EFFECTS OF MODERATE- AND HIGH- INTENSITY WARM-UP ON EXERCISE PERFORMANCE AND PSYCHOPHYSIOLOGICAL RESPONSES DURING SELF-PACED INTERVAL RUNNING

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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)

JUN

CERTIFICATE

This is to certify that the dissertation entitled EFFECTS OF MODERATE- AND HIGH-INTENSITY WARM-UP ON EXERCISE PERFORMANCE AND PSYCHOPHYSIOLOGICAL RESPONSES DURING SELF-PACED INTERVAL RUNNING is the bona fide record of research work done by Mr MUHAMMAD SYAMIL BIN MOHD PAUZI during the period of September 2020 until 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 Science (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 SYAMIL BIN MOHD PAUZI

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LIST OF ABBREVIATIONS AND ACRONYMS

%	Percentage
>	Greater than
<	Less than
ACSM	American College of Sports Medicine
ANOVA	Analysis of variance
ATP	Adenosine Triphosphate
BMI	Body mass index
^{o}C	Degree celcius
C-IR	Stretching exercise followed by self-paced interval running
ES	Effect size
FAS	Felt arousal scale
FS	Feeling scale
H-IR	High-intensity warm up followed by self-paced interval running
HEPA	Health-enhancing physical activity

HIIE	High intensity interval exercise
HR	Heart rate
HREC	Human Research Ethics Committee
HR_{max}	Maximal heart rate
HR_{peak}	Peak heart rate
IPAQ-M	International Physical Activity Questionnaire Malay Version
kg	Kilogram
km	Kilometer
Km/h	Kilometer per hour
m	Meters
M-IR	Moderate-intensity warm up followed by self-paced interval running
MAS	Maximal aerobic speed
min	Minute
mM/L	Millimoles per liter
N	Total sample size
P	Significant effect
PACES	Physical activity enjoyment scale
PAR-Q	Physical activity readiness questionnaire

RPE	Rating of perceived exertion
s	Second
SD	Standard deviation
USM	Universiti Sains Malaysia
VO_2	Aerobic capacity
VO_{2max}	Maximal aerobic capacity
VO_{2peak}	Peak aerobic capacity
VT	Ventilatory threshold
W	Work interval
WHO	World Health Organization

Kesan-kesan Pemanasan Badan Berintensiti Tinggi dan Rendah Terhadap Prestasi Senaman dan Tindak Balas Secara Psikofisiologi Ketika Larian Berselang dengan Kelajuan yang Ditetapkan Sendiri

ABSTRAK

Pemanasan badan berintensiti tinggi boleh mengurangkan prestasi senaman dan menimbulkan perasaan negatif semasa bersenam, bahkan ketika aktiviti yang dirasakan dan tekanan fisiologi menjadi tinggi pada orang dewasa. Walau bagaimanapun, impak daripada intensiti pemanasan badan yang berbeza pada prestasi senaman dan reaksi psikofisiologi masih belum jelas. Kajian ini meneliti afektif genting, pengerahan tenaga yang dirasakan, dan tindak balas kardiorespirasi terhadap larian berselang secara mandiri dengan intensiti pemanasan yang berbeza pada orang dewasa. Keadaan pemanasan termasuk pemanasan intensiti tinggi (90% daripada kelajuan aerobik maksimum (MAS)), pemanasan intensiti sederhana (50% daripada MAS), dan tiada pemanasan diikuti dengan 5 x 1 minit larian berselang secara mandiri diselangkan dengan pemulihan 75 saat pada hari yang berlainan untuk peserta (N = 12; 7 lelaki, 5 wanita; usia 23.0 ± 1.1 tahun). Tindak balas afektif, kadar nadi (HR) dan penilaian pengerahan tenaga (RPE) dicatat sebelum dan selepas pemanasan dan sebelum, ketika dan setelah larian berselang secara mandiri. Ketika pemanasan dan interval kerja 1 hingga 5, tindak balas afek menurun pada semua keadaan ($P < 0.05$), meskipun pemanasan intensiti tinggi menimbulkan tindak balas afek yang jauh lebih sedikit daripada intensiti sederhana dan tanpa pemanasan. RPE secara signifikan adalah lebih tinggi selama pemanasan intensiti tinggi daripada intensiti sederhana dan tanpa pemanasan ketika situasi pemanasan dan interval kerja 1 sampai 5 (semua $P < 0.05$, $ES > 0.6$). HR pada kondisi kontrol secara signifikan lebih rendah daripada kondisi intensiti tinggi dan intensiti sederhana pada interval kerja 1 dan 2, tetapi mulai interval kerja 3 hingga 5, HR pada semua kondisi pemanasan tidak mempunyai perbezaan yang signifikan. Walaupun prestasi senaman meningkat untuk semua interval bagi ketiga-tiga

kondisi pemanasan, impak menyenangkan yang dialami selama berlari secara mandiri selepas intensiti sederhana dan tanpa pemanasan dapat digunakan sebagai pendekatan untuk memotivasi orang dewasa untuk memulakan dan tetap berpegang pada senaman.

EFFECTS OF MODERATE- AND HIGH- INTENSITY WARM-UP ON EXERCISE PERFORMANCE AND PSYCHOPHYSIOLOGICAL RESPONSES DURING SELF-PACED INTERVAL RUNNING

ABSTRACT

A high-intensity warm-up can reduce exercise performance and induce negative feelings during exercise, even when perceived exertion and physiological stress are high in adults. The impact of different warm-up intensities on exercise performance and psychophysiological reactions, on the other hand, remains unclear. This study examined the acute affective, perceived exertion and cardiorespiratory responses to self-paced interval running with different warm-up intensities in adults. Warm-up conditions included high intensity warm-up (90% of maximal aerobic speed (MAS)), moderate intensity warm-up (50% of MAS), and no warm-up followed by 5 x 1-minute self-paced interval running separated by 75 seconds recovery on separate days for participants ($n = 12$; 7 men, 5 women; age 23.0 ± 1.1years). Affective responses, heart rate (HR) and rating of perceived exertion (RPE) were recorded before and after warm-ups and before, during and after self-paced interval running. During the warm-up and work intervals 1 to 5, affective response decreased in all circumstances ($p < 0.05$), although high intensity warm-up evoked substantially less affective response than moderate intensity and no warm-up. RPE was significantly higher during high intensity warm-up than moderate intensity and no warm-up condition during warm-up and work intervals 1 to 5 (all $P < 0.05$, $ES > 0.6$). During the high-intensity warm-up, the majority of the participants reached 90% HRmax, but not during the moderate-intensity warm-up or no warm-up. HR in control condition was significantly lower than high intensity and moderate intensity condition at work intervals 1 and 2, but starting from work intervals 3 to 5, the HR of all warm-up conditions had no significant difference. Despite the fact that exercise performance improved for all intervals under all three warm-up conditions, the pleasant

impact experienced during self-paced running after moderate intensity and no warm-up could be used as an approach to motivate adults to start and stick to an exercise regimen.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Performing a warm-up prior to an exercise session may lead to the adjustment of the physiological responses requires during subsequent exercise. These physiological adjustments [e.g. increase in muscle temperature and oxygen uptake (VO_2)] could enhance subsequent physical performance in exercise. Indeed, a systematic review conducted by Fradkin et al. (2010) have revealed that changes in physiological responses such as heart rate (HR) and VO_2 after completion of warm-up activities have led to improvements in myriad physical performances (e.g. running speed, peak power, time trial) in running and cycling exercise. Nevertheless, the enhancement of these physical performances depending on specific warm-up strategies (e.g. intensity and duration) (Fradkin et al., 2010; McGowan et al., 2015). Consequently, these findings reinforce the need to evaluate specific warm-up strategies on cardiorespiratory responses and subsequent exercise performance.

The effect of the warm-up is determined by several strategies, including warm-up intensity and duration. Previous studies have shown that the enhancement of exercise performance is influenced by the intensity of the warm-up. For example, Bishop and colleagues (2001) reported that a warm-up performed at ~70% of peak oxygen uptake (VO_{2peak}) elicited greater running performance (e.g. running speed) during exercise that last for 70s – 120s. A recent finding by Fujii et al. (2018) have revealed that both work-matched moderate- (~40% VO_{2peak}) and high- (~80% VO_{2peak}) intensity warm-ups improved final sprint (~30 s) in cycling performance during the late stage of a 120-s supramaximal exercise bout. Additionally, the authors found that high-intensity warm-up provides greater improvement of maximal sprinting performance (i.e. peak power) compared to moderate-intensity warm-up. These observations may indicate that different intensities of warm-up could influence subsequent exercise performance that are related to individual's maximal effort (e.g. exercise intensity) during intense short bout of exercise such as interval type of exercise. This report was based on physical performance in athletes; however, little is known about the concomitant effects of warm-up intensity on the selection of exercise intensity during self-paced interval type of exercise in non-athletic adults. Elucidation of this information is therefore important as exercise intensity is not only a crucial component of exercise prescription to promote multiple health benefits, but this exercise component also could influence future exercise adherence.

It has been documented that the future engagement in exercise is related to the relationships between affective response (i.e. pleasure/displeasure), enjoyment responses and exercise intensity (Ekkekakis et al., 2011). Consideration of maintaining positive affect responses (pleasurable feelings) during exercise is important because negative affect (unpleasant feelings) may reduce the likelihood that individuals will continue it in future (Rhodes and Kates, 2015., Williams, 2008). Ekkekakis and colleagues (2011) have revealed that continuous high-intensity exercise may lead to a decline in affect responses (less pleasurable feelings) when compared to continuous moderate-intensity exercise. This was mainly because high-intensity exercise may generate ~~the~~ higher physiological stress (increased HR) and effort responses [rating of perceived exertion (RPE)] during the exercise. These observations establish the notion that individual's perceptual responses (affect, enjoyment and RPE) are mediated by the exercise intensity. Also, previous studies have shown that other factors such as pre-exercise affect response (baseline affect) (Astorino and Vella, 2018) and perceived autonomy (self-selected) (Ekkekakis, 2009) may influence the changes of affect response during exercise. Yet, both researches are limited by measuring the affect responses before the warm-up session. Identifying factors such as these that mediate how individuals perceive exercise is important as it helps to potentially tailor exercise as has been recommended.

Research has yet to determine how warm-up with different intensities could influence the magnitude of change in perceptual responses and exercise performance during subsequent self-paced interval exercise. Therefore, the purpose of the present study was to determine the effects of moderate and high intensity warm-up on exercise performance, HR responses and psychological responses during self-paced interval exercise in adults.

1.2 PROBLEM STATEMENT

Previous evidences have shown that exercise performances (e.g. running speed and cycling peak power) are influenced by the warm-up intensity (moderate vs. high intensity) (Bishop, 2003b; Edholm, et al., 2014; Stewart & Sleivert, 1998). This observation was mainly due to the changes in the physiological responses generated during warm-up. However, these studies are limited to the athletic performance strategy rather that health promotion strategy. Currently, it is unclear whether different warm-up intensity could also change the pattern of psychological responses (affect, enjoyment and perceived exertion) during interval exercise. This is important because different warm-up intensity strategy may lead to either greater or lower selection of work intensity during self-paced interval exercise. Consequently, it may alter the pattern of psychological responses during exercise as these responses (affect and perceived exertion) are influenced by the exercise intensity. It is vital to understand the pattern of affective responses during exercise, as previous research has indicated that the affect response experienced during exercise can influence future physical activity (PA) motivation and behaviour in adults (Ladwig, 2013). This study will possibly give rules to exercise and warm-up prescription which will guarantee more prominent behavioural engagement and adherence to exercise and exercise.

1.3 OBJECTIVES OF THE STUDY

1.3.1 General Objective

1. To determine the effects of moderate and high intensity warm-up on exercise performance and psychophysiological responses during self-paced interval running.

1.3.2 Specific objectives:

1. To compare the HR responses between moderate and high intensity warm-up during self-paced interval running.
2. To compare the psychological responses (affective responses, RPE and enjoyment) between moderate and high intensity warm-up during self-paced interval running.
3. To compare the exercise intensity performed after moderate and high intensity warm-up during self-paced interval running.

1.4 RESEARCH QUESTIONS

1. Is there any significant difference between moderate and high intensity warm-up on exercise intensity during self-paced interval running exercise?
2. Is there any significant difference between moderate and high intensity warm-up on cardiorespiratory responses during self-paced interval running exercise?

3. Is there any significant difference between moderate and high intensity warm-up on perceptual responses during self-paced interval running exercise?

1.5 HYPOTHESES OF THE STUDY

H_{O1}: There is no significant difference in the cardiorespiratory responses between moderate and high intensity warm-up during self-paced interval running.

H_{A1}: There is a significant difference in the cardiorespiratory responses between moderate and high intensity warm-up during self-paced interval running.

H_{O2}: There is no significant difference in the perceptual responses between moderate and high intensity warm-up during self-paced interval running.

H_{A2}: There is a significant difference in the perceptual responses between moderate and high intensity warm-up during self-paced interval running.

H_{O3}: There is no significant difference in the exercise intensity performed after moderate and high intensity warm-up during self-paced interval running.

H_{A3}: There is a significant difference in the exercise intensity performed after moderate and high intensity warm-up during self-paced interval running.

1.6 SIGNIFICANCE OF THE STUDY

Documentation of the data related to psychological, HR and exercise performance will enable researchers, educators or coaches to safely, accurately, and effectively prescribe the proper warm-up session before performing interval exercise protocol in adults. Specifically, this study will possibly provide feasible protocol consisting of warm-up and exercise prescription which may facilitate future exercise maintenance and behavioural engagement.

1.7 OPERATIONAL DEFINITION

Affect response

A general, valenced response (positive or negative) that does not require higher cortical processes to precede it.

Ratings of perceived exertion

A psychophysiologic approach in which the exerciser rates on a numerical scale perceived feelings relative to exertion level. This scale can be used in addition to oxygen consumption, heart rate, and blood lactate to indicate exercise intensity.

Enjoyment

A psychological state directly connected to that stimulus. It is an emotion and as such, requires a cognitive appraisal of a stimulus as having positive or negative implications for one's goals or well-being.

Warm-up

The running activity that consists of high (90% of MAS) and moderate (50% of MAS) intensity to prepare the body for the running interval.

Exercise performance

The running speed and distance covered during self-paced interval running.

Psychophysiological response

Psychology; affect response, enjoyment and RPE and physiology; HR response to the different intensities of warm-up, during running interval and cool down period.

Self-paced

Participants required to set their own speed during running interval in which the best speed they can run for 1 minute across five work intervals.

Interval running

short periods of high-intensity activity interspersed with periods of recovery. In the present study, the interval running involved with 5 x 1 minute work interval separated by 75 s active recovery.

CHAPTER 2: REVIEW OF LITERATURE

2.1 TYPE OF WARM-UPS

Most athletes will perform a warm-up routine before athletic events in the hope that it will improve their performance (Bishop, 2003a). Warm-up that affects physiological functions (e.g. increase blood flow to the muscles involved and increase muscle temperature) are performed for 5 to 15 minutes before the main exercise session is conducted. Warming up is intended to prepare the individuals from various aspects: mentally and physiologically in a coordinated and incremental manner so that individuals can participate effectively in training or competition. However, the impact of warm-up is decided by several factors, including the warm-up intensity (Bishop et al., 2002), duration (Baklouti et al., 2015) and time of transition after warm-up (Frikha et al., 2016).

Warm-up strategies can be divided generally into two main categories: (i) passive warm-up; or (ii) active warm-up. Passive warm-up involves increasing the muscle or core temperature by some external means such as using foam roller (Laffaye et al., 2019). Peacock et al. (2014) reported that the implementation of foam roller exercises in a warm-up routine has an effect on sprint time, although others indicated that there was no direct change in performance (Healey et al., 2014; Richman et al., 2019). Passive warm-up before exercise was consistently correlated with improved high-intensity efficiency, including maximum voluntary contraction (Davies & Young, 1983). These immediate performance improvements were due to increased turnover of anaerobic adenosine triphosphate (ATP), muscle fibre conduction velocity and enhanced cross-bridge cycling ability in the sarcomeres (Ferguson et al., 2002; Gray et al., 2006). However, through different types of massage, a similar no beneficial effects on sprint performance were observed (Goodwin et al., 2007). Active warm-up requires exercise and may cause greater metabolic and cardiovascular changes than passive warm-up

(Bishop, 2003a). Typical examples of active warm up include jogging, calisthenics, cycling and swimming. The 'active' aspect of a warm-up, is intended to increase core temperature, blood flow and prepare the body for exercise, and it has long been shown to benefit performance (Bergh & Ekblom, 1979). Chwalbińska-Moneta & O (1989) found that an additional warm-up carried out prior to an incremental exercise test allows for higher power at the anaerobic threshold to be achieved. Moreover, Mohr et al. (2004) reported a substantially improved repetitive sprint period (3 x 30-meter field sprints with 25-second active recovery) when followed by a submaximal active warm-up (7 minutes, 60% maximum heart rate, (HRmax)). Conversely, Gregson et al. (2002) indicated that active and passive warm-ups increasing core temperature to approximately 38^{o}C reduced running time to exhaustion (60 minutes) during an intermittent motorised treadmill test (repeated 30 seconds at 90% VO_{2max} and 30 seconds at 30% VO_{2max}).

Latest warm-up protocols involve 3 phases following a specific order, from low-level aerobic activity to core temperature increases through joint mobility and dynamic flexibility exercises up to higher intensity sport-specific dynamic movements that prepare the athlete for competition (Beachle et al., 2000). A recent review of warm-up practice for pre-competition found that the effectiveness of a warm-up is determined by its intensity and duration, as well as by the period between the completion of the warm-up and the start of the competition (McGowan et al., 2015). Tomaras and Macintosh (2011) suggest that warm-ups of low intensity are better than those of high or moderate intensity, since they are also less likely to cause fatigue. A previous research found that low-intensity warm-up [i.e. 39% of maximum oxygen uptake (Vo_{2max})] improved the subsequent cycling sprint performance compared to moderate-intensity (i.e. 56% of Vo_{2max}) or high-intensity (i.e. 74% and 80% of Vo_{2max}) warm-up (Sargeant & Dolan, 1987). Similarly, Wittekind et al. (2012) reported that a warm-up of low intensity (i.e. 40% of peak aerobic power) was more efficient in improving cycling sprint performance than a warm-up of high intensity (i.e. 110% of peak aerobic power). In contrast, Grodjinovsky and Magel (1970) reported that a high-intensity warm-up (a 5-minute jog plus 161 m run at near maximum speed) led to greater improvements in 1-mile (1.6 km) run time than a low or moderate warm-up (5-minute jog) in untrained males. These findings may suggest that specific warm-up intensities could lead to different exercise performance.

2.2 EFFECTS OF WARM-UP ON PHYSIOLOGICAL RESPONSES

Even though the warm-up may be based on conventional and scientific principles, physiological responses that occur during warm-up may make the process advantageous for athletes and individuals both in terms of improved performance and reduced injury risk. Robergs et al. (1991) reported a higher aerobic output to a typical high-intensity exercise after an active warm up, whereas an improvement in the output from anaerobic sources was observed after a local passive warm-up during a similar high-intensity exercise (Febbraio et al., 1996). In both studies, it was proposed that there were changes in physiological response when exercise was correlated with muscle temperature elevations. Hence, the circulatory system provides the blood needed to the tissues during warm-up and the rise in body temperature maintains the body heat steadily. The higher muscle temperature enhances performance; thus, it is proposed that temperature will improve performance by reducing muscle viscous resistance, speed up oxidative reactions, or increasing oxygen supply to the muscles (Bishop, 2003b). The rise in muscle temperature caused by priming exercises has also been suggested to lead to different physiological and metabolic changes, affecting performance (Neiva et al., 2014).

Furthermore, it was indicated that warm-up exercise could reduce the initial oxygen deficit and restrict the involvement of anaerobic metabolism when exercise starts (Gerbino et al., 1996). This may be because warm-up improves nerve conduction (Pearce et al., 2012) as well as increasing oxidative enzyme activity, motor unit recruitment (Gurd, et al., 2006), and the kinetics of oxygen uptake (Poole & Jones, 2012). According to a research, a general warm-up routine can reduce lactate build-up in muscles and blood after intensive dynamic exercise (Gray et al., 2002). This research was only focused on high intensity exercise, while a research proposed that a warm-up with enough intensity to raise the concentration of blood lactate to about 2.4 mM/L can profoundly alter the VO_2 kinetics and have the potential to improve exercise performance. This is due to the accumulation of several high-intensity exercise by-products, such as lactic acid, will increase the flow of muscle blood and therefore make more oxygen available to muscles (Sousa et al., 2014). Nevertheless, De Bruyn-Prevost and Lefebvre (1980) proposed that when exercise is immediately preceded by an active low-intensity warm-up (30-60% VO_{2max}), maximum peak power and exercise time to exhaustion are increased, whereas those performance parameters decrease after a higher-intensity warm-up (70-100% VO_{2max}). There is little evidence, however, whether difference in warm-up intensities lead to a different change in physiological responses in non-athletic adults.

2.3 EFFECTS OF WARM-UP ON PSYCHOLOGICAL RESPONSES

Novices and experts alike are all, or at least should be, aware of the vital physiological benefits of a warm-up. What many athletes seem to forget throughout the sporting continuum, however, are the important psychological benefits that are also shown in a warm-up. Previous study have shown that athletes who warm-up before physical activity seem to be more mentally prepared for their activities, particularly if they use a warm-up system that enables them to rehearse the event although the psychological aspects of warm-up have not been fully studied. This warm-up activities could potentially boost their motivational and mental preparation for their subsequent training or competition performances (deVries & Herbert, 1980). (Reference?)

One of the key factors of motivational perspectives to enhance subsequent exercise activity is known as affective responses (pleasure and displeasure feelings). Positive affective responses (pleasurable feelings) to exercise may drive the person in the exercise to try appropriate doses of physical activity and to prevent maladaptive emotion (Ekkekakis & Lind, 2005). Acute bursts of exercise will result in immediate changes in both positive and negative affect (e.g., increased vigor) (e.g., decreased anxiety) (Reed, 2005). Evidence is clear that a positive affective reaction to exercise helps people stick to their exercise schedule (Annesi, 2005; Carels, et al., 2006; Williams, et al., 2008). This predicts that exercisers favour activities that promote the preservation of a homeostatic state, such as aerobic exercise, as opposed to those that interfere with that state, such as anaerobic exercise. Using a warm-up will increase the probability that a trainer can sustain a homeostatic state for a longer period of time than a trainer who does not use a warm-up routine (Woods, et al., 2007). This could lead to higher rates of exercise-related enjoyment in the short and long term, as well as increased motivation for exercise and commitment to an exercise regimen (Heisz, et al., 2016).

Kahneman et al., (1999) argued that an overriding motivation in individuals is to try pleasurable circumstances and avoid painful ones, and the resulting recollection of such experiences may have an impact on later decision making. Based on this notion, one can argue that if an exerciser experiences an uncomfortable workout, the exercise would recall the memory for this occurrence more quickly than if the experience were more enjoyable. Exercisers who warm up before exercise may have more positive memories of their exercise routines (Ladwig, 2013), although some stressors are linked to increased exercise activity (e.g. new romantic relationships, retirement, big accomplishments, distressing harassment) (Stults-Kolehmainen & Sinha, 2014). The positive memory for the workout, in effect, will lead the exercise to consistently use the warm-up routine that initially created this positive experience. Moreover, Acevedo et al. (2003) found that exercises of increasing intensity are linked to lower cognitive affective responses. As a result, lower-intensity exercise may be attributed to more positive affective response during and after exercise than high-intensity exercise.

Borg's (1982) "Perceived Exertion Scale of Rating" (RPE) scale of perceived exertion appears to be the most useful all over the world. This psycho-physiological measurement is characterised by an individual's emotions of stress, strain, discomfort, and exhaustion when exercising (Robertson & Noble, 1997). The variation in perceived exertion might be accounted by physiological and psychological factors because it is a subjective judgement (Morgan, 1994). When the warm-up intensity is too great, it might lead to excessive tiredness and so impede the performance (Zois et al., 2015). The RPE ratings throughout the exercise might be influenced by environmental and dispositional factors such as personality, motivation, and attentiveness (Morgan, 1994). Hence, this is when the RPE score will be used to determine the participants' level of fatigue. To date, there is no evidence related to the role of affect responses during warm-up exercise that could potentially impact the subsequent exercise performance.

2.4 EFFECTS OF WARM-UP ON EXERCISE PERFORMANCE

Knowing how warm-ups influence the human body is relevant, but the primary concern for peoples is how those changes improve performance as well as reduce the risk of injury. Most of the available research on warm-up has concentrated on short-duration performance measure compared to intermediate-duration event and long-duration event. This is mainly because most of the sports (football, hockey, basketball, soccer, and baseball) are essentially anaerobic and intermittent in nature. Recent systematic review of 32 studies has revealed that warm-up can maximised performance in specific sports and activities such as running, swimming and jumping (Fradkin, et al., 2010). After a prior bout of intense exercise, a recent research found a considerable improvement in time to exhaustion (about 30–60%) during perimaximal leg cycling (Jones et al., 2003). On the other hand, Koppo and Bouckaert (2002) found no differences in time to exhaustion after either moderate or intense activity. However, both researches did not include psychological aspects during the exercise. Furthermore, using time to exhaustion as a measurement for physical performance is not ecologically valid (Hopkins et al., 1999). Bishop reviewed these studies (Bishop, 2003a; Bishop, 2003b), and found that warm-up enhanced muscle blood flow, increased oxygen release from haemoglobin and/or myoglobin, sped up metabolic responses, and raised baseline oxygen consumption, potentially increasing exercise performance. Moreover, warm-up causes performance increases ranging from 1% to 20% in sports like cycling (Burnley et al., 2005) and running (Stewart & Sleivart, 1998).

Although the ideal warm-up cannot be determined at this time, the impact of warm-up on subsequent performance has been studied since the 1930s (Simonson, et al., 1936). Considering how much emphasis and significance professional athletes put on warm-up, there is a surprising lack of ‘‘good" research assessing whether or not a warm-up enhances performance (Bourne, 1992). As a result, rather than being focused on scientific research, warm-up routines are normally based on the athlete's or coach's trial and error experience. Even though some of the suggested warm-up components are commonly used, the importance of warm-up has become a worthwhile topic of research because it is unclear if warming-up is beneficial, harmful, or has no impact on an individual's results. There is little current research on exercise performance and the advantages of performing a warm-up in non-athlete cohort, indicating the important of this area of investigation. Non-athlete participants do not seem to rely as heavily on warming-up as elite athletes do (Fradkin, et al., 2007); however, they may potentially benefit from warm-up exercises. This is due to the role of warm-up that prepare the individuals to the subsequent exercise participations.

2.5 GAPS OF THE LITERATURE

Despite evidence for the benefits of moderate and high intensity warm-up to the athletic performance (e.g. speed, maximal effort), little is known about the factors (e.g. intensity) that mediate the changes of physiology and psychology that could influence the subsequent exercise performance especially for non-athletic performance. These observations are due to the fact that most of the HIIE-adult studies designed for non-athletic individuals have (e.g. obese, inactive individuals) adopted low to moderate intensity running/cycling of warm-up (Batacan et al., 2017; Wewege et al., 2017) prior to HIIE, which does not allow in-depth understanding of the role of warm-up intensity on psychological and physiological factors observed during HIIE. Indeed, previous evidence has highlighted that prior exercise experience (e.g. warm-up) or familiarity could impact individual's psychological responses (e.g. enjoyment, affect responses and RPE) during subsequent exercise (Rhodes et al., 2009).

CHAPTER 3: METHODOLOGY

3.1 STUDY DESIGN

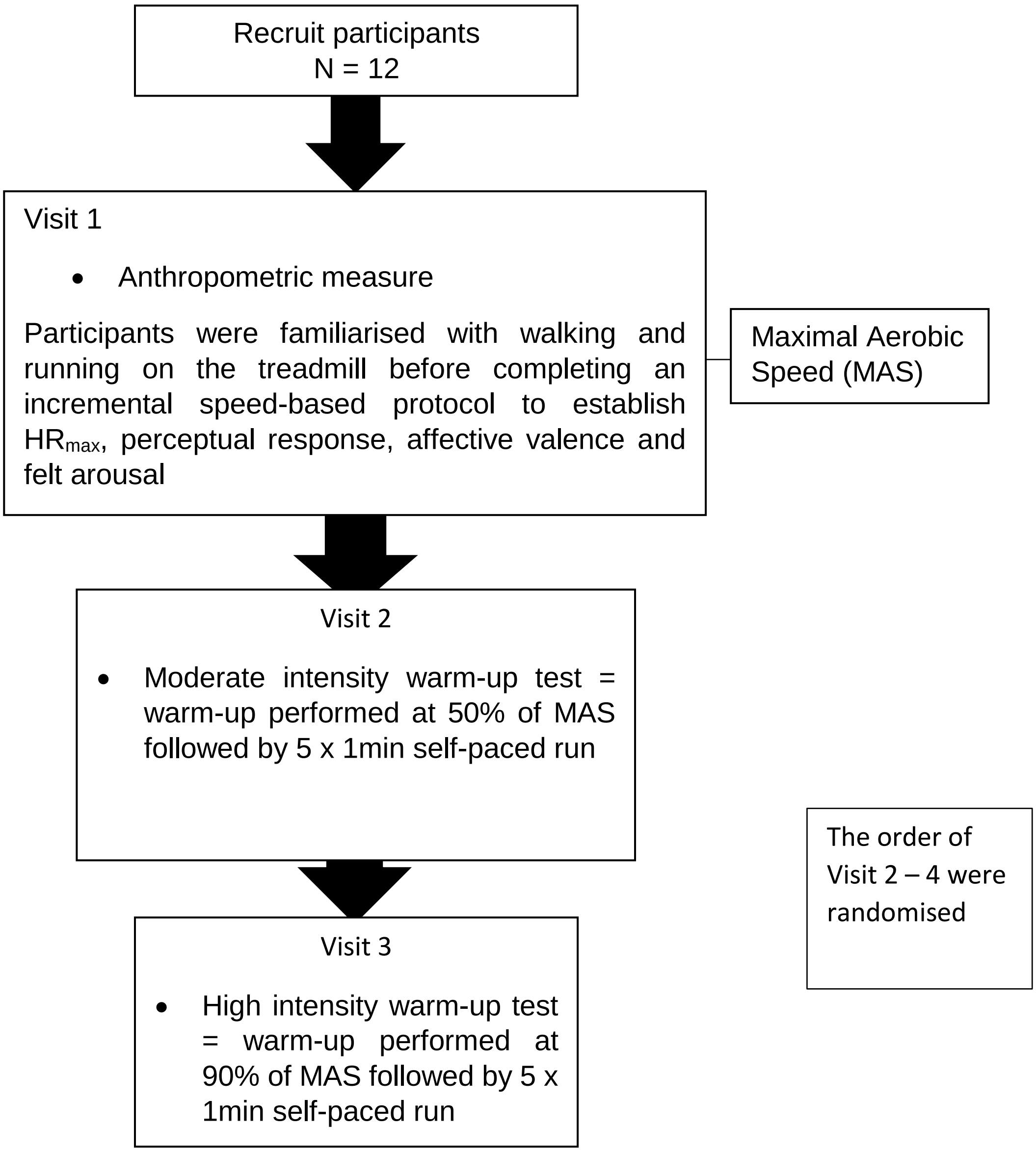
The present study required four experimental trials (i.e. incremental test and self-paced interval running with three different warm-up conditions) in the laboratory, separated by a minimum 48 hours rest period, and incorporated a within-measures design. The study procedures have been approved (Appendix A) by the Human Research Ethics Committee (HREC), Health Campus of Universiti Sains Malaysia (USM/JEPEM/ 20040223). Written informed consent (Appendix E) from the participants were obtained. The informed consent form advised participants of all potential risks involved, including the possibility of muscle soreness and injury. Participants were not compensated for participating in the study. Participants were able to leave the study at any time if necessary and the involvement of the participant in his study required for approximately five weeks duration. This study is a randomised crossover design.

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.

3.3 SAMPLE SIZE CALCULATION

Sample size was calculated by using G*Power version 3.1.9.2. The sample size is based on related research (Fujii et al., 2018) for the differences in exercise intensity (i.e. power output) during cycling performed after moderate and high intensity warm-up that has been shown to have a large effect size. For the purposes of the present study, where three conditions and 6 repeated measurements will be analysed using a two-way repeated measure analysis of variance (ANOVA). It would take a sample size of 8 participants to detect a large effect with a power of 0.8, an alpha of 0.05 and an effect size, ES, of 0.40 (large). Therefore, assuming a dropout of four participants, 12 Potential participants (University Sains Malaysia students or staff) were recruited via advertisement that was posted via Whatsapp or poster (Appendix B) throughout the University Sains Malaysia Health Campus. The sampling method was a random sampling and participation in this study was expected to last up to 5 weeks.



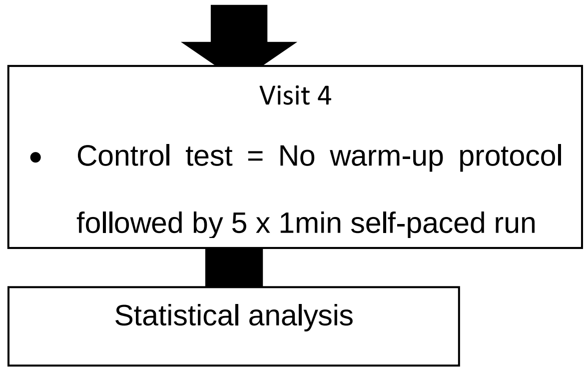


Figure 3.1: Flow chart of the study procedures

3.4 PARTICIPANTS

The inclusion and exclusion criteria of the participants in the present study are shown in Table 3.1. This study was limited to healthy males and females between the ages of 18 and 25 years old. The total number of participants was twelve with seven males and five females (aged 23.0 ± 1.1 years). All participants were low-to-moderate-risk and displayed no signs or symptoms of musculoskeletal injuries disease that would compromise their safety during participation in the study. Participants were recruited (Universiti Sains Malaysia students or staff) via advertisements that have been posted via Whatsapp or poster (Appendix B) throughout the University Sains Malaysia Health Campus. The sampling method was random sampling and participation in this study was expected to last up to 5 weeks.

Table 3.1: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Male and female adults	Musculoskeletal injuries especially to lower limbs which prevents participants from running
Aged between 18 to 25 years old	Presence of any condition or infection which could alter mood and exercise performance
Healthy	On medication
No pre-existing health problem such as hypertension, heart disease and high blood sugar; and not engage in any exercise training programme	

3.5 STUDY PROCEDURES

During the recruitment process, participants were approached by researcher and they were thoroughly explained regarding the objectives, procedures, possible harm/risk and benefits of the research study. Participants were requested to complete a Physical Activity Readiness Questionnaire (PAR-Q) (Warburton, et al., 2011) (Appendix C) and informed consent form (appendix E) to assess if exercise is safe or poses a danger depending on their medical history, present symptoms, and risk factors once they have met all the inclusion criteria of the present study. All of the questions are meant to identify any potential health concerns linked with physical activity (Warburton, et al., 2011). Participants completed Malay versions of the International Physical Activity Questionnaire (IPAQ-M) (Appendix D) short form to determine habitual PA levels. IPAQ-

M was 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). All participants completed the informed consent form (Appendix D). Following that, participants completed the following four experimental visits separated by a minimum two days: pre-test, high-intensity warm up followed by self-paced interval running (H-IR), moderate-intensity warm up followed by self-paced interval running (M-IR) and stretching exercise followed by self-paced interval running (control, C-IR). The specific protocol for each warm-up session has been highlighted in the warm-up protocol section (see 3.5.3 section) The first visit (pre-test) was to measure anthropometric variables, determine cardiorespiratory fitness and familiarisation session with the measurement scales and experimental protocol. This was followed by three experimental visits involving the H-IR, M-IR and C-IR, the order of which was counterbalanced to control any order effect, (please refer to warm-up protocols for details). Average running speed (Km/h) and perceptual responses (affect, enjoyment and RPE responses) were obtained during the running intervals. All exercise tests were performed using a motorised treadmill (3017 Full Vision Drive, Newton, Kansas USA) at the same time of the day between the hours of 08:00 to 13:00 in order to minimise the effects of diurnal biological variation.

3.5.1 Anthropometric measurements

Body mass and stature were measured to the nearest 0.1 kg and 0.01 m, respectively, using standard procedures (the participants were shoeless and wear light clothing) by a body composition analyser (Tanita, Japan) and a stadiometer (Seca, China) respectively. Body mass index (BMI) was calculated as body mass (kg) divided by stature (m) squared

3.5.2 Determination of maximal aerobic speed and heart rate

Participants were familiarized with walking and running on the treadmill before completing an incremental speed-based protocol to establish maximum aerobic speed (MAS) and HR_{max}. Participants began a warm-up with a speed of 4.0 km/h for 3 min, then followed by running at the speed of 6.0 km/h with 0.5 km/h increments for every 30 seconds until volitional exhaustion before a 5 min cool down at 4.0 km/h. Throughout the incremental test, the treadmill gradient was set at 1% to reflect the outdoor energy cost of running (Jones and Doust, 1996). Along with vocal encouragement until the exhaustion, MAS and HR_{max} was obtained. The incremental test to exhaustion protocol has previously been used for determining VO_{2max} in adults.

3.5.3 Warm-up protocols

Participants completed 1) a 5 mins of high-intensity warm-up protocol which consist of running at 90% of VO_{2max} (high-intensity); 2) moderate intensity that consists of running at 50% of VO_{2max} (moderate-intensity), where the durations were matched the distance performed during high-intensity warm-up for each participant; and 3) static stretching (control). The two warm-up protocols (moderate- and high-intensity) were based on those used in previous work (Fujii et al., 2018). For the control condition, all the participants ~~were~~ performed static stretching for 3 to 5 mins prior to the self-paced interval running. Examples of the static stretching include neck rotations, arm rotations, hip rotations, torso rotation, knee flexors, and knee extensors. of stretching. A 2-min active rest (i.e. walking paced) were provided to the participants after each warm-up sessions.

3.5.4 Self-paced interval running protocols

Self-paced interval running consists of 5 x 1 minute work interval performed at self-paced intensity separated by 75 s recovery interval. 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 5 repetitions of work intervals. For self-paced run, participants were informed that there was no right or wrong speed rather just set the belt at the speed they feel was their highest effort of running given the testing situation. Participants dismounted from the treadmill during the active recovery periods and were encouraged to walk around the laboratory to avoid venous pooling and feeling light-headedness. Participants were given verbal instructions on how to utilise the scales in visit one and before undertaking the exercise protocols (as it were in to begin with week).

HR was measured continuously during incremental test using a telemetry system (Polar Electro, Kempele, Finland), respectively.

3.5.5 Running performance

The distance travelled (m) and running speed (km/h) for each interval were used to assess running performance. The distance and running speed were shown on the treadmill. A better performance for each interval was indicated by greater distance covered and a faster running speed.