

EXERCISE AND ITS RELATION TO STUDENTS' WORKING MEMORY- A PRELIMINARY STUDY

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Abstract

The practice of cardiovascular exercise triggers a cascade of neurobiological mechanisms that enhance human memory processing. The objective of this study was to understand the relationship of acute, moderate-intensity exercise to working memory (WM) performance by using N-back task as a performance measure. In a within-participants design, students from second semester Diploma, Faculty of Sport Science, Universiti Teknologi MARA, Pahang aged between 19 to 24 years old, females ($n = 31$) performed a N-back task: 1) a rest-cognition intervention, in which they performed a cognitive task without exercising; 2) an exercise-cognition intervention, in which they performed a cognitive task 5-minutes immediately after the task. 8 subjects had increment in N-back load compared to before exercise session and 9 subjects had similar N-back load performance. However, 7 subjects had decrement in performance. The exercise-only intervention resulted in an increment pattern of hit rate and decreased reaction times, suggesting that simple aerobic exercise had a beneficial impact on working memory. However, for memory reaction time ($p=0.515$) and accuracy ($p=0.216$), both did not show significant differences. A few subjects had decreased in performance which is indicative of cognitive fatigue caused by the additional cognitive demands. In summary, our findings suggest that acute, moderate-intensity exercise differentially influence the subject's performance. Subjects can maintain and improve the N-back level, gives some initial indication that this activity may help to improve students' WM cognition. While the decrement in performance among other 8 subjects may be caused by cognitive fatigue may interfere the beneficial post-exercise outcomes.

Keyword: acute, moderate-intensity exercise, N-back task. working memory

Introduction

Working memory (WM) refers to temporary memory where the information must be retrieved within a brief interval (Postle, 2006). It is the structures and processes used for momentarily storing and managing information in the context of ongoing processing and distraction. It plays a vital role for cognitive function such as in reading comprehensive, reasoning, fluid intelligence, second language skill of adult learner and academic attainment (Dai *et al.*, 2019). Involving the central executive function, WM is very active and accountable for the selection, initiation, and termination of processing routines like encoding, storing, and recalling information. In daily life, WM is used for a multipurpose task like preparing or deciding, troubleshooting problems in stressful situations and engage in a condition where robust habitual responses or temptations are involved (Baddeley, 2003). One of the validated measures of WM performance is the N-back task. Participants are presented with a sequence of stimuli one-by-one. The task is to decide whether each stimulus is matched as the one presented in N trials before (Jaeggi *et al.*, 2010). The difficulty of the task is increasing as the number of N increased. It was shown that the processing load can be

varied systematically by manipulating the value of N, which is expressed with changes in accuracy and reaction time (RT) (Blacker *et al.*, 2017). Performance of the N-back task that depends on familiarity and recognition-based discrimination processes gives a critical explanation to WM function as it is able to occupy the demand of WM function for active recall (Ludyga *et al.*, 2018). Besides, the N-back task is tightly linked to performance on evaluating the fluid intelligence that relates to the individual capability to solve complications and is essential to the functioning of WM (Mitchell, 2019). There are signifying relationships between exercise, cognition, and human brain function. Extensive research has proven that aerobic exercise may enhance processing speed, focus and memory executive function in healthy adults (Castells *et al.*, 2019). Then, the type of exercise that people are involved with may affect the influence of exercise on cognition (Tomprowski *et al.*, 2008). Since much of the reported research were conducted among elderly and adolescents in laboratory settings, the interest here was in examining the short-term effects of exercise on WM performance among university students, in a real leisure activity environment. The goal of the present paper is to understand the relationship of acute, moderate-intensity exercise to WM performance by using N-back test as a performance measure.

Materials and Methods

Participants A total of 31 female students (age 19-24 years old) had volunteered to take part in the experiment. The participants were in the second semester of Diploma in Sports and Recreation, Faculty of Sport Science, Universiti Teknologi MARA, Pahang. Research informed consent was signed by the participants before engaging in the physical exercise. The participants were excluded if the ages are not within the given range. If there was any existence of acute or chronic disease and any injuries or disease affecting the functionality of vision and hand. To screen for possible medical risks that could be aggravated by the exercise, Physical Activity Readiness Questionnaire (PAR-Q) Form was assessed. Any rejection of the PAR-Q condition would lead to exclusion. Data from 6 participants were discarded from the analyses for did not complete all experimental conditions. Thus, data from 25 subjects was analyzed.

Monitoring heart rate for recognising the exercise intensity Heart rate was monitored using sphygmomanometer before exercise and after exercise. It was an assessment of the physiological exertion on monitoring the achievement of the targeted medium heart rate. The percentage increment of was calculated as follows in (1):

$$\frac{(\text{Heart rate of Exercise cognition condition} - \text{Heart rate of rest cognition})}{\text{Heart rate of Rest Cognition}} \times 100 \quad (1)$$

Research Design **Figure 1** illustrates the experimental protocol. A within-participants repeated-measures design was used. After a trial mode, two experimental conditions were investigated: the rest-cognition condition (pre-test) and the exercise-cognition condition (post-test). Firstly, participants performed an N-back task at resting-cognition (pre-test). The load level they can achieved highest was recorded. Then, they were randomly divided into two groups to perform the acute, moderate-intensity exercise: jogging and ball game. The duration of exercise was set up to 15 minutes for exertion of the targeted moderate-intensity exercise (it should achieve 50 to 70% increment of the average maximum heartbeat). In 5 minutes after the intervention, while sitting calmly, they performed N-back task of exercise-cognition (post-test). The load level they can scored highest was recorded. N-back task in pre-test and post-test were performed in triplicates (Kamijo & Abe, 2019). The N-back task was performed by using the application of N-Back Memory Training Free Version 5.9© downloaded from PlayStore of participants' smartphone.

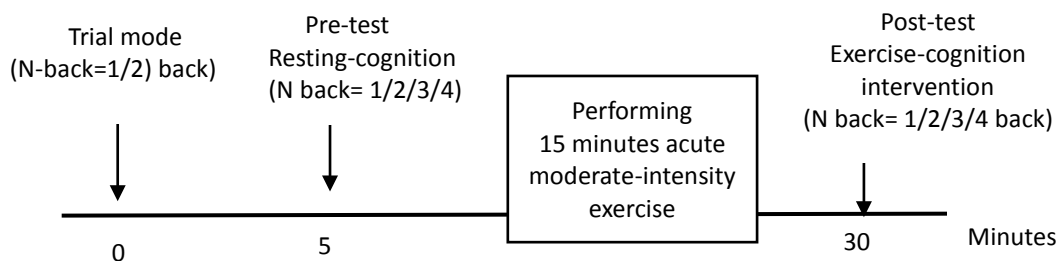


Figure 1 Experimental protocol where N-back task was performed in minute-5 before exercise and minute-5 after exercise.

Examples of test protocol is illustrated in **Figure 2**. 0-back as the control position and the cognitive load is elevated with the operating number of N. In the 0-back task, the participants had to decide whether the color they saw on the screen was an instructed color. While, in the 2-back task, participants were presented with a continuous sequence of colored circles and were instructed to identify whether each color tallied the color presented two circles back in the sequence.

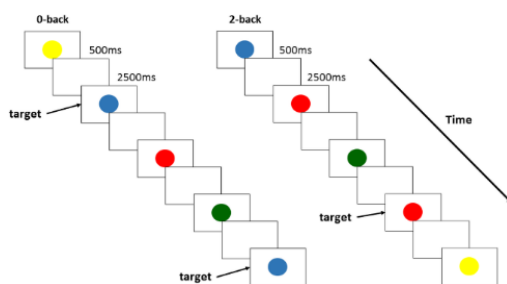


Figure 2 N-back test protocol (Yamazaki *et al.*, 2018)

In this experiment, the N-back task was performed by using a single visual N-back position. The smartphone screen will show a series of blue squares per trials with 9 possible positions where it will appear. The subject must remember the position in which blue square appeared in 2-trials previously according to the load of n-back. As the test started, the participant that achieved score 1.0 would undergo the increase of level load. If they scored 0.75, they had to stay on the same level. If the score were only 0.50, the level load would be decreased. Each block condition included 22 trials in random order and 2.5-sec stimulus displayed per trials with the 0.2 level of interference. The participants were instructed to respond to the targets trial by pressing a button “position” on the keyboard with her right finger if it matched the stimulus. The performance was assessed in terms of reaction times (RTs; hits only) and accuracy (Pr, proportion hits minus false alarms) which served as the dependent variables (Snodgrass & Corwin, 1988).

Data Analysis The data collected was analyzed by using Graph Pad Prism® version 8.1 software. Each N-back task reaction time (RT) and accuracy was analyzed using a repeated-measures two-way analysis of variance (ANOVA). The significance level was set at $p < 0.05$.

Result and Discussion

Intervention

Analysis of heart rate (HR) revealed that HR was higher exercise-cognition condition (post-test) relative to the rest-cognition condition (pre-test) (**Table 1**). Mean HR in exercise-cognition condition showed an increment of 32.30% meet the criterion used in previous studies to examine the consequences of acute aerobic exercise on cognition (Kao *et al.*, 2017, Hilman *et al.*, 2003).

Table 1 Mean (SD) values for heart rate in rest-cognition condition (pre-test) and exercise-cognition condition (post-test)

Condition	Heart Rate,bpm, Mean (SD)
Rest-cognition condition (pre-test)	89.04 (11.11)
Exercise-cognition condition (post-test)	117.8 (13)

Measuring N-back task performance

In the present study, we examined performance of volunteered students from UiTM Pahang to perform the N-back task in order to investigate changes in WM after performing acute, moderate-intensity exercise in a real leisure activity environment. The trend of performance in **Figure 3** displays majority 16 of the subjects could match the stimuli positions up to 3-back in N-back task, and no one could achieve 4-back load. Meanwhile, the trend after the exercise shows that majority 11 of the subjects achieved up to 2-back load, lesser subjects in 3-back load compared to before exercise. Fortunately, there were additional 5 subjects that were able to reach at the maximum point 4-back load, to give the record of the highest achievement level.

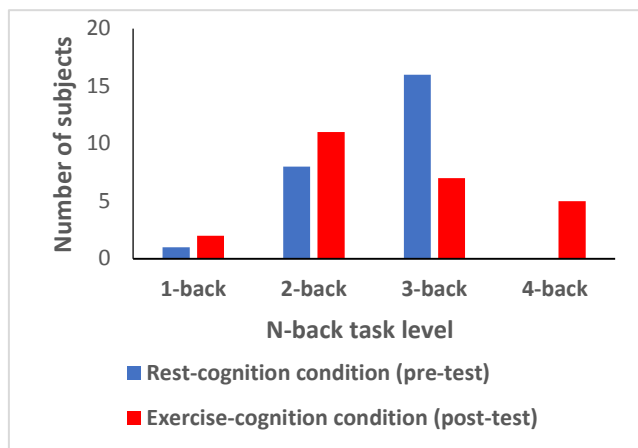


Figure 3 Comparison of the number of subjects in different N-back task level in rest-cognition condition (pre-test) and exercise-cognition condition (post-test)

By assessing the progress subjects performance in detail for each individual subject in **Figure 4**, 8 subjects showed performance increment while 9 subjects showed identical performance between pre-test and post-test. Only 7 subjects had reduced in performance after acute, moderate-intensity exercise intervention.

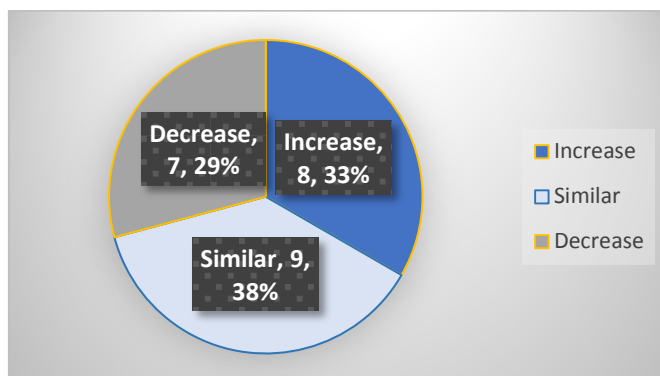


Figure 4 Comparison of the number of participants showing changes in N-back performance after exercise.

The increment of performance up to 4-back load indicates a positive result to the hypothesis that shows exercise could trigger the WM performance. Aerobic exercise delivers a moderate improvement in neurocognitive function among healthy older adults with the enhancement in attention and processing reaction, executive function, and memory. Compared to aerobic exercise only, the combined aerobics interventions and strength training were able to provide greater increased attention, speed and WM (Smith *et al.*, 2010). However, 7 subjects had reduced in performance could be based on attention restoration theory (Berman & Kaplan 2008) that occurred and might be due to cognitive fatigue from additional cognitive demands during the ball game and jogging exercise.

There was no significant effect ($p=0.216$) of N-back level, session, and their interaction on the all N-back accuracy (**Table 2**). **Figure 5** displays comparison of accuracy where in the pre-test and post-test conditions, both showed the increasing pattern in the difficulty of load level. However, there were distinct differences that there was less accuracy on correct stimuli after the exercise. The researchers focused on interpreting accuracy results as the actions of the participants were usually more focused on executing the task accurately than responding as quickly as possible (Meule, 2017). Different load levels involve varying demands in the manipulation of information. The greater the load level, the greater executive control demands required (Pelegrina, 2015).

Table 2 Descriptive measures of the N-back accuracy and reaction time

	Rest-cognition condition (pre-test)			Exercise-cognition condition (post-test)		
	M	SD	Range	M	SD	Range
Accuracy						
1-back	42.43	45.58	-14,100	43.1	25.75	0 ,100
2-back	57.36	28.67	-7,100	48.38	35.92	-6 ,100
3-back	51.36	25.46	4 ,100	44.65	39.08	-28,100
4-back	65	0.00	0,65	55.46	36.08	-25,100
Reaction time						
1-back	0.61	0.32	0.25,1.0	0.63	0.18	0.50,0.75
2-back	0.70	0.29	0.10,1.0	0.67	0.28	0.25,1.0
3-back	0.72	0.23	0.25,1.0	0.72	0.24	0.25,1.0
4-back	1.00	0.00	0,1.0	0.81	0.23	0.50,1.0

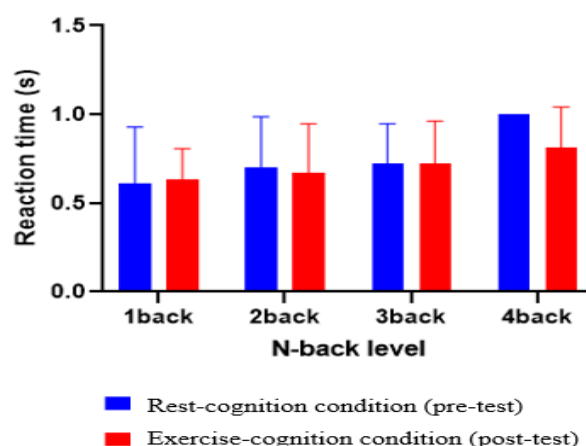


Figure 5 The subjects' reaction time at two different time points (pre-test and post-test) The two-way ANOVA analysis revealed that there was no significant effect ($p=0.515$) of N-

back level and their interaction in all level RT (**Table 2**). **Figure 6** displays the comparison of reaction time before exercising and after exercising. In both conditions, it shows an increasing pattern of RT as the difficulty of load level increase. In the 3-back, the performance of reaction time was similar for before and after exercise by 0.72 sec, while 4-back show increasing reaction time after exercise. In this situation, the participants took longer time to respond on the correct stimuli. Reaction times and accuracy usually correlate negatively as the greater number of errors correspond with faster response times. While this relationship exists, reaction times and accuracy tend to have dissociable correlations (Jaeggi *et al.*, 2010). Tasks with higher strategic processing requirements usually produce higher levels of score variation, particularly when success is measured in multiple learning trials. Hence, reaction time performance from participants may be more vulnerable as there is a tendency of reduced focuses and boredom during task assessment (Christ *et al.*, 2018). Individuals often slow down their responses after an error compared to an accurate performance as it requires several adjustments that is very essential for survival and adaptation. In the neutral condition, the attention demands are typically low, where the performance of the participants can depend primarily on their fundamental cognitive function (Li *et al.*, 2020).

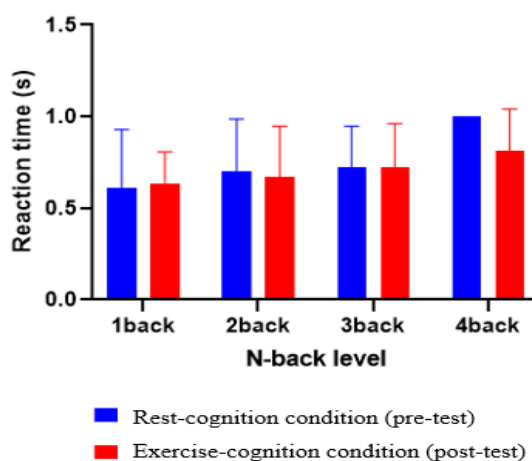


Figure 6 The subjects' reaction time at two different time points (pre-test and post-test)

While we showed that 8 subjects had an improvement in work memory output and 9 subjects has similar performance, some caution is required in interpreting the current findings. First, cognitive fatigue was likely to have been produced after cognitively demanding exercise. This fatigue in turn may have underlain the observed impaired WM performance. Further research should investigate whether the effects of cognitively demanding exercise on executive function differ according to the amount of cognitive demand during exercise. Second, as we only examined female participants here, our findings may not be generalized to male populations. More importantly, the present study showed that the effects of acute moderate-intensity exercise on executive function in 19-24 years old females, who have received little research attention, were similar to those of other age groups, as reported in a meta-analysis (Ludyga *et al.*, 2016). Third, since the order of conditions was counterbalanced for all 31 participants, and data from six participants were discarded from the analyses, the presentation order was not perfectly counterbalanced for the remaining 25 participants that were included in the current analyses. Therefore, this difference could make it difficult to generate a simple comparison between the current study and the past studies. Future studies are needed to fulfill the gap of this preliminary study to deeply discover the exercise effects on cognition especially for WM.

Conclusion

In summary, our findings suggest that acute, moderate-intensity exercise differentially influence the subject's performance in N-back test. With the 17 subjects maintain and increase in the N-back performance, it gives some initial indication that this activity may help to improve students' WM cognition. While the decrement in performance among other 8 subjects may be caused by cognitive fatigue. Thus, for future recommendation, if these findings can be replicated across other samples, this pattern of results could provide a basis to explore potential mechanisms that may be responsible for exercise-induced changes in working memory.

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Conflict of interests

The authors declare no conflict of interest in this paper.

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