Psychomotor Speed in Young Adults with Different Level of Physical Activity

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SUMMARY

Aim. This paper presents the relationship between physical activity and cognitive function in young adults. We set a hypothesis that there might be a relationship between the level of physical activity and psychomotor response on the Trial Making Test (TMT). Physical exercise influences on many aspects of cognitive functioning and has a huge effect on the general mental health. The benefits of exercise are best defined in the field of learning, memorizing of information and executive functions, protection from neurodegenerative changes and onset of depression.

Methods. This investigation included 90 healthy subjects with mean age of 21.2 years, range from 16 to 35 years, divided into three groups according to the level of physical activity: low, moderate and high. Each group consisted of 30 subjects, adjusted by gender, age and level of education. TMT was applied and it assessed visual conceptual abilities and visual motor tracking.

Results. Statistical analysis showed a significant difference of the TMT results between the examined groups. Subjects in the group with a low level of physical activity required a longer time to finish both parts of the test (TMT A=31.98 ± 10.14; TMT B=79.70 ± 22.33) than subjects in the group with a moderate level of physical activity (26.37±9.45; 68.23 ± 22.39). Time necessary for completion of the test in the group with a moderate level of physical activity was longer (25.30 ± 5.12; 60.67 ± 14.24) than in athletes without a statistical significance. Conclusion. The results obtained support the hypothesis that physical activity can have a positive impact on psychomotor abilities in young adults.

Key words: physical activity, cognitive function, Trail Making Test, psychomotor speed, young adults.

1. INTRODUCTION

Many studies about the impact of physical activity on cognitive functions performed on people and animals have documented the positive effect of regular physical activities on cognitive abilities. Physical activity has been defined by the American College of Sports Medicine (ACSM) as motion produced by contracture of skeletal muscle that basically increases energy expenditure (ACSM, 2000). The same institution defines exercise as a sequence of physical activities that are planned, organized and repeated body motions aimed at improving and maintaining one or several components that comprise physical fitness (1).

Physical exercise influences many aspects of cognitive functioning and has a huge effect on general mental health (1,2,3,4,5,6,7). The benefits of exercise are best defined in the sphere of learning and memory, protection from neurodegenerative changes and onset of depression, especially in elder people (8). Investigations about the influence of physical activity on cognitive functions have yielded several theories of the mechanisms that explain this relationship. One of the possible explanations is the increased cerebral blood flow during physical activity. By using modern diagnostic equipment it has been verified that moderate and high-intensity physical activity produces a substantial increase of cerebral blood flow (9). The increased blood flow leads to better supply with indispensable nutrients. Another mechanism that adds to the explanation about the effect of physical activity on brain function is stimulation of neurotransmitter secretion in the brain. Investigations have shown that there is an increased level of norepinephrine and its precursors, norepinephrine and serotonin (5, 6, 7). Additional physiological explanation of the positive impact of exercise on certain brain functions is that it gives permanent structural changes in the brain.

Experimental mice studies have proven that mice subjected to increased physical activity had higher vascularization of cerebral cortex and smaller vascular diffusion distance in comparison with mice that did not have physical exercise. Results obtained in animal studies have demonstrated that physical activity, such as voluntary running on a running wheel, improved brain functions owing to the increased production of BDNF (brain-derived neurotrophic factor). Elevated plasma BDNF concentration has also been registered in young adults after a five-week program of intensive cycling training (endurance) and mainly of the moderate-intensity activity (6).

In general, investigations conducted on humans support the hypothesis that physical activity has a positive effect on the cognition process. The extensive and systematic meta-analyses about the effect of physical activity on cognition (11, 12) have shown that there is a larger number of studies conducted in the elderly. This population is of bigger interest for the researchers because of the reduced cognitive abilities with aging and evident changes in the cognitive status. Several investigations have suggested that aerobic exercises have greater effect on more demanding cognitive tasks than on simple automatic processes in older people (9, 13, 14).

Kramer et al. stated that aerobic fitness in older adults can be connected with selective improvement of execu-
Meditative functions, such as coordination, planning, and working memory. Another study that used the technique of neuro-painting showed that older adults who practiced aerobic exercises had a higher activity in those segments of the brain that are responsible for executive functions (15).

There is considerably a smaller number of studies about the effect of physical activity on cognitive functions in young adults. We have analyzed results of TMT (Trail Making Test) in young adult subjects with different levels of physical activity. Our aim was to examine whether chronic physical exercise activity is associated with better neurocognitive performance in young adults. We investigated cross-sectional relationships between performance in Trail Making Test in young healthy population in Skopje, the capital city of the Republic of Macedonia.

2. METHODS AND MATERIALS

2.1. SUBJECTS

This investigation included 90 subjects, healthy young adults, divided into three groups according to the level of physical activity. Each group consisted of 30 subjects, adjusted by gender, age and level of education. The examined sample consisted of 42 men and 47 women, mean age of 21.2 years, range from 16 to 35 years. The sample was constituted by healthy adults recruited as volunteers from undergraduate university classes and university staff, mostly from the Medical Faculty from the city of Skopje (R. Macedonia). The subjects with a high level of physical activity were recruited as volunteers from the Laboratory of Functional Diagnostics at the Institute of Physiology where athletes have their regular semi-annual controls. A self-reported history of medical and psychiatric problems was obtained from each participant. Any data of neurological or psychiatric disease, substance abuse or learning disabilities were exclusion criteria in this sample. The testing was done in the Laboratory of Neurophysiology at the Institute of Physiology in Skopje.

2.2. PROCEDURE

After completing the questionnaire on the amount of physical activity practiced during one typical week over the past year, the participants were divided into three groups. Group of participants with a high level of physical activity (with ≥4 trainings weekly and participation in competition activities) was the group of athletes. The second group consisted of participants with 1-3 trainings per week or with a moderate level of physical activity, and this was the group involved in leisure-time activities. The third group involved participants with a low level of physical activity, that is, subjects who have sedentary lifestyle. For assessment of the level of physical activity Baek’s questionnaire was used, which provides information on the total bodily activity during one typical day or week (16). This questionnaire has been used in the EUROFIT projects for assessment of the physical activity of subjects over the past year. It consists of 16 questions related to physical activity during working hours (8 questions) and during leisure time (4 questions). A choice of 5 answers is offered for each question and scores from 1 to 5 are given. Activities were assessed by the criteria frequency, training duration and intensity (energy expenditure – MET/metabolic equivalent). According to the obtained information from the self-reported questionnaire, the participants were divided into three groups: a control group or a group of sedentary individuals, that is, with a low level of PA; a group of individuals that participate in recreational activities or participants with a moderate level of PA; a group of athletes or participants with a high level of PA.

2.3. COGNITIVE ASSESSMENT

Trail Making Test (TMT) is used for assessment of cognitive functioning. This test assesses the visual conceptual and visuo-motor memory. Originally this test was part of the Army Individual Test Battery (1944) and later it was incorporated in the Halstead-Reitan Battery of neuropsychological tests (17). The test evaluates information on speed of processing, visual scanning ability, integration of visual and motor functions, letter and number recognition and sequencing, and the ability to maintain two different trains of thought. Scoring is simply the time to complete each part. Errors naturally increase the total time. For adults, scores above 40 seconds for Part A and 91 seconds for Part B have traditionally indicated brain impairment. Current research discourages the use of such traditional cut-offs, preferring ranges depending on age, education, and gender. For example, one study reported that for ages 15 to 19, the average time to complete Part A was 25.7 seconds and the time to complete Part B was 49.8 seconds. For ages 80 to 85, however, the average time to complete Part A was 60.7 seconds and the time to complete Part B was 152.2 seconds. This demonstrates the importance of considering other variables when scoring. TMT provides information on visual search, scanning, information processing speed, mental flexibility and executive functions (18). The test consists of two parts, Part A and Part B. TMT Part A is the simpler part of the test. It requires from the participant to draw lines as quickly as possible to connect the numbers from 1 to 25 in ascending pattern that are encircled and distributed without order on a sheet of paper. This cognitive engagement asks for visual scanning, identification, number recognition, number sequencing, and motor speed. TMT Part B is much more complex than the first part. In this part, the participant has to draw lines to connect the numbers and letters in alternating pattern by connecting the first number with the first letter (from the alphabet), continuing to connect pairs number-letter until the last number 13 (for e.g. 1, A, 2, B, 3, C, etc.). This part of the test has also 25 circles that have to be connected, but in addition to activating mental processes, executive functions, the duration of the test measured as a sum of the lengths of lines that connect all circles is longer than the summed line in TMT Part A. In Part B, the participant has to present mental flexibility in order to accomplish two types of stimuli, numbers and letters. The score on each part represents the amount of time required to complete the task. In spite of the popularity of the TMT, few comprehensive sets of norms exist. Research clearly revealed that age, education and intelligence affected TMT performance.

The test has been adapted for Macedonian Cyrillic alphabet, which order slightly differs from the Bosnian/Croatian/Serbian alphabet. The testing was done in line with the ethical standards recommended in the Declaration of Helsinki.

2.4. STATISTICAL ANALYSIS

Statistical analysis of data was done with the Statistica 7.0 statistical program. Data obtained were analyzed.
as mean values and standard deviation, minimal and maximal value of analyzed parameters (descriptive statistics). Depending on the data distribution, significance of difference in analyzed parameters was tested with Kruskal-Wallis test (H) and Wilcoxon’s matched pairs test (Z). Correlation between age and education and analyzed parameters was done with Pearson’s test of correlation (r).

3. RESULTS

Descriptive statistics of the entire examined sample is given in Table 1, categorized by groups of participants with different level of PA: low, moderate and high. Table 1 presents the basic demographic data: age, years of education and gender. The examined groups did not differ between themselves concerning these demographic features.

Difference in the results obtained on both parts of TMT (A and B) between men and women was statistically insignificant in all of the three tested groups. For Z=-0.73 and p>0.05 (p=0.47) between men (31.00±10.21 sec.) and women (32.81±10.33 sec.), there was no significant difference in the simple (TMTA) memory. For Z=-1.22 and p>0.05 (p=0.23) between men (74.43±19.11 sec.) and women (84.31±24.46 sec.), there was no significant difference in the complex (TMTB) memory.

Correlation between age and years of education in all of the three groups was very weak and insignificant. The group with a low PA showed a very weak positive correlation between the results of TMT and age of the participants (r=0.17 for p<0.05) as well as years of education (r=0.16; p<0.05). In both groups who were physically active (a moderate and high level of PA) a weak negative correlation between the results of the test and these demographic variables were obtained: rm=-0.05; rh=-0.01 for years of education, but with no statistical significance (p>0.05). [ rm = pearson’s coefficient for group with moderate level of PA; rh = pearson’s coefficient for group with high level of PA]

Descriptive statistics for TMT variables: TMT A, TMT B, TMT total score for all of the examined groups is presented in Table 2. Testing of the significance of difference of the results on TMT (A and B) between the examined groups was done with the Kruskal-Wallis test. For TMT A variable, there was a significant difference between sedentary, recreational individuals and athletes for H = 11.68 and p < 0.01. For TMT – B variable H = 15.29 and p < 0.001 (p = 0.0005), there was also a significant difference between sedentary, recreational individuals and athletes. The results of the statistical analysis of significance of difference for the obtained TMT variables between the examined groups done with the Wilcoxon’s test are shown in Table 3.

4. DISCUSSION

The major clinical utility of the current study is that it provides a set of data for neuropsychological indices in young healthy people in the Republic of Macedonia regarding their level of physical activity. The aim of this investigation was to examine the possible relationship between psychomotor speed expressed by the TMT results and level of PA in young healthy adults. Numerous observational studies have shown that physical exercise has a positive impact on cognitive abilities. In comparison to numerous studies that have examined the benefit of physical activity on cognitive functioning in older population (over 60 years of age), there is considerably a smaller number of studies conducted in children, adolescents and young adults. Examination of the relationship between PA and cognition in younger age (the first third of lifespan) is of a delicate nature due to the influence of a great number of external factors that affect the development of cognitive abilities in this period of life (11, 12, 13).

Evidence from many studies has indicated that TMT test assesses the quality of the attention process, including visual search, visual spatial sequencing and psychomotor speed. Thus, TMT assesses several cognitive processes and some of them are included in both of its parts: spatial organization, graphomotor speed, number recognition, visual pursuit, vigilance and number sequencing (19). Part A assesses the simple attention or the so-called rote memory. Part B is connected with the process of differentiation between numbers and letters, integration (connection) of two independent series, ability to learn the principle of organization and systematic application of serial retention and integration. TMT is dependent on many factors. Intelligence, level of education and age might influence on the TMT results. Motor delay, coordination disorders,
visual scanning impairment, bad motivation or conceptual confusion might have negative effect on the test results (19). Normative values stratified by age groups and years of education have shown that age has a higher effect on the test results than education. With increasing age the time for completion of the test is increased (the result is becoming worse) while the level of education has an insignificant positive influence on successful test completion (19). The latest studies on healthy subjects have detected that age accounted for 31% and 35% of the variance for Part A and Part B while education accounted for only 3% and 7%, respectively. Gender accounted for less than 1%. Similar results were obtained by Heaton et al. (2004) presenting that age accounted for 25% on both TMT parts. Majority of the results have shown that gender has no influence on the TMT results (20).

Our results have shown that relationship between age and years of education in all of the three examined groups are very weak and insignificant. The examined sample in this study comprised a wide age range, that is, young adults who were in their physically mature period of cognitive development and who were from 16 to 35 years old. Inside the three groups, participants of approximately the same age predominated, that is, 60-65% of them were students (19-23 years old) and the mean age was 21.2 years. Since the groups were very homogenous in relation to age and level of education, we did not expect any correlation between the test results and these parameters. Consequently, the group with a low PA has presented with a very weak positive correlation between both parts of the test and age of the participants while both groups that were physically active (moderate and high level of PA) have presented with a weak negative correlation between the test results and these demographic variables, but without any statistical significance (p<0.05).

Regarding gender of the participants, it was demonstrated that there was no statistically significant difference between the results on TMT A and TMT B in men and women in all of the three groups.

Normative values of the test results are stratified by age and level of education. According to Strauss (17) the average time necessary to complete part A of TMT is 26.52 (±11.66), and part B 72.05 (±45.22). According to Lezak, the average time necessary to complete TMT A for the age 18-24 years is 22.93 (±6.87), for TMT B 48.97 (±12.69). For the age group of 25-34 years, the average time for TMT A is 24.4±8.71 and for TMT B is 50.68±12.66 sec. These results are valid for the population of the English speaking world. Investigations have proved that cultural variables have effect on performance of this and many other cognitive tests. Comparison of data about normative values for TMT from eleven different countries has shown that there is a substantial difference among the obtained norms, which implies the cultural influence on the results of this test (21).

Our analysis of TMT A has revealed a significant difference of the results between sedentary individuals, those involved in recreational activities and athletes. Sedentary participants have spent longer time to finish the test in comparison with participants involved in leisure-time activities and athletes. Participants involved in recreational activities needed a bit longer time to complete the test than athletes but the difference was not significant. Analysis of TMT B, which is much more complex in its cognitive demanding has also shown a significant difference in the results between the three examined groups. Time necessary to complete the test was much longer for the sedentary participants compared to the participants involved in leisure-time activities (p=0.02) and athletes (p=0.0001). However, although participants in the group with a high level of PA (athletes) finished the test more quickly than their peers involved in a moderate-intensity physical activity, this difference was statistically not significant.

Our analysis of TMT has shown that participants included in sport activities, either recreationally or competitively, have better cognitive performance than sedentary individuals. Capabilities of spatial orientation during this paper-and-pencil test, psychomotor speed, and cognitive flexibility have been expressed to a higher degree in physically active participants than in physically inactive. Participants in the group with a high level of PA who are members of sport teams, that is, competitors, have shown better results in both parts of the test than their peers who practice sport only on recreational basis, but this difference was not statistically significant. These results are in agreement with the earlier studies that revealed no difference in cognitive performance between subjects involved in a moderate-intensity physical activity and those with a high-intensity activity, especially when speaking about the chronic effect (22). Examinations of cognitive abilities after acute training of different intensity have displayed a poorer cognitive performance in subjects who had a more intensive physical training than those who had a moderate physical strain (23).

Several shortcomings are evident in this study. First of all, this is a cross-sectional study and therefore improvement in cognitive performance that is ascribed to (different amount of) physical activity might be provoked by some other factors that were not taken into consideration. Adjusted age, gender, and level of education decrease the influence of these factors, however, they do not eliminate the influence of some other factors that might have effect on cognitive functions of the participants. The other drawback might be determination of the physical activity in an indirect manner, with a questionnaire and not directly with objective parameters (for e.g. pedometer, accelerometer, VO₂ expenditure). However, the advantage of this investigation is that it comprised participants of adolescent and young adult age, who are rarely included in this kind of studies. To summarize, the major value of the present study is providing new data of the effect of physical activity on cognitive functioning, particularly on the psychomotor speed in young healthy population. Additionally, the results obtained provide information about the Macedonian population for whom there are no normative values for TMT in the young adults.

5. CONCLUSION

Subjects who have a long-term physical activity of a moderate and high intensity have successfully completed the test in a significantly shorter time than sedentary individuals. This test required simple and complex attention, meaning visuomotor agility and mental flexibility. Our results suggest that regular physical activity could have a positive impact on cognitive processes.
psychomotor speed in young adults with different levels of physical activity during the adolescence period and in the first years of adult age. The results obtained point out that psychomotor performance is better in subjects who practice physical activity than in those who have a sedentary lifestyle. Investigations of this kind might stimulate young people to have regular physical activity for the benefit on the physical, psychic and mental health in this period of life and later.

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