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Aerobic Fitness Level and its Association with Short-Term Memory and Sustained Attention among University Students

Ng Kit Foh[1], *Ayu Suzailiana Muhamad[1] & Garry Kuan[1]

[1]Exercise and Sports Science Programme, School of Health Sciences,
Health Campus, Universiti Sains Malaysia,
16150 Kubang Kerian, Kelantan, Malaysia

*Corresponding author's email: ayu_suzailiana@usm.my

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ABSTRACT

Memory and sustained attention are critical cognitive functions that significantly impact academic performance. Numerous studies have demonstrated that regular exercise can improve both short-term memory and sustained attention. However, to date, the association between aerobic fitness level and short-term memory and sustained attention among university students has not been extensively explored. Hence, the present study was carried out using a cross-sectional study design. A total of 38 participants (N=38) were recruited among university students. After obtaining their informed consent, participants' height, weight, and body mass index (BMI) were recorded. In addition, participants performed the digit span test to measure their short-term memory and the digit vigilance test to measure their sustained attention. A 20-m shuttle run was also carried out, and the data obtained from the shuttle run was used to calculate their estimated maximal oxygen uptake. All the data obtained were analysed using descriptive statistics and the Pearson correlation test (SPSS version 28). Results showed that participants had a normal BMI (22.28 ± 4.03 kg/m²). Majority (36.84%) of the female participants had a very poor aerobic fitness level (27.19 ± 4.71 ml/kg/min), and majority (15.79%) of the male participants had a poor aerobic fitness level (37.07 ± 7.45 ml/kg/min). Regarding the correlation analysis, there were no significant correlations ($p>0.05$) between aerobic fitness level and short-term memory and sustained attention. In conclusion, the present study found that short-term memory and sustained attention were not affected by aerobic fitness level. However, further studies may address the limitations highlighted in the present study.

Keywords: *Digit span test, digit vigilance test, exercise*

INTRODUCTION

Memory can be defined as the process of encoding, storing, and retrieving information (Zlotnik & Vansintjan, 2019). Short-term memory is defined as the capacity for holding a small amount of information available for a short period of time (Cowan, 2008). To create a new memory, information must be changed into a usable form which is also known as encoding process. Once the information has been successfully encoded, it will be stored in memory for later use. Meanwhile, sustained attention can be defined as process that enables the maintenance of response persistence and continuous effort over extended periods of time. It is also referred as the ability to focus on an activity or stimulus over a long period of time (Ko et al., 2017). Sustained attention is divided into two which is vigilance (detecting the appearance of a stimulus) and concentration (focusing the stimulus). Memory plays a crucial role in students' academic performance as it directly influences their ability to learn, retain, and recall information. It was found that people with working memory difficulties showed poor academic progress, forget crucial task information, fail to follow instructions, and do not complete activities (Roberts et al., 2011). Similarly, sustained attention is positively related with academic performance (Steinmayr et al., 2010).

Acute exercise can improve memory even when occurring before memory encoding or during memory consolidation (Loprinzi et al., 2019). Similarly, a few other studies also found that acute exercise can improve memory function (Chang et al., 2012; Roig et al., 2013; Bloomstrand & Engvall, 2020). Notably, these beneficial effects occur across the lifespan, including children, young adults, and older adults (Loprinzi et al., 2021). In 1997, Etnier et al. reported a beneficial effect of chronic exercise engagement on memory function compared to acute exercise. Several other studies also reported that chronic exercise was effective in enhancing short-term memory (Roig et al., 2013; Rathore & Lom, 2017). There are two mechanisms to interpret the relationship between exercise and cognitive functions; physiological, and developmental mechanisms (Sibley & Etnier, 2003). The physiological mechanisms include increased in blood flow, brain neurotransmitters alterations, structural changes in central nervous system, and modified arousal levels due to exercise.

Although a substantial amount of studies have investigated the effects of exercise on cognitive performance (Colcombe & Kramer, 2003; Hillman et al., 2008), the relationship between aerobic fitness and sustained attention are not well established. Aerobic fitness is a factor that seems to positively contribute to vigilance capacity is aerobic fitness (Pontifex et al., 2009). Therefore, this study aimed to investigate association between aerobic fitness level and short term memory and sustained attention among university students.

METHODOLOGY

This study is a cross-sectional, quantitative study that involved collection and observation of data at a single point in time. In this study, a total of 38 participants were recruited from the USM Health Campus via convenience sampling method. Ethical approval was acquired from the Human Research Ethics Committee of the Universiti Sains Malaysia (USM) before the study was commenced (USM/JEPeM/KK/23010032). This research took place at USM Health Campus which is located at Kubang Kerian, Kota Bharu, Kelantan. Data collections were conducted between May and June 2023. The selection criteria included healthy, age between 19 and 25 years, and have no physical disabilities. After obtaining their informed consent, participants' height, weight, body fat percentage, and body mass index (BMI) were recorded. Then, the Digit Span Test (DST), Digit Vigilance Test (DVT), and the 20m shuttle run test were carried out.

Digit Span Test

The Digit Span Test (DST) was used to measure the participant's short-term memory. All participants were required to memorise the presented digits and write them down on the paper provided. The digits were clearly spoken out loud by the researcher, with one second apart between each digit. The number of digits increased by one number for each subsequent item. For example, item one has two digits, followed by item two that has three digits. The test was divided into two parts; digits forward (i.e., memorize the digits as how it is heard) and digits backwards (i.e., memorize the digits from backward order). There were seven items for digit forward and backward. One point was given for each correct answer, whereby a zero point

was given for incorrect answer. If there were three consecutive incorrect answers, no more points were totalled after that item. Participants performed two trials where scores for both trials were totalled. The maximum total score for each trial is 14, and the maximum total score for two trials is 28.

Digit Vigilance Test

The Digit Vigilance Test (DVT) was used to measure sustained attention. It consists of single digits ranging from 0-9 arranged in rows and columns in random order. There are total of 30 columns and 50 rows and the numbers were arranged randomly. The participants were required to find and circle number 6 and 9 as fast as they can. They were reminded not to cross other digits and be sure not to miss any of the targetted digit. The time spent to finish the task and frequency of errors done by the participants were recorded.

20m Shuttle Run Test

The 20m shuttle run test is a commonly used test for aerobic fitness . It is a maximal test involving continuous running between 20m apart in time following to recorded 'beeps'. During this test, the participants were instructed to stand behind a start-line facing the second line and began the running once instructed by the audio recording. The speed at the start of level 1 was slow. They started running between the two lines and turning back when signaled by recorded 'beeps', which was considered as one shuttle. After completing a level that lasting approximately one minute, another sound indicates the start of the next level, in which there was an increase in speed and the time between the 'beeps' decreased. This continued for each minute (level). If the line was reached before the beep sounds, they had to wait for the beep sounds before continuing. If the line was not reached before the beep sounds, they were given a first warning to catch up with the pace within two more 'beeps'. The participants were eliminated (stop the test) after the second warning. Data collected was recorded in a form. Results from the test were used to estimate the participants' maximum oxygen uptake (VO_2max) by using the following formula (Cipryan & Gajda, 2011):

$$VO_2max = 3.46 * (L + SN / (L * 0.4325 + 7.0048)) + 12.2$$

L: level completed
SN: shuttle number completed

Statistical Analysis

The data analysis was conducted using the Statistical Package for Social Sciences (SPSS) Version 27.0. The descriptive statistics were used and results were recorded as mean ± standard deviation (SD) for numerical data and frequency (%) for categorical data. Pearson correlation test was used to test the significant correlation between DST and aerobic fitness level (estimated VO_2max value) and between DVT and aerobic fitness level (estimated VO_2max value).

RESULTS & DISCUSSION

Demographic of Participants

The total sample in this study was 38 participants (N = 38), including 22 females and 16 males. The mean age, body weight, body height, and BMI are shown in Table 1.

Table 1: Demographics of the Participants

No.	Demographic	Mean ± SD	Frequency	Percentage
1	**Gender**			
	Male		16	42%
	Female		22	58%
2	**Age (year)**	21.29 ± 0.84	-	-
3	**Weight (kg)**	59.32 ± 14.33	-	-
4	**Height (cm)**	162.41 ± 7.87	-	-
5	**BMI (kg/m^2)**	22.31 ± 4.07	-	-

Aerobic Fitness Level and VO_2max

In this study, aerobic fitness level was measured through the 20m shuttle run test. Data collected from the test was used to calculate participants' estimated VO_2max. Mean estimated VO_2max for male and female participants were 37.19 ± 4.71 ml/kg/min and 27.07 ± 7.45 ml/kg/min, respectively. Percentage of the participants for each aerobic fitness level categories according to gender are shown in Table 2.

Table 2: Aerobic Fitness Category of the Participants

No.	Rating categories	Female n (%)	Male n (%)
1	**Excellent**	0	0
2	**Good**	0	1 (6.3)
3	**Above average**	0	0
4	**Average**	1 (4.5)	3 (18.8)
5	**Below average**	2 (9.1)	3 (18.8)
6	**Poor**	5 (22.7)	6 (37.5)
7	**Very poor**	14 (63.6)	3 (18.8)

Short Term Memory

The mean score for short-term memory of the participants was carried out from the DST was 27.4 ± 1.5. This indicates an excellent short-term memory possessed by the participants. Pearson's correlation reveals a non-significant relationship between short term memory scores and estimated VO_2max ($r = 0.019$; $p = 0.107$) (Figure 1).

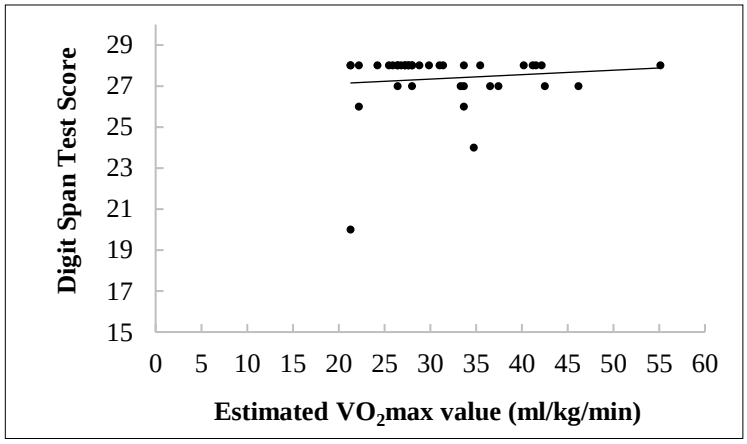

Figure 1: Correlation between digit span test scores (short term memory) and estimated VO_2max

Sustained Attention

The sustained attention was measured from the digit vigilance test where, frequency of errors and time taken to finish the test was recorded. The average frequency of errors is 26.1 ± 4.8, and average time taken to finish the test is 7.9 ± 6.2 minutes.

Pearson's correlation reveals a non-significant relationship between frequency of erors and estimated VO_2max of the participants (r = 0.016; p = 0.305) (Figure 2). There was no significant relationship between time taken to finish the test and estimated VO_2max (r = 0.012; p = 0.305) (Figure 3).

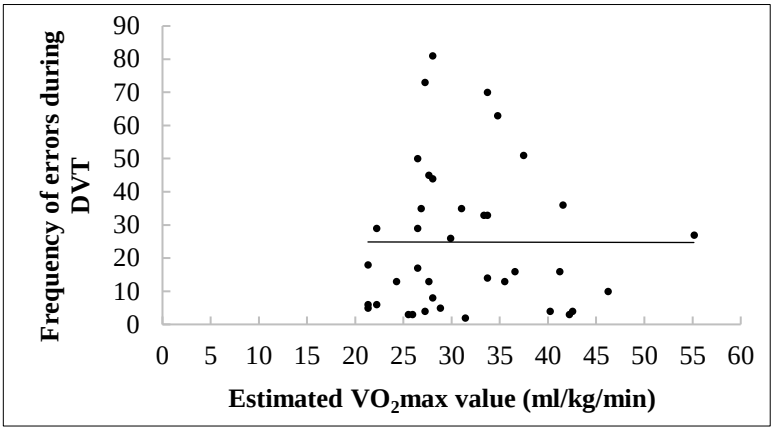

Figure 2: Correlation between frequency of errors and estimated VO_2max

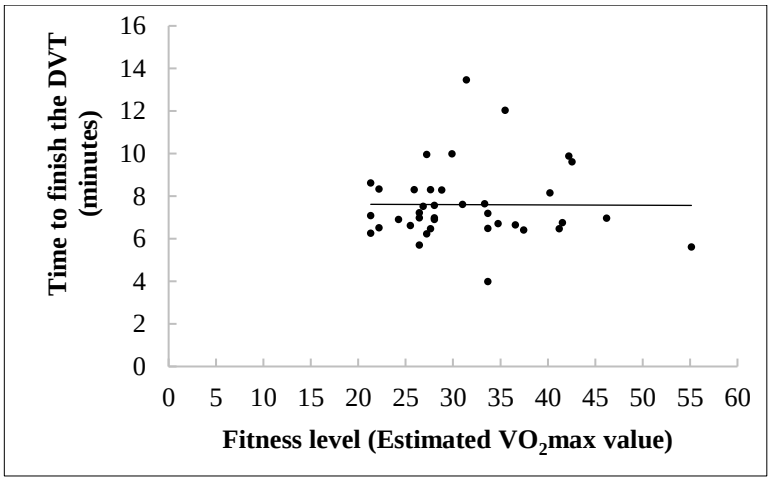

Figure 3: Correlation between time taken to finish the DVT (minutes) and estimated VO_2max

The present study found that short-term memory and sustained attention were not significantly correlated with aerobic fitness levels, as measured by the 20-meter shuttle run test. A possible explanation for the non-significant findings could be the narrow distribution of fitness levels among participants. The results indicated that participants' fitness levels ranged from very poor to poor. It is speculated that if the distribution of aerobic fitness levels had been wider, the correlation might have been more meaningful.

As mentioned earlier, despite numerous studies reported effects of exercise on cognitive function, to date, association between aerobic fitness level and short-term memory as well as sustained attention among university students is lacking. However, a review article reported that higher childhood aerobic fitness is linked to a better cognitive abilities and differences in brain structure and function (Chaddock et al., 2011).

A growing body of multidisciplinary research shows that aerobic exercise benefits brain function and cognitions throughout life (Hillman et al., 2008). For example, one study reported a significant 11.66% reduction in the total time taken for DVT and a 31.90% decrease in error scores following a 21-day integrated yoga module (Sheela et al., 2013). These findings suggest that yoga can enhance sustained attention, potentially improving students' academic performance.

In a separate study, researchers found that 12 months of once-weekly or twice-weekly resistance training benefited the cognitive function (e.g., short-term memory) assessed through DST, among senior women (Liu-Ambrose et al., 2010). In addition, regular exercise could contribute to increased mental health of older adults with cognitive frailty (Yoon et al., 2018). In addition, researchers found that older adults were less likely to develop dementia if they exercised at least 3 times a week, thus proving a positive association between exercise and cognitive function (Larson et al., 2006; Bherer et al., 2013).

There are a few possible meachnisms that can explain positive effects of exercise on cognitive function. As reported by previous study, regular exercise enhances blood flow to the brain through improved circulation where, physical activity increases heart rate thus boosts blood flow to the brain (Thomas et al., 2020). This improved circulation enhances the delivery of oxygen and nutrients necessary for optimal brain function (Liu et al., 2023). Furthermore, exercise also stimulates the production of brain-derived neurotrophic factor and new neurons, particularly in the hippocampus, a region crucial for memory and learning (Liu & Nusslock, 2018).

Previous research has also reported that regular physical exercise enhances neurotransmitter activity through the actions of dopamine, norepinephrine, and serotonin which are associated with cognitive function (Basso & Suzuki, 2017). Additionally, exercise reduces cortisol production, a stress hormone that can negatively impact memory if elevated for prolonged periods (Nys et al., 2022). Moreover, exercise promotes relaxation and reduces anxiety, creating a more conducive mental state for maintaining focus (Sharma et al., 2006; Anderson & Shivakumar, 2013). Another possible mechanism is that regular physical activity improves sleep quality, which is crucial for cognitive functions, including sustained attention. Better sleep enhances the brain’s ability to focus and maintain attention during waking hours.

One of the limitation in this study is this study did not measure biochemical parameters such as dopamine, norepinephrine, serotonin, and cortisol hormone. Measurement of these hormones will provide scientific evidence of their role in enhancing cognitive function following exercise. It is also recommended for future studies to incorporate various exercise protocols (moderate intensity, high intensity, continuous exercise, interval exercise) to examine which is most effective in enhancing cognitive function. In addition, it is recommended to measure actual VO_2max rather than using 20m shuttle run test to determine estimated VO_2max.

CONCLUSIONs

In colclusion, this study found no significant correlation between aerobic fitness level and short-term memory as well as sustained attention. However, further studies are warranted with larger sample size, diverse population, measurement of biochemical parameters, incorporating exercise intervention, and measuring of the actual VO_2max level.

CONTRIBUTION OF AUTHORS

NKF, ASM and GK designed the study; NKF and ASM collected the data; NKF and ASM analysed the data; NKF draft the manuscript; ASM and GK revised the draft of the manuscript; NKF, ASM and GK agree with the final version of the manuscript.

CONFLICT OF INTREST

Authors declare that there is no conflict of intrest involved.

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