PSYCHOPHYSIOLOGICAL RESPONSES AND RUNNING PERFORMANCE DURING TREADMILL AND OVERGROUND SELF-PACED INTERVAL RUNNING IN NON-REGULAR RUNNERS

NUR SHAHILA AFIZA BINTI MOHD LIZA

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By

NUR SHAHILA AFIZA BINTI MOHD LIZA

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 "PSYCHOPHYSIOLOGICAL RESPONSES AND RUNNING PERFORMANCE DURING TREADMILL AND OVERGROUND SELF-PACED INTERVAL RUNNING IN NON-REGULAR RUNNERS" is the bona fide record of research work done by NUR SHAHILA AFIZA BINTI MOHD LIZA during the period from September 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 fulfillment for the degree of Bachelor of Health Sciences (Honours) (Exercise and Sports Science).

Dr. Adam Abdul Malik

Lecturer,

Exercise and Sports Science Programme,

School of Health Sciences,

Health Campus, Universiti Sains Malaysia,

16150 Kota Bharu, Kelantan, Malaysia.

Date: 23 June 2021

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.

NUR SHAHILA AFIZA BINTI MOHD LIZA

Date : 23 JUNE 2021

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LIST OF ABBREVIATIONS AND ACRONYMS

>	Greater than
<	Less than
ACSM	American College of Sport Medical
BMI	Body mass index
BP	Blood pressure
cm	centimetre
CO_2	Carbon dioxide
FAS	Felt Arousal Scale
FS	Feeling Scale
HIIE	High-intensity interval exercise
HR	Heart rate
HR_{max}	Maximal heart rate
HRR	Heart rate reserve
IPAQ	International Physical Activity Questionnaire
IR	Interval running
kg	Kilogram
Kmh^{-1}	Kilometre per hour
m	Metre
MAS	Maximal aerobic speed
MET.min.wk-1	Metabolic equivalent minutes per week
MICT	Moderate-intensity continuous training
min	Minutes
n	Total sample size
PA	Physical activity
PACES	Physical Activity Enjoyment Scale

PAR-Q	Physical activity readiness questionnaire
RPE	Rating of perceived exertion
s	Seconds
SPIR	Self-pace interval running
VO_{2max}	Maximal aerobic capacity
VT	Ventilatory threshold
W	Work interval
WHO	World Health Organization

TINDAK BALAS PSIKOFISIOLOGI DAN PRESTASI LARIAN MENGGUNAKAN TREADMILL DAN DILUAR KETIKA BERLARI SECARA SELANG MASA MENGIKUT KELAJUAN SENDIRI DALAM PELARI BUKAN BIASA

ABSTRAK

Tujuan kajian ini adalah untuk menentukan pengaruh penetapan senaman yang berbeza (treadmill vs overground) semasa selang diri berlari pada tindak balas psikofisiologi (perasaan keseronokan dan ketidakpuasan hati, keseronokan, tindak balas kadar jantung) dan prestasi senaman (kelajuan berlari) dalam pelari bukan biasa. Seramai dua belas pelari bukan biasa (N = 12, 6 lelaki dan 6 perempuan, min ± SD; umur 21.3 ± 1.7 tahun) melakukan tiga lawatan eksperimen sepanjang kajian dengan jurang minimum 48 jam antara setiap lawatan. Lawatan pertama (pengukuran pra-ujian dan pembiasaan) adalah untuk mengukur pembolehubah antropometrik, kelajuan aerobik maksimum (MAS) yang ditubuhkan dan kadar jantung maksimum (HRmax) dan pembiasaan protokol eksperimen. Berikutan lawatan pertama, peserta melakukan dua keadaan senaman yang tidak seimbang; Treadmill IR dan Overground IR (8 ulangan x 1 minit selang kerja pada intensiti senaman yang dipilih sendiri). Selang kerja dari setiap pengulangan berselang dengan 75 saat pemulihan aktif. Jarak yang dilalui (meter), kelajuan purata berjalan (Km/j), pembolehubah kadar jantung, RPE, tindak balas yang menjejaskan dan keseronokan yang dilihat direkodkan sebelum bersenam, setiap selang kerja dan selepas bersenam. Langkah berulang dua hala ANOVA dilakukan untuk memeriksa perbezaan dalam semua pembolehubah. Keputusan menunjukkan bahawa terdapat kesan utama keadaan yang ketara mengikut selang untuk semua ukuran

(P<0.05). Overground IR menunjukkan kelajuan berlari lebih tinggi (ES = 1.06 hingga 2.75) dan jarak yang dilalui (ES= 1.73 hingga 3.57) berbanding Treadmill IR. Berhubung dengan data psikologi, Overground IR menunjukkan FAS yang lebih tinggi (ES = 0.40 hingga 0.67) serta RPE (ES = 0.56 hingga 0.91) berbanding Treadmill IR. Walau bagaimanapun, Treadmill IR menunjukkan FS yang lebih tinggi (ES = 0.85 hingga 0.68) berbanding dengan Overground IR. Kesimpulannya, kajian sekarang menunjukkan bahawa tindak balas psikofisiologi dan prestasi berlari semasa selang diri berlari dipengaruhi oleh tetapan senaman (treadmill dan overground).

PSYCHOPHYSIOLOGICAL RESPONSES AND RUNNING PERFORMANCE DURING TREADMILL AND OVERGROUND SELF-PACED INTERVAL RUNNING IN NON-REGULAR RUNNERS

ABSTRACT

The purpose of this study is to determine the influence of different exercise setting (treadmill vs overground) during self-paced interval running on psychophysiological responses (feelings of pleasure and displeasure, enjoyment, heart rate responses) and exercise performance (running speed) in non-regular runners. A total of twelve non-regular runners (N = 12, 6 males and 6 females, mean ± SD; age 21.3 ± 1.7 years) performed three experimental visits throughout the study with a minimum of 48 hours gap 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 (HR_{max}) and familiarization of experimental protocol. Following the first visit, participants performed two counterbalanced exercise conditions; Treadmill IR and Overground IR (8 repetitions x 1 minute work interval at self-selected exercise intensity). The work intervals from each repetition interspersed with 75 seconds active recovery. Distance covered (meter), average running speed (Km/h), variables of heart rate, RPE, affective responses and perceived enjoyment were recorded before exercise, every each of the work intervals and after exercise. Two-way repeated measures ANOVA was performed to examine differences in all variables. The results showed that there was a significant main effect of condition by interval for all the measurements ($P<0.05$). Overground IR elicited greater running speed (ES = 1.06 to 2.75) and distance covered (ES= 1.73 to 3.57) compared to Treadmill IR. In regards to

the psychological data, Overground IR elicited greater FAS (ES = 0.40 to 0.67) as well as RPE (ES = 0.56 to 0.91) compared to Treadmill IR. However, Treadmill IR elicited greater FS (ES = 0.85 to 0.68) compared to Overground IR. In conclusion, the present study indicates that psychophysiological and running performance to self-paced interval running is influenced by the exercise setting (treadmill and overground).

CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Physical activity (PA) has become an important element of health promotion in many countries over the past few decades. The World Health Organisation (WHO) recommends a minimum of 150 minutes of moderate-intensity physical activity per week or 75 minutes of vigorous-intensity PA three times per week for adults to maintain or improve health (WHO, 2010). While the advantages of physical activity (PA) are well reported, physical inactivity during adult is widespread globally including in Malaysia (Chan et al., 2017). High-intensity interval exercise (HIIE) has emerged as a feasible strategy for improving and encouraging PA participations in adult populations. The most prominent advantage of HIIE is that this form of exercise can be completed in a short period of time as compared to traditional continuous type of exercise (Babraj et al., 2009) As a result, HIIE can mitigate the most commonly cited barrier to physical activity which is 'lack of time' (Reichert et al., 2007)**.**

Despite available evidence to indicate that HIIE protocol to promote a myriad of health benefits in adult, the application of HIIE as health strategy in a population-based level is controversial. This contentious is mainly because HIIE may generate less pleasurable feelings and greater exertional stress due to the high-intensity exercise performs during this protocol. Consequently, the negative psychological responses (i.e. feelings of displeasure and greater exertional stress) could lead to poor exercise maintenance and adherence as reported in previous studies in adult (reference). There is growing evidence to shows the effects of HIIE on perceptual responses (affect, enjoyment and perceived exertion) in adults, but these studies were limited to the

prescribed based protocol conducted in a laboratory setting (Thiago et al., 2016). This approach does not represent individual's real-world affective responses (feelings of pleasure and displeasure) and lack of ecological validity. Previous studies have shown that both mode of exercise (prescribed vs self-paced exercise) and environmental setting (treadmill vs overground exercise) could influence individual's perceptual responses and exercise performance (e.g. exercise intensity/ or pace) in adult (Williams, 2008). Nevertheless, it is impossible to extrapolate data from the previous studies as it utilised continuous type of exercise. Elucidating this information was important as affective evaluation during exercise may influence future attitudes towards PA behaviour in adult (Schneider et al., 2009).

Self-paced interval running can be performed either in overground/outdoor conditions or on a treadmill. The treadmill presents an environment where variables such as velocity and gradient can be standardised and reproduced (Schache et al., 2001). Despite the widespread use of treadmills in self-paced-based studies in adult, there remain concerns about whether treadmill running could evoke desire physiological demands and running performance required during overground running. Previous studies have suggested that self-paced treadmill running evoked similar rate of perceived exertion (RPE), and heart rate (HR) responses but different running pace in healthy adult. These findings are limited, however, to the continuous running exercise with the duration ranged from 3 minutes to 60 minutes, and also based on fixed ranged of running pace (i.e. prescribed/imposed protocol) from 3 km/h to 16 km/h. Currently, there is very little information regarding the effects of treadmill and overground running on physiological responses and running performance (distance covered) during interval running exercise. Documenting this information will enable researchers,

educators and coaches to safely, accurately, and effectively prescribe HIIE in different environmental settings in adult.

Evidence has revealed that depending on work-intensity, self-paced continuous walking could generate greater enjoyment and pleasurable feeling when compared to the imposed walking paced protocol in adult (P. Ekkekakis & Lind, 2006). However, it is not possible to extrapolate this previous evidence to the other exercise modalities (e.g. running) due to the potential difference in psychological (e.g. perceived exertion, affect responses and enjoyment) and physiological responses (e.g. HR responses) However, a single study by Turner et al., 2017 has shown that similar positive affect responses (pleasurable feelings) during and after continuous high-intensity exercise performed by regular runners in the outdoor and indoor gym. Whether treadmill and overground interval running exercise are perceived as similar affect responses (pleasure/displeasure) by non-regular runners is currently unknown.

Therefore, the purpose of the present study was to examine the psychological, physiological and running performance to self-paced interval running with different exercise setting (treadmill vs overground) in non-regular runners.

1.2 PROBLEM STATEMENT AND STUDY RATIONALE

There is evidence that demonstrates the effects of HIIE on psychological and physiological responses but the relevant research is limited to researchers' prescribed work intensity in a laboratory setting, and fewer studies have investigated the impact of interval form of exercise with different exercise setting (Treadmill vs. Overground), especially in non-regular runners. Previous environmental-based studies in adult have shown that 'natural setting' or overground exercise setting may elicit greater exercise

performances and positive psychological responses (greater enjoyment and pleasurable feelings) as compared to the treadmill-based protocol. This observation may indicate that both factors are influenced by the exercise setting, but it is not possible to extrapolate findings form continuous type of exercise to the other exercise mode such as interval form of exercise. This study will provide potentially valuable information pertaining to the impact of exercise setting to interval exercise on their perceptual responses, running performance and physiological responses and cardiorespiratory fitness. This proposed study will potentially provide guidelines to exercise prescription that may promise greater behavioural engagement and adherence to exercise and PA.

1.3 OBJECTIVES OF THE STUDY

1.3.1 General objective

To evaluate the psychophysiological responses and running performance during self-paced interval treadmill running (Treadmill IR) and self-paced interval overground running (Overground IR) in non-regular runners.

1.3.2 Specific objectives

1. To compare the running performance (running speed and distance covered) between Treadmill IR and Overground IR in non-regular runners.

2. To compare the psychological responses (affective, enjoyment, RPE) between Treadmill IR and Overground IR in non-regular runners.

3. To compare the heart rate responses between Treadmill IR and Overground IR in non-regular runners.

1.4 RESEARCH QUESTIONS

1. Is there any significant difference in running performance between Treadmill IR and Overground IR in non-regular runners?

2. Is there any significant difference on psychological responses between Treadmill IR and Overground IR in non-regular runners?

3. Is there any significant difference on heart rate (HR) responses between Treadmill IR and Overground IR in non-regular runners?

1.5 HYPOTHESES OF STUDY

H_{O1} : There are no significant differences in running performance between Treadmill IR and Overground IR in non-regular runners.

H_{A1} : There are significant differences in running performance (running speed and distance covered) between Treadmill IR and Overground IR in non-regular runners.

H_{O2} : There are no significant differences in the psychological responses between Treadmill IR and Overground IR in non-regular runners.

H_{A2} : There are significant differences in the psychological responses between Treadmill IR and Overground IR in non-regular runners.

H_{O3} : There are no significant differences in the HR responses between Treadmill IR and Overground IR in non-regular runners.

H_{A3} : There are significant differences in the HR responses between Treadmill IR and Overground IR in non-regular runners.

CHAPTER 2 : LITERATURE REVIEW

2.1 HIGH-INTENSITY INTERVAL EXERCISE

High-intensity interval training (HIIE) is a form of interval training, a cardiovascular exercise strategy alternating short periods of intense anaerobic exercise with less intense recovery periods, until too exhausted to continue. HIIE is commonly involves (~4 – 10 repetitions) with short bursts (20 seconds – 5 minutes) of high-intensity exercise (80 to 100% of HR_{max}) of work interval interspersed with low-to-moderate intensity exercise of recovery interval. The main appeal of HIIE is that this type of training can be completed in a short period of time and physical adaptations are comparable (or superior) to those resulting from continuous type of exercise. This means HIIE requires less time be spent on exercising while providing similar or greater health-related benefits, compared to established physical activity recommendations (Ciolac et al., 2010; Gibala et al., 2012). Given the less time spent require when performing HIIE protocol, it has been proposed that HIIE can mitigate most commonly cited barrier to physical activity especially in adult which is 'lack of time' (Reichert et al., 2007).

HIIE also became known as an effective and safe strategy for increasing conditioning in both athletes and non-athletes (Gibala et al., 2014; Gibala & Little, 2010; Osawa et al., 2014; Rozenek et al., 2016). The sessions were made up of repeated high-intensity stimuli followed by a brief rest period, which can be performed using ergometers, such as a stationary bike or treadmill (Gibala et al., 2014; Rozenek et al., 2016) or with individual body weight (Mcrae et al., 2012; Gist et al., 2014; Nicholas Gist et al., 2015). According to prior research, the overall duration of the HIIE workout

might range between 4 and 32 minutes. Furthermore, this time range has been established in the literature to be sufficient for achieving favourable adaptations to weight loss and increased physical fitness fast and efficiently. (Gibala & Little, 2010; Mcrae et al., 2012; Buchheit & Laursen, 2013; Gibala et al., 2014; Rozenek et al., 2016).

While HIIE may represent a promising strategy for improving health outcomes, sceptics argued that HIIE will be perceived as aversive, and thus it would be unlikely that people would pursue this type of exercise (Biddle & Batterham, 2015; Hardcastle et al., 2014). This suggests poor implementation and adoption of HIIE as a way to improve health and well-being at the population level. Consequently, the relevance of HIIE may be questionable from a public health perspective. The growing interest of HIIE protocol as an alternative strategy to continuous moderate intensity of exercise has led to investigation in an area of affective responses. Affect is a generic term that represents the feelings of pleasure and displeasure of individuals during exercise.

Indeed, according to Tjønna et al. (2008), participants performed HIIE found it more motivating to have varied procedure to follow during each training sessions, whereas those in the moderate-intensity continuous group found it ‘‘quite boring" to exercise continuously for the entire duration. Such responses appear to support the idea HIIE is more fun than moderate-intensity continuous exercise. One study found that, despite higher RPE ratings during interval exercise, recreationally active men find high-intensity interval running to be more fun than moderate-intensity continuous running (Bartlett et al., 2011). This study also indicates that HIIE could be an effective strategy for increasing long-term exercise participation and improving human health. However, there was a study that differed from the results observed by Bartlett et al. (2011), where

they observed negative feeling scale responses in HIIE compared to continuous training during and after the exercise session (Oliveira et al., 2013).

Previous evidence also reveals that when compared to continuous high-intensity exercise, HIIE elicited more pleasurable feelings, but less pleasurable or similar to continuous moderate-intensity exercise.(Jung et al., 2014; Martinez et al., 2015). These findings suggest that when high-intensity exercise is conducted in brief bursts interspersed with periods of recovery, low-intensity exercise conducted during the HIIE recovery intervals may not hold negative feelings and high exertion stress (i.e. perceived exertion).Therefore, there was strong rationale to investigate alternative strategy to facilitate the applicability of HIIE protocol in adult populations. An alternative strategy may focussing on exercise setting and self-paced type of exercise as these two strategies have been shown to influence individual exercise motivation and exercise performance in adult populations. This area of research is in its infancy with related to the interval form of exercise as majority of available evidence limited to the continuous type of exercise.

2.2 EXERCISE PERFORMANCE DURING TREADMILL AND OVERGROUND EXERCISE SETTING

The factor that can cause differences is the characteristic of the running surface, and thus the momentum runners gain from the moving treadmill belt or a change in locomotion characteristics on the various running surfaces (Jones & Doust, 1996). Treadmills are widely used and considered valid for the measurement of overground running performance. Jones & Doust (1996) emphasized the use of a 1% treadmill

gradient to achieve the most strongly correlated oxygen uptake (VO2) measures between such running modalities.

During self-paced running, the energy cost of the task performed depends upon a number of biomechanical, physiological, and environmental factors. Running modality is an environmental factor that can affect both biomechanical and physiological factors and can have a great impact on runners' energy costs during training or a race. Running outdoor has generally been found to incur greater energy costs compared to running on a treadmill (Williams., 1990). This may be due to a number of factors, such as air resistance when running on a track, visual cues from moving surroundings, or the athletes' extent of familiarity with the chosen modality (Jones & Doust, 1996; Hopker et al., 2009). The effect of air resistance becomes more pronounced at high running speeds, and higher differences in energy costs between outdoor running and treadmill running, therefore likely to be observed as velocity increases (Daniels, 1985).

There were some evidence showing differences when running on a treadmill and overground in several variables which are stride frequency, ankle, knee, and hip kinematics, muscular activity (Wank & Schmidtbleicher, 1989), contact time (Mckenna & Riches, 2007) energy expenditure, shock attenuation (Hines and Mercer, 2004) and plantar pressure (Hong et al., 2012). These differences could be due to treadmill familiarisation, intra-stride treadmill speed variations because of the interaction between the runner and the device, air resistance and the runner trying to reach a stable and safe running pattern on the treadmill (Nigg et al., 1995).

According to William (1985), the differences observed between treadmill and overground increase as the speed increases. These observations may indicate that the

difference in exercise intensity (moderate vs high intensity exercise) performed in both environmental setting could influence exercise performance due to the familiarity or running experience of the individuals. Whether similar pattern of exercise performance will be observed during interval exercise in non-regular runners is currently unclear. Also, available studies in this area of research were limited to the imposed based protocol rather than self-paced based protocol in an athletic population which does not reflects the implementation of health strategy in a population-based level.

2.3 PSYCHOLOGICAL RESPONSES TO TREADMILL AND OVERGROUND EXERCISE SETTING

The process of self-monitoring and self-regulation in physical exercise deals with how well individuals are capable of adjusting the intensity of any exercise modality in order to reach a level that is best suited to their state of health and fitness (Burke and Collins, 1984; Hage, 1981). Allowing individuals to pace themselves during exercise has been shown to evoke greater perceived autonomy, and consequently enjoyment and adherence. For instance, a review paper of 31 studies by (Panteleimon Ekkekakis, 2009) has shown that by allowing individuals to self-select their own exercise intensity compared to an external person prescribing an intensity elicits more positive affective responses. However, there are differences in perceptual and physiological responses between self-paced interval running in overground and treadmill.

Certain environments may lead to greater use of dissociative cognitive strategies. Most of the studies showed that exercising in natural environments (outdoor)

may results in more favourable changes in pleasant affective responses relative to exercising in laboratory environments (Gauvin et al., 1995; Gauvin & Rejeski, 1993). Researchers suggest that the novel stimuli in outdoor environments provide a pleasant distraction from feelings of exertion, resulting in greater enjoyment and positive affect than indoor exercise (Focht, 2009; Harte & Eifert, 1995). However, there was a study showed that regular runners experience positive affective responses in both outdoor environment and an indoor gym (Turner et al., 2017). Furthermore, participants in past studies have typically been experienced runners or elite athletes, who tend to use more associative strategies during exercise than non-regular runners. Thus, the purpose of the present study is to determine the perceptual responses during Treadmill IR and Overground IR in non-regular runners.

For perceived exertion, LaCaille and colleagues (2004) found that outdoor running was perceived to be less strenuous than indoor treadmill running (Lacaille et al., 2004). Some studies found that even when participants self-selected higher exercise intensities outdoors, outdoor exercise has been found to encourage a more externally-focused attention style and result in lower RPE than indoor exercise (Ceci & Hassmén, 1991; Harte & Eifert, 1995). Meanwhile, no differences in perceived exertion between treadmill and outdoor running were recorded in other study (McMurray et al., 1987).

2.4 HEART RATE RESPONSES DURING TREADMILL AND OVERGROUND EXERCISE SETTING

Heart rate is the most common, non-invasive measure of exercise intensity. In exercise testing, HR responses to exercise are used to monitor the progression. HR has

typically been used to prescribe suitable intensities of aerobic exercise for individuals exercising to develop or maintain cardiorespiratory fitness. The American College of Sports Medicine (ACSM) uses percentage of HR reserve or maximal HR to describe intensity by assigning intensity levels to each percentage from light to near maximal/maximal (Riebe et al,. 2013). Target HR zones were used to assure an appropriate and safe exercise intensity.

Different HR recommendations for walking, jogging, or running on a treadmill versus walking, jogging, or running on the overground would be justified based on differences in HR response. The difference in physiological responses, such as HR, to treadmill and overground running is limited. Although some studies support the idea that physiological responses to exercise on the treadmill are comparable to exercise on the overground, however, research has definitely found significant differences in technique and some physiological responses to overground and treadmill (McMiken & Daniels, 1976; Meyer et al., 2003; Riebe et al., 2013).

In a study showed that treadmill exercise elicited HR responses which were on the average about 5 bpm less than exercise at overground. Differences in the biomechanics of running, muscle activity, and air resistance may explain the lower HR response to treadmill running. It has been reported that stride length shortens, stride rate increases, and the contact time of the foot to the ground is significantly decreased while running on the treadmill compared to running on overground (Elliott & Blanksby, 1976; Wank & Schmidtbleicher, 1989) . Less muscular contraction time may result from the reduced contact time and greater “non-support” time. The decreased contact time may be a result of the moving treadmill belt, allowing for less propulsion, which also contributes to a reduction in muscle contraction as well as a reduction in heart rate.(Nigg et al., 1995).

Changes in muscle activity and recruitment produced by biomechanical variations in treadmill running vs running on the ground could result in a modest difference in energy requirement, resulting in a slightly lower heart rate (Wank & Schmidtbleicher, 1989)**.** However, air resistance to jogging or running is considered to be an important factor in the differences between treadmill and overground running. Overcoming air resistance was said to account for 8% of the overall energy cost of running overground at intermediate distance speeds (Pugh, 1967).

CHAPTER 3 : METHODOLOGY

3.1 RESEARCH DESIGN

This study utilized a repeated measures cross-over design, whereby each participant completed two different exercise conditions, namely self-paced interval treadmill running (Treadmill IR) and self-paced interval overground running (Overground IR). No control group was included for this study. This study had no conflict of interest.

3.2 STUDY LOCATION

All the data collections were conducted at Sport Science Laboratory and Sports Complex 1, Universiti Sains Malaysia Health Campus, Kelantan for both treadmill and overground exercise, respectively.

3.3 SAMPLE SIZE CACULATION

Sample size was calculated by using G*Power version 3.1.9.2. The sample size is a reflection of related research for the differences in the outcome variables (i.e. affect responses and RPE) across difference exercise settings (i.e. treadmill and outdoor exercise) which has been shown to have an effect size (ES) ranging from medium to large (d=0.45-0.85) (LaCaille et al., 2004; Miller et al., 2019) . For the purpose of the current study, where two conditions and eight repeated measurement points (i.e. pre 5-min, was analyzed using a two-way repeated measure analysis of variance (ANOVA), a sample size of 8 participants would be required to detect a

moderate effect using a power of 0.8, an alpha of 0.05 and an effect size, F, of 0.30 (medium). Therefore, assuming a dropout of four participants, for the current study we proposed to recruit 12 participants.

3.4 CRITERIA OF PARTICIPANTS

3.4.1 Inclusion criteria

The inclusion criteria for participation in this study included men and women which are non-regular runners (jogging or running not more than once per week), ages between 18 to 25 years old, had no musculoskeletal injuries especially to lower limbs, which may prohibit the study testing and can running on treadmill. None of the participants had any medical conditions or illnesses that could affect their mood or ability to exercise. All participants were also unfamiliar with HIIE regimes.

3.4.2 Exclusion criteria

Criteria for exclusion included smoking, hypertension, dyslipidemia, impaired fasting glucose, not using any medication or substance known to influence cardiorespiratory or metabolic responses to exercise (type of medication can be referred to previous review by Peel and Mossberg (1995)), and they were currently participating in any exercise program.

3.5 SAMPLING METHOD AND SUBJECT RECRUITMENT

All participants (students of Universiti Sains Malaysia) were recruited via an advertisement that has been posted via poster (Appendix B) and disseminated throughout the Health Campus in Universiti Sains Malaysia and social media. The

basic information of the participants was recorded in the Data Collection Form (Appendix H). All the participants were required to fill up physical activity readiness questionnaire (PAR-Q) (Appendix C) before commencing experimental tests. This self-administered questionnaire was to assess any health condition that can exclude the volunteer from participate in this study. The sampling method will be a random sampling and participation in this study was expected to last up to 4 weeks.

3.6 DATA COLLECTION METHOD

Participants completed three experimental visits throughout the study with a minimum of 48 hours gap 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 (HR_{max}) and familiarization of experimental protocol. Following the first visit participants completed two experimental conditions, namely, self-paced interval treadmill running (Treadmill IR) and self-paced interval overground running (Overground IR), the order of which counterbalanced to control for any order effect. Distance covered (meter) average running speed (Km/h), variable of heart rate, perceptual responses consisting of affective valence (pleasure/displeasure feelings), enjoyment and perceived exertion were measured during each exercise session. Participants were performing the exercise session on a motorized treadmill (Trackmaster). Outdoor exercise was conducted on a 400 m outdoor field track.

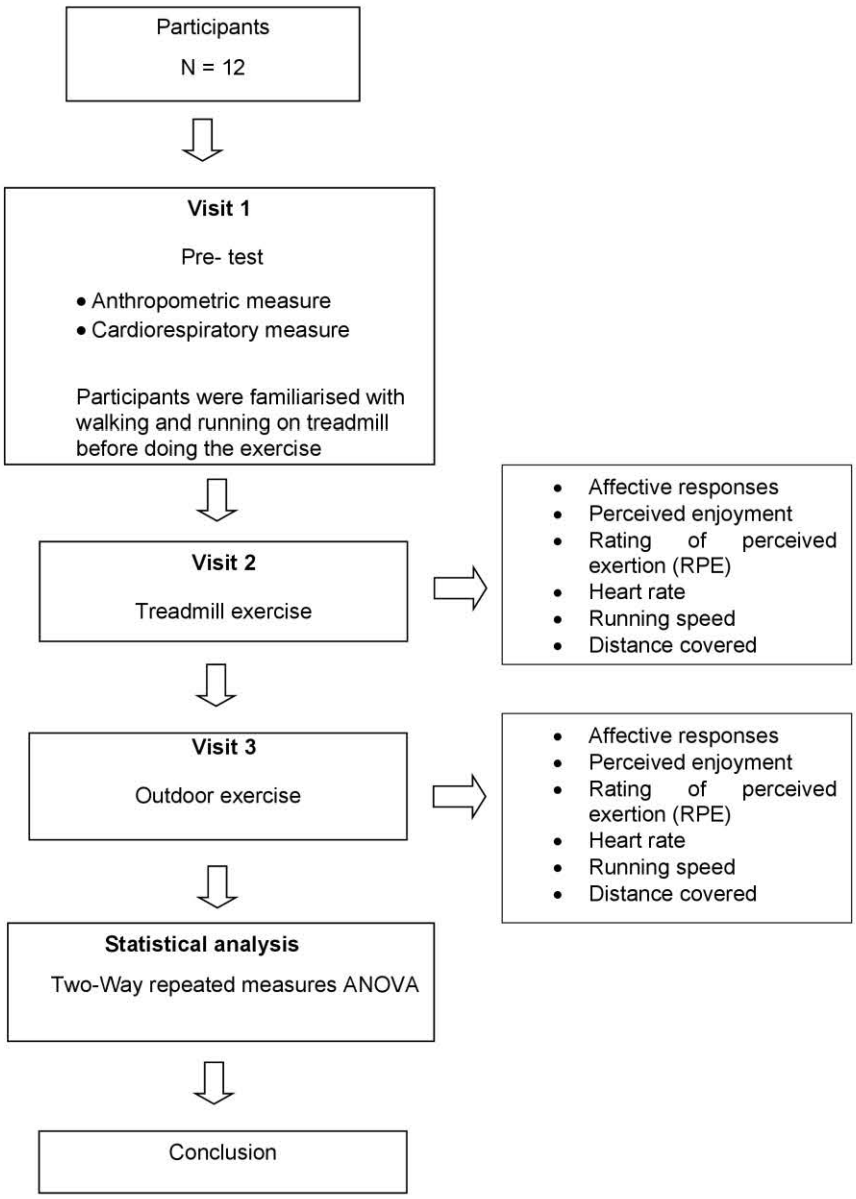

Figure 3.1 : Flow chart of the study procedures

3.7 MEASUREMENTS INSTRUMENTS AND PROCEDURE

3.7.1 Anthropometric and physical activity

Body mass and stature were measured to the nearest 0.1 kg and 0.1 cm, respectively (the participants were shoeless and wear light clothing) by a body composition analyzer (Tanita, Japan) and a stadiometer (Seca, China) respectively. Body mass index (BMI) was calculated as body mass (kg) divided by height (m) squared. Participants completed Malay versions of the International Physical Activity Questionnaire sort form (IPAQ-M; reference) to determine habitual PA levels. 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).

3.7.2 Determination of maximal aerobic speed (MAS) and maximal heart rate (HR_{max})

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

3.7.3 Affective responses

The Feeling Scale (FS; Hardy & Rejeski, 1989) was used as a measure of ‘‘basic’’ or ‘‘core’’ affective valence (pleasure–displeasure). Participants responded to how they feel on an 11-point bipolar scale ranging from "Very Good" (+5) to "Very Bad" (-5). Perceived activation levels was measured using the single-item felt arousal scale (FAS**;** (Svebak & Murgatroyd, 1985)**.** Participants were asked to rate 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). Participants responded to the FS and FAS 5 minutes before exercise, last 15 s of each work interval, and immediately after exercise. Participants were also given standardized verbal instructions on how to use the scales before undertaking the incremental test and at the start of the exercise session using the below sentences:

Feeling Scale: *While participating in exercise, it is quite common to experience changes in mood. Some individuals find exercise pleasant, whereas others 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. How does above scenario make you feel during the exercise?*

Felt arousal scale: *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 variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness.*

3.7.4 Rating of perceived exertion

Perceived exertion was defined as the subjective intensity of effort, discomfort, strain, and/or fatigue that was felt during exercise (Noble B & Robertson R., 1996). The 10-point Category-Ratio 10 Scale (CR-10; Borg 1998), also commonly referred to as the Rating of Perceived Exertion 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). Similar to FS and FAS, participants responded to RPE 5 minutes before exercise, last 15 seconds of each work interval and immediately after the exercise.

3.7.5 Perceived enjoyment

Participants' enjoyment of each exercise conditions were examined using a Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991) 10 minutes post- exercise. This 18-item measure scored on a 7-point bipolar scale. Example items were ''it's not very refreshing/It's very refreshing'' and ''I would rather be doing something else/ there is nothing else I would rather be doing''. The score for each item was summed to calculate a total enjoyment score out of 119 for each exercise conditions.

3.7.6 Exercise Protocols

For the Treadmill IR, participants performed 3 minutes warm-up at 5.0 $km.h^{-1}$ followed by 8 repetitions of 1-minute work intervals (8 x 1 minute work interval) at self-selected exercise intensity. Immediately after the warm-up, participants were

asked to begin the session by setting the treadmill to the highest possible running speed they feel they could maintain for 1 minute knowing they need to perform 8 repetitions. Participants also were informed that there was no right or wrong running speed rather just set the belt at the speed they felt as their highest effort given the exercise situation. Participants were allowed to increase, decrease, or maintain the treadmill speed. The work intervals from each repetition separated with 75 seconds active recovery performed at self-selected walking paced. Specifically, participants dismounted form the treadmill during recovery intervals of Treadmill IR protocol. A 2 minutes cool down at self-selected walking paced was also provided after exercise. Distance covered (meter) and average running speed (Km/h) during self-paced were obtained from the treadmill and variables of heart rate, RPE, affective responses and perceived enjoyment were recorded every each of the work intervals.

Overground exercise was conducted on a 400 m outdoor field track. Participants performed similar set of self-paced interval running protocol (8 x 1 minute work intervals interspersed with 75 s recovery intervals), as in treadmill running, during the overground running condition. Similarly, distance covered (meter) and average running speed (Km/h) were also recorded using Runkeeper software version 4.4.3 (FitnessKeeper). This software has been previously validated to measure distance travelled and running speed during exercise in healthy and physically active adult (Adamakis, 2017). The dependent variables of this present study including heart rate, RPE, affective responses and perceived enjoyment were recorded every each of the work intervals. Overground exercise were undertaken separately to eliminate any possible effect of group dynamic or social contact on the psychophysiological responses to exercise. The laboratory temperature was set similar to the outdoor temperature (range between 24° and 26° C, humidity range between 55% and 60%).

3.8 STATISTICAL ANALYSIS

All statistical analyses were conducted using SPSS (SPSS 26.0; IBM Corporation, Armonk, NY, USA). All the date was presented as mean ± standard deviation (SD). Data was analyzed using a two-way repeated measures ANOVA to examine differences in affect, enjoyment RPE, HR responses during self-pace interval running with different exercise setting (treadmill and outdoor running) over time (before and during self-pace work intervals). In the event of significant effects ($p<0.05$), follow-up Bonferroni post hoc test was conducted to examine the location of mean differences. The magnitude of mean differences was interpreted using effect size (ES calculated using Cohen's d Cohen, 1988), where an ES of 0.20 was considered to be a small change between means, and 0.50 and 0.80 interpreted as a moderate and large change respectively.

CHAPTER 4 : RESULTS AND ANALYSIS

4.1 PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS

A total of twelve non-regular runners (6 men and 6 women) from Universiti Sains Malaysia, Health Campus participated and completed the self-paced interval running during treadmill and overground exercise. All the participants were categorized as a moderately active adult based on the habitual PA levels data measured using IPAQ-M. **Table 4.1** shows the descriptive characteristics of the participants. The data were analysed by descriptive statistics and expressed in means ± standard deviations (SD).

Table 4.1 Descriptive characteristics of the participants (N = 12)

	Mean ± SD	**Min**	**Max**
Age (y)	21.3 ± 1.7	19	25
Body mass (kg)	55.8 ± 9.2	42.2	69.4
Stature (m)	1.63 ± 0.07	1.49	1.76
BMI ($kg \cdot m^2$)	20.9 ± 2.7	17.7	26.25
Body fat (%)	22.6 ± 7.1	12.8	39.4
HR_{max} (bpm)	194 ± 8.3	177	209
MAS ($km \cdot h^{-1}$)	13.5 ± 2.4	10.0	16.5
RPE_{max}	7.5 ± 1.8	5	10
IPAQ (MET.min.wk-1)	2446 ± 1238	838	4053

Values are reported as mean ± standard deviation. Abbreviations: BMI, body mass index; HR_{max}, maximal heart rate; MAS, maximal aerobic speed; RPE_{max}, maximal rating of perceived exertion; IPAQ, International Physical Activity Questionnaire.