altering BP and which can raise public health concerns (Brook *et al*., 2011; Chen *et al*., 2013; Gómez-Acebo, Llorca, & Dierssen, 2013).
Quindry *et al*., (2013) stated that during cool environment exercise core temperature can elevate by several degrees and thus identified that the impact of the temperature of the environment on exercise, needs further researching. Numerous studies have examined the effects of temperature on BP (see Table 1.). One way of investigating the effect of temperature on individuals exercising and which has been utilised in several studies (Gayda *et al*., 2012; Imamura *et al*., 2001; Kihara *et al*., 2002; Miyamoto *et al*., 2005) is to use saunas to examine the effects of heat on BP. In healthy young people there are cardiovascular responses to saunas which include changes in HR, cardiac output and peripheral vascular vasodilation. However, in relation to BP there have been conflicting findings of either no change, decrease or increase in normotensive individuals as a result of high temperatures (Hannuksela & Ellahham, 2001).

3.2 Effects of Heat

On the other hand there have been beneficial outcomes in patients with chronic heart failure and coronary risk factors who have taken part in two week repeated sauna sessions which have demonstrated a reduction in systolic BP. Also, repeated sauna therapy has resulted in a decrease of BP in hypertensive patients (Imamura *et al*., 2001; Kihara *et al*., 2002; Miyamoto *et al*., 2005). However, these studies have limitations in that there was no control group and the patients' criteria were not clearly defined. If BP responses are affected by temperature then this may also be the case for PEH. A study on less extreme temperatures (Franklin *et al*., 1993) examined the effects of BP in three recovery temperature conditions, neutral (21.4 ± 0.5 °C), warm (31.1 ± 0.4°C), and cool (17 ± 0.8 °C) and found that there were differences for HR measurements in the warm and cold environments in terms of a linear time to treatment interaction effect, this means that there was a decrease over time as well as the treatment, in this case temperature having an effect. For instance, in the warm condition, HR was slower to decrease than in the cool condition (Fig. 1). Measurements of BP in relation to baseline found that systolic BP was significantly lower (115.4 ± 2.7 versus 121.9 ± 3.3 mmHg) at 60 minutes recovery in the warm condition. For diastolic BP there were no significant differences amongst any of the three recovery conditions relative to baseline. In addition, during the post-exercise period there were no significant differences between any conditions for systolic, however, in regards to diastolic BP this was significantly lower in the warm condition. Hence, these results suggest that after exercise with the temperature gradient between core and skin temperature manipulated, there is an influence on post-exercise BP. For example, in cool recovery temperatures there is a faster decrease of core and skin temperatures which could diminish the hypotensive effects caused by exercise. Hence, the Franklin *et al*., (1993) results indicate that thermoregulatory mechanisms do indeed affect the prevalence of peripheral vasodilatation which leads to hypotension during recovery from exercise. Despite these findings there is a concern that the BP responses caused by the three temperature conditions were not independent of the exercise due to there being no control group. Consequently, measurements should be taken at baseline, after exercise and throughout the recovery periods.

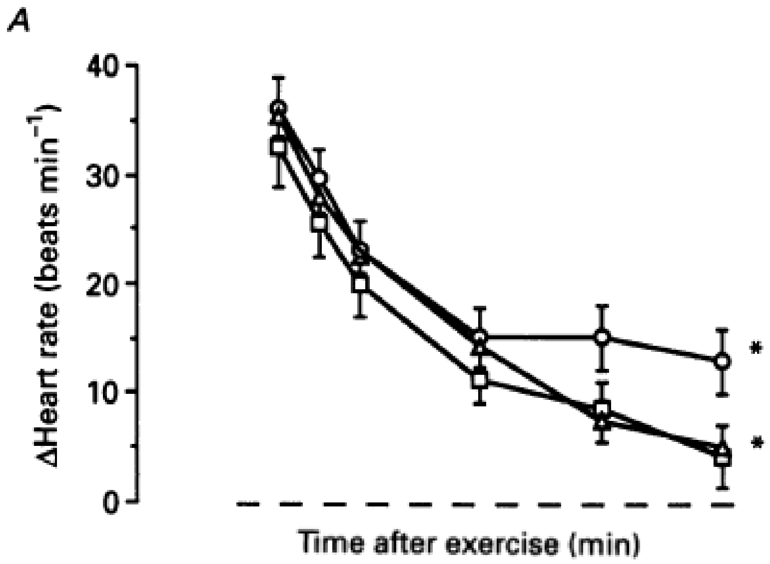

Figure 1. Changes in heart rate relative to pre-exercise baseline values (dashed line) under the neutral (□), cool (△) and warm (○) recovery conditions. Results are expressed as means ± S.E.M. *P < 0 05 for Student's t test between baseline and 60 min post-exercise values (Franklin *et al*., 1993).

3.3 Effects of Cold

There is evidence that supports the notion that colder ambient temperatures can lead to higher levels of BP both acutely (1-7 days) but also chronically (between seasons) thus helping to explain why mortality of CVDs and higher reports of BP increase during cold seasons (Brook *et al*., 2011; Chen *et al*., 2013; Hong *et al*., 2012; Madsen & Nafstad, 2006). This seasonal mortality has been acknowledged since 1960 (Kunst, Looman & Mackenbach, 1993) and could be due to one or more cardiovascular risk factors, which are related to temperature variations (Schneider *et al*., 2008). Hong *et al*., (2012) found evidence that ambient temperature had an inverse association with BP with high levels of BP being found during winter. Exposure to the cold stimulates an increase in sympathetic activity which causes vasoconstriction and directs blood to central circulation, thereby increasing BP (Youn *et al*., 2007). This has been supported by Komulainen, Oja, Rintamäki, Virokannas, and Keinänen-Kiukaanniem (2004) who reported an increase of 30/20 mmHg in BP, a decrease in HR by 12 beats per minutes and also reported that BP reacted within three minutes to changes in ambient temperature. Consequently, it is important to examine further and gain a better understanding of the effect of cold temperatures on BP after exercise due to it being a risk factor for hypertension, in not only people with cardiac diseases, but also for healthy individuals who are frequently exposed to cold environments as there is likely to be a larger load on the heart (Hong *et al*., 2012; Lubkowska & Suska, 2011; Schneider *et al*., 2008; Westerlund, Smolander, Uusitalo-Koskinen, & Mikkelsson, 2004).

Therefore, based on the published research, the effect of cold temperatures on BP after exercise needs to be explored further, as the health implications may be serious for patients who are increasing their physical activity as a form of intervention to reduce hypertension. One form of exercise which produces PEH in participants and is a more enjoyable form of exercise (Gibala *et al*., 2013), is interval exercise, this seems an appropriate form of exercise to use for examining the effects of temperature on PEH.

Table 1. Brief descriptions of several studies which show the effects of temperatures on blood pressure

Study	Subjects	Procedure	Measurements	Findings*	Conclusions
Franklin et al., (1993)	11 healthy M	VO_2 max test 3 x 30 min on EM at 70% VO_2 max 60 min randomized recovery at NT, WT & CT	BP, CT, ST, HR & OC	BP ↓ WT HR ↑ in HT & CT PE VO_2 max ↑ NT CT ↑ in WT & PE ST ↑ PE in WT & ↓ in CT	PEH in WT recovery PE BP influenced by CT and ST
Gayda et al., (2012)	16 untreated H patients	3 conditions resting control, sauna session & exercise & sauna intervention	BP, HR, CO, SV, VE, EV, TVR	BP ↓ in exercise sauna condition CO ↑ in sauna & exercise sauna	Ex followed by sauna had positive effects on short term BP
Chen et al., (2013)	1831 H patients	Longitudinal study 3 year follow up	AT, BP	AT associated with BP	BP negatively associated with AT
Lubkowska & Suska (2011)	40 healthy M	VO_2 max test 3 min in cryogenic chamber (-130°C)	BP, HR	↑ BP after 3 min whole body cryostimulation ↑ BP after exercise on EM	Cold exposure is risk factor for hypertension
Quindry et al, (2013)	12 M	VO_2 max test Randomised 3 temperature exercise trails CT, RT & WT at 60% VO_2 max for 60 min	CT, Blood samples	In recovery WT caused ↑ CT ↑ plasma in WT	Hyperthermia & oxidative stress physiologic response to exercise ↑ CT causes ↑ in BP

Key: M = male, F = female, H= hypertensive, EM = ergometer, NT = neutral temperature, WT = warm temperature, CT = cool temperature, RT = room temperature, BP = blood pressure, CT = core temperature, ST = skin temperature, HR = heart rate, OC = oxygen consumption, CO = cardiac output, SV = stroke volume, VE = ventricular ejection, EV = end-diastolic volume, TVR = total vascular resistance, AT = ambient temperature, * = significant differences, ↓ = decrease, ↑ = increase, PE = post-exercise, PEH = post-exercise hypotension.

CHAPTER 3

METHODS

1.1 *Subjects*

Ten healthy participants (five male, five female) from Cardiff Metropolitan University volunteered to take part in the study. All subjects were healthy active sport students and were normotensive in relation to their blood pressure. Each subject was given an information sheet (Appendix A), gave written informed consent (Appendix B) to the procedures and filled in a Par-Q (Appendix C) along with a test preparation questionnaire (Appendix D) before each protocol. Ethical Approval was accepted by the School Research Ethics Committee (Appendix E).

Table 2. Anthropometric Characteristics of Participants (mean ± standard deviations [S.D.])

Characteristic	
Age (years)	19.9 ± 0.7
Height (cm)	171.7 ± 7.8
Mass (kg)	76.2 ± 12.0
Resting SBP (mmHg)	113.9 ± 9.7
Resting DBP (mmHg)	66.5 ± 5.3
Resting Heart Rate (beats per min)	77.5 ± 9.0
Resting Body Temperature (ºC)	35.8 ± 0.7
VO_2 max (ml/kg/min)	38.8 ± 8.2

2. *Procedure*

Subjects were asked to attend three laboratory sessions, the first being a preliminary test to determine VO_2 max followed by two sessions where the environment temperature was controlled (19°C and 24°C). Before testing subjects were asked not to take caffeinated (3 hours before) and alcoholic (24 hours before) drinks and it was suggested they should eat at least three hours before each session. Body mass and height were collected at each session using digital scales (SECA-Model 770, Vogel & Halke, Hamberg, Germany) and a stadiometer (Holtain Fixed Stadiometer, Pembs, UK).

2.1 ***Preliminary Test.*** The first session determined each subject's maximum aerobic power (VO_2 max). Participants were seated on a LODE ergometer (Excalibur Sport, Groningen, The Netherlands), and started at a set power output (females: untrained 0 watts (W), trained 25 W, males: untrained 25 W, trained 50 W) which then increased by 25 W every 3 minutes until exhaustion. Subjects were given verbal encouragement throughout the test.

Expired gas was collected throughout using a breath by breath system (Oxycon Pro / Oxycon Mobile, Warwick, England) and an electronic gas analysis system (Servomex Gas Analyser, 1440C, East Sussex, England). To determine that participants had reached VO_2 max their heart rate (HR) was observed throughout the test and at exhaustion to ensure that it was near maximum HR.

Once completed participants were asked to cool down until they wanted to stop.

2.2. ***Calculating Intensities.*** The VO_2 max data for each participant was saved with data points at every 30 seconds which was then copied into an Excel spreadsheet. For the last minute of each power output stage averages were calculated for VO_2 (ml/min). This value was then used to determine each %VO_2 max at each power output stage (100 x [average of last minute of VO_2 in each stage/highest value of VO_2]). A line graph was produced with power output on the x axis and % VO_2 max on the y axis. By using the equation $y = mx + C$, the gradient of the line was calculated to determine what power output each participant should be working at, for example at 30%, 50% and 85% of their VO_2 max.

2.3 ***Experimental Protocol.*** The two experimental sessions used an identical testing protocol. After height and mass were taken baseline levels of blood pressure (BP), heart rate (HR) and body temperature (BT) were recorded when participants first arrived. Participants then completed a 2 minute warm up at 30% of their VO_2 max. To ensure that participants were not exercising in the two temperature conditions the LODE ergometer was moved to a different room.

After the warm up subjects performed a bout of interval exercise for 28 minutes which consisted of 4 bouts of 4 minutes at 85% VO_2 max and 3 minutes at 50% VO_2 max. Both the warm up and interval exercise were completed using the same LODE ergometer which was used for the preliminary test.

Water intake was controlled during the study by giving participants 3ml of water per kg of their body mass at 0, 16 and 28 minutes of exercise.

After completing the interval exercise participants were seated and remained quiet in a temperature controlled laboratory for one of two conditions (19°C and 24°C) for a recovery period of 60 minutes. A standard mercury thermometer was used to measure the laboratory temperature.

During the recovery period participant's BP, HR and BT were all recorded every 10 minutes.

Following the recording of the 50 minute measurements participants then performed a light period of exercise on the same cycle ergometer for 8 minutes at 30% VO_2 max. Once this final exercise was completed measurements of participant's BP, HR and BT were recorded at 60 minutes into the recovery period and when once again seated.

The order of the two conditions was randomised and protocols were conducted at least 48 hours apart.

3. *Measurements*

3.1 *Blood Pressure.* Blood pressure, both diastolic and systolic were measured using a manual blood pressure monitor (Yamasu, Tokyo, Japan) and stethoscope with the cuff being placed over the brachial artery on the left arm with two recordings being taken so that an average could be calculated in order to improve precision. For each reading participants were seated with the left arm resting on a table. For each given participant one investigator took each collection of blood pressure values for all conditions.

3.2 *Heart Rate.* HR was measured with a heart rate monitor (Polar Electro. S610i, Kemple, Finland) this was placed on the subject's chest with the monitor watch being placed on the preferred wrist.

3.3 *Body Temperature.* Body temperature measurements were taken by a hand held electronic spirometer (Micro Medical Ltd, Kent, England) in the same ear throughout the experiment.

3.4 *Oxygen Consumption.* Expired gases were collected throughout the preliminary test for VO_2 max but not for the experimental protocol. This was collected using a breath by breath system (Oxycon Pro / Oxycon Mobile, Warwick, England) and an electronic gas analysis system (Servomex Gas Analyser, 1440C, East

Sussex, England) which was first calibrated to the surrounding humidity, temperature and barometric pressure as well as the breath by breath system before testing.

4. Statistical Analysis

The results are expressed as means (± S.D.) for both general characteristics and the results. The differences between each condition (i.e 'cool' environment temperature at 19ºC and 'neutral' environment temperature at 24ºC) were calculated using a two-way ANOVA (repeated measures) for each measurement with SBP and DBP being separate. If sphericity was below 0.05 then Huynh-Feldt correlation is applied for that analysis. Further syntax analysis was used to identify where the significant differences occurred between the two temperature conditions.

CHAPTER 4

RESULTS

1. *Pre-Exercise Resting Variables*

There were no significant differences ($p > 0.05$) between the two temperature conditions for the baseline measurement values of SBP, DBP, HR and BT (Table 3.).

2. *Blood Pressure*

2.1 SBP

After 50 minutes of recovery SBP showed slightly higher values for the neutral (24ºC) than the cool (19ºC) temperature. Although, there were no significant differences between the two conditions, there was a negative trend, meaning that values generally decreased over time in relation to both temperature conditions ($p = 0.06$) (Figure 2.).

Comparing the baseline values for SBP against each ten minute recovery period showed that there were no significant differences ($p > 0.05$) between time and temperature (Table 3.).

2.2 DBP

The results showed that DBP in the cool condition were lower than the neutral condition (Figure 2.). Results also showed that temperature alone produced significant results ($p \leq 0.02$), although both the effects of temperature and time had no significant impact on DBP.

Comparing baseline values against each recovery value for DBP showed that there were no significant differences ($p > 0.05$) between time and temperature.

Table 3. Averages (mean ± standard deviation [S.D.] of the differences between the baseline value and each 10 minute recovery value for SBP, DBP, HR and BT during the 'Cool' (19 ºC) and 'Neutral' (24 ºC) temperature condition (- numbers indicate an increase from baseline value)

	SBP		DBP		HR		BT	
	Cool	Neutral	Cool	Neutral	Cool	Neutral	Cool	Neutral
Baseline Value	113.7 ± 10.4	114.1 ± 12.1	65.0 ± 7.0	68.0 ± 6.4	76.7 ± 12.2	78.3 ± 10.7	35.7 ± 0.8	35.9 ± 0.8
10	0.9 ± 9.5	2.3 ± 7.7	-1.0 ± 8.0	-4.2 ± 7.5	-22.5 ± 9.8	-18.8 ± 11.1	-0.5 ± 0.7	-0.5 ± 0.7
20	2.0 ± 8.4	5.4 ± 9.3	-0.7 ± 8.3	-1.3 ± 9.0	-15.1 ± 8.9	-12.5 ± 9.8	-0.4 ± 0.7	-0.5 ± 0.7
30	5.4 ± 6.8	3.2 ± 7.8	-0.2 ± 7.7	-2.5 ± 7.9	-10.3 ± 7.8	-9.2 ± 9.1	-0.3 ± 0.6	-0.5 ± 0.8
40	6.2 ± 6.1	5.2 ± 6.3	-1.0 ± 7.8	-1.2 ± 5.1	-6.4 ± 7.5	-7.4 ± 9.0	-0.1 ± 0.7	-0.5 ± 0.8
50	4.6 ± 8.1	4.0 ± 7.5	0.3 ± 7.2	-1.0 ± 6.3	-0.6 ± 10.0	-6.6 ± 6.6	-0.1 ± 0.7	-0.4 ± 0.9

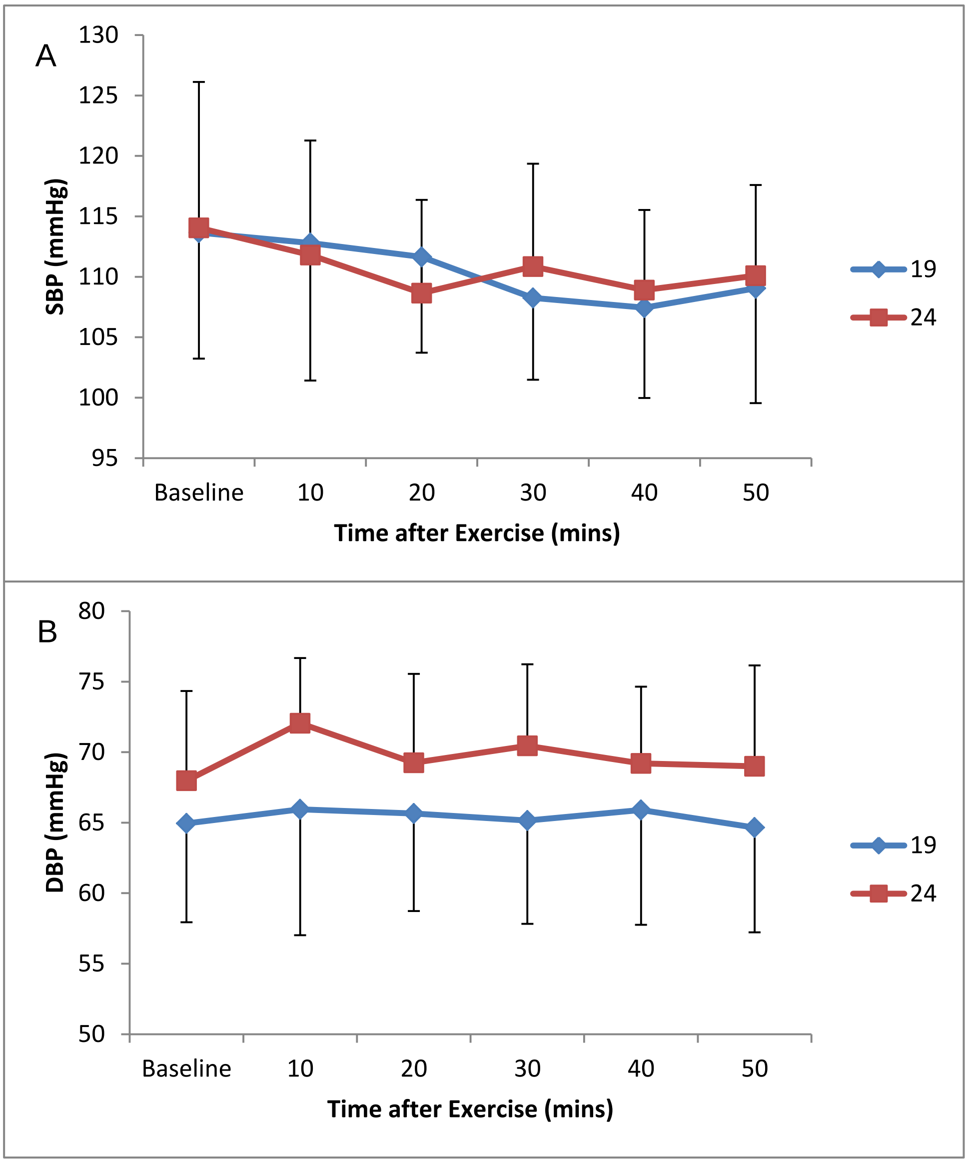

Figure 2. Systolic (SBP) (A) and diastolic (DBP) (B) blood pressures over time after exercise (minutes) under cool (triangle) and neutral (square) temperature conditions with standard deviation errors bars.

3. Heart Rate

HR measurements over the 50 minute recovery period for both temperature conditions declined over time (Figure 3.). The results showed that time had a significant effect on the recovery HR values with a significant difference of ($p = 0.00$) and that the effect of time and temperature also had a significant ($p \leq 0.01$). Further analysis showed that only at 50 minutes there was a significant difference ($p \leq 0.02$) between the cool and neutral temperature conditions on HR, with the cool condition values being considerably lower than the neutral condition. Comparing the baseline values to each 10 minute recovery time showed that there was a significant difference ($p = 0.00$) of time alone on the HR. There was also a main effect of time and climate on the differences from baseline to each 10 minute recovery HR value ($p \leq 0.01$). However, further analysis resulted in no significant difference.

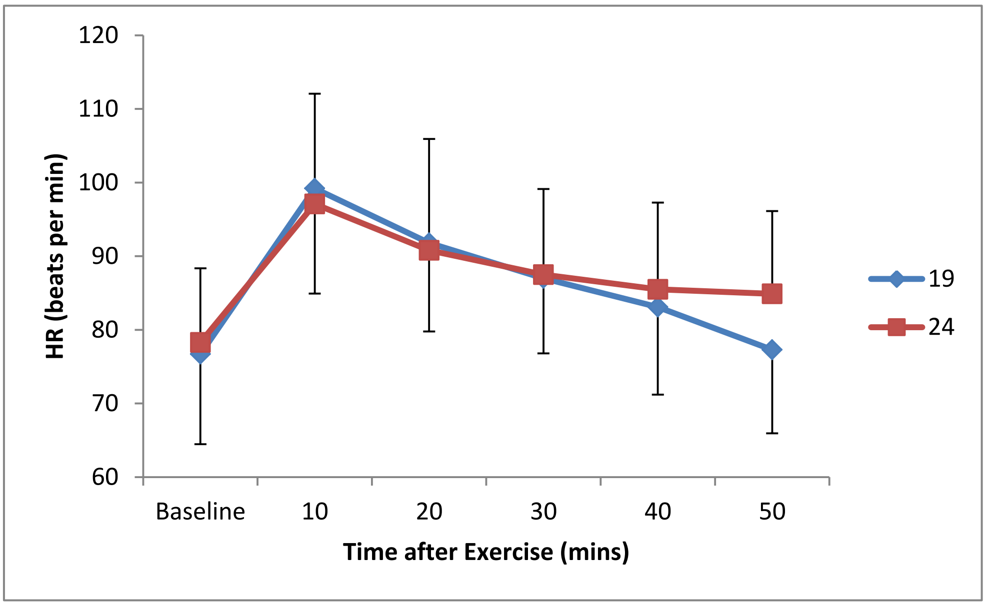

Figure 3. HR (beats per min) over time after exercise (minutes) under cool 19ºC (triangle) and neutral 24ºC (square) temperature conditions with ± S.D. error bars.

4. Body Temperature

Body temperature remained fairly constant for the neutral (24ºC) condition whereas for the cool (19ºC) condition body temperature decreased slowly which was generally not significant ($p > 0.05$) (Figure 4.). Temperature and time showed no significant effects, whereas time had an effect on BT with a significant difference of ($p \leq 0.02$).

Comparing baseline values against each 10 minute recovery time showed that time again had a significant impact on BT ($p \leq 0.02$). The results indicated that the interaction of time and temperature was not significant ($p = 0.095$).

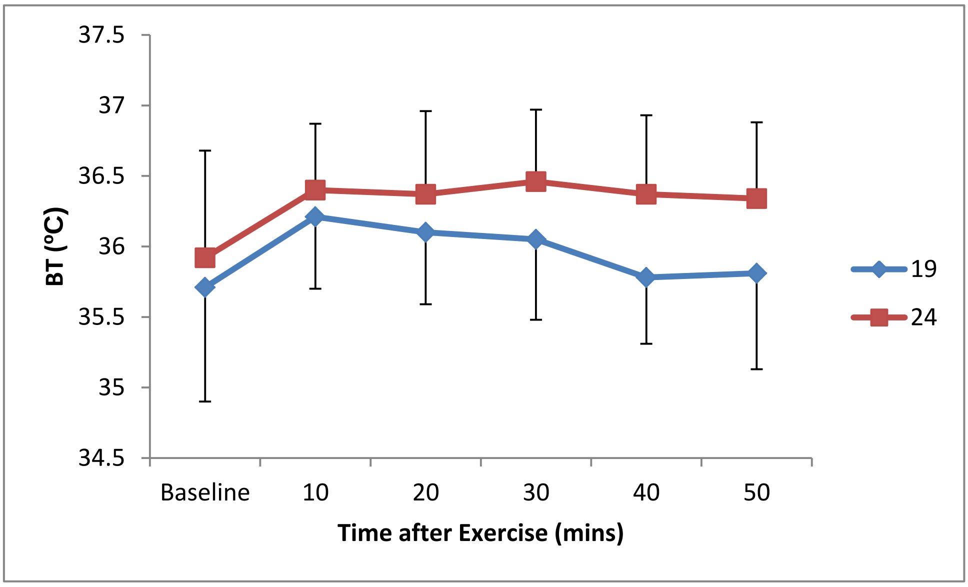

Figure 4. BT (ºC) over time after exercise (minutes) under cool 19ºC (triangle) and neutral 24ºC (square) temperature conditions with ± S.D. error bars.

CHAPTER 5

DISCUSSION

1. Previous Research

Previous research examining the effects of exercise on blood pressure has shown contradictory results. Similar to this study, Stuckey *et al.,* (2012) found no significant reduction in SBP two hours after participants performed one or four thirty second sprints on an ergometer. Whereas, one study found reduced arterial stiffness, aortic and brachial systolic and diastolic BP 60 minutes after sprint interval exercise (Rossow *et al.,* 2010). Another study found significantly reduced SBP and DBP two hours after exercise (Chan & Burns, 2013); and Lacombe, Goodman, Spragg, Liu, and Thomas (2011) found that there was a reduction in SBP of 15 mmHg in borderline hypertensive individuals with mean reductions of 4 mmHg over 60 minutes, which was actually considered to be a low reduction.

PEH has been documented in borderline hypertensive, hypertensive and normotensive individuals (De Morais *et al*., 2014; Franklin *et al*, 1993; Pescatello *et al*, 2004). However, MacDonald (2002) stated the incidence of PEH in normotensive individuals was inconsistent, which may explain why the present study did not show a large significant decrease in BP, (largest decrease of 3.7 mmHg), due to the use of normotensive participants rather than hypertensive. This appears to be supported by other studies where reductions in BP were found to be greater for hypertensive individuals than normotensive after exercise (MacDonald, 2002; Pescatello *et al.,* 2004).

As well as considering the effects of exercise on BP, the main focus of the study was to examine whether the environment temperature had an impact on BP. Studies have also identified an influence of lower ambient temperatures being associated with a rise in systolic and diastolic BP (Argilés, Mourad & Mion, 1998; Gómez-Acebo *et al.,* 2013; Hong *et al.,* 2012; Jansen, Leineweber & Thien, 2001; Schneider *et al.,* 2008). It has also been stated that changes in ambient temperature can cause alterations in BP in a period of just three minutes (Komulainen *et al.,* 2004). It was also found that whole body cold exposure (-15ºC), even with suitable clothing, resulted in a dramatic rise in BP (SBP 28-34 mmHg & DBP 20-22 mmHg) in those who were mildly hypertensive (Komulainen *et al.,* (2004). The same study showed that HR decreased by 2-7 beats/min during cold exposure. These results support the hypothesis that cold environments cause BP to increase. However, the results from the present study suggest the cool temperature effects on SBP were not significantly different from those in the neutral temperature, and in regards to DBP the measurements were lower during the cool recovery temperature in comparison to the neutral condition. Although, the cool temperature was not as low as -15ºC and could be considered not cold enough for a 'cool' temperature, consequently, different results may have occurred if a lower temperature had been adopted for the study.

A key issue of concern which makes comparisons of the various studies examining BP difficult is the variability of methodology. Past research has used a variety of techniques, for instance, ambient temperature (Chen *et al.,* 2013; Hong *et al.,* 2012), water baths (Hildenbrand, Barbosa-Leiker & Melchioor, 2012), saunas (Gayda *et al.,* 2012) or even cryotherapy (Komulainen *et al.,* 2004) as the mechanism of controlling temperature to allow observation of the changes on BP and other cardiovascular parameters. There is also limited research examining the effects of temperature on BP after interval exercise, and as a consequence, this suggests that the present study contributes to new knowledge in the area.

One study similar to the present study was undertaken by Franklin *et al.,* (1993), when the influence of thermoregulatory mechanisms on post-exercise hypotension in healthy males was examined. However, one main difference between the studies is that the exercise in the study by Franklin *et al.,* (1993) study was 30 minutes of 70% of the participants VO_2 max, whereas, the present study used interval exercise of 4 bouts of 4 minutes at 85% VO_2 max and 3 minutes at 50% VO_2 max. This is therefore an issue when comparing studies because Arazi *et al*., (2013) stated that different intensities of exercise can cause different responses on BP. This is supported by the literature which has shown that continuous and interval exercise affects BP in different ways (Bhammer *et al.,* 2012; Burns *et al.,* 2012; Halliwill *et al.,* 2000; Kenny & Seals, 1993; Rognmo *et al.,* 2004; Whyte *et al.,* 2010). This may also explain why there are different findings between Franklin *et al.,* (1993) and the present study.

Franklin *et al.,* (1993) measured BP, core temperature, skin temperature, HR and oxygen consumption and used three temperature conditions, neutral (21.4ºC), warm (31.1ºC) and cool (17ºC). Results from the Franklin *et al.,* (1993) study found that during the post-exercise period there were no significant differences for any of the three conditions for SBP, which is the same as the results of the present study. DBP was significantly lower during the post-exercise recovery for the warm condition in Franklin *et al.,* (1993) study compared to neutral and cool temperatures, whereas, in the present study, it was found that DBP was generally lower during the cool recovery although the effect of temperature and time produced no significant difference on DBP.

The results of the Franklin *et al.,* (1993) study found that there were no differences between temperature conditions on HR which is in contrast to the results of the present study, as the results indicated that time alone, as well as the interaction of time and temperature, produced significant differences with the cool condition being lower than the neutral condition ($p \leq 0.01$).

As expected, the results from both studies indicated that body temperature was higher in the warmer condition and in the present study time was a significant factor on body temperature ($p \leq 0.02$) as BT decreased over time. The temperatures used in both studies were similar with the largest difference being approximately 3ºC; although differences in temperatures would contribute to dissimilar results it is unlikely that the small difference between the studies caused the various differences in the result outcomes. Other explanations for differences in results between the two studies may be due to Franklin *et al.,* (1993) only using male participants meaning that there may have been a bias with the results and generalisation may be limited, whereas, the present study used an equal number of males and females. However, MacDonald (2002) suggested that there were not any gender differences for PEH.

2. Findings

2.1 Blood Pressure

SBP reduces for several hours after exercise (Bhammar *et al.,* 2012; Burns *et al*., 2012). The findings of the present study suggested that PEH does occur for SBP after interval exercise in both the cool and neutral temperature conditions due to the fact that the mean baseline value was higher than all of the ten minute values over the fifty minutes of recovery. Although, the reduction of BP would probably not be seen for a long period of time as there was not a dramatic decrease in SBP.

There was no significant difference for SBP between the two temperature conditions ($p = 0.07$), although SBP did decrease over the recovery period with the largest difference of 5.3 mmHg for the cool condition and 3.1 mmHg for the neutral condition. However, this hypothesis conflicts and is inconsistent with previous research which indicated that a colder environment caused BP to rise (Hong *et al*., 2012; Schneider *et al*., 2008). The results of the present study do not support the previous research as there BP did not rise during the cool temperature condition. The results from the present study equally conflict with the hypothesis that an increase in BP is due to an increase in sympathetic nervous system activity and peripheral vasoconstriction which then directs blood to the central circulatory system due to cold exposure (Komulainen *et al.,* 2004; Youn *et al.,* 2007). MacDonald (2002) also indicated that an increase in cardiac output and vasoconstriction increased SBP but vasodilation due to exercise in the working muscle could cause a buffer effect and so produce a small increase in DBP. This could clarify why the present study saw no reduction in DBP which was found to stay reasonably consistent over the recovery period. A possible reason why the results of the present study are not similar to previous research may be due to the cool temperature not being sufficiently low compared to the neutral condition as the difference was only 5ºC. Therefore, for any further studies it is suggested that the temperature difference should be greater. For instance, Gayda *et al.,* (2012) used sauna temperatures between 85-90ºC and Komulainen *et al.,* (2004) had a temperature of -15ºC.

2.2 Heart Rate

MacDonald (2002) stated that after exercise the mechanisms that lie behind a sustained decrease in BP in hypertensive individuals are due to a drop in resting HR and a decrease in circulatory catecholamines (e.g. adrenaline, noradrenaline and dopamine) which are associated with a decrease in sympathetic nerve activity. BP can remain fairly constant due to vasodilation in the arteries even though there is an increase in HR (McArdle *et al.,* 2010).

In the present study after the first ten minutes of recovery HR was higher than baseline with the cool condition having an increase of 23 beats/min and the neutral condition of 19 beats/min, which is consistent with the fact that after exercise HR increases due to the demand of the working muscles needing more oxygen due to the demand of energy expenditure. Overall, HR declined over the fifty minute recovery period for both temperature conditions. After the fifty minutes of recovery HR had still not recovered to baseline levels which could be due to excess post-exercise oxygen consumption, as oxygen is still needed to be pumped around the body in order to restore glycogen stores and to remove the accumulation of lactate acid (McArdle *et al.,* 2010).

The results also showed that at the fifty minute time period in the cool condition HR was closer to the baseline value than the neutral condition. At this time point there was also a significant difference of both time and temperature ($p \leq 0.02$) as the cool condition value was considerably lower than the neutral condition. Overall time ($p = 0.00$) and the interaction of time and temperature ($p \leq 0.01$) had a significant effect on HR. This indicates that environment temperature does have an effect on HR and that a cooler environment can increase the rate of HR recovery.

2.3 Body Temperature

Body temperature was measured to determine whether the intervention of the two temperature conditions caused the differences in results rather than the interval exercise or time. Due to the BT differences between the two temperature conditions not being significant this could suggest that the intervention had limited impact on the result measurements.

Research reports that the mechanisms that control thermoregulation after exercise could contribute to PEH. Exercise causes various alterations in the body, such as an increase in body and skin temperature, which, in turn, changes peripheral blood flow to regulate heat output and also decreases systemic vascular resistance (Cheung, McLellan & Tenaglia, 2000). MacDonald (2002) stated that the main mechanism of heat loss is cutaneous vasodilation and that this redistribution of blood flow to the periphery could cause PEH. However, analysing this further indicates that these alterations can decrease arterial BP due to a decrease in thoracic blood volume, central venous pressure, stroke volume and cardiac output thus producing PEH (Chen & Bonham, 2010; Kenney & Seals, 1993).

Franklin *et al.,* (1993) supports the theory that cutaneous vasodilation mediates PEH due to their results showing that only the warm condition produced hypotension in the participants. However, MacDonald (2002) suggested that this was probably due to a different phenomenon, suggesting that due to the differences in PEH responses for the normotensive participants and that following exercise the body's heat dissipation would have most likely returned to normal. Therefore, MacDonald (2002) suggested that cutaneous vasodilation was an unlikely primary mechanism which contributed to PEH in the Franklin *et al.,* (1993) study. This proposition could similarly help to explain why in the present study there is only a small decrease in SBP and none in DBP as BT was found to increase from the baseline value but remained fairly constant during the fifty minute recovery period altering by 0.5 ^{o}C for both neutral and cool temperature conditions. This could suggest that because BT did not alter significantly it had an impact on BP which caused there not to be such various changes in BP between the two temperature conditions.

3. Limitations

Limitations of the present study include that the protocols took place in a laboratory setting. Kenney and Seals (1993) stated that arterial BP was influenced significantly by the environment in which measurements were taken and that the majority of investigations have documented PEH only in quiet resting conditions set in a laboratory. Such environments do not represent everyday lifestyles, hence reducing generalisation to real life stressors and the validity of the results (Ming *et al.,* 2004). Trivedi, Sherwood, Strauman and Blumenthal (2008) supported this assertion and indicated that twenty four hour ambulatory measures of BP were considered to be more beneficial in determining preclinical and clinical disease than laboratory measures due to the fact that the method allowed for real world stimuli. However, Somer, Conway, Coats, Isea and Sleight (1991) challenged this and found no differences in BP measurements between a laboratory setting compared to measurements in normal living conditions in both normotensive and hypertensive individuals. However, it would have been very difficult to conduct the present study in a non-laboratory environment as there was a need to control temperature which would have been more variable in a real life conditions.

As well as considering the methodology (i.e. the experimental design), the time of day when the exercise is performed and BP is taken needs to be considered as a potential variable. Previous research has found that after a thirty minute bout of continuous exercise PEH increased further when the exercise was performed in the afternoon rather than the morning (Jones, Pritchard, George, Edwards & Atkinson, 2008). Hence, a limitation of the present study is that when participants performed each protocol they should have completed the exercise at the same time of day, but due to the organisation of the laboratory, the availability of participants and time constraints this was not possible.

4. Positives

A positive from the present study was that water intake was controlled for each participant and was relative to each individual’s body mass. The amount of water was also less than 300ml as it has been stated that drinking 300-500ml of water can mediate the effects of PEH (Popkin, D’Anci & Rosenberg, 2010). Water was given to ensure that participants were not in any discomfort or dehydrated from the exercise performed but also to standardise the amount of water given to ensure that blood volume was not dramatically altered. As blood volume can fluctuate through loss of body water e.g. sweat which can cause alterations in HR and BP (Popkin *et al.,* 2010). There is also evidence that blood pressure can recovery more quickly with fluid replacement and is also beneficial towards the cardiovascular response during exercise (Gagnon, Lynn, Binder, Boushel & Kenney, 2012; Hamilton, Gonzalez-Alonso, Montain & Coyle, 1991).

Another positive was that to ensure reliability throughout the study the equipment, such as the cycle ergometer, thermometer, BP cuffs and HR monitors were kept the same. During the protocols BP was measured by the same investigator for each person, the objective being to limit variations between inter and intra readings.

5. Summary of Study Results

The main conclusion from the present study is that the results show inconsistency with previous similar research findings, particularly in relation to cool or cold temperatures and BP.

The present study found that SBP decreased over the fifty minutes recovery period from the baseline values, however, the two temperature conditions were not significantly different. DBP was significantly affected by temperature with a difference of ($p \leq 0.02$), with the cool condition resulting in lower responses than the neutral condition. For BP measurements there was no significant influence from recovery time and temperature on the results. HR was found to decline for both the temperature conditions over the recovery period and both time alone ($p = 0.00$) and time and temperature ($p \leq 0.01$) produced significant differences. Further analysis showed that at the fifty minute measurement the cool temperature condition was significantly lower ($p \leq 0.02$) for both time and temperature than the neutral temperature condition. The final measurement of BT was decreased for the cool condition but remained fairly constant for the neutral condition, however, all values were higher than the baseline measurement and time of recovery caused a significant difference ($p \leq 0.02$).

In conclusion, the present study provided some contradicting results when compared to previous research. The present study highlighted the range of variables that need to be considered and controlled. Due to time and resource constraints the number of participants involved in the study was limited, and so further extensive study is suggested to conclusively prove the findings.

6. Implications

Due to the fact that the present study's results do not support previous literature it would be unsuitable to suggest any implications for health practitioners or hypertensive individuals.

7. Future Research

Future research should replicate the present study to determine whether the results are accurate, reliable and consistent. This will help conclude if the results from the present study do in fact provide contradicting evidence to previous research or if there were inaccuracies in the results. Future research should also build on the limitations and positives from the present study, for instance each exercise should be performed during the same time of day and the same investigator should measure the same individual for each protocol.

A consideration which should be explored is the position of recovery. Kenney and Seals (1993) reported that body position contributed to variations which were detected in post-exercise systemic hemodynamics. For instance, in Franklin *et al.*, (1993) the participants were in the supine position whereas, in the present study the participants were seated during recovery. Consequently, the position of the body could have effects on BP as research has shown that cardiac output decreased and total peripheral resistance increased while participants were seated compared to those who were in supine position. However, others have found the opposite (Cléroux *et al.,* 1992; Coats *et al.,* 1989). Therefore, it would be beneficial to assess which body position has the most advantageous effects on BP.

Another consideration could be to include a real life setting which mimics daily life may have implications on measurements. Including a real life setting could also allow comparisons with contrasting laboratory results to those found in everyday life. Generally, this would be more time consuming and would need greater control of extraneous variables, but the results would have greater generalisation. Finally, future research could also examine the difference between normotensive and hypertensive individuals due to the research having implications on hypertensive patients.

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APPENDICES

APPENDIX A

INFORMATION SHEET

Ethical code number: 14/5/10U
Title of Project: The Effect of Cool (19 ºC) and Neutral (24 ºC) Room Recovery Temperature on Blood Pressure after Interval Exercise.

Participant Information Sheet

Background

The amount of people suffering from cardiovascular disease is increasing and one treatable risk factor is hypertension (high blood pressure). One way to treat this problem is to increase the amount of physical exercise people do. One way which may help in interventions is to know which environment i.e. hot or cold is best suited to help with recovery of patients with hypertension. Therefore, this projects aim is to attempt to understand the effects of blood pressure by changing the room temperature during the recovery period after participants complete a set amount of exercise. However, this study will use participants without hypertension.

Your participation in the research project:

What will happen if you undertake in this project?

1. Firstly preliminary measurements and tests will be done before data collection this will include measurements of height, weight, resting heart rate and blood pressure. A VO_2 max will also be completed to determine power output for the interval exercises. The VO_2 max test involves an incremental increase in intensity until exhaustion; this will be performed on a cycle ergometer.

2. In the next three weeks you will be asked to complete interval exercise sessions followed by an hour's recovery period. The interval exercise includes (4 x 4 minutes) at 85% VO_2 max and (4 x 3 minutes) at 50% VO_2 max. Once completed you will be moved into a temperature controlled laboratory which will be set to one of three conditions, hot, room temperature and cold, where you will be asked to sit quietly and relax.

3. Measurements of blood pressure, heart rate and body temperature (via the ear) will be taken before the exercise occurs and blood pressure and heart rate will be taken again once finished. In the recovery period where again blood pressure and heart rate will be taken every 20 minutes. In the last 8 minutes of recovery you will be asked to undergo some light activity where measurements will continue to be taken. Body temperature will be measured again when leaving the laboratory.

4. Before each test we will ask you complete a short questionnaire to check your suitability to perform the exercise. We want you to prepare similarly for each of the

5. three exercise sessions, to avoid caffeine in any food or drink in the 3-hours before the laboratory visit. You must not consume alcohol in the 24-hrs before tests.

Are there any risks?
There is a very minor chance of feeling unwell after the VO_2 max test. It is also important that any changes in health or the ability to perform the exercise before you complete the session.

What happens to the results of the study?
After you have completed all three data collection weeks these results will then be analysed, however, participants will be given a subject number so that no names will be used and you so will not be able to be identified.

What happens after?
Once completed a copy of results will be emailed to you and at any time you can withdraw your data from this experiment.

How privacy is protected
Everyone working on the study will respect your privacy. Careful steps will be taken so that you can't be identified from any information that we have about you.

Further information
If you have any questions about this research or how it is intended to be conducted please contact me.

Rosie Tregear & Sophie Baldwin
st20018679@outlook.cardiffmet.ac.uk

APPENDIX B

CONSENT FORM

Ethical code: 14/5/10U

Title of Project: The Effect of Cool (19 ºC) and Neutral (24 ºC) Room Recovery Temperature on Blood Pressure after Interval Exercise

Name of Researcher: Rosie Tregear & Sophie Baldwin

Participant to complete this section: **Please initial each box.**

1. I confirm I have read and understood the information sheet dated …….. for this study. I have had the opportunity to consider this information, ask questions and had these answered with satisfaction. ☐
2. I understand that I am volunteering and it is possible for me to withdraw without reason at any point. ☐
3. I understand that the information from this study may be used but that confidentially will be ensured. ☐
4. I confirm that I have completed the Par-Q form honestly and have no medical concerns that are known to alter heart rate and blood pressure. ☐

_______________________________________ ____________________

Your Name Date

____

Your Signature

- When completed, one copy for participant and one copy for researcher’s files.

APPENDIX C

PAR – Q

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ______________________________

SIGNATURE OF PARENT ____ WITNESS ______________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

APPENDIX D

PREPARATION QUESTIONNAIRE

Test preparation

Additionally, please answer the following questions, adding detail in the space provided

a) Are there any changes to your health or suitability for exercise (i.e., injury) since your last test?

b) Have you eaten in the last 3 hours ? (give details if so)

c) Have you exercised in the last 24 hours ? (if so give details)

d) Are you currently performing your typical amount of exercise training ?

e) Does your participation in today's test conform to the guidelines given at the start of the study regarding caffeine (none in last 3 hours / alcohol consumption (none in last 24 hours)?

When you have answered these questions and you are happy with the explanations given, you can sign below if you consent to participate in the tests.

I have read this form and understand the test procedures that I will perform. I consent to participate in the test.

Signed ________________________ Date _____________

Name (print) __________________

APPENDIX E

ETHICAL APPROVAL FORM

PART ONE

Name of applicant:	Rosie Tregear
Supervisor (if student project):	Mike Hughes
School:	Cardiff School of Sport
Student number (if applicable):	St20018679
Programme enrolled on (if applicable):	Sport and Exercise Science
Project Title:	Effect of recovery temperature on blood pressure after exercise.
Expected Start Date:	01/11/2014
Approximate Duration:	6 months
Funding Body (if applicable):	N/A
Other researcher(s) working on the project:	Sophie Baldwin
Will the study involve NHS patients or staff?	No
Will the study involve taking samples of human origin from participants?	No

In no more than 150 words, give a non technical summary of the project
The amount of people suffering with hypertension has increased dramatically over the years, which is a concern as it is a risk factor for cardiovascular disease. Hypertension is however, treatable, and one way of doing so is to increase the amount of exercise that person does. Although, one element which needs to be taken into account is temperature as this is known to have an influence on blood pressure. This study will look at recovery in different room temperatures and the effects on blood pressure. Therefore, hoping to provide some insight into how hypertensive patients should recovery after exercise which benefits them the most.

Does your project fall entirely within one of the following categories:	
Paper based, involving only documents in the public domain	No
Laboratory based, not involving human participants or human tissue samples	No
Practice based not involving human participants (eg curatorial, practice audit)	No
Compulsory projects in professional practice (eg Initial Teacher Education)	No
If you have answered YES to any of these questions, no further information regarding your project is required. If you have answered NO to all of these questions, you must complete Part 2 of this form	

DECLARATION: **I confirm that this project conforms with the Cardiff Met Research Governance Framework**	
Signature of the applicant:	Date:
FOR STUDENT PROJECTS ONLY	
Name of supervisor:	Date:
Signature of supervisor:	

Research Ethics Committee use only	
Decision reached:	Project approved ☑ Project approved in principle ☐ Decision deferred ☐ Project not approved ☐ Project rejected ☐
Project reference number: Click here to enter text.	
Name: MGHughes (as supervisor)	Date: 24/10/2014
Signature:	
Details of any conditions upon which approval is dependant: Screening should happen with a PAR-Q form in addition to the forms within this file	

PART TWO

A RESEARCH DESIGN	
A1 Will you be using an approved protocol in your project?	No
A2 If yes, please state the name and code of the approved protocol to be used[3]	
N/A	
A3 Describe the research design to be used in your project	

Overview

Testing will be completed in two Cardiff Metropolitan physiology laboratories, one being temperature controlled. The participants will need to attend 4 sessions a minimum period of 48 hours will be allowed between each session. Participants will perform a VO_{2max} (maximal oxygen consumption) test to determine the power output for the three sessions of interval exercises.

Influence of temperature control

The interval exercises of (4 x 4 minutes) at 85% VO_{2max} and (4 x 3 minutes) at 50% has been shown to bring down blood pressure and there has also been justification of using interval exercise in research (Burns, Oo & Tran, 2012).
Exercise will be completed in the same temperature in one laboratory (room temperature), once completed participants will be moved into the temperature controlled laboratory which will be set before the sessions. These three conditions will be cool, room temperature and warm.
Hydration will also be controlled. The recovery phase will consist of the participants sitting stationary for an hour where blood pressure will be taken manually every 10 minutes.
Within the last 8 minutes of the recovery hour participants will undergo a light activity.

Outcome measures

Blood pressure will be measured at the beginning of exercise and on completion. As stated above blood pressure will be taken throughout recovery. Within the light activity blood pressure will be measured while participants complete the eight minutes. Heart rate will also be measured as will each participant's body temperature via the ear when they come into the laboratory and again when leaving.

Participants

Participants will be 8-12 healthy normotensive individuals and will be given a subject number for confidentiality. They will be recruited via personal communication and email from the population of School of Sport.

Data analysis

Means of heart rate and blood pressure will be calculated for each temperature condition using a repeated measure two way ANOVA. Body temperature means can be calculated using a paired t test.

A4 Will the project involve deceptive or covert research?	No
A5 If yes, give a rationale for the use of deceptive or covert research	
N/a	

[3] An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website here

B PREVIOUS EXPERIENCE
B1 What previous experience of research involving human participants relevant to this project do you have?
I have been a participant myself in other dissertation studies and completed data collection in both biomechanics and physiology laboratory seminars for the last two-three years.
B2 **Student project only** What previous experience of research involving human participants relevant to this project does your supervisor have?
Dr Michael G Hughes has extensive experience in research and use of procedures using human participants. The researcher has been a BASES-accredited exercise physiologist since 2001. He has been involved in a wide range of projects using human participants, including testing for his own PhD research (between 2000 & 2004), on various other research projects and on professional consultancy work for a variety of sport bodies with adult (including FIFA, Badminton England, Welsh Badminton, Welsh Athletics) and junior participants (Chelsea FC for the 'Football Icon project', Badminton England and Welsh Badminton) and from his three years employed as a physiologist with the British Olympic Association. He has been involved in academic studies that have been published in a range of journals (including Journal of Applied Physiology, Medicine and Science in Sports & Exercise, Journal of Sports Sciences and International Journal of Sports Medicine).

C POTENTIAL RISKS
C1 What potential risks do you foresee?
1. There could be a minor risk of injury as there is with all physical activity. 2. With interval training participants could become dizzy or faint. 3. By controlling fluid intake as to not interfere with outcome measures dehydration may potentially occur.
C2 How will you deal with the potential risks?
For <u>point 1 and 2</u> participants will be screened using the PAR-Q form before involvement within the study. If unsuitable they will not take part in the study. Before each test they will be asked if there have been any changes to their health and wellbeing. Participants will be advised not to eat before coming to sessions but be hydrated. They will also be monitored closely after exercise, if participants do feel dizzy or faint they will be instructed to lie on the floor with feet up. Intensity for the three bouts of exercise has been selected to avoid feelings of faintness after exercise. Regarding <u>point 3</u>, as stated above participants will be asked to be hydrated before coming to sessions, once the session has been completed participants are able to rehydrate.