EFFECTS OF ENVIRONMENTAL TEMPERATURE ON PSYCHOPHYSIOLOGICAL RESPONSES DURING HIGH INTENSITY INTERVAL EXERCISE

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EFFECTS OF ENVIRONMENTAL TEMPERATURE ON PSYCHOPHYSIOLOGY RESPONSES DURING HIGH INTENSITY INTERVAL EXERCISE

By

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Dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Health Sciences (Exercise and Sport Science)

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CERTIFICATE

This is to certify that the dissertation entitled "Effects of Environmental Temperature on Psychophysiology Responses during HIIE in Healthy Adult" is the bona fide record of research work done by Muhammad Alif Bin Mustafa during the period from February 2020 to June 2021 under my supervision. I have read this dissertation and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Health Sciences (Honours) (Exercise and Sports Science).

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DECLARATION

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

MUHAMMAD ALIF BIN MUSTAFA

Date: 23rd June 2021

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LIST OF ABBREVIATIONS AND ACRONYMS

%	Percentage
>	Greater than
<	Less than
BMI	Body mass index
BP	Blood pressure
cm	centimetre
FAS	Felt Arousal Scale
FS	Feeling Scale
HIIE	High-intensity interval exercise
HR	Heart rate
HR_{max}	Maximal heart rate
kg	Kilogram
m	Metres
MAS	Maximal aerobic speed
n	Total sample size
PAR-Q	Physical activity readiness questionnaire
RPE	Rating of perceived exertion
USM	Universiti Sains Malaysia
VO_2max	Maximal aerobic capacity
WHO	World Health Organization

KESAN SUHU PERSEKITARAN TERHADAP TINDAK BALAS PSIKOFISIOLOGIKAL SEMASA SENAMAN BERSELANG BERINTENSITI TINGGI

ABSTRAK

Tujuan kajian ini adalah untuk mengetahui kesan suhu persekitaran yang berbeza terhadap tanggapan persepsi dan kardiorespirasi semasa latihan selang intensiti tinggi, HIIE. Seramai dua belas peserta (N = 12, 7 lelaki dan 5 perempuan, Mean ± SD; umur 22.7 ± 0.7 tahun) dari Kampus Kesihatan Universiti Sains Malaysia telah direkrut. Peserta menyelesaikan keempat-empat lawatan sepanjang kajian dengan rehat sekurang-kurangnya 48 jam antara setiap lawatan. Kunjungan pertama (pengukuran pra-ujian dan pembiasaan) adalah untuk mengukur pemboleh ubah antropometri, menetapkan kelajuan aerobik maksimum (MAS) dan denyut jantung maksimum (HRmax) dan pembiasaan protokol eksperimen. Untuk lawatan kedua hingga lawatan terakhir, para peserta melakukan HIIE yang terdiri daripada pemanasan 3 minit pada 5.0 km.h-1 diikuti dengan 8 pengulangan selang kerja 1 minit pada kelajuan aerobik maksimum (MAS) 90% yang ditentukan dari ujian kenaikan hingga keletihan. Selang kerja dari setiap keadaan diselingi dengan pemulihan aktif 75 saat pada 4 km.j-1. 2 minit sejuk pada 5.0 km.h-1 disediakan selepas setiap keadaan. Tindak balas persepsi yang terdiri daripada valensi afektif (perasaan senang / tidak senang), kenikmatan dan aktiviti yang dirasakan diukur sebelum, semasa dan selepas setiap keadaan latihan. Suhu timpani (termometer telinga: Microlife 1R1DB1, Switzerland) juga diukur sebelum, semasa dan selepas setiap keadaan latihan. Peserta melakukan sesi latihan di treadmill bermotor (h / p / kosmos merkuri med 4.0, Jerman) pada waktu yang sama hari untuk mengurangkan kesan variasi biologi diurnal. Hasil untuk degupan jantung menunjukkan bahawa tidak ada keadaan yang signifikan oleh interaksi selang atau pengaruh utama keadaan (P = 0.39) Walau

bagaimanapun, terdapat perbezaan yang signifikan dalam tindak balas ΔHR antara keadaan ($P = 0.02$). Terdapat keadaan yang signifikan oleh kesan interaksi nombor selang ($P < 0.05$) untuk suhu timpani. Khususnya, H-HIIE menghasilkan suhu timpani yang lebih besar pada selang kerja 2 hingga 8, tetapi tidak terdapat perbezaan yang signifikan antara R-HIIE dan C-HIIE (semua $P > 0.53$, $ES < 0.21$). Selanjutnya, FS menunjukkan keadaan yang signifikan oleh interaksi nombor selang untuk FS ($p < 0.05$). Khususnya, H-HIIE menimbulkan FS yang lebih rendah pada selang kerja 5 hingga 8 (semua $P < 0.01$, semua $ES > 0.57$), tetapi tidak ada perbezaan yang signifikan antara R-HIIE dan C-HIIE (semua $P > 0.54$, $ES < 0.19$) Seterusnya, FAS tidak menunjukkan keadaan yang signifikan oleh kesan interaksi nombor selang ($P = 0.96$), tetapi ada kesan utama waktu ($P <0,01$) untuk FAS. RPE melaporkan keadaan yang signifikan oleh kesan interaksi nombor selang untuk RPE. Khususnya, H-HIIE menghasilkan RPE yang lebih besar pada selang kerja 5 hingga 8 (semua $P < 0.001$, H-HIIE vs R-HIIE, $ES = 1.45$ hingga 2.10), tetapi tidak ada perbezaan yang signifikan antara R-HIIE dan C-HIIE ($P > 0.34$, $ES <0.15$). Sebagai kesimpulan, kajian ini menunjukkan bahawa suhu persekitaran mempengaruhi tindak balas psikofisiologi semasa latihan selang intensiti tinggi.

EFFECTS OF ENVIRONMENTAL TEMPERATURE ON PSYCHOPHYSIOLOGICAL RESPONSES DURING HIGH INTENSITY INTERVAL EXERCISE

ABSTRACT

There is a growing interest among researcher to investigate the influences of high-intensity interval exercise (HIIE) on physiological [heart rate (HR)] and psychological (affect, perceived exertion and enjoyment) responses in adults as both factors play a significant role to facilitate health and future exercise adherence in adult. However, it is unclear whether environmental temperature can give an impact on these responses during HIIE in adult. The purpose of the present study is to determine the effects of different environmental temperature on psychological and HR responses during HIIE. A total of twelve participants (N =12, 7 males and 5 females, Mean ± SD; age 22.7 ± 0.7 years) from Health Campus of Universiti Sains Malaysia were recruited. Participants completed all four visits throughout the study with a minimum at least 48 hours rest between each visit. The first visit (pre-test measurements and familiarization) was to measure anthropometric variables, established maximal aerobic speed (MAS) and maximal heart rate (HRmax) and familiarization of experimental protocol. For the second visit until last visit, participants performed HIIE consisting of a 3-minute warm-up at 5.0 km.h-1 followed by 8 repetitions of 1 minute work intervals at 90% maximal aerobic speed (MAS) determined from the incremental test to exhaustion. The work intervals from each condition were interspersed with 75 seconds active recovery at 4 km.h-^{1}. 2 minutes cool down at 5.0 km.h-^{1} was provided after each condition. Psychological responses consisting of affective valence (pleasure/displeasure feelings), enjoyment and perceived exertion were measured before, during and after each exercise conditions. Tympanic temperature (ear thermometer: Microlife 1R1DB1, Switzerland) also measured before, during and after each exercise conditions. Participants performed the exercise session on motorised treadmill (h/p/cosmos mercury med 4.0, Germany) at the same time of the day to minimise the effects of diurnal biological variation. The results for heart rate shows that there was no significant condition by interval interaction or main effect of condition ($P=0.39$). However, there was a significant difference in ΔHR responses between conditions ($P=0.02$). There was a significant condition by interval number interaction effect ($P< 0.05$) for tympanic temperature. Specifically, H-HIIE elicited greater tympanic temperature at work interval 2 to 8, but no significant difference was found between R-HIIE and C-HIIE (all $P>0.53$, $ES<0.21$). Furthermore, FS showed a significant condition by interval number interaction for FS ($p<0.05$). Specifically, H-HIIE elicited lower FS at work interval 5 to 8 (all $P<0.01$, all $ES> 0.57$), but no significant difference was found between R-HIIE and C-HIIE (all $P>0.54$, $ES<0.19$).Next, FAS showed no significant condition by interval number interaction effect ($P=0.96$), but there was a main effect of time ($P<0.01$) for FAS. RPE reported a significant condition by interval number interaction effect for RPE. Specifically, H-HIIE elicited greater RPE at work interval 5 to 8 (all $P<0.001$, H-HIIE vs R-HIIE, $ES=1.45$ to 2.10), but no significant difference was found between R-HIIE and C-HIIE ($P>0.34$, $ES<0.15$). In conclusion, the present study indicates that both psychological and physiological to HIIE are influence by the environmental temperature in adult

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

HIIE has been shown as a feasible and time efficient approach for enhancing cardiometabolic health and cardiorespiratory fitness across multiple populations including in adults (Batacan et al., 2017). High-intensity interval exercise (HIIE) generally consists of intense type of exercise separated by the recovery period. The adoption of HIIE to promote health benefits, however, has been disputed with some arguing that HIIE will generate negative affect (feelings of displeasure) due to the greater physiological stress (e.g. increased in body temperature and heart rate (HR)), thus leading to poor implementation and maintenance in future sessions (Biddle and Batterham, 2015). Therefore, it is vital to understand factors (e.g., environmental factor) that may contribute to the changes in affect responses (i.e. feelings of pleasure and displeasure) during HIIE, particularly in adult. Elucidation this information is important as previous research has indicated that the affect experienced (pleasure/displeasure) during exercise can influence future PA motivation and behaviour in adult (Saanijoki et al., 2015).

Previous studies in adult have shown that HIIE results in an intensification of interoceptive/physiological cues (e.g., thermoreceptor, baroreceptor) due to the physiological adjustments taking place in the body when performing this intense exercise protocol. The physiological adjustments (e.g. changes in oxygen uptake, lactate concentration, and core temperature) may contribute to the changes in affective experience during high-intensity exercise (Ekkekakis, 2003). There is available evidence in adult to indicate that the decline in pleasurable feelings with the increased in the physiological strain such as HR and lactate concentration (Follador et al., 2018) during HIIE in adults. Also, a single study by Legrand and colleagues (2015) have shown that pattern of pleasure-displeasure is not dependent on body temperature during high-intensity exercise in adults, indicating that a negligible effect of core temperature on changes in affect responses. However, it is unclear whether exposure from external temperature (i.e. environmental temperature) will influence the pattern of affect responses during HIIE in adult. Documenting this information will enable researchers and coaches to identify factor that may facilitate the applicability of HIIE which related to the external factor in adult populations.

Exposure to different environmental temperature is also one of the factors that could lead to the changes in the body temperature during exercise. The human body is physiologically regulated to keep it homeostatic when exercise during environmental conditions change. Humans produce or lose heat through thermoregulation to maintain the homeostasis of body temperature and protect themselves against excessive heat or cool. In the same way, environmental temperature may influence physiological responses to exercise through thermoregulation. In tropical countries like Malaysia, exercise in a hot, humid conditions for prolonged periods, typically leading to impaired exercise performance (Saat et al., 2005; Tatterson et al., 2000). For example, prolonged cycling in hot environment reduced exercise performance in highly trained men. This is mainly because of that human body's ability to dissipate the additional heat generated during exercise may be impaired (Morris et al., 1998; Kenney & Johnson, 1992). Currently, it is unclear how different environmental conditions will influence physiological changes (e.g., body temperature, HR responses) and perceptual resnses (affect, enjoyment and RPE) during HIIE in adult. Previous study by (Legrand, Joly & Bertucci, 2015) have revealed that changes in body temperature may predict the changes in affect responses during high intensity exercise, but this finding is limited in continuous type of exercise in the same environmental temperature.

Therefore, the purpose of the present study was to examine the acute affective and enjoyment responses to HIIE with different environmental temperature which is cool environment (18°C), room temperature (24°C) and hot environment (31°C) during an 8 rep × 1-minute HIIE protocol in healthy adults. The secondary aim was to describe the acute cardiorespiratory and perceived exertion responses during the HIIE protocols and examine relationships with the affect responses among healthy adults.

1.2 PROBLEM STATEMENT

. Given the low levels of physical activity in adults, HIIE has been adopted as an efficient health strategy. Previous studies have shown that enhancement in affective responses during HIIE could play a significant role to facilitate future exercise engagement in adults. This observation may indicate that the manipulation of any factor that could influence changes in affective responses is important. Indeed, factors such as exercise intensity and physiological responses are associated with the changes in affective responses during HIIE. Currently, it is unclear whether external factors such as t environmental temperature could have an impact on affective responses during HIIE. Hence this study was proposed to determine the effects of environmental temperature on psychological and physiological responses in adults.

1.3 OBJECTIVES OF THE STUDY

1.3.1 General objective

1. To determine the effects of different environmental temperature (H-HIIE; 31ºC, C-HIIE; 18ºC & R-HIIE; 24ºC) on psychological and HR responses during high intensity interval exercise, HIIE.

1.3.2 Specific objectives

1. To compare the different between hot, cool and room temperature to HR responses during HIIE in adults.
2. To evaluate the different between hot, cool and room environmental condition to psychological responses (affect, enjoyment and perceived exertion) during HIIE.

1.4 RESEARCH QUESTIONS

1. Is there any significance different between hot, cool and room temperature on psychological responses (affect, enjoyment and perceived exertion) during HIIE in adults?
2. Is there any significance different between hot, cool and room temperature on HR responses during HIIE in adults?

1.5 HYPOTHESES OF THE STUDY

H_{O1} : There is no significance different of the HR responses between hot, cool and room temperature during HIIE in adults.

H_{A1} : There is no significance difference of the HR responses between hot, cool and room temperature during HIIE in adults.

H_{O2} : There is no significance different of the psychological responses between hot, cool and room temperature during HIIE in adults.

H_{A2} **:** There is a significance difference of the psychological responses between hot, cool and room temperature during HIIE in adults.

1.6 SIGNIFICANCE OF THE STUDY

The present study will provide valuable information pertaining to the impact of allowing individuals to run at their 90% of maximal aerobic speed, (MAS) during HIIE in three different environmental temperature (hot (31^{o}c), cool (18^{o}c) and room (24^{o}c) and their psychological responses, HR fitness and health outcomes. This proposed study will potentially provide guidelines to exercise prescription that may promise greater behavioural engagement and adherence to exercise and PA.

1.7 OPERATIONAL DEFINITIONS

High-intensity interval exercise (HIIE)

Repeated, brief bouts of high intensity exercise (≥80% of maximal heart rate [HR_{max}]), interspersed by short recovery period either light-intensity exercise (40 - 50 % HR_{max}) or rest.

Perceptual response

Psychology and physiology response to the different environmental temperature during HIIE, during running interval and cool down period.

Environmental temperature

If an inanimate body of the same shape and size as a given organism is positioned at the same point in space as the organism, it can reach equilibrium with its surroundings. Radiative and convective effects on the organism are included in the temperature.

Hot environment (31ºC) (70 % of relative humidity)

Water bath and halogen lamp used for controlling and maintaining the relative humidity and temperature of the room.

Cool environment (18ºC) (70% of relative humidity)

Water bath and air conditioner used for controlling and maintaining the relative humidity and temperature of the room.

Room environment (24ºC) (70% of relative humidity)

Water bath and exhaust fan used for controlling the temperature of the room.

CHAPTER 2: REVIEW OF LITERATURE

2.1 High Intensity Interval Exercise

High-intensity interval exercise (HIIE) has been shown as the topmost of top 20 trends in global survey of fitness trends for the past two sequential years (Thompson, 2020). High intensity interval exercise (HIIE) is easy to adjust for people at all levels at health and medical conditions, such as overweight and diabetes. HIIE can be done in all types of exercise, including running, walking, swimming, water conditioning, elliptical cross training, and in many forms of group exercise. HIIE provides similar health advantages to regular endurance workouts but in shorter time periods. This is because, particularly after exercise, HIIE appears to burn more calories than typical workouts (Roy, 2013). HIIE involving daily 30–300 seconds of aerobic exercise at an intensity varying from 85 to 100 percent of VO2max interspersed with recovery periods of equivalent or shorter length (Hazell et al., 2010; Daniels & Scardina, 1984). The most obvious advantage of HIIE is the shorter time frame needed to expend an appropriate amount of energy (Department of Health, 2008).

Therefore, there is a significant factor because when balancing energy consumption, the weight loss is the same as when exercising at a moderate intensity for 300 minutes / week or at a high intensity for 200 minutes / week (Ross, Stotz, & Lam, 2015). HIIE involving brief, regular bursts of intense PA, interspersed with intervals of light recovery, has therefore, been adopted as a technique to improve wellbeing. Recent studies have shown that HIIE training is a feasible and time efficient approach for improving cardio metabolic safety and cardiorespiratory fitness (Corte de Araujo et al., 2012; Costigan et al., 2015). There numerous studies had revealed that high-intensity interval exercise when compared to moderate intensity continuous exercise; it can create faster and more significant adaptations in VO_{2max} (Helgerud et al., 2007; Gibala & Mcgee, 2008). A widely used HIIE protocol in paediatric literature involves repetitions of 8 to 12 work intervals of 1 minute, interspersed with 60-75 seconds of successful recovery (Bond et al., 2015; Cockcroft et al., 2015; Malik et al., 2017; Thackray, Barrett, & Tolfrey, 2016).

This protocol, according to Francois and Little (2015), could be an ideal method for introducing vigorous exercise in individuals who are unhealthy or unfamiliar with high-intensity physical activity. This protocol is usually done at a lower heart rate than maximal heart rate, so it is not considered "all-out" exercise. This procedure has been used in both young, healthy participants and clinical populations like those with coronary artery disease, congestive heart failure, and metabolic syndrome patients (Rognmo et al., 2004; Warbuton et al., 2005; Wisloff et al., 2007; Tjonna et al., 2008). It is useful in individuals that are inadequate or unaccustomed to vigorous-intensity physical exercise.

Khammassi et al. (2018) investigated the impact of a 12-week high-intensity interval exercise (HIIE) program without caloric restriction on body composition and lipid profile in sedentary healthy overweight/obese youth (N = 20). They were divided into two classes at random: the HIIE group (3 sessions per week, 30 seconds of work at 100 percent maximal aerobic speed, (MAS) interspersed by 30 seconds of recovery at 50 percent of MAS) and the control group. The waist circumference, body mass index (p 0.01), and fat mass percent (p 0.05) all decreased significantly in this research, as did MAS and VO2max.

RPE (ratings of perceived exertion) has previously been identified as a predictor of affective responses (Oliveira et al., 2015). In fact, Oliveira et al. (2015) and Frazao et al. (2016) found that RPE and affective responses are inversely related. During incremental exercise, this pattern was observed, with affect decreasing as perceived intensity increased (Welch et al., 2007). Based on the foregoing data, it is reasonable to conclude that exercise sessions that disrupt metabolic homeostasis causes more negative affective responses. Because the affective response is thought to be a predictor of exercise adherence (Rhodes & Kates, 2015), it is critical to prescribe exercise sessions that produce positive affective responses. In this regard, while lower intensities are associated with positive affective responses (Ekkekakis, Parfitt, & Petruzzello, 2011), higher intensities are associated with greater physical benefits, particularly intensities that approach or exceed maximal aerobic capacity, such as more than 90% V O2Max (Gormley, 2008). These intensities, it's worth noting, are far higher than those associated with moderate-intensity continuous exercise (MICE). The resulting situation, in which more beneficial exercise intensities produce fewer positive affective responses while slightly less beneficial intensities produce more positive affective responses, presents a challenge for the professional prescribing aerobic exercise.

As a result, exercise sessions that allow individuals to perform at higher intensities while maintaining positive affective responses must be prescribed. In this case, high intensity interval exercise (HIIE) may be a beneficial strategy not only for affective responses but also for cardiometabolic benefits (Tjpnna et al., 2008; Wisloff, Loennechen, & Rognmo, 2007). Because the rest intervals between intense work intervals may contribute to reduced discomfort and a more positive affective response, HIIE becomes a viable exercise programming option. The research into the effects of HIIE on affective responses is relatively new, and scientific interest in this area has grown in recent years (Gibala et al., 2006). These studies looked at enjoyment responses in general (Gibala et al., 2006), possibly because enjoyment could be a mediator for exercise adherence (Jekauc, 2015). While some studies found HIIE to be more enjoyable than MICE (Bartlett et al., 2011), others found it to be less enjoyable (Oliveira et al., 2013)

The methodological differences between studies could explain the contradictory data. While Bartlett et al. (2011) used a 1:1 stimulus-recovery ratio, Oliveira et al. (2013) used a 1:0.5 stimulus-recovery ratio in their strenuous HIIE session. The proportion between stimulus and recovery durations may have influenced these results, contributing to the positive results seen in Bartlett et al (2011). Given these discrepancies, it is necessary to determine whether HIIE training can be effective in terms of cardiometabolic effects while causing decreases in affective or enjoyable responses when compared to continuous training (CT). The current study's goal was to conduct a systematic review and meta-analysis of the literature on the acute effects of HIIE and MICE on affective and enjoyment responses. In this study, HIIE was categorized as any type of interval training (e.g.: sprint interval training).

2.2 Effects of High Intensity Interval Exercise on Psychophysiological Responses.

Short periods of intense physical activity (PA) can lead to many health benefits (Barker et al., 2018; Carson et al., 2014; Hay et al., 2012; Malik et al., 2019) However, High-intensity interval exercise, (HIIE) protocols use exercise intensity domains within the heavy or severe (i.e. exercise above the first ventilation threshold [VT] up to the maximum exercise capacity level) (Bond et al., 2017; Malik et al., 2017) which may evoke negative affective responses such as feelings of disappointment and lead to poor adherence to exercise (Biddle and Batterham, 2015; Hardcastle et al., 2014; Malik et al., 2019). Observational studies in children and adolescents have shown that cardiometabolic risk factors are associated more closely with vigorous physical activity (PA) than light or moderate intensity PA (Malik et al., 2017; Ruiz et al., 2006; Steele et al., 2009). HIIE involving short, repeated bouts of vigorous physical activity, interspersed with periods of light recovery, has therefore been adopted as a strategy to promote health in adolescents.

Recent reviews have shown that HIIE preparation is a feasible and time-efficient method for enhancing adolescent cardiometabolic safety and cardiorespiratory fitness (Costigan et al., 2015; Logan et al., 2014; Malik et al., 2017). A widely used HIIE protocol in pediatric literature involves repetitions of 8 –12 work intervals of 1 minute, interspersed with 60 to 75 seconds of active recovery (B. Bond et al., 2015; Cockcroft et al., 2015; Thackray, Barrett & Tolfrey, 2016). Despite evidence for this HIIE protocol to facilitate a variety of adolescent health benefit, little is known about the acute cardiorespiratory [i.e. Intake of heart rate (HR) and oxygen (VO2)] and perceptual [i.e. Level of perceived exertion (RPE)] answers in this population during HIIE.

These observations are because previous HIIE studies report the average cardiorespiratory and perceptual response to the entire HIIE protocol, which does not allow for the provision of a thorough quantification of the HIIE protocol, rather than an interval-by-interval basis. In addition, interval by interval quantification of HR data may demonstrate a participant's compliance with the HIIE protocol using a predefined percentage (percent) HR maximum threshold (Malik et al., 2017; Taylor, Weston & Batterham, 2015). Furthermore, the accessible evidence recommends that HIIE may suggest a more time-efficient approach to negate time from being a barricade to exercise and thus assist in increasing the physical activity levels. (Wisloff et al., 2007; Tjonna et al., 2013)

Therefore, as the strength and length of the work and recovery periods during HIIE will affect the profile of V as much as O2, HR, RPE (Kilpatrick et al., 2015; Malik et al., 2017; Tschakert & Hofmann, 2013) and differences between men and women (Laurent et al., 2014). Recent evidence, however, suggests that a widely used HIIE protocol in youth (8 repetitions x 1 minute performed at 90 percent peak power separated with 75 seconds active recovery) generates greater pleasure after HIIE compared to continuous moderate intensity or interval exercise and has no prominent negative affective reactions (Malik et al., 2017). The authors (Malik et al., 2018) argued that the low intensity exercise during the intervals of recovery that maintain positive feelings during the intervals of the HIIE research.

Nevertheless, the HIIE protocol used in the above-mentioned studies focused on a single HIIE work intensity (90 percent peak power), but it has been shown that a range of HIIE work intensities (e.g. 70 to 100 percent maximum exercise capacity) are successful in promoting health benefits for children and adolescents (Bond et al., 2017; Malik et al., 2019). In addition, more research is required into the effects of HIIE on acute psychological responses and exercise adherence. Wisloff et al., (2007) and Tjonna et al., (2013) recommended that greater post exercise feeling of enjoyment are due to the varied nature of the activity profile inherent to high intensity interval exercise compared with the “boring” steady-state continuous method. It is critical to understand how people respond to HIIE on a cognitive and behavioral level if this method of exercise is to be promoted to clients and patients. For the time being, patients are advised to think about HIIE as a useful method for promoting health and fitness across a broader range of communities (Kilpatrick, Jung & Little, 2014).

Different combinations of these variables elicit different physiological and psychological responses (Buchheit & Laursen, 2013; Islam et al., 2017). (Martinez et al., 2015; Townsend et al., 2017). Affective responses to exercise, such as pleasure and enjoyment, have been found to have a significant impact on active behavior (Freese et al., 2014; Motl et al., 2001; Williams, 2008), implying that a time-efficient exercise that promotes pleasure and enjoyment may improve the general population's participation and adherence to an exercise program (Garber et al., 2011; Kinnafick et al., 2018). Participants will struggle to maintain exercise long enough to achieve desired health outcomes without these psychological responses to exercise (Burn & Niven, 2019; Kong et al., 2016). Affective and enjoyable reactions to HIIE have been uneven and contradictory (Decker & Ekkekakis, 2017), In addition, participants in this previous study completed the Physical Activity Enjoyment Scale to assess their enjoyment of the exercise session (PACES; Kendzierski & DeCarlo, 1991). When it comes to exercise-related improvements in psychological health, such as reducing depression, anxiety, and fatigue symptoms, mood dimensions are an important psychological construct to consider (Freese et al., 2014). In fact, there were other studies that investigated psychological responses to HIIE, this variable was overlooked (Martinez et al., 2015; Olney et al., 2018; Stork et al. 2018; Townsend et al., 2017; Tucker et al., 2015; Vella et al. 2017).

2.3 Effects of Environmental Condition During Exercise

The human body is physiologically regulated in such a way that it stays homeostatic when conditions change. Via thermoregulation, humans produce or lose heat to maintain homeostasis of the body temperature and to protect themselves against extreme heat or cold (Johnson, Minson, & Kellogg, 2014; No & Kwak, 2016). In contrast, our body promotes heat dissipation in sweat evaporation by heat exposure (Manou et al, 2015; No & Kwak, 2016). Physiological responses to thermoregulation exercise may be affected by ambient temperature in the same way. Our body, for example, minimizes heat dissipation by decreasing the body surface under cold conditions, encouraging heat output by skeletal muscle contraction (i.e. shivering), and preventing heat loss by contracting skin blood vessels (i.e., vasoconstriction) (Smith & Johnson., 2016; No & Kwak, 2016). In a hot and humid climate, the ability of the human body to dissipate the extra heat generated during exercise may be impaired (Kenney and Johnson, 1992; Morris et al., 1998; Nadel, 1992). The key finding of this study was that output being less in a hot environment (~30 ° C, ~66 percent relative humidity) than in a moderately hot (~21 ° C, ~71 percent relative humidity) environment during a prolonged, sporadic, high intensity running test to exhaustion (Morris et al., 1998).

It has been generally known for some time that the stress associated with training and competition is frequently exacerbated by environmental factors, and that heat stress can accelerate the onset of fatigue during prolonged exercise (Edwards et al., 1972; MacDougal et al., 1974; Maxwell, Aitchison, & Nimmo, 1996; Nielsen, 1992). During extreme climatic conditions there is competition for cardiac efficiency, with the need for enhanced skin circulation and heat dissipation, in addition to the metabolic requirements of the exercise muscle (Cedaro, 2000; Katayama et al., 2003). Some of the limited research on heat stress and high intensity exercise have shown that short ends of maximum exercise may not be affected by heat stress as much as prolonged activity (Maxwell, Aitchison, & Nimmo, 1996; Williams et al., 1962; Wyndham et al., 1970).

In support of these results, (Maxwell, Aitchison, & Nimmo, 1996) observed that children had the same anaerobic output when exercising under thermoneutral (22 °C, 25-30 percent relative humidity (rh), humid (30 °C, 85-90 percent rh) and hot, dry (38-39 °C, 55-60 percent rh) conditions, using a single 30 second Wingate test. (Hoffman et al., 1994; Maxwell, Aitchison, & Nimmo, 1996) did not notice any harmful effects on the outcomes of repeated 15 seconds hot surroundings (35 °C) relative to thermoneutral (22 °C) studies. Such research has, however, not used rigorous supramaximum exercise, and the results of Dotan & Baror (1980) do not extend to an adult population. Cold exposure is responsible for the many physiological responses within the human body. Cold exposure has been reported to cause elevated heart rate and systolic blood pressure (No & Kwak, 2016; Prior JO et al., 2007; Seigrist et al., 2006). Cold induced heart rate changes can be associated with decreased vagal activation as opposed to sympathetic cold response. In addition, cold exposure results in peripheral vasoconstriction resulting in increased systemic vascular resistance and diastolic blood pressure (Heindl S et al., 2004; No & Kwak, 2016).

CHAPTER 3: METHODOLOGY

3.1 STUDY DESIGN

This study utilized a repeated measures cross-over design in which all the participants completed three experimental conditions: a) HIIE with cool environment (18 ºC) (HIIE-C); b) HIIE with room temperature (24ºC) (HIIE-R); and c) HIIE with hot environment (31ºC) (HIIE-H). Participants were recruited based on the inclusion and exclusion criteria that were set for this study. All the psychological and physiological measurements were taken before, during and after the exercise conditions. This study protocol has been approved (Appendix A) by Human Research Ethics Committee (HREC), Health Campus of Universiti Sains Malaysia. (JEPeM Code: USM/JEPeM/20040203). This study had no conflict of interest.

3.2 STUDY LOCATION

The data collection was conducted at Exercise and Sport Science Laboratory of School of Health Sciences, Health Campus, USM, Kubang Kerian, Kelantan. All exercise conditions were performed using a motorized treadmill (h/p/cosmos mercury med 4.0, Germany) located inside the environmental room of the laboratory.

3.3 SAMPLE SIZE CALCULATION

Sample size was calculated by using G*Power version 3.1.9.2. The sample size reflects the related research (No & Kwak, 2016) for the differences in cardiorespiratory responses which has been shown to have moderate effect size large. For the current study, where three conditions and 10 repeated measurement points (pre, during HIIE work intervals) were analysed using a two-way repeated measure analysis of variance (ANOVA), a sample size of 9 participants would be required to detect moderate effect using a power of 0.8, an alpha of 0.05 and an effect size, F, of 0.30 (moderate). Therefore, assuming a dropout of three participants, for the current study we recruited a sample of 12 participants.

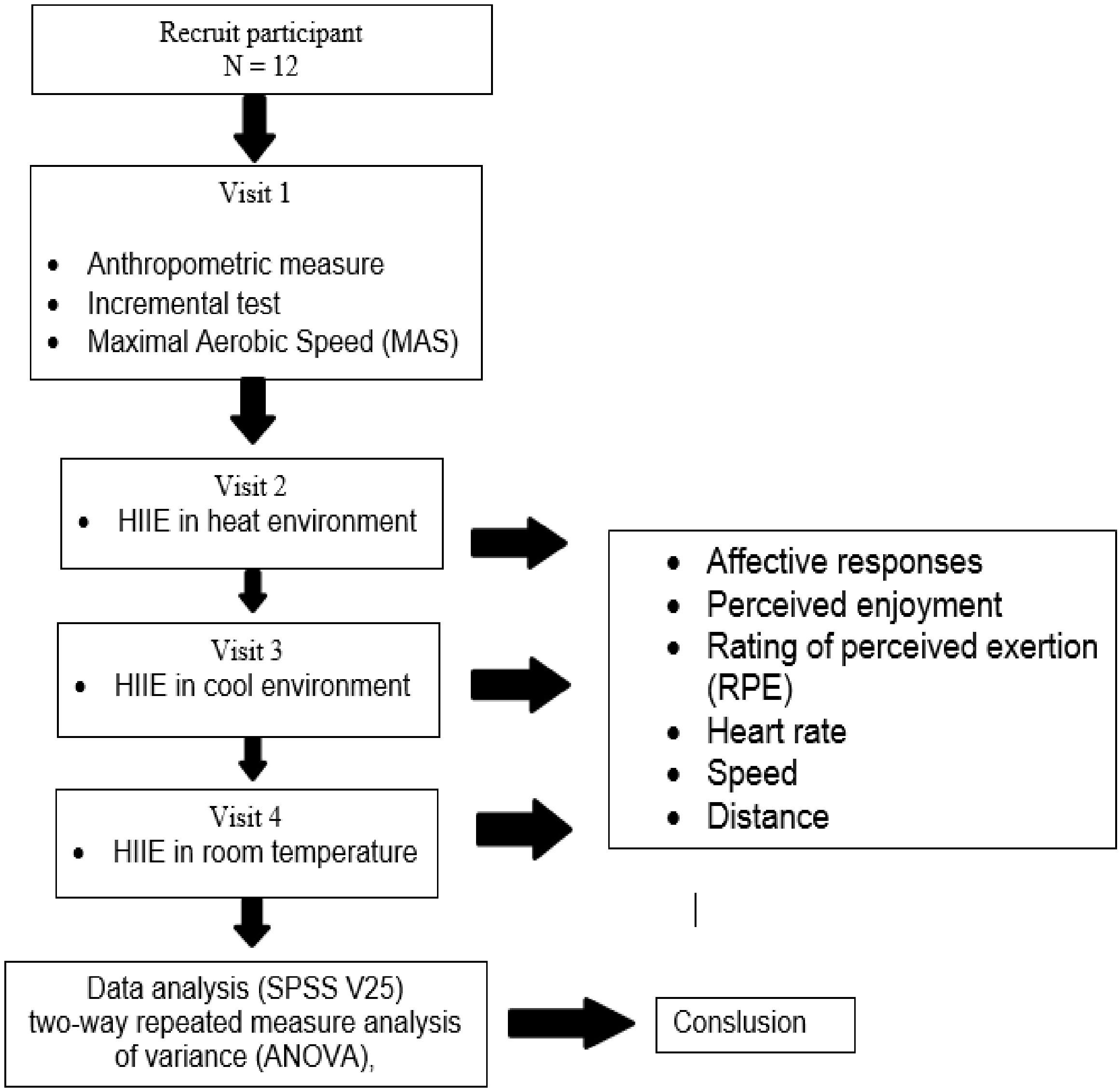

Figure 3.1: Flow chart of the study procedures

3.4 PARTICIPANTS

A total of twelve healthy adults male (n=7) and female (n=5) were recruited among students and staffs of USM via poster advertisement (Appendix B) placed in and around USM. The participants gave informed consent form after being advised of all possible risks and discomforts associated with the procedures used in the study. The selection criteria were as follows:

Table 3.1: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Male and female adults	Pre-existing health conditions
Aged between 18 to 25 years old	Having illness
Healthy	On medication
Can run on treadmill	musculoskeletal injury especially to lower limbs which prevents participants from running, the presence of any condition or infection which could alter mood and exercise performance

3.5 STUDY PROTOCOLS

During the recruitment process, potential participants were approached by researcher and they were thoroughly explained regarding the objectives, procedures, possible harm/risk and benefits of the research study. These information have been highlighted in the consent form provided to all the participants Potential participants were requested to complete a Physical Activity Readiness Questionnaire (PAR-Q) (Appendix C) to assess their level of physical fitness and their ability to engage in any physical activity. Participants' habitual physical activity were also measured using the Malay version of International Physical Activity Questionnaire (IPAQ-M) (Chu & Moy, 2015). Those who were voluntarily to participate and met the study participant were enrolled for the study. All participants completed the informed consent form (Appendix D). The first visit was to measure anthropometric variables and familiarize participants with the measurement scales. This was followed by three experimental visits each involving a running HIIE with different environmental temperature conditions, namely, room (24ºC, R-HIIE), hot (31ºC, H-HIIE) and cool (18ºC, C-HIIE), the order of which was counterbalanced to control for an order or learning effect. All exercise tests were performed using a motorized treadmill (3017 Full vision drive, Newton, Kansas, USA).

First visit (anthropometric measures and maximal aerobic speed determination), participants' weight, height and fat percentage were measured using weighing scale (TANITA Corporation, Japan). Then, calculation of body mass index was done as follows:

$$\text{BMI (kg.m}^{-2}\text{) = weight (kg) / height (m) x height (m)}$$

Participants were familiarised with walking and running on the treadmill before completing an incremental speed-based protocol to establish maximal aerobic speed (MAS) and maximal heart rate (HRmax). Participants began their warm-up against a speed of 5.0 km.h-^{1} for 3 minutes, followed by running at the speed of 6.0 km.h-^{1} with 0.5 km.h-^{1} increments every 30 seconds until volitional exhaustion, before 5 minutes cool down at 4.0 km.h-^{1}. Throughout the incremental test, the treadmill gradient was set at 1% to reflect the outdoor energy cost of running (Jones and Doust, 1996).

3.5.1 HIIE protocol with different environmental temperature

For the second visit until last visit, participants performed HIIE consisting of a 3-minute warm-up at 5.0 km.h^{-1} followed by 8 repetitions of 1 minute work intervals at 90% maximal aerobic speed (MAS) determined from the incremental test to exhaustion. The work intervals from each condition were interspersed with 75 seconds active recovery at 4 km.h^{-1}. A 2 minutes cool down at 5.0 km.h^{-1} was provided after each condition.

For room condition, water bath and exhaust fan used for controlling and maintaining the relative humidity (70% of RH) and temperature (24ºc) of the room. For hot environment, Water bath and halogen lamp used for controlling and maintaining the relative humidity (70% of RH) and temperature (31ºc) of the room. Temperature can be control by turning on or off the halogen lamp. Next, for the cool environment, air conditioner and water bath used for controlling and maintaining the relative humidity (70% of RH) and temperature (18ºc) of the room.

Each exercise session was separated by a minimum two-day rest period (48 hours). Psychological responses consisting of affective responses (pleasure/displeasure feelings), enjoyment and perceived exertion were measured before, during and after each exercise conditions. Tympanic temperature (ear thermometer: Microlife 1R1DB1, Switzerland) also measured before, during and after each exercise conditions. Participants performed the exercise session at the same time of the day to minimise the effects of diurnal biological variation.

3.6 MEASUREMENT INSTRUMENTS AND PROCEDURES

3.6.1 Anthropometric and habitual physical activity

Body mass and stature was measured to the nearest 0.1 kg and 0.1 cm, respectively (the participants were shoeless and wear light clothing). Body mass index (BMI) was calculated as body mass (kg) divided by stature (m) squared. IPAQ-M can be divided into three levels of categorical score that consists of Category 1 (Inactive; <600 MET- min/week), Category 2 (moderately active; <3000 MET-minutes/week) and Category 3 (health-enhancing physical activity (HEPA); >3000 MET-minutes/week) (Ainsworth et al., 2006).

3.6.2 Cardiorespiratory fitness

Participants were familiarised with walking and running on the treadmill before completing an incremental speed-based protocol to establish the maximal aerobic speed (MAS) and maximal heart rate (HRmax). Participants began a warm-up against a speed of 5.0 $km.h^{-1}$ for 3 minutes, followed by running at the speed of 6.0 $km.h^{-1}$ with 0.5 $km.h^{-1}$ increments every 30 seconds until volitional exhaustion, before 5 minutes cool down at 5.0 $km.h^{-1}$. HR was measured continuously during incremental test using a telemetry system (Polar Electro, Kempele, Finland). HR responses was measured continuously during each exercise conditions. Throughout the incremental test, the treadmill gradient was set at 1% to reflect the outdoor energy cost of running (Jones and Doust, 1996). The incremental test to exhaustion protocol has been used previously for determining MAS in adults (Huggett, Connelly & Overend, 2005).

3.6.3 Affective responses

Affective valence (pleasure/displeasure) was measured using the feeling scale (FS; Hardy and Rejeski, 1989) according to previous work in overweight/obese adult (Ekkekakis, 2009). Participants responded to how they feel on an 11-point bipolar scale ranging from "Very Good" (+5) to "Very Bad" (-5). Perceived activation levels were measured using the single- item felt arousal scale (FAS; Svebak and Murgatroyd, 1985). Participants rated themselves on a 6-point scale ranging from 1 'low arousal' to 6 'high arousal'. FS and FAS exhibited correlations ranging from 0.41 to 0.59 and 0.47 to 0.65, respectively, with the Affect Grid (Russell et al., 1989), indicative of convergent validity with similar established measures (Van Landuyt et al., 2000). ΔFS represent the change in the affective response from work interval 1 to the work interval 8 across all conditions Participants responded to the FS 5 minutes before exercise; 20 seconds before the end of the warm-up session; and 20 seconds before the end of each work interval. Participants were given standardised verbal instructions on how to use the scales before undertaking the incremental test and before start warm up during HIIE session.

Feeling scale (FS): *While participating in exercise it is quite common to experience changes in mood. Some individuals find exercise pleasant, whereas other find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise in heat, cool and room environmental temperature.*

Felt arousal scale (FAS): *Estimate here how aroused you actually feel. By "arousal" we meant how "worked up" you feel. You might experience high arousal in one of a number of different ways, for example as relaxation or boredom or calmness.*

3.6.4 Perceived enjoyment

Participants' enjoyment of each exercise conditions examined using a Physical Activity Enjoyment Scale (PACES; Kendzierski and DeCarlo, 1991) 10 minutes post-exercise. Post-enjoyment was measured using the physical activity enjoyment scale (PACES) after cooldown that includes 18 items that are rated on a 7-point bipolar scale (Kendzierski & DeCarlo, 1991). After eleven items were reverse-scored which were "I enjoy it/I hate it", "I find it pleasurable/I find it unpleasurable", "I am very absorbed with exercise/I am not all absorbed with exercise", "I find it energizing/I find it tiring", "It's very pleasant/It's very unpleasant", "I feel good physically while doing it/I feel bad physically while doing it", "It's very invigorating/It's not at all invigorating", "It's very gratifying/It's not at all gratifying", "It's very exhilarating/It's not at all exhilarating", "It gives me a strong sense of accomplishment/It's does not give me a strong sense of accomplishment", "It's very refreshing/It's not at all refreshing", the total pleasure was calculated by adding the 18 responses. This procedure resulted in a potential score range of 18 to 156, with a higher number indicating greater enjoyment.

3.6.5 Rating of perceived exertion, RPE

The 10-point Category-Ratio 10 Scale (CR-10; Borg 1998), also commonly referred to as the Rating of Perceived Exertion) was used to assess participants' perceived effort during exercise. The CR-10 is a 10-point scale ranging from 0 to 10 with anchors ranging from ‘‘No exertion at all’’ (0) to ‘‘Maximal exertion’’ (10). Participants responded to the RPE 20 seconds before the end of the warm-up session and 20 seconds before the end of each work interval. ΔRPE represent the change in the affective response from work interval 1 to the work interval 8 across all conditions.