A SINGLE BOUT OF CYCLING EXERCISE EFFECTS ON SHORT TERM MEMORY

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A SINGLE BOUT OF CYCLING EXERCISE EFFECTS ON SHORT TERM MEMORY

By

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CERTIFICATE

This is to certify that the dissertation entitled

A SINGLE BOUT OF CYCLING EXERCISE EFFECTS ON SHORT TERM MEMORY

is the bona fide record of research work done by

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During the period of March 2018 to July 2018

under my supervision

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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 postgraduates at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

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NAJIHAH BINTI MOHBIN

Date: ……..

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LIST OF ABBREVIATIONS

BDNF	Brain-derived neurotrophic factor
bpm	beats per minute
cm	centimeters
et al.	et alia (others)
IPAQ-M	International Physical Activity Questionnaire - Malay version
kg	Kilogram
kp	Kilo pound
m	Meter
MET	Resting metabolic rate
MHR	Maximum heart rate
MVPA	Moderate-vigorous physical activity
NSLT	Numerical String Learning Test 9
PAR-Q	Physical activity readiness questionnaire
RCT	randomized controlled trial
RPE	Rating of Perceived Exertion
rpm	Round per minutes
s	Seconds
SD	Standard deviation
%	Percentage

A Single Bout of Cycling Exercise Effects on Short Term Memory

ABSTRACT

Exercise plays a role in enhancing neurogenesis and brain plasticity. Actively involved in a musculoskeletal and cardiovascular activities at moderate intensity influences brain systems that involve in working memory processes. The aim of this study was to investigate the effects of single bout exercise on short term memory. *Methods*: A total of 16 female university students with mean age of 23.63 ± 1.46 year old were involved in this study. Participants completed free recall test twice which was once pre- and once post-exercise. Exercise session involved a single bout cycling ergometer at 50 watts while maintaining 60 rpm for 30 minutes and two five minutes periods of warm up and cools down at 20 watts. *Results*: Percentage of words recalled in free recall test post-exercise did not improved compared to pre-exercise. Percentage of recency words recalled post-exercise (51.25 ± 21.87 %) is higher than pre-exercise (48.75 ± 21.87 %) but no significant difference compared to pre-exercise (p=0.751). The percentage of words recalled post-exercise was correlated with heart rate during exercise (r = -0.59, p=0.015). Participants with higher heart rate during exercise had a lower percentage of words recalled at post compared to pre-exercise. *Conclusion*: A single bout of cycling exercise did not improve short term memory.

Kesan Satu Pusingan Senaman Berbasikal Terhadap Memori Jangka Pendek

ABSTRAK

Senaman memainkan peranan dalam mengalakkan neurogenasis dan keplastikan otak. Penglibatan secara aktif di dalam aktiviti kardiovaskular pada intensiti sederhana mempengaruhi sistem otak yang melibatkan proses memori bekerja. Tujuan kajian ini adalah untuk mengkaji kesan satu sesi senaman terhadap memori jangka pendek. *Kaedah:* Seramai 16 orang pelajar perempuan universiti dengan purata umur 23.63 ± 1.46 tahun terlibat dalam kajian ini. Peserta-peserta perlu melengkapkan ujian mengingat bebas sebanyak dua kali iaitu sekali sebelum dan sekali selepas senaman. Sesi senaman melibatkan satu sesi senaman mengayuh ergometer basikal pada 50 watts sambil mengekalkan 60 rpm selama 30 minit dan dua tempoh masa lima minit untuk memanaskan dan menyejukkan badan pada 20 watts. *Keputusan:* Peratusan perkataan yang diingati di dalam ujian mengingat bebas selepas senaman tidak meningkat berbanding sebelum senaman. Peratusan perkataan kebaharuan yang diingati selepas senaman (51.25 ± 21.87 %) adalah lebih tinggi daripada selepas senaman (48.75 ± 21.87 %) tetapi tiada perbezaan yang ketara berbanding sebelum senaman (p=0.751). Peratusan perkataan yang diingati selepas senaman telah dikaitkan dengan kadar degupan jantung semasa senaman (r = -0.59, p=0.015). Peserta dengar kadar degupan jantung yang lebih tinggi semasa latihan mempunyai peratusan perkataan yang diingati lebih rendah selepas senaman berbanding dengan sebelum senaman *Konklusi:* Oleh sebab itu, senaman berbasikal satu sesi tidak meningkatkan daya ingatan jangka pendek.

CHAPTER 1

INTRODUCTION

1.1: Background of Study

Exercise is defined as ‘a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective” (World Health Organization, 2018). Exercise playing role in enhancing neurogenesis and brain plasticity in addition to common benefits of exercise in reducing heart disease, enhance weight loss, strengthens muscles including the heart while improving overall health (Chang *et al.*, 2012). According to Roig *et al.* (2013), acute exercise causes moderate to large impacts on long term memory and more moderate impacts on short term memory. Meanwhile, long term cardiovascular exercise does not have any significant effect on long term memory and gives only little enhancements in short-term memory (Roig *et al.*, 2013).

Actively involved in a musculoskeletal and cardiovascular activity at moderate intensity influences brain systems involving in working memory processes specifically within acute phase after one session (Weng *et al.*, 2015). Thus, working memory has been defined as ‘short term memory applied to cognitive tasks, as a multi-component system that holds and manipulates information in short term memory, and as the use of attention managing short term memory’ (Cowan, 2008). Memory and learning are the cognitive functions (Sahana *et al.*, 2015). According to Sahana *et al.* (2015), short term memory is ‘the memory which can only be measured in seconds or at most minutes unless converted to long term memory’. Meanwhile, information that stays in memory for shorts period about 10 to 15 seconds without repeating over and over is short term memory or working memory (Goldstein, 2014).

Moderate physiological or emotional arousal modulates memory. According to Coles and Tomporowski (2008), exercise-induced arousal may facilitate the consolidation of information into long-term memory. As stated by Quelhas *et al.* (2013) working memory was enhanced by dynamic exercise at moderate intensities and short duration. However, effects of acute exercise on short-term memory showed to be greater when the exercise conducted at low intensities (Roig *et al.*, 2013). Meanwhile, a study on effects after a single bout may assist in understanding better benefits of regular exercise on cognition as regular exercise consists of repeated exercise bouts accumulated over time (Weng, 2015). A study on single bout effect on short-term memory is not common as studying the effect on long-term memory or long bout effects of exercise. Since there is lacking of study on this, results from past studies showed various outcomes due to the different standard of memory test and exercise protocols.

1.2: Problem Statement

Awareness towards exercise improving cognitive function especially memory is lacking despite exercise has been related to enhancing physical health. Meanwhile, improvement of cognition function and academic performance in both children and young adults has been a well-established educational policies goal. Besides, regular exercise also helping to delay declination of cognitive function in normal aging. A single bout of exercise which composing regular exercise may aid understanding benefits of regular exercise on memory function enhancement. However, a clear scientific evidence on which standard of exercise that more efficient is still lacking to date. Therefore, this study is planned to be conducted.

1.3: Research Objectives

1.3.1: General Objective

1. To compare the effect of single bout exercise on short term memory in young adults.

1.3.2: Specific Objectives

1. To compare the short term memory pre and post-single bout exercise among young adults by using free recall test.
2. To examine the correlation between heart rate during single bout exercise and short term memory post-single bout exercise.

1.4: Research Questions

1. Is short term memory performance score different pre and post-single bout exercise among young adults by using free recall test?
2. Is there a correlation between heart rate during single bout exercise and short term memory post-single bout exercise among young adults?

1.5: Hypotheses

H_{1o}: There are no significant differences of short term memory performance score pre and post-single bout exercise.

H_{1a}: There are significant differences of short term memory performance score pre and post-single bout exercise.

H_{2o}: There are no significant correlation between heart rate during single bout exercise and short term memory post-single bout exercise among young adults?

H_{2a}: There are significant correlation between heart rate during single bout exercise and short term memory post-single bout exercise among young adults?

1.6: Significance of The Study

Since the effects of single bout exercise on short-term memory have not been well-established due to an unclear common standard of exercise is defined, this study will give some insight on the possible beneficial effects of single bout exercise on short-term memory. Comprehensive understanding effects of single bout exercise on memorizing also can help maximizing effects of long-term exercise. Results will be obtained from this finding can be used to develop cognitive function and academic performance in both children and young adults through exercising by formulating guidelines of enhancement.

CHAPTER 2

LITERATURE REVIEW

2.1: Introduction of Exercise

According to Centers for Disease Control and Prevention (2015), exercise is considered as part of the physical activity which done during leisure time with the main aim of boosting or maintaining physical fitness, physical performance, or health. Physical activity is an important component of a healthy lifestyle and it influences the health and wellness of individuals. Animals studies showed that physical activity has been enhanced functional and structural changes, especially in the hippocampus and to improve memory by modulating the release of neurotrophic factors (Hötting *et al.*, 2016). Cognitive function can be influenced by exercised involving cognitively and socially demanding open skill activities (Pontifex et al., 2009).

2.1.1: Single Bouts Aerobic Exercise

In general, scientific and medical communities agree that exercise is beneficial for body and mind. However, many kinds of literature studying on the relationship between exercise and cognitive performance have mainly focused on chronic exercise. Recently, expanding the body of research has focused on the effects of acute exercise on cognitive mainly in term of memory (Coles and Tomporowski, 2008). Meta-analyses revealed that acute exercise had moderate whereas long-term had small effects on short term memory (Roig *et al.*, 2013).

Meanwhile, aerobic exercise is neuroprotective and that starting an exercise regimen later in life is worthy of either improving cognition or raising brain volume (Erickson *et al.*, 2011). Particularly in the elderly increased aerobic exercise correlated with increased

hippocampus volume and enhanced memory (Erickson et al., 2009). Roig *et al.* (2013) stated that generally, young-adults had a greater tendency towards improvements in short and long term memory with acute exercise even they showed the largest enhancement in short term memory after long-term exercise. Though fitness level did not affect the outcome of acute exercise on short-term memory, subjects with average fitness level showed greatest effects on long-term memory.

Significantly larger effects of acute exercise showed for executive function tasks than for alternative cognitive tasks such as information processing, reaction time and memory (Chang *et al.*, 2012). Then, meta-analysis results have also stated that impairment of cognitive performance when measured during exercise and increased when measured following exercise (Lambourne and Tomporowski, 2010). Specifically, exercise mode such as running cause negative effect while cycling cause positive effect on cognitive while exercise duration less than 20 minutes cause negative effects and it is become positive when longer than that (Quelhas *et al.*, 2013). However, in a study on a single bout of brisk 10-minute walk before studying among college students showed enhancement of memory on following test (R. Salas *et al.*, 2011). There was an increment of 25% of words recalled for students who in the walking condition compared to the sitting condition (R. Salas *et al.*, 2011).

Type of exercise is a factor which must be contemplated when testing acute exercise effects on cognitive processes (Lambourne and Tomporowski, 2010). Further, they also stated that smaller effects sizes were showed following treadmill running than ergometer cycling protocols. Besides, Chang *et al.* (2012) also mentioned that presence of argument that anaerobic and muscular resistance exercise result in negative effects. Resistance exercise and aerobic exercise show a differ spectrum of exercise that is characterized by different physiological demands such as cardiovascular, musculoskeletal and metabolic (Pontifex *et al.*, 2009).

Chang *et al.* (2012) noticed the dependency on objective physiological measures such as heart rate and oxygen consumption, as a major issue in the study of exercise effect on cognitive function. However, these measures fail to show the perception of exercise or effort intensity. Thus, a study by Razon *et al.* (2017) used RPE as the first indicator followed by heart rate as secondary to define the intensity of exercise. In study effects of single bout graded exercise using ergometer cycling on executive functioning, short term and long term memory assessed heart rate for every 30 seconds and rate of perceived exertion (RPE) to control the intensity Coles and Tomporowski (2008).

2.1.2: Moderate-Intensity Aerobic Exercise

General enhancement in cognitive performance happened after acute aerobic exercise of moderate intensity, especially when task conditions put greater demands upon working memory capacity (Pontifex *et al.*, 2009). In a meta-analysis study, it stated that the effect of acute exercise on memory may differ according to time, type of memory such as acquisition, consolidation or recall (Roig *et al.*, 2013). Specifically, lack of emphasis has been shown on studying the effects of moderate intensity of cardiovascular exercise on cognitive tasks involving memory (Erickson *et al.*, 2011).

A study by Weng *et al.* (2015) found an effect of a single bout of 30-minute moderate intensity aerobic cycling was significant on working memory performance on 2-back condition of a facial n-back task. Submaximal aerobic exercise for duration of 60 minutes improved specifics aspects of information processing in adults but the longer duration of exercises which leading dehydration deteriorates both information processing and memory functions (Nanda *et al.*, 2013).

In study by Pontifex et al. (2009), there was positive effects of treadmill running on working memory performance began immediately post acute exercise protocol and lasted until 30 min after exercise. However, running exercise performed at maximal intensity will cause physical fatigue and has a negative effect on short term memory (Sahana *et al.*, 2015). In that study, results of Numerical String Learning Test 9 (NSLT) points measuring used to determine the short term memory performance following 90% loaded running exercise had reduced. However, results from recent studies by Hötting *et al.* (2016) showed that high-intensity physical exercise causing less forgetting of newly learned vocabulary compared to a relaxing group.

A longitudinal randomized controlled trial (RCT) of elderly subjects showed that 12 months of moderate-intensity cardiovascular exercise produced an increase in hippocampal volume which was associated to an improvement in visuospatial memory (Erickson *et al.*, 2011). Besides, in review of the effects of acute exercise on cerebral oxygenation as measured using near-infrared spectroscopy found that moderate intensity exercise increased while very high intensity exercise decreased the levels of oxygen levels in the prefrontal cortex (Rooks *et al.*, 2010). In contrast, acute and intense bout of exercise improved learning while increasing long-term retention in adults due to rising of brain-derived neurotrophic factor (BDNF) and catecholamines (Winter *et al.*, 2007). Then, they also found an increase in levels of BDNF, dopamine and epinephrine can act as mediators in enhancing short-term, intermediate and long-term memory respectively.

2.2: Heart Rate

Heart rate during moderately intense activities is about 50-69% of maximum heart rate while heart rate during hard physical activity is about 70% to less than 90% of the maximum heart rate. According to American Heart Association (2015), estimated maximum heart rate is about 220 minus your age and average target heart rate zone 50 -85% is 100 -170 beats per minute with average maximum heart rate, 100% is 200 beats per minute for 20 years old.

Weng *et al.* (2015) found that active exercise leads to a higher mean of heart rate compared to passive exercise which leading towards better results of working memory performance among participants in the previous exercise. Elevation amount of oxygen supplied to the brain by increased respiration and heart rate will lead an enhancement in the amount of information an individual can store in short-term memory (Stowell *et al.*, 2012). In a recent study by Most *et al.* (2017), it stated that there was a positive correlation between increase in heart rate following exercise and memory accuracy among woman who involved in 5 minutes of low-impact exercise immediately after learning.

2.3: Free Recall Test

Free recall test is an unconstrained which providing a rich source of information on the nature of the retrieval cues when memory search is used (Miller *et al.*, 2012). Then, Miller *et al.* (2012) also stated free recall test conducted by studying a list of items (typically words) and after that participants were asked to recall the list items in any order. Review study by Roig *et al.* (2013) stated that verbal memory free recall task which including recall a series of words presented 100 s before as one of acute interventions of short term or working memory.

In past study by Coles and Tomporowski (2008), the free recall test was conducted on a group of young adults to study the influence of exercise on short term memory. Besides, Coles and Tomporowski (2008) also used the free recall test to assess the short term memory and long term memory performance by measuring recall index after 100s and 12 minutes of consolidation respectively. When comparing immediate recall, participants recalled significantly more words compared to delay recall which tested after 12 minutes. However, both of immediate and delayed words recalled performance by participants declined from pre to post-test (Coles & Tomporowski, 2008). A later study by Pesce *et al.* (2009) also used the free recall test to study effects of physical activity performance in preadolescents during three sessions. However, the later study conducted this test manually by using printed posters whereas the previous one using slides on the computer to shows the words for memorization task during the test.

As the Coles and Tomporowski (2008) study conducted on young adults, therefore participants needed to pronounce the words during recall session while in the study by Pesce *et al.* (2009) demanded participants to write down the words. Both of study also had a total of 100 s presentation time before consolidation period. Both studies for young adults and preadolescents indicated similar findings as the beneficial effect of prior exercise on delayed recall. Findings showed that delayed recall of recency items was better after physical activity than without (Pesce *et al.*, 2009). Commonly tendency to remember the first few and last few words is higher and those in the middle of the list usually more likely to be forgotten (Simply Psychology, 2008). It is known as serial position effect with primacy effect is tendency to recall earlier words and recency effect is tendency to recall the later words (Simply Psychology, 2008).

2.4: Memory

Cognitive psychology is the scientific study of the mind which creates and controls mental capacities such as perception, attention and memory which creating representations of the world that enable us to function (Goldstein, 2014). Memory is the process involved in retaining, retrieving and using information about stimuli, images, events, ideas and skills after the original information is no longer present (Goldstein, 2014). There are three types of memory which are a long-term, short-term, and working memory. Meanwhile, long and short term memory could differ in two common ways, with only short term memory showing temporal decay and chunk capacity limits (Cowan, 2008). Memory can be encoded in three means which are visual, acoustically, and semantically. Coding is form of which how stimuli are represented. Auditory coding usually predominant in short term memory and semantic coding predominant in long term memory (Goldstein, 2014).

2.4.1: Short Term Memory

When people must recall items from a category in long term memory like the states of the United States, they do so in rush of about three items on average. According to Cowan (2008), this is as if the list of short term memory is filled from the well of long term memory and must be vacated before it is refilled. Moreover, working memory does not completely differ from short term memory as working memory includes short term memory and other processing mechanisms that assist application of short term memory (Cowan, 2008). Short term memory is concerned with storing information for a brief period of time while working memory is concerned with the manipulation of information that occurs during complex cognition (Goldstein, 2014). Short term memory from the temporarily activated subset of information in

long-term memory which may decay as a function of time unless it is refreshed and to be limited in chunk capacity (how many separate items can be included at once) (Cowan, 2008).

Memory performance can be measured as percentage of the stimuli that are remembered in recall method in which subjects are presented with stimuli and after a delay, are asked to report back as many of the stimuli as possible (Goldstein, 2014). According to measurements of digit span, the average capacity of short term memory is about five to nine items which is about the length of a phone number (Goldstein, 2014). Then Roig *et al.* (2013) stated that if the retention of information within a few seconds to 1-2 minutes it considered to assess short term memory while long-term memory tests when involving the retention of information characterised as delay which is more than two minutes.

CHAPTER 3

METHOD

3.1: Study Design and Sample Size

A cross-sectional study design was adopted. Data collection among subject for a single sample group required six weeks. The two levels of independent variable were before exercise and after exercise. The dependent variables of short-term memory were free recall test performance and heart rate. This study conducted at Sports Science Lab, Health Campus of Universiti Sains Malaysia.

A power analysis was performed by using G* Power 3 software to determine the study's sample size. For objective 1, paired t test comparing difference between two dependent means was used. The effect size of the exercise-prior group over the exercise-after group was $d = 0.75$ (Labban and Etnier, 2011). The power of this study was 0.80 and alpha value was 0.05. Based on these parameters, the estimated sample size was 16. For objective 2, correlation analysis was used. The parameters used in estimating the sample size included expected correlation value of 0.65, alpha value of 0.05 and power of 0.80. Thus the estimated sample size was 16. Based on objective 1 and 2, the total sample size needed in the present study was 16.

3.2: Recruitment of Participants

A total of 16 female university students from the School of Health Sciences, Universiti Sains Malaysia were recruited and randomly chosen to participate in this study. Subjects were recruited via words of mouth which spreading among university students. Purposive sampling was used in this study as this study already had predefined target groups. The subjects were chosen on the basis they met criteria of the study. Thus, opinion was being received from the target population. Participation in this study was based on voluntary basis. The entire subject was informed by the researcher about the purpose of the study, flow, procedures, test and expected outcomes. All participants were assigned to a single pre-test and post-test experimental group. Participants selection consisted of several criteria which were:

Inclusion criteria:

1. Participants must be between 19 – 25 years old.
2. Able to cycle for 40 minutes.

Exclusion criteria:

1. Participants with any health issues affecting their cognition or ability to raise their heart rate.
2. Participants have any musculoskeletal injury.
3. Answer ‘YES’ in Physical Activity Readiness Questionnaires (PAR-Q).

3.3: Instruments and protocols

1. **A physical activity readiness questionnaire (PAR-Q)** is self-administered questionnaire which assessing any health condition that can exclude the volunteer from participate. It was used to pre-screen volunteers for participation in this study.
2. **International Physical Activity Questionnaire – Malay Version (IPAQ-M)** is a self-administered instrument to access physical over last seven days which available in short-form or long form and available in many languages including Malay.
3. **Rating of Perceived Exertion Scale (RPE)** scale was used to measure perceived effort during exercise such as how heavy and strenuous the exercise felt and how tired the participant will be.
4. **Heart rate monitor** (Polar heart rate monitor) was used continuously to monitor heart rate throughout the entire experiment.
5. **A single bout cycling exercise protocol** was begun with a 5 minutes warm-up and ended with 5 minutes cooling down, during which resistance is set at 0.5 kp (20 watts). After the warm-up, resistance was increased to 1 kp (50 watts) and cycling for 30 minutes.
6. **Free recall test protocol** was used in this study to assess participant's short term memory. Each 20-item word list was presented 1 word at a time for five s each with a total of 100 s presentation time.

3.3.1: Physical Activity Readiness Questionnaires (PAR-Q)

A physical activity readiness questionnaire (PAR-Q) was used to pre-screen volunteers for participation in this study. This self-administered questionnaire was assessing any health condition that can exclude the volunteer from participate. PAR-Q basically consists of seven consisted general health and physical activity questions which required a yes/no answer. According to Adams (1999), a revised version of the PAR-Q having increased validity compared to previous versions as fewer individuals being incorrectly excluded from physical activity participation. All the participants needed to fill up this questionnaire before involving experimental tests.

3.3.2: International Physical Activity Questionnaire – Malay Version (IPAQ-M)

International Physical Activity Questionnaire (IPAQ) is a self-administered instrument to access physical over last seven days which available in short-form or long form and available in many languages including Malay. Malay version of IPAQ (IPAQ-M) revealed a good reliability and validity for the evaluation of physical activity among this Malay population with validity tests showed that time spent in moderate-vigorous physical activity (MVPA) (min wk-1) from IPAQ-M was significantly correlated with MVPA from accelerometer (ρ=0.32, $p<0.01$) (Shamsuddin *et al.*, 2015). The IPAQ-M consists of questions related to vigorous, moderate, walking, sitting and sleeping activities.

The IPAQ consist domains of leisure time physical activity, domestic and gardening (yard) activities, work-related physical activity and transport-related physical activity. Participants in this study reported the activities performed during the last seven days and to include only activities that lasted 10 minutes or more per session. Domain-specific scores require the summation of the scores for walking, moderate-intensity and vigorous-intensity

activities within the specific domain, whereas activity-specific scores require the summation of the scores for the specific type of activity across domains. Computation of MET-minutes per each domain as below:

Work Domain

Walking MET-minutes/week at work = 3.3 × walking minutes × walking days at work.

Moderate MET-minutes/week at work= 4.0 × moderate-intensity activity minutes × moderate-intensity days at work.

Vigorous MET-minutes/week at work= 8.0 × vigorous-intensity activity minutes × vigorous-intensity days at work.

Total Work MET-minutes/week =sum of Walking + Moderate + Vigorous MET-minutes/week scores at work.

Active Transportation Domain

Walking MET-minutes/week for transport = 3.3 × walking minutes × walking days for transportation.

Cycle MET-minutes/week for transport= 6.0 × cycling minutes × cycle days for transportation.

Total Transport MET-minutes/week = sum of Walking + Cycling MET-minutes/week scores for transportation.

Domestic and Garden [Yard Work] Domain

Vigorous MET-minutes/week yard chores= 5.5 × vigorous-intensity activity minutes × vigorous-intensity days doing yard work.

Moderate MET-minutes/week yard chores= 4.0 × moderate-intensity activity minutes × moderate intensity days doing yard work.

Moderate MET-minutes/week inside chores= 3.0 × moderate-intensity activity minutes × moderate intensity days doing inside chores.

Total Domestic and Garden MET-minutes/week =sum of Vigorous yard + Moderate yard + Moderate inside chores MET-minutes/week scores.

Leisure-Time Domain

Walking MET-minutes/week leisure = 3.3 × walking minutes × walking days in leisure.

Moderate MET-minutes/week leisure = 4.0 × moderate-intensity activity minutes × moderate-intensity days in leisure.

Vigorous MET-minutes/week leisure = 8.0 × vigorous-intensity activity minutes × vigorous-intensity days in leisure.

Total Leisure-Time MET-minutes/week = sum of Walking + Moderate + Vigorous MET-minutes/week scores in leisure.

Data from IPAQ-M long form reported as continuous measure via resting metabolic rate (MET) and presented as MET-minute which was computed by multiplying the MET score of an activity by the minutes performed. An overall total physical activity MET-minutes/week score computed as:

Total physical activity MET-minutes/week = sum of Total (Walking + Moderate + Vigorous) MET-minutes/ week scores.

IPAQ-M score used to gain clarity used to gain clarity of participant's habitual physical activity.

3.3.3: Borg's Rating of Perceived Exertion Scale

Borg's Rating of Perceived Exertion Scale (RPE) (6- 20 scale) was used to measure perceived effort during exercise such as how heavy and strenuous the exercise felt and how tired the participant will be. RPE was shown to be a reliable measure of perceived effort and physical discomfort with high intra-test ($r = .93$) and test–re-test ($r = .83 – .94$) reliabilities while correlating with heart rate (Razon *et al.*, 2017). Then, Razon *et al.* (2017) also stated that RPE increases gradually under any type of exercise either strength or endurance while changes in heart rate during the attempted effort fail to differentiate perception between strength and endurance exercise. RPE is scale range from 6 – 20 which '6' means no exertion at all while '20' corresponds of maximal exertion. ACSM defines a moderate intensity occurring at an RPE of approximately 12 and 13 according to the Borg scale (American College of Sports Medicine, 2010). In this study, participants corresponded to on RPE within range of 12 – 15 (moderate intensity) while the measures were taken at the beginning of and every five minutes during exercise.

3.3.4: Heart Rate

Heart rate measurements continuously monitored throughout the entire experiment to ensure appropriate heart rate levels by using Polar heart rate monitor. The strap of heart rate sensor was fastened around the chest and watch wore by the subjects at wrist to see the heart rate beat per minutes. Primarily, each participant's heart rate was monitored using heart rate monitor to maintain consistency in aerobic exercise among the participants. Participants needed to maintain her heart rate above 100 beats per minute (bpm) during exercise. According to American Heart Association (2015), the 100 bpm is determined via formula of maximum heart rate and the definition of aerobic exercise as being 50% to 85% of the maximum heart rate:

Maximum heart rate (MHR) = 220 – age
Lower bound of target heart rate = MHR × 0.50
Upper bound of target heart rate = MHR × 0.85

3.3.5: Exercise Protocol

The protocol of exercise was a single bout of moderate intensity aerobic exercise and duration on a Lode cycle ergometer with adjusted seat position suitable for participants' height. To control for energetic variables not related to exercise, participants need to prevent from taking caffeine and exercise or strenuous physical activity for 12 hours before testing (Weng *et al.*, 2015). According to study protocol of acute exercise effects on long term memory by Labban and Etnier (2011), the protocol began with a five minutes warm-up, during which resistance is set at 0.5 kp (20 watts). After the warm-up, resistance was increased to 1 kp (50 watts), and participants were asked to pedal at a rate resulting in RPE ratings within the prescribed 12–15 range. Participants were exercise at a moderate intensity for 30 minutes to control for factors associated with exercise bouts of high intensity and longer duration (e.g., fatigue, dehydration) that may also influence memory performance. For this reason, water was

provided to the participants throughout the session. Exercise was concluded with a five minutes cool-down period. Duration of exercise in current study was longer compared to study by Labban and Etnier (2011) with duration of exercise is 20 minutes. This happened as according to Quelhas *et al.* (2013), duration of exercise longer than 20 minutes will contribute towards positive effects on cognitive performance.

3.3.6: Free Recall Test Protocol

Free recall test was used in this study to assess participant's short term memory. This test was used by Coles and Tomporowski (2008) to investigate effects of physical exertion on memory storage in adults. Besides, it also used by Pesce *et al.* (2009) to study the effects of physical activity on memory performance in preadolescents. According to a procedure by Pesce *et al.* (2009), four 20-items word lists created by selecting 80 highly concrete and image able nouns from the normative list by Paivio, Yuille, and Madigan (Christian *et al.*, 1978). Similar with Pesce *et al.* (2009) study, the words were printed on posters and manually presented by the researcher to the participants in the lab with 7.5 cm height of the letters composing the words and the average distance of the participants from the posters was 330 cm. This letter size and average distance was selected to obtain similarity to that method used by Coles and Tomporowski (2008) who used letters in 48 points Arial font viewed from a distance of two feet.

Each 20-item word list (as shown in Figure 3.2) was presented a word at a time for five seconds each with a total of 100 seconds presentation time. Then, a 100 seconds consolidation period happened during which participants could - without clear instruction – rehearse the word list. After this period, a recall was taking place as a verbal cue signalling participant to recall, within 100 seconds, as many words as possible regardless of their sequential presentation order

(as shown in Figure 3.1). Then, participants were briefed about the next exercise session and memory test afterward. Words which will recall from each list assume as correct if minor pronunciation errors or singular–plural substitutions occur (Coles and Tomporowski, 2008). After that, calculation of recall percentages was done. Measurement of memory obtained from recall test was percentage number of correct words recalled that showed an index of free recall memory.

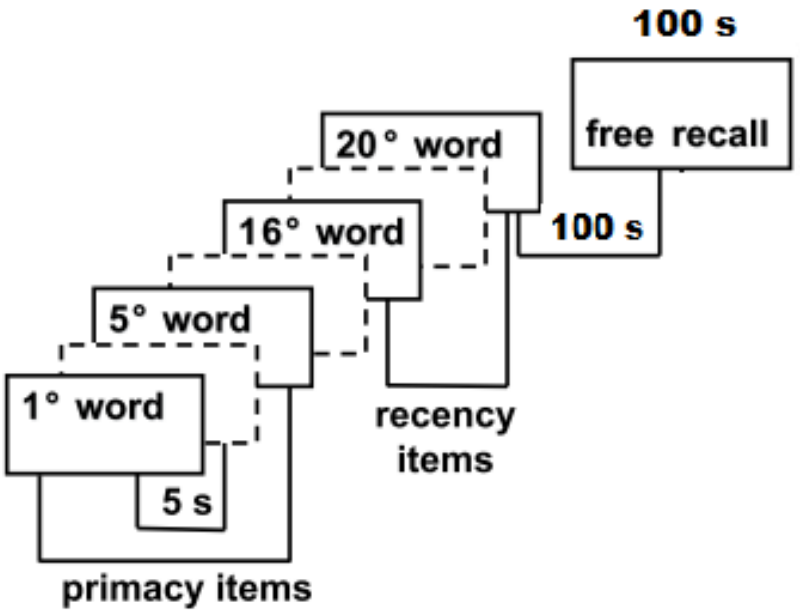

Figure 3.1: Timing of the event sequence within a session of free recall test.

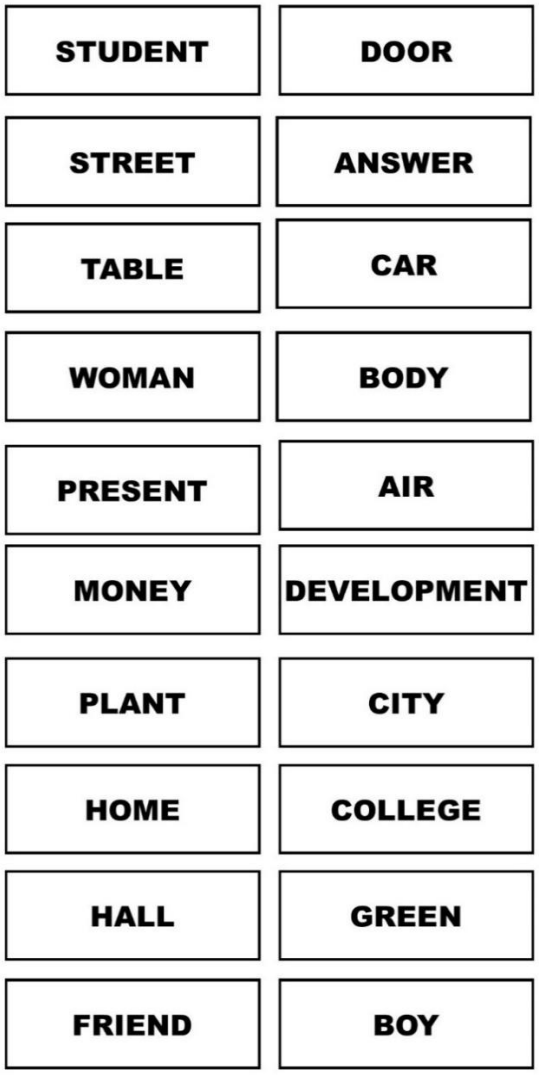

Figure 3.2: 20-Items Words List (Free Recall Test Instrument)

3.4: Procedures

All participants visited the laboratory once. Participants were provided with written consent, a physical activity readiness questionnaire (PAR-Q) and International Physical Activity Questionnaire (IPAQ-M) before being assigned with familiarization session of free recall test. Then, participants were administered with pre-exercise memorization followed by exercise and memorization after that. Free recall test was used as a measure of short term memory. Mode of exercise will be ergometer cycling. The intensity of exercise was set at a moderate intensity according to Borg's Rating of Perceived Exertion Scale as the first measure

and maximum heart rate according to American Heart Association's formula. All the tests were administered by an investigator.

Pre-exercise memorisation

Participants were sat at rest while heart rate monitor placed on them. Then, they completed free recall test. After that, participants started to exercise.

Post-exercise memorisation

Participants were sat at rest for 3 minutes after dismounting the ergometer. Then, free recall test was administered according to its procedure.

3.5: Data Analysis

Statistical Package for Social Sciences (SPSS) version 24.0 software was used to analyse the data that collected in this study. For objective 1, paired t-test was used to assess whether significant difference between pre-exercise and post-exercise in terms of free recall test index in term of moderate intensity of aerobic exercise. If the assumption of normality is not met, non-parametric Wilcoxon signed-rank test would be used. Then Pearson correlation test was used to examine the relationship between heart rate at last five minutes of exercise and index of free recall test post-exercise. If the assumption of bivariate normality was not met, non-parametric Spearman correlation would be used. In this study, significance level was set at 0.05 resulting in a single confidence interval of 95%.