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CLINICAL STUDY

Exercise is good also for a healthy hippocampus

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ABSTRACT

OBJECTIVES: The aim of the study was to compare the hippocampus sizes of healthy medical faculty students, who were exposed to an intense data input and who underwent serious learning activity and those of healthy sport faculty students who did sports regularly by using MR images and to examine the relationship between a hippocampus size and intelligence.

METHODS: We made the study with 58 healthy young males (27 sport sciences faculty students and 31 medical faculty students). R. B. Cattell 3A Culture Fair Intelligence Test was administered to the volunteers. Following this, we got MR images of our volunteers.

RESULTS: We could not find a statistically significant difference between medical faculty students and sport sciences faculty students in terms of hippocampus volumes. We could not find a correlation between IQ values and hippocampus volumes. Also, we could not find a significant difference between a right and left hippocampus.

CONCLUSION: While doing sport, blood flow increases in the hippocampus, as in all areas of the body. This increased blood flow creates a stimulating effect on neurogenesis. Neurons, which develop as the result of neurogenesis, mean an increase in volume *(Tab. 4, Ref. 54)*. Text in PDF *www.elis.sk.*

KEY WORDS: hippocampus volume, exercise, intelligence, male, healthy.

Introduction

Humans, who are in a perpetual interaction with their environment in order to continue their life need to develop reactions suitable for the outside impacts. They are exposed to and develop solutions suitable for the problems they encounter. They need to be able to adapt to the environment they live in. Learning is the permanent change that occurs in behaviors as the result of experiences gained through the life cycle (1). Learning is neurophysiologically defined as the formation of new synaptic connections in the nervous system as the result of newly encountered experience (2). What we learn has to be coded and stored suitably and be taken out of the store when necessary, so that it can be useful for us. Memory enables this. Learning and memory are very important abilities for us.

The area called hippocampus, which is in our brain, is an important center in terms of memory and learning, (3) because it was found that individuals with damaged hippocampus cannot learn new information and cannot remember what they learned before the damage (4). Hippocampus is located in the medial part of the temporal lobe and it is a part of the limbic system, which is on the base of cornu temporale of lateral ventricle (5).

In hippocampus, functions about learning and memory take place through neurogenesis. Until recently, it was thought that the adult human body did not include neurogenesis and continued the life with the presence of neurons in prenatal period. However, at the moment, we know that neurogenesis continues for a lifetime in subgranular area of gyrus dentatus at the hippocampus (6).

Creation of new neurons through neurogenesis and the integration of these new neurons to neural circuits form the basis of learning activity. Creation of new neurons and thus new neural connections means an increase in volume. Under normal circumstances, the size of a brain area is the indicator of that area's processing capacity (7). This means that there are more neurons inside, more connections between neurons and more interaction between them.

There is a great number of studies in literature comparing the sizes of many neurologic structures with different body compositions, diseases or situations. There is a great number of studies, in which hippocampus size is examined. There are studies comparing hippocampus with stress (8), depression (9), steroid use (10), exercise (11), alcoholism (12), sex hormones (13), borderline personality disorder (14), Alzheimer (15), head trauma (16) and intelligence (17). When these studies are examined, we can see that factors such as: stress, alcohol, gender hormones, age and head trauma have an influence on hippocampus size.

In this study, our purpose is to compare the hippocampus sizes of medical faculty students, who have been exposed to an intense data input and who are in a serious learning activity and those of healthy sport faculty students who do sport regularly by using MRI

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images and to examine the relationship between hippocampus size and intelligence by examining the IQ values of both groups.

Materials and methods

Participants

For our study, 2016/115 numbered ethical board approval was taken from Malatya Clinical Researches Ethical Board Directorate. 84 (38 sport sciences faculty students and 46 medical faculty students) male volunteers, who did not smoke and did not use alcohol, drugs and steroid, who did not have psychological diseases and posttraumatic stress disorder, who did not have any seizures in childhood and later, who did not have any head trauma, who did not undergo any surgical intervention and who were using their right hands were determined. The volunteers were informed about the study and they read and signed the informed consent form. We choose our volunteers from individuals, who were away from all of the factors argued to have an influence on hippocampus size in literature. We did not include women in the study since hippocampus size differs even between the phases of menstrual cycle (13). We aimed to form a sterile study group by choosing healthy male individuals all of whom were using their right hands. Our purpose was to compare the effects of only information load and exercise on hippocampus size. We eliminated all the other factors as much as possible.

First of all, we found and recorded the ages, heights, weights and body mass indices (BMI) of our volunteers. Later, we assessed whether our volunteers were psychologically well-being state with Posttraumatic Stress Disorder Checklist. Following this checklist, which was assessed by our psychologist friend in the study team, we excluded 14 (13 medical faculty students and 4 sport sciences faculty students) students from the study.

IQ Test

Next, R. B. Cattel 3A Culture Fair Intelligence Test was administered to the volunteers. We recorded the results of this intelligence-performance test, which can easily be applied on all societies independent of culture.

Neuroimaging

Following this, we got MR images of our volunteers. Neuroimaging was performed using a 3T Siemens Skyra syngo MR E11 version, Germany. Structural images were acquired using T1-weighted 3D (MPRAGE) sequence in sagittal plane, using these parameter: TE/TR = 2300 ms/2.32s, flip angle = 8°, FOV = 240 mm^2 and slice thickness = 0.9 mm. At this stage, 9 (7 sport sciences faculty students and 2 medical faculty students) students left the study by stating that they did not want to get inside the MR device. In the end, we got the images of 58 volunteers, 27 sport sciences faculty students and 31 medical faculty students. We downloaded MR T1 data from the scanner, transferred and processed using different software. We saved MR images as hdr and img formats. For this purpose, we used a personal computer on a 32-bit Dell PC, running Windows 10 operating system. We used mricloud to calculate the volume (www.mricloud.org). Web-based module, which did not require any installation, configuration or training was used. The mricloud volumetric analysis system works remotely through a web interface and automatically provides a report containing volumetric information from any submitted case.

Data analysis

IBM SPSS Statistics 22.0 program was used for the statistical analysis of our results. Shapiro–Wilk test was conducted to test the normality distribution of our data. Median and minimum and maximum values of the data, which were not normally distributed were used. Spearman's Rho correlation analysis was used for the correlation analysis. $p < 0.05$ value was considered statistically significant.

Results

The median age of the medical faculty students in the study was 22 (19–24), while their median height was 177 (165–197) cm., their median weight was 75 (63–103) kg., and their median body mass index was 24,28 (17,43–30,09) kg/m^2. The median age of the sport sciences faculty students in the study was 21 (19–27), while their median height was 178 (172–187) cm., their median weight was 72 (52–90) kg., and their median body mass index was 22,26 (18,82–28,4) kg/m^2 (Tab. 1).

The median IQ value of the medical faculty students in the study was 133 (84–162), while their median right hippocampus volume was 3931 (3493–4474) mm^3 and their median left hippocampus volume was 3940 (3363–4465) mm^3. Median IQ value of the sport sciences faculty students in the study was 96 (68–143), while their median right hippocampus volume was 3975 (3332–5066) mm^3, and their median left hippocampus volume was 3866 (3324–4902) mm^3. We could not find a statistically significant difference between medical faculty students and sport sciences faculty students in terms of hippocampus volumes. We found a statistically significant difference between the IQ values of medical faculty students and those of the sport sciences faculty students (Tab. 2).

As the result of our study, we could not find a correlation between IQ values and right and left hippocampus volumes of medical faculty students and sport sciences faculty students within each group (Tab. 3).

Tab. 1. The values as median (min – max) of some parameters of volunteers.

Groups	Age	Length (cm)	Weight (kg)	BMI (kg/m^2)
SFs	21 (19–27)	178 (172–187)	72 (52–90)	22,26 (18,82–28,4)
MFs	22 (19–24)	177 (165–197)	75 (63–103)	24,28 (17,43–30,09)

SFs: Sport Sciences Faculty Students, MFs: Medical Faculty Students

Tab. 2. Right and left hippocampus volumes of sport sciences faculty students and medical faculty students.

Groups	IQ	Right hippocampus volume (mm^3)	Left hippocampus volume (mm^3)
SFs	96 (68–143)	3975 (3332–5066)	3866 (3324–4902)
MFs	133 (84–162)	3931 (3493–4474)	3940 (3363–4465)
p	,000	,911	,678

SFs: Sport Sciences Faculty Students, MFs: Medical Faculty Students

Tab. 3. The correlation of IQ with hippocampus volume in medical faculty students and sport sciences faculty students.

	Groups	Spearman's rho	Right hippocampus	Left hippocampus
IQ	SFs	r	,033	,106
		p	,896	,598
	MFs	r	–,132	–,080
		p	,488	,675

SFs: Sport Sciences Faculty Students, MFs: Medical Faculty Students

Tab. 4. Results of Mann-Whitney U test to compare left and right hippocampus volumes of volunteers.

Groups	Right hippocampus volume (mm^3)	Left hippocampus volume (mm^3)	p
SFs	3975 (3332–5066)	3866 (3324–4902)	,562
MFs	3931 (3493–4474)	3940 (3363–4465)	,838

SFs: Sport Sciences Faculty Students, MFs: Medical Faculty Students

In our study, we could not find a statistically significant difference between the right and left hippocampus of our volunteers (Tab. 4).

Discussion

Medical faculty students, who participated in our study, were students with a high academic achievement, who were in the first 1% in university exams; however, none of them were doing sport regularly and all of them had a sedentary lifestyle. These students are in a continuous learning activity and exam cycle as required by the existing education system in our country. These students, who were exposed to a serious amount of information loading until they got a place at university found themselves within disciplines they had never experienced before such as: anatomy, biochemistry, physiology and pathology, all of which have a terminology of their own. They learned a lot of new information by studying and repeating all the time and they completed their exams successfully by storing all these information in their minds and recalling what they stored from their memory both in theoretical and in practical exams. We started our study with the thought "the size of a brain is the indicator of its processing capacity" that we stated at the beginning and the thought that medical faculty students have big hippocampus since they are in a serious learning activity and neurogenesis takes place at the hippocampus.

Sport sciences faculty students were, on the other hand, students, who had low exam concentration and lesson participation rates. Their acceptance to university took part through special ability exams, in which their physical capacities are assessed. All of these students were doing sport regularly. When their hippocampi were compared with medical faculty students, who conduct more learning activities, we could not find a difference. This was the result that we did not predict at all at the beginning the study. This could have occurred due to two reasons;

1) While doing sport, blood flow increases in the hippocampus, as in all areas of the body (18, 19). It has been shown that blood flow also increases to the area, where neurogenesis takes place (20). This increased blood flow creates a stimulating effect on neurogenesis. Neurons, which develop as the result of neurogenesis, mean an increase in volume. A great number of animal studies conducted reported a positive effect of exercise on hippocampal neurogenesis. In many studies conducted on old-age (11, 21) and pediatric age group (22), exercise has been shown to cause an increase in hippocampal volume and to have a positive effect on cognitive functions. However, there aren't too many studies conducted on the age group we assessed in our study.
2) Students of the faculty of sport sciences consisted of individuals, who were doing sport regularly. Despite the mental abilities of medical faculty students such as: continuous reading, data input and repetition, we believe that as the result of doing sport regularly, sport sciences faculty students' efforts to get the most suitable position during sportive activities, their quick assessment of previous experiences and information against moves from opponents by recalling these experiences and information from the memory and their states of being alert all the time increased intercellular connections and relations in the hippocampus and their processing capacity. Athletes, who have to compete with different opponents and different tactics in each competition are continually exposed to an intense mental and cognitive activity during the game period. We believe that with the results of our study, we contributed to views, which put forward the positive effect of regular sportive activities in humans on the volume of hippocampus, which is the center for learning and memory.

Two types of intelligences are mentioned in literature. Fluid intelligence and crystallized intelligence (23, 24). Crystallized intelligence is an intelligence type directly proportional to human beings' level of knowledge and vocabulary and it remains stable and can even be increased as the age increases. Fluid intelligence is a type of intelligence, which depends on the ability of abstract thinking not based on knowledge and finding a quick solution to a problem encountered and it decreases as the age increases (25). In our study, we measured fluid intelligence because it does not depend on the knowledge and we used R B Cattell 3A Culture Fair intelligence test for this measurement. In this study, we could not find a correlation between IQ values and hippocampus sizes, both when the volunteers were assessed as a whole and when the students of medical faculty and sport sciences faculty were assessed separately within their own groups. Studies conducted about intelligence and hippocampus size reported a correlation between hippocampal atrophy and low intelligence scores especially in old population. However, such a correlation has not been reported in young population (26, 27, 28). Some studies conducted in a young population reported a negative correlation between the hippocampus size and memory functions (29, 30). Similarly, in a study conducted on healthy young adults (17), a negative correlation was found between the hippocampus size and intelligence. When literature is reviewed, it can be seen that there are very different results about the association between hippocampus size and intelligence. One of the possible reasons of this is the fact that intelligence is not associated with only one area of the brain. Intelligence is a process, which functions through networks built between different parts of the brain (31, 32). Some studies have associated intelligence with medial and lateral prefrontal cortex (33, 34). Song et al (35) associated the intelligence scores they found in their study with frontal, parietal, occipital and limbic area. In their study, Heuvel et al. (36) found that frontal and parietal lobes were strongly correlated with intelligence. There are also studies, which state that mesolimbic structures, which include hippocampus, are associated with intelligence (37, 38). It has even been reported that the differences in the rates of gray matter and white matter in the related brain area cause a change in intelligence levels (31, 39). Thus, comparing intelligence with a single neurological structure such as hippocampus size does not seem to be very significant in line with the results of other studies in literature and the results of our study.

One of the results of our study was the statistically significant higher IQ levels of medical faculty students, when compared to sport sciences faculty students. This result is also an indicator that intelligence alone is not associated with hippocampus size. Is it possible to interpret the difference between the IQ values of these two groups where hippocampus sizes was not different otherwise since their fluid intelligence, which does not depend on their knowledge was measured? The possible answer that we can give to this question can be that sport sciences faculty students' are not adapting to the intelligence test that we applied. Before the test was administered, these students answered our question "have you ever taken an intelligence test before" as "no". Thus, we think that they could not fully concentrate on such a test that they have never experienced before for a specific period of time and that they got bored. The result that they got higher scores in the first two parts and very low scores in the last part of the test consisting of four parts supports this view. Probably in the last part of the test they lost their concentration by waiting for the time to end. However, a great number of medical faculty students had taken an intelligence test before and they had a high awareness and concentration about intelligence tests. We think that they got high scores for this reason.

Hippocampus is in both hemispheres of our brain, the right and the left. The right hippocampus is related with visual memory, while the left hippocampus is related with verbal memory (40). There are studies mentioning asymmetry in some structures in both hemispheres of our brain (41). Similarly, an asymmetry of right>left has been addressed between the right and left hippocampus (42, 43, 44). Presence or absence of asymmetry in neurological structures can be associated with some pathological situations. Studies have been conducted to find out whether there is hippocampal asymmetry in many situations such as: schizophrenia (45), posttraumatic stress disorder (46), Alzheimer (47), depression (48) and psychopathy (49) and the resulting asymmetry findings have been used as an auxiliary method in the diagnosis of the disease. In children and newborns, the right hippocampus is bigger than the left (50). Hippocampal asymmetry increases with age (51). What is the situation in healthy population, when asymmetry is mentioned in pathological situations? In a metaanalysis (42), which reviewed 82 studies (n=3564) conducted between 1990 and 2002, it has been found that the right hippocampus is bigger than the left hippocampus in healthy adults. However, the lower age limit in this study is 18, there are 2258 individuals older than 31 and there is no information about the age distribution of individuals older than 31. Our study was conducted on healthy young individuals in their 20s and we did not find a statistically significant difference between right and left hippocampus sizes. Although limited in number, there are studies in literature, which have not found hippocampal asymmetry (52, 53, 54).

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