THE EFFECT OF SUBMAXIMAL EXERCISE ON THE ATTENTION OF HEALTHY ADULTS

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ABSTRACT

Introduction: Submaximal exercise uses intensity below 85% of the predicted maximum pulse for age. One example of a submaximal exercise is the Three-minutes step test (TMST) which is practical, easy to implement in the subject's routine, and has clear measurement standards. After TMST is done, VO_2max can be calculated which is the main indicator used to determine cardiorespiratory capacity. There have been no studies evaluating the effect of submaximal exercise and VO_2 max on domain attention in healthy adults. **Aim:** This study aims to evaluate the effect of submaximal exercise on the attention of healthy adults. **Method:** Using a controlled before-and-after study, sixty healthy adults, aged 25-40 years, were divided into control and intervention groups (TMST). Attention function was measured with SDMT (Symbol Digit Modalities Test) before and after TMST or 3 minutes rest. **Result:** There was a significant difference in the intervention and control groups (p-values <0.001 and 0.0029). The values of SDMT in the intervention group with the control group were significant with the p-value <0.0001. The effect of the TMST intervention on SDMT was significant, with p-value <0.0001. **Conclusion:** Submaximal exercise can improve attention function in healthy adults.

Keywords: Submaximal Exercise, TMST, Attention, VO_2max, Healthy Adults

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INTRODUCTION

Cognitive function is the main human capital in activities of daily life. This function is divided into five major domains, namely attention, memory, visuospatial, language, and executive functions, which are constantly interconnected. Good cognitive function is vital for maintaining a satisfactory quality of life and also work performance.[1]

Attention is an increase in brain activity in the form of sorting and categorizing received stimuli[1]. Posner et al divide attention into three distinct pathways, namely alerting, orientation, and executive control. The latter pathway assists in the resolution of conflicts and decisions involving attention and mainly involves the anterior cingulate and frontal areas of the brain.[2]

Disorders of attention often occur among many professionals, especially in productive age groups such as early (26-35 years) and late adulthood (36-45 years). Several strategies have been developed to improve the function of attention, one of which is physical exercise, which can improve cognitive function through indirect and direct pathways. The indirect pathway affects systemic and central nervous system inflammation and increases cerebral blood flow. The direct pathway exerts its effect through 2 mechanisms, namely increasing neurotrophic development factors (including BDNF/brain-derived neurotrophic factor) and increasing neurotransmitters (especially norepinephrine and dopamine). Increased BDNF will help neuroplasticity, neurogenesis, and neuroprotection.[3]

Submaximal exercise is a potential intervention that can be implemented for the improvement of cognitive function among professional young adults, as it is performed below 85% of the predicted maximum pulse according to age, and does not cause fatigue[4]. After submaximal exercises, the VO_2max value of individuals can be measured through the use of a simple formula. To date, VO_2 max is the main indicator used to determine cardiorespiratory capacity and function. Traditionally, this is measured by indirect calorimetry, subjects are required to perform a maximal test for causing fatigue and oxygen consumption. This test can be quite expensive and time-consuming. So, submaximal exercise can be an option that is more practical.[4]

Various studies have been developed showing a positive effect of submaximal exercise on improving cognitive function.[3,5] A potential test is the three-minute step test, as it is practical, requires minimal time and equipment, has clear measurement standards, and is hence easily implemented in routine activities[5]. To date, no studies have looked at the effects of TMST on cognitive function despite said qualities. In this study, we aimed to assess the effects of the three-minute step test (TMST) exercise on cognitive domains, is attention domains, of healthy young adult professionals.

METHOD

Study Design and Data Collection

This was a *controlled before-and-after study* conducted between February to April 2022 on healthy adults. The study has been approved by the Human Research Ethics Committee of the Medical Faculty of Hasanuddin University, South Sulawesi, Indonesia (Ethics number 125/UN4.6.4.5.31/PP36/2022, Protocol number UH22020051).

The inclusion criteria in this study were: (1) healthy adult working as professional medical staff, (2) age between 25-40 years, and (3) willing to participate in the study with signed informed consent. Criteria for exclusion include: (1) visual and hearing impairment, (2) diagnosed with any type of dementia, (3) had a comorbid disease, such as hypertension, diabetes mellitus, dyslipidemia, heart disease, (3) leg pain, (4) brain disorder, such as stroke, tumor, trauma, (5) pregnancy, (6) consumed sedative drugs and alcohol, (7) had consumed caffeine in <6 hours before the test, (8) after TMST, maximal pulse >85%. Subjects who withdrew their willingness to participate in this study or failed to complete the entire series of the study procedure were considered dropout subjects.

Subjects were divided into 2 groups, namely the intervention group (TMST) and the control group (3 minutes rest). TMST was performed by asking the subject to move up and down the bench four steps per cycle (right leg up-left foot up-right foot down-left foot down). Within 3 minutes, male subjects had to complete 24 cycles regularly with the metronome set to 96 strokes per minute. Meanwhile, female subjects had to complete 22 cycles regularly with the metronome set to 88 strokes per minute for 3 minutes. Before and after TMST or resting for 3 minutes, physical and neurological examinations were carried out as well as measurements of attention using the Symbol Digit Modalities Test (SDMT).

Smartphone-Based Symbol Digit Span Modality Test (SDMT)

The Symbol Digit Modalities Test (SDMT) is a substitution test that is used specifically to evaluate attention[6]. Within 90 seconds, the subject must be able to match a specific number to the given geometric image. This test was invented by Smith in 1984[7]. The sensitivity and specificity of computerized SDMT were

71% and 84%, respectively, while the sensitivity and specificity of paper SDMT were 67% and 95%, respectively[8].

In this mobile smartphone application, the initial display (Figure 1A) is the homepage with 'Start' to begin the test, 'Instruction' contains an explanation of the test steps, and selecting 'Language: English' will change the language to Indonesian. Figure 1B shows a test display that contains the keys, questions, and the numbers keypad after pushing the 'Start' button. The key contains numbers 1 until 9 with their pair of geometric symbols (randomly assigned to prevent memorization) above each number. Subjects were asked to fill in the blank box in the 'test' with numbers 1 to 9 according to the key. Subjects can empty the boxes that are considered difficult and jump to the next box by pressing the target box. Press 'next' to go to the next test page with the same key. The duration of this test is 90 seconds, questions automatically cannot be refilled when time runs out (Figure 1C) and by pressing 'Show Score', the number of correct answers will be seen (Figure 1D). When 'Back to Home' is selected, the test begins again with randomized symbols to avoid bias (immediate memory).

The assessment of the test is made by the number of correct answers. A decrease of 4 points or 10% or 0.5 standard deviations is considered significant cognitive deterioration. On the other hand, an increase of 4 points or 10% or 0.5 standard deviation is considered an improvement in cognitive function[3].

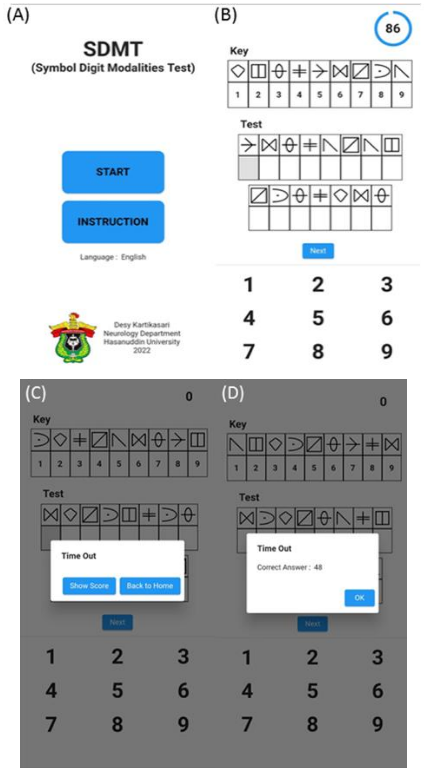

Figure 1. The SDMT mobile smartphone application: (A) Home screen, (B) The test with key above, (C) Time out, (D) Total score.

Measurement of VO_2max

In the intervention group, VO_2max was calculated using the formula for men = 70,597 - 0.246 × (age) + 0.077 × (height) - 0.222 × (weight) - 0.147 × (pulse), or women = 70,597 - 0.185 × (age) + 0.097 × (height) - 0.246 × (weight) - 0.122 × pulse). VO_2max is then compared with the difference between SDMT and BDS.

Data Analysis

All data was analyzed using GraphPad Prism v9. Changes in scores before and after treatment (intervention group) and after rest (control group) on each test were assessed using the Wilcoxon test. Comparison of the Δ_{SDMT} between the intervention and control group was assessed using the Mann-Whitney test. The chi-square analysis was used to assess associations between SDMT with submaximal exercise in intervention group, compared with the control group. In the intervention group, see relationship between the VO_2max value with the SDMT was assessed using the Spearman collaboration. A p-value <0.05 was considered to indicate statistical significance for all tests.

RESULT

Table 1 shows the distribution of subjects based on gender, age, BMI, time, and type of exercise performed in a week. In the intervention group, the number of male subjects was 16 people (53.3%) while the female subjects were 14 people (46.7%). Meanwhile, in the control group, the number of male and female subjects was the same, each 15 people (50%). The mean age in the intervention group was 32.23 years, while in the control group was 32.23 years.

Most of the subjects (70% in the intervention group and 66.7% in the control group) exercised 1 to 150 minutes in 1 week. There were 16.7% in the intervention group and 23.3% in the control group who never exercised at all. There were 13.3% in the intervention group and 10% in the control group who exercised >150 minutes in 1 week. The main mode of exercise in was jogging, performed by 43.4% of subjects in the intervention group and 40% in the control group. In addition, other common exercises include football, badminton, cycling, HIIT, swimming, fitness, table tennis, and yoga.

Table 1. Baseline characteristics of study subjects.

Variable	Intervention Group		Control Group		p value
	n	%	n	%	
Gender					
Male	16	53,3%	15	50%	>0,9999
Female	14	46,7%	15	50%	
Age					
25-29 years	4	13,3%	8	26,6%	
30-34 years	19	63,3%	13	43,3%	0,2185
35-39 years	6	20%	9	30%	
Mean	32,23 ± 2,64		32,23 ± 3,18		
One week exercise					0,9069
0 minutes	5	16,7%	7	23,3%	

Variable	**Intervention Group**		**Control Group**		**p value**
	n	**%**	n	**%**	
1-150 minutes	21	70%	20	66,7%	
>150 minutes	4	13,3%	3	10%	
Type of exercise					
Cycling	1	3,3%	1	3,3%	
HIIT	1	3,3%	1	3,3%	
Badminton	2	6,7%	5	16,7%	
Football	8	26,7%	6	20%	
Jogging	13	43,4%	12	40%	
Swimming	1	3,3%	0	0%	
Fitnes	1	3,3%	0	0%	
Table tennis	1	3,3%	0	0%	
Yoga	0	0%	1	3,3%	
Heart rate					
• Before (mean)	85,43		77,97		
• After (mean)	115,37		77,60		

A significant change in the SDMT score of subjects was observed in both the intervention (p-value < 0.001) and control (p-value < 0.0029) groups can be seen in **Figure 2.** It is apparent that the intervention results in a larger improvement of SDMT scores relative to the control.

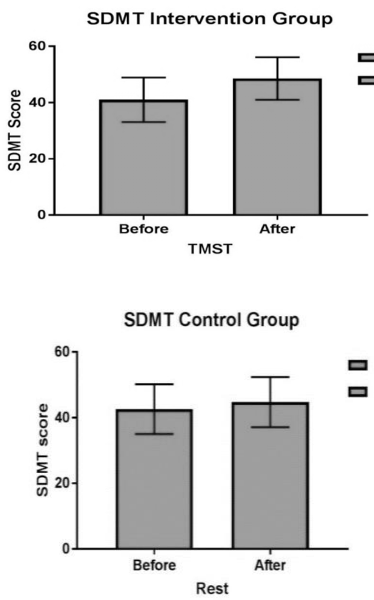

Figure 2. SDMT Score on Intervention and Control Group

The Mann-Whitney test was then used to compare the values of ΔSDMT in the intervention group with the control group, with a result of $p < 0.0001$ for ΔSDMT **(Figure 5)**. Chi-square analysis was also performed to see an effect between attention function with the TMST intervention. The p-value <0.0001 on the SDMT score was obtained. This indicates that there is an influence between attentional function with the TMST intervention.

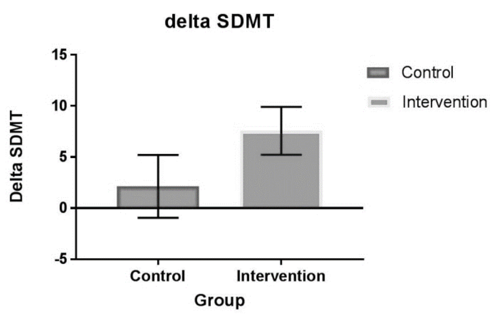

Figure 3. Comparison of ΔSDMT scores between interventional and control groups.

DISCUSSION

Regular exercise, especially aerobic exercise, can increase the efficiency of the aerobic energy production system by increasing maximal oxygen uptake and cardiorespiratory endurance. Physical activity can increase the activity of the prefrontal cortex, namely attention, short-term memory, problem-solving, cognitive flexibility, decision-making, and inhibition control. Acute exercise or just one exercise can increase the activity of the prefrontal cortex (related to cognitive function), improve mood, and reduce stress levels (Basso, J. & Suzuki, W.,2017).

WHO in 2020 recommended doing at least 150-300 minutes of moderate aerobic physical activity or 75-150 minutes of vigorous aerobic activity in 1 week. The subjects of this study were only 7 people (11.7%) who exercised regularly ≥150 minutes in 1 week. This shows that the research subjects are still exercising less than what the body needs.

The data above shows that there are only 10 subjects (16.7%) who have a normal backward digit span at the beginning of the examination. The rest have short-term memory disorders. Therefore, it is necessary to do physical exercise to improve cognitive function. The physical exercise carried out in this study was TMST submaximal exercise.

In this study, there were significant differences in SDMT scores before and after the intervention, with p-values <0.0001. In the control group, there was a significant difference in SDMT scores before and after a 3-minute rest with a p-value of 0.029. However, the p-value in the control group was higher than that in the intervention group.

The significant difference in the SDMT test in the control group was probably caused by the time gap between the pretest and post-test examinations which was too close (3-5 minutes) so that the subject still had an immediate memory of the questions being worked on. In addition, it may also be because the subject has become accustomed to working on the problem so that he is more capable. In the SDMT test application, the final score is immediately displayed. This allows the subject to be motivated to work on the SDMT questions better on the post-test.

Chang, Y, et al. 2014 investigated the effect of acute exercise on cognitive function and found a positive effect, especially on the domains of attention and executive function, on all fitness levels of young adults[9]. While Manadhar et al. in his 2020 study in Nepal on the Effect of the Three Minutes Step Test on Cognitive Function of Medical Students concluded that there was an increase in cognitive function in the domains of attention and executive function as assessed by the Stroop test[5]. This is consistent with this study, which also found an increase in cognitive function, but in a different domain (attention). The increase in cognitive function in this study may be associated with an increase in blood flow which will improve brain health, one of which is cognitive function[3].

Research conducted by Flodin P, et al. in 2017 regarding the effect of VO_2max on cognitive function showed that VO_2max is not related to cognitive function, possibly due to differences in imaging tools with previous studies, differences in study design and analysis with previous studies, and different types of exercise[10]. In our study, the type of exercise that the subjects did in the control and intervention groups also varied.

CONCLUSION

From this study, it can be concluded that there are differences in changes in SDMT scores between the intervention and control groups, and there is an effect of submaximal exercise on increasing SDMT scores in healthy adults. Therefore, TMST (Three Minutes Step Test) can be performed in daily life to improve short-term memory function and attention.

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