ORIGINAL ARTICLE

# A single bout of cycling exercise effects on short-term memory

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## ABSTRACT

**Introduction:** Exercise plays a role in enhancing neurogenesis and brain plasticity. Actively involved in musculoskeletal and cardiovascular activities at moderate intensity influences brain systems involved in working memory processes. This study aimed to investigate the effect of memorising before and after a single bout exercise on short-term memory.

**Materials and Methods:** A total of 16 female university students with a mean age of 23.63 ± 1.46 years old were involved in this study. Participants completed a free recall test twice at pre- and post-exercise. The exercise session involved a single bout cycling ergometer at 50 watts while maintaining 60 rpm for 30 min and two five minutes periods of warm-up and cool down at 20 watts.

**Results:** The percentage of words recalled in the free recall test post-exercise did not improve compared to pre-exercise. The percentage of immediate 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 ($r = -0.59$, $p = 0.015$).

**Conclusions:** Participants with a higher heart rate during exercise had a lower percentage of words recalled at post compared to pre-exercise. However, a single bout of cycling exercise did not improve short-term memory.

**Key Words:** Cycling exercise, short-term memory, young adults

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## INTRODUCTION

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 plays a role in enhancing neurogenesis and brain plasticity in addition to the common benefits of exercise in reducing heart disease, enhance weight loss, strengthens muscles, including the heart, while improving overall health (Chang et al. 2012). Actively being involved in musculoskeletal and cardiovascular activities at moderate intensity influences the brain systems that involve working memory processes, specifically within the acute phase after one session (Weng et al. 2015).

Memory and learning are the cognitive functions (Sahana et al. 2015). According to Sahana et al. (2015), short-term memory is the memory that can only be measured in seconds or at most minutes unless it is converted to long-term memory. 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). Meanwhile, information that stays in memory for a short period of about

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10 − 15 s without repeating over and over is short-term memory or working memory (Goldstein 2014). Auditory coding is usually predominant in short-term memory and semantic coding predominant in long-term memory (Goldstein 2014).

Meta-analyses revealed that acute exercise had a moderate effect on short-term memory compared to long-term, which had smaller effects (Roig et al. 2013). Lambourne and Tomporowski (2010) stated that smaller effects sizes were showed following treadmill running compared to ergometer cycling protocols. Weng et al. (2015) found an effect of a single bout of 30-min moderate-intensity aerobic cycling was significant on working memory performance on 2-back condition of a facial n-back task.

Weng et al. (2015) found that active exercise leads to a higher mean heart rate compared to passive exercise, which leads to better results of working memory performance among participants in the previous exercise. An elevated amount of oxygen supplied to the brain by increased respiration and heart rate will lead to 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, Kennedy and Petras (2017), it stated that there was a positive correlation between an increase in heart rate following exercise and memory accuracy among woman who is involved in 5 min of low-impact exercise immediately after learning.

The purpose of this study was to compare the effect of memorising before and after single bout exercise on short-term memory in young adults. Such finding would be beneficial to raise the awareness towards exercise improving cognitive function, especially memory is lacking despite exercise has been related to enhancing physical health.

## MATERIALS AND METHODS

### Participants

A total of 16 female university students with a mean age of 23.63 (standard deviation = 1.46) years from the School of Health Science, Universiti Sains Malaysia, were recruited to participate in this study. Participants must be able to cycle for 40 min. All participants were assigned to a single pre-test and post-test experimental group. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional Research Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

### Procedures

All participants visited the laboratory once. Participants written consent were obtained before they were included in the study. Participants completed the physical activity readiness questionnaires and International Physical Activity Questionnaire (IPAQ-M) before being assigned with a familiarisation session of free recall test. Then, participants were administered with pre-exercise memorisation followed by exercise and memorisation after that. A free recall test was used as a measure of short-term memory. The mode of exercise was ergometer cycling. The intensity of exercise was set at a moderate intensity according to Borg's Rating of Perceived Exertion (RPE) Scale as the first measure, and maximum heart rate was measured according to American Heart Association's formula. All the tests were administered by an investigator.

### Pre-exercise memorisation

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

### Post-exercise memorisation

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

### International Physical Activity Questionnaire – Malay Version

IPAQ is a self-administered instrument to access physical over the last 7 days. Malay version of IPAQ (IPAQ-M) revealed 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 the accelerometer ($\rho = 0.32$, $p < 0.01$) (Shamsuddin et al. 2015). IPAQ-M score used to gain clarity about participant's physical activity level for the last 7 days.

### Borg's Rating of Perceived Exertion Scale (1988)

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. 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 (Razon et al. 2017). American College of Sports Medicine 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 the range of 12–15 (moderate intensity) while the measures were taken at the beginning of and every 5 min during exercise.

### Heart rate

Heart rate measurements continuously monitored throughout the entire experiment to ensure appropriate heart rate levels by using a Polar heart rate monitor. The strap of the heart rate sensor was fastened around the chest, and the watch wore by the subjects at the wrist to see the heart rate beat per minutes. Primarily, each participant's heart rate was monitored using a heart rate monitor to maintain consistency in aerobic exercise among the participants. Participants needed to maintain their heart rate above 100 beats/min (bpm). The 100 bpm is determined through American Heart Association's formula for maximum heart rate

and the definition of aerobic exercise as being 50% to 85% of the maximum heart rate.

### 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 h before testing (Weng et al. 2015). The protocol began with a 5-min 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 min to control for factors associated with exercise bouts of high intensity and longer duration (e.g. fatigue and dehydration) that may also influence memory performance. For this reason, water was provided to the participants throughout the session. The exercise was concluded with a 5-min cool down period.

### Free recall test

According to a procedure by Pesee et al. (2009), four 20-item word lists created by selecting 80 highly concrete and imageable nouns from the normative list by Paivio, Yuille and Madigan (Christian et al. 1978). The words were printed on posters and manually presented to the participants in the laboratory 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 were 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 was presented one word at a time for 5 s, each with a total of 100 s of presentation time. Then, a 100 s consolidation period happened during which participants could-without clear instruction – rehearse the word list. After this period, an immediate recall was taking place as a verbal cue, signalling participant to recall, within 100 s, as many words as possible regardless of their sequential presentation order. Then, participants were briefed about the next exercise session and memory test afterwards. Words that are recalled from each list are assume as correct if minor pronunciation errors or singular-plural substitutions occur (Coles and Tomporowski 2008). After that, a calculation of exercise (%) Percentage of words recalled post-immediate recall percentages will be done. Measurement of memory obtained from recall test was several correct words recalled during the immediate recall tests would show an index of free recall memory.

### Data analysis

Statistical Package for the Social Sciences (SPSS) version 24.0 software (Armonk, NY: IBM Corp.) was used to analyse the data collected in this study. Data were screened for normality and outliers. Paired *t*-test was used to assess whether an index of free recall test differs from pre-exercise memorisation and post-exercise memorisation in term of moderate-intensity of aerobic exercise. Pearson correlation test was used to determine the relationship between heart rate and index of free recall test for both pre- and post-exercise. In this study, the significance level was set at 0.05, resulting in a single confidence interval of 95%.

## RESULTS

Table 1 showed the average age of the 16 female participants in the current study was 23.63 ± 1.46, and the mean BMI was 24.52 ± 4.69 kg/m$^2$, which was within the normal average. The average IPAQ-M score was 6055.47 ± 4286.30 MET-min/week, which was more than 3000 MET-min/week. This indicated that, on average, participants are in the high physical activity group. According to the scoring guideline stated in IPAQ (2005), low physical activity scored ≤3000 MET-min/week while high physical activity scored higher than 3000 MET-min/week.

Table 2 showed no significant difference in the mean percentage of immediate words recalled and percentage of both primary and recency words recalled between pre-exercise and post-exercise. This study shows that percentage of words recalled post-exercise has decreased compared to pre-exercise. Mean percentage of immediate recency words recalled post-exercise, 51.25 ± 21.87% is higher than pre-exercise, 48.75 ± 21.87%. However, the improvement was not statistically significant ($p = 0.751$).

Figure 1 shows a statistically significant, fair negative linear correlation between the percentage of words recalled post-exercise and heart rate ($r = -0.59$, $p = 0.015$). Heart rate was measured during the last 5 min of cycling exercise before cooling down. When the heart rate went up to a high level during the last 5 min of exercise, the percentage of words recalled decreased.

## DISCUSSIONS

In the present study, there was no statistically significant difference percentage of immediate words recalled between pre-exercise and post-exercise. A single bout of cycling exercise do not appear to influence the percentage of free recall test among young female adults. It contradicted with Pesce et al. (2009) study that showed better verbal memory scores in 11–12 years old pre-adolescents when a free-recall word test was done following by a single class of physical education consisting of either aerobic circuit training or group games.

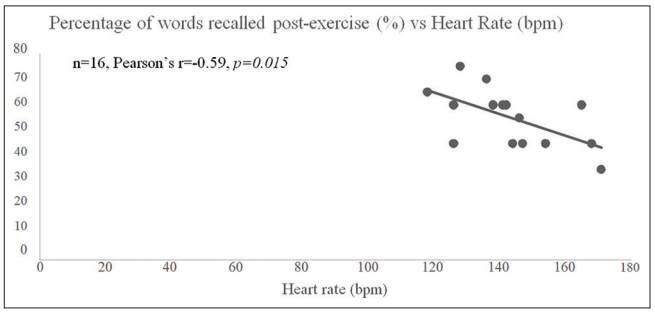


**Figure 1:** A correlation between the percentage of words recalled post-exercise and heart rate

In another study that implemented graded exercise by Coles and Tomporowski (2008), which used the Brown-Peterson memory test to assess visual short-term memory performance, suggested that acute bouts of exercise did not facilitate short-term memory. Further, that study mentioned that exercise-induced arousal does not affect executive function processes involved in the reconfiguration of information in working 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 min of consolidation, respectively. When comparing immediate recall, participants recalled significantly more words compared to delay recall which tested after 12 min. However, both immediate and delayed performance by participants declined from pre to post-test (Coles and Tomporowski 2008).

In term of the percentage of immediate recency, words recalled post-exercise is slightly higher than pre-exercise even though it is not statistically significant. Coles and Tomporowski (2008) found that primacy and recency delayed the recall of the words decreased from pre- to post-test for the rest and exercise control interventions but was maintained following the exercise intervention. The finding in the present study illustrates no significance but shows that percentage of primary recalled words decreases following the acute exercise intervention, similar to the previous study (Coles and Tomporowski 2008). Meanwhile, immediate recall of both primacy and recency items in the free recall test among pre-adolescent significantly influenced by only the team game activities (Pesce et al. 2009).

Pesce et al. (2009) presumed that observed short-term facilitation of memory performance after the team game is influenced by cognitive activation induced by open skill activities characterised by rapidly changing interactive situations and by a corresponding need to carry out perceptual, memory and decisional processes under time pressure. The game activity of tactical ball game had the greatest influence on working memory compared to the aerobic and resistance exercise (Zach and Shalom 2016).

**Table 1: Characteristics of the study population**

| Variables | *n*=16 |
|---|---|
| Height (m) | 1.59±0.056 |
| Weight (kg) | 62.44±15.18 |
| BMI (kg/m$^2$) | 24.52±4.69 |
| Age (years) | 23.63±1.46 |
| IPAQ-M (MET-min/week) | 6055.47±4286.30 |

BMI: Body mass index, IPAQ-M: International Physical Activity Questionnaire – Malay Version

BDNF-TrKB signalling and neuroplasticity in different brain regions influence learning and memory performance (Nanda et al. 2013). According to Hötting et al. (2016), acute exercise in humans leads to a transient rise of BDNF, and it might contribute towards the effects of acute exercise on the memory process. There was a positive correlation between memory consolidation and BDNF increase when being assessed after 20 min and 24 h of intervention (Hötting et al. 2016). Enhancement of hippocampal volume and cognitive function attributed to exercise improved BDNF concentrations in the serum (Erickson et al. 2011). Increased levels of serum BDNF were detected immediately after exercise cessation and persisting up to 60 min after exercise in a study by Weng et al. (2015). In that study, it found that improvement of working memory assessed by using performance on the face n-back task due to BDNF-related mechanisms in the hippocampus.

In the current study, the percentage of words recalled post-exercise will decrease when the heart rate measured during the last 5 min of the exercise rise too high. This finding contradicts with previous by Most et al. (2017) which found a weak, positive correlation between memory performance and exercise-induced change in heart rate. Although both study the correlation of exercise-induced change in heart rate with percentage recall of memory, the duration and type of activity are different. In the study by Most et al. (2017), exercise implemented was low-impact walking for 5 min of low duration intensity, while the current study used cycling exercise for 30 min of moderate duration intensity. Besides, in the previous study, the heart rate was measured immediately after exercise, and the memory performance was assessed after 24 h. The differences between these studies can lead to different outcome.

In conclusion, this study shows there are no effects of single bout cycling exercise on short-term memory as shown by the results of free recall memory. Participants with a higher heart rate during exercise had a lower percentage of words recalled at post compared to pre-exercise. However, it important to consider that the sample size in this study quite small compares with others study which found the positive effects of single bout exercise on short-term memory. Besides, in the future, the type of activities that demand a higher cognition process, such as the game activity of tactical, can be used as the exercise protocol. Rather than using recall methods, measurements of digit span to find the average capacity of short-term memory can be used as the memory test.

## Acknowledgements

We are grateful to the participants in this study for their co-operation and time.

**Table 2: Percentage of immediate words recalled pre- and post-exercise**

| Variables | Pre-exercise | Post-exercise | *P** |
|---|---|---|---|
| Percentage of words recalled (%) | 56.56±11.79 | 55.31±10.87 | 0.615 |
| Percentage of primacy words recalled (%) | 78.75±17.08 | 68.75±30.08 | 0.204 |
| Percentage of recency words recalled (%) | 48.75±21.87 | 51.25±21.87 | 0.751 |

Values are mean±SD, $p<0.05$, $n=16$, *Tested using paired *t*-test. SD: Standard deviation

### Ethical approval

The study procedures were granted by the university ethical advisory committee.

### Financial support and sponsorship

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### Conflicts of interest

There are no conflicts of interest.

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