# AN ANALYSIS OF THE LEVEL OF FITNESS, PHYSICAL PERFORMANCE AND CONCENTRATION OF THE BRAIN-DERIVED NEUROTROPHIC FACTOR IN SALIVA IN ADOLESCENTS PRACTICING COMPETITIVE SPORTS AND THEIR PEERS

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***Abstract***

The purpose of the study was to compare BDNF in saliva before and after a maximum physical effort in adolescents practicing sports and their non-training peers, related to the body composition and physical fitness. The study comprised 64 individuals aged 13-14 (39 practicing sports). Physical fitness was measured using the EUROFIT test. The maximum oxygen uptake was determined on a mechanical treadmill. Saliva BDNF concentration was measured (R&D, USA) at rest and after an exercise. The research results prove that body composition was different depending on the sex, the EUROFIT results were not. The percentage of body fat correlated negatively with the strength of the lower body and the strength of the trunk muscles. There was a positive relationship between the muscle mass and the cardiorespiratory fitness, regardless of the level of training. BDNF in saliva was comparable in non-training and training individuals.
BDNF was significantly dependent on the body composition only in girls and negatively correlated with the content of adipose tissue. Training and non-training teenagers did not differ in fitness, but in the level of cardiorespiratory fitness. Non-training teenagers showed a higher concentration of BDNF in saliva and further increase after the exercise stress test. In the training individuals, the exercise stress test did not lead to an increase in BDNF concentration.

***Keywords***: *brain-derived neurotrophic factor; physical fitness.*

## Introduction

The aim of this work is to investigate whether the BDNF (brain-derived neurotrophic factor) concentration measured in saliva differs between teenagers practicing sports regularly and their peers who do not practice sports, as well as whether one-time maximum physical effort causes a change in its concentration. Reports that BDFN levels are significantly higher in well-trained youth and that these levels may depend on body composition (Pareja-Galeano, Brioche, Sanchis-Gomar, Montal, Jovaní, Martínez-Costa et al., 2013) were the starting point for this study. Bioimpedance is one of the possible methods of assessing body composition. Maintaining the methodological assumptions of its implementation, this method (Tarnoki , Tarnoki, Medda, Cotichini, Stazi, Fagnani et al., 2014) is simple and reliable.

Serum BDNF was reported to become increased after physical exercise, but the saliva level reports were contradictory: on the one hand increases of saliva BDNF were described after physical exercise, on the other - a decrease due possibly to uptake by the central nervous system was found. (Babaei, Damirchi, Soltani Tehrani, Nazari , Sariri, Hoseini, 2016; Marquez, Vanaudenaerde, Troosters, Wenderoth, 2015), especially aerobic boost (Babaei, Damirchi, Mehdipoor, Tehrani, 2014; Erickson, Voss, Prakash, Basak, Szabo, Chaddock et al., 2011; Lee, Yoo, Kang, Woo , Shin, Kim et al. 2014; Ruscheweyh, Willemer, Kru¨ger, Duning, Warnecke, Sommer et al., 2011; Zoladz, Pilc, Majerczak, Grandys, Zapart-Bukowska, Duda, 2008). It is thus not clear whether the salivary level reflects the peripheral production and central uptake, or whether the central production is reflected in the salivary level.

Since 1988, when it was created, the Eurofit test has become the most popular battery of tests to check the physical fitness of children and adolescents. Eurofit includes many health and skill related fitness tests: flamingo balance FLB (balance), plate tapping PLT (upper body speed), sit-and-reach SAR (extent flexibility), standing broad jump SBJ (lower body muscular power), handgrip strength HGR (upper body muscular strength), sit-ups SUP (abdominal muscular endurance), bent arm hang BAH (upper body muscular endurance), 10×5 m agility shuttle run SHR (running speed-agility) and the 20m shuttle run ESR (cardio-respiratory endurance) (Kemper, Van Mechelen, 1996; Tomkinson, Olds, Borms, 2007). Eurofit is used in many centers due to the fact that it is cheap and easy to perform, it is easy to be carried out in a school or club environment, it requires minimum personnel and equipment, and it can be used in mass testing.

The Eurofit tests demonstrate very good test-retest reliability and good criterion validity for tests where appropriate criterion measures have been identified (Artero, España-Romero, Castro-Piñero, Ortega, Suni, Castillo-Garzon, et al; 2011; Tomkinson, Carver, Atkinson, Daniell, Lewis, Fitzgerald et al, 2017). Tomkinson et al., in their research, developed sex-specific and age-specific normative values for physical fitness in European children and adolescents using the Eurofit (Tomkinson, Carver, Atkinson, Daniell, Lewis, Fitzgerald, et al., 2017; Stupnicki, Przewęda , Milde, 2003).

The cardiopulmonary exercise test (CPET) is used to assess cardiorespiratory fitness. This test makes it possible to control the physiological response of the body to the applied exercise load and at the same time to determine the $VO_2$max index (maximal oxygen uptake) using a direct method. The maximum oxygen uptake (VO2 max) is an index of the body's oxygen potential and determines the ability of the subject to perform endurance activities (Hansen, Jacobs, Thijs, Dendale, Claes, 2016). The aim of the study is to compare the concentration of BDNF in saliva before and after a maximum exercise stress test on a mechanical treadmill in adolescents practicing competitive sports and their non-training peers. The concentration of BDNF in saliva was also related to the body composition assessed by the bioimpedance method and physical fitness measured by the Eurofit test.

**Methods**

64 individuals aged 13-14 participated in the study, including 25 non-training junior high school students and 39 junior high school students practicing sports regularly. Detailed anthropometric data broken down by sex are given in Table 1. In all subjects, the body composition was assessed by means of bioimpedance using the multi-frequency analyzer Tanita MC-980MA (Japan). Physical fitness was measured using the European Physical Fitness Test (EUROFIT). The following tests were used in the study: flamingo balance, plate tapping, sit-and-reach, standing broad jump, handgrip strength, sit-ups. The obtained results of the Eurofit physical fitness test were compared with centile grids developed by Stupnicki et al. for Polish children and adolescents (Stupnicki, Przewęda, Milde, 2003). The following day, the maximum oxygen uptake was determined by the direct method. For this purpose, the subjects performed a running activity of gradually increasing intensity on the HP Cosmos (Germany) mechanical treadmill. The initial load was 7 km/h, then every 2 minutes it was increased by a further 2 km/h until maximum individual loads were obtained or until the subject refused to continue the activity. During the test, the following parameters were measured on a continuous basis using the Start 2000 stationary gas analyzer from MES (Poland). These parameters characterize the respiratory system and the circulatory system functions: current one minute oxygen uptake ($VO_2$), relative value of one minute oxygen uptake ($VO_2$/kg), one minute lung ventilation (VE), heart rate (HR), respiratory rate (BF) and tidal volume (TV). In addition, saliva was collected at rest and after the completion of the maximum exercise stress test with Salivette samplers (Sarstedt). In the saliva collected in this way, the determination of BDNF concentration was performed using the ELISA diagnostic kit from R&D, USA.

For all of the collected data, first an analysis of the normality of the distribution was made using the Lilleforce and Shapiro-Wilk test. In view of finding a non-normal distribution, all descriptive data were presented in the form of medians and quartiles (Me; Q25-Q75), and non-parametric tests, Mann-Whitney U test for intergroup comparisons, $chi^2$ test for the subgroup number comparison, and the assessment of Spearman's rho, were used for the analysis. A significance level of $p < 0.05$ was assumed for all tests. The calculations were made using the Statistica.pl statistical package.

**Results**

The investigated parameters of the body composition were different due to the sex of subjects. In boys, a significantly higher percentage of muscle tissue was found, which is reflected in the higher energy requirements of the body. Body fat mass content expressed both in absolute (kg) and relative (%) values was significantly higher in girls than in boys. It is worth noting, however, that BMI did not differ in terms of sex and was within the range of normal values for the age for both sex groups in the whole study group (around 75 percentile). Detailed data are provided in **Table 1.**

Table 1.

Anthropometric, fitness and performance data depending on sex and regular physical training. Differences between the junior high school and the training group were calculated using the Mann-Whitney U test, with the z and p values provided.

| | Girls | Girls from junior high school n = 16 | Girls Training girls n= 17 | Difference in the junior high school/ Training girls z= p= | Boys | Boys junior high school n = 9 | Training boys n= 22 | Difference in the junior high school/ Training boys z= p= | Differences between girls/boys Z=.; p=. |
|---|---|---|---|---|---|---|---|---|---|
| **ANTHROPOMETRY** | | | | | | | | | |
| Age [years] | 14 (13-14) | 13 (13-14) | 14 (14-14) | NS | 14 (13-14) | 13(13-14) | 14(14-15) | NS | NS |
| Body height [cm] | 166 (160-170) | 162 (157-168) | 168 (165-172) | -2.47 0.013 | 173 (168-180) | 170 (164-174) | 174 (169-180) | NS | 3.45 0.001 |
| Body weight [kg] | 55.6 (53.2-64.0) | 54.8 (52.7-59.6) | 62.2 (53.8-68.6) | NS | 63.5 (55.1-71.4) | 58.4 (54.3-66.1) | 65.9 (56.0-72.0) | NS | NS |
| Fat [%] | 25.4 (24.2-28.2) | 26.8 (24.9-30.2) | 24.9 (23.9-26.2) | NS | 17.3 (14.5-20.5) | 19.3 (12.7-20.9) | 16.8 (14.5-19.0) | NS | -5.19 0.000 |
| Fat [kg] | 15.1 (13.0-18.0) | 15.1 (13.0-17.8) | 15.0 (13.0-18.0) | NS | 10.9 (8.0-14.7) | 11.0 (7.0-15.2) | 10.8 (8.1-14.3) | NS | -3.57 0.000 |
| Weight mm [kg] | 23.0 (22.2-26.5) | 22.5 (21.7-23.3) | 26.5 (23.0-28.3) | -3.05 p=0.002 | 27.4 (24.5-27.2) | 23.7 (22.2-26.6) | 30.7 (26.5-34.4) | -3.10 p=0.002 | NS |
| Weight mm [%] | 11.8(11.3-12.2) | 11.4(11.1-12.3) | 11.9(11.6-12.1) | NS | 14.4(13.7-14.8) | 14.3(13.8-14.4) | 14.4(13.6-15.0) | NS | 6.47 0.000 |
| BMI [kg/m²] | 21.2 (19.6-22.7) | 20.9 (19.6-22.4) | 21.7 (19.6-23.6) | NS | 21.0 (19.2-22.6) | 19.3 (18.3-23.3) | 21.7 (19.8-22.5) | NS | NS |
| **FITNESS (EUROFIT)** | | | | | | | | | |
| (FLB) no fall/fall | 30/1 | 16/0 | 14/1 | NS | 20/7 | 7/2 | 13/5 | NS | Chi²= 6.25 p=0.012 |
| HGR right | 37 (15-74) | 37 (15-70) | 27 (15-74) | NS | 46 (25-76) | 51 (17-60) | 45 (25-81) | NS | NS |
| HGR left | 38 (15-67) | 38 (12-64) | 35 (15-75) | NS | 40 (12-60) | 37 (10-50) | 42 (15-71) | NS | NS |
| SAR | 100 (94-100) | 99 (88-100) | 100 (98-100) | NS | 98 (90-100) | 95 (92-99) | 99 (88-100) | NS | NS |
| SBJ | 80 (70-93) | 86 (55-92) | 78 (73-95) | NS | 91 (60-96) | 92 (75-95) | 90 (51-97) | NS | NS |
| SUP | 40 (20-60) | 25 (7-40) | 50 (35-75) | -3.14 0.002 | 32 (18-56) | 25 (19-37) | 40 (18-58) | NS | NS |
| PLT | 10 (1-30) | 6 (1-15) | 25 (3-50) | -2.14 0.032 | 10 (2-32) | 1 (1-3) | 25 (10-60) | -3.23 0.001 | NS |
| **PERFORMANCE/PHYSIOLOGY** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BF | 58(50-62) | 53.6 (46.0-60.5) | 61.6 (52.7-69.4) | -2.10 0.036 | 58 (50-66) | 56.4 (49.1-63.4) | 58.8 (50.1-67.0) | NS | NS |
| TV | 1.57 (1.35-.176) | 1.36 (1.22-1.58) | 1.69 (1.56-1.86) | 2.64 0.008 | 1.97 (1.49-2.31) | 1.60 (1.33-1.69) | 2.09 (1.77-2.42) | -2.55 0.011 | 2.95 0.003 |
| VE | 84.7 (71.7-106.0) | 73 (66-80) | 106 (88-112) | -3.86 0.000 | 120.3 (86.5-132.0) | 83 (72-101) | 127 (112-135) | -2.50 0.012 | 3.44 0.001 |
| HR | 198 (186-204) | 191 (180-205) | 199 (192-204) | NS | 196 (194-203) | 199 (195-207) | 196 (194-199) | NS | NS |
| $VO_2max$ [ml/kg/min] | 40.8 (35.1-46.9) | 35.2 (31.6-39.9) | 46.7 (40.8-49.8) | -3.43 0.001 | 50.0 (45.2-60.4) | 45.2 (41.4-48.1) | 53.5 (48.6-61.0) | -2.22 0.027 | 3.48 0.000 |
| Speed max [km/h] | 13.6 (12.0-14.4) | 12.0 (11.2-12.8) | 14.4 (13.6-15.2) | -3.96 0.000 | 15.2 (12.8-16.0) | 12.0 (12.0-13.6) | 16.0 (14.8-16.8) | -3.42 0.001 | 2.24 0.025 |
| **BDNF** | | | | | | | | | |
| BDNF at rest [pg/ml] | 3.3 (3.1-4.0) | 3.3 (3.2-3.6) | 3.3 (2.9-4.4.) | NS | 3.5 (3.1-3.7) | 3.5(3.1-3.7) | 3.4(2.8-3.7) | NS | NS |
| BDNF after physical effort [pg/ml] | 3.6 (3.1-4.3) | 3.6 (3.1-4.6) | 3.7 (3.1-4.4) | NS | 3.3 (3.3-3.7) | 3.5(3.2-3.7) | 3.3(3.0-3.7) | NS | NS |

Legend to Table 1.

Flamingo balance FLB, plate tapping PLT, sit-and-reach SAR, standing broad jump SBJ, handgrip strength HGR, sit-ups SUP. Current minute oxygen consumption ($VO_2$), relative oxygen consumption ($VO_2$/kg), minute pulmonary ventilation (VE), heart rate (HR), respiratory rate (BF) and tidal volume (TV). NS- non significant

The results of selected tests from EUROFIT batteries, converted into percentiles for the Polish population, did not differ in terms of sex. It can be assumed that in the study group adolescents of both sexes showed similar fitness. The only significant difference is the worse result of the boys' balance test.

The results of BDNF concentration measured in saliva were comparable in non-training and training individuals of both sexes under the study. In response to the maximum physical effort, a statistically insignificant increase in BDNF concentration was observed only in the group of training and non-training girls, whereas a statistically insignificant decrease in BDNF concentration measured in saliva was found only in the group of non-training boys.

**Comparison of training and non-training individuals within a given sex**

There were significant differences related to the height of the body between girls from the junior high school and those involved in regular physical training. Training girls were significantly taller. Despite the insignificant difference in the total body weight, training teens were much better muscled. The results of the majority of EUROFIT battery tests, converted into percentiles for the Polish population, generally did not differ in girls due to whether teenagers were training regularly or not. Training girls were better in terms of coordination (PLT test) and flexibility (SUP test). There were statistically significant differences in cardiorespiratory fitness parameters between training and non-training girls. The training subjects were characterized by a higher maximum oxygen uptake and maximum running speed. The cardiopulmonary response to the applied exercise load was statistically significantly higher in the training girls. The subjects, training regularly and non-training boys, just like girls, differed only in terms of musculature. No differences were found in the other anthropometric parameters. The results of selected tests from the EUROFIT battery generally did not differ in boys depending on whether the teenagers were training regularly or not. In the training individuals, only the coordination test (PLT) was performed better - just as in girls. There were statistically significant differences in cardiorespiratory fitness parameters between training and non-training boys. Differences in the level of maximum oxygen consumption between subjects were similar to those of girls. The exercise heart rate values indicated that the subjects performed the maximum physical effort.

### Study of the relationship between the parameters of body structure and fitness tests

Subsequently, an analysis of the relationship between selected parameters of body composition and the results of cardiorespiratory fitness and fitness tests, separately for girls and boys, was conducted. Greater muscle mass and greater fat mass were associated with greater strength of the upper limbs (HGR) (both right and left). The percentage of body fat correlated negatively with the strength of the lower body (SBJ) and the strength of the trunk muscles (SUP). Although the studied group of girls (neither junior high school students nor training individuals) was not obese, the percentage of fat worsened the explosive power and trunk muscle strength **(for details, see Table 2)**.

**Table 2.** Correlations between anthropometric parameters, and fitness and physical performance for girls. The value of the Spearman's rho coefficient was given only if the correlation was statistically significant ($p<0.05$)

| Girls | Body Body height [cm] | Body weight [kg] | Fat [%] | Fat [kg] | Weight mm [kg] | Weight mm [%] | BMI |
|---|---|---|---|---|---|---|---|
| FLB no fall/fall | | | | | | | |
| HGR right | 0.421 | 0.595 | 0.472 | 0.569 | 0.488 | 0.412 | 0.410 |
| HGR left | 0.406 | 0.615 | | 0.508 | 0.549 | | 0.499 |
| SAR | | | | | | | |
| SBJ | | | -0.393 | | | 0.469 | |
| SUP | | | -0.364 | | | | |
| PLT | | | | | | | |
| BF | | | -0.505 | | | 0.512 | |
| TV | 0.563 | 0.618 | | | 0.707 | | 0.383 |
| VE | 0.570 | 0.469 | | | 0.681 | 0.456 | |
| HR | | | | | | | |
| $VO_2$max [ml/kg/min] | | | -0.760 | -0.456 | | 0.798 | |
| Speedmax [km/h] | | | -0.719 | -0.368 | | 0.745 | |

Legend to Table 2.

Flamingo balance FLB, plate tapping PLT, sit-and-reach SAR, standing broad jump SBJ, handgrip strength HGR, sit-ups SUP. Current minute oxygen consumption ($VO_2$), relative oxygen consumption ($VO_2$/kg), minute pulmonary ventilation (VE), heart rate (HR), respiratory rate (BF) and tidal volume (TV).

In addition, there was a positive statistically significant relationship between the muscle mass content and the cardiorespiratory fitness level ($VO_2$max), maximum speed of running on the mechanical treadmill (speed max) of all subjects, regardless of the level of training.

The boys also showed a relationship between upper limb muscle strength (HGR) and absolute muscle mass content (kg). There was also a similar, or even stronger than in girls, negative relationship between explosive power (SBJ) and trunk muscle strength (SUP) and fat content in percentages. Obesity worsened these boys' performance indices, while the higher absolute muscle mass increased **(for details, see Table 3).**

**Table 3.** Correlations between anthropometric parameters, and fitness and physical performance for boys. The value of the Spearman's rho coefficient was given only if the correlation was statistically significant (p<0.05)

| Boys | Body Body height [cm] | Body weight [kg] | Fat [%] | Fat [kg] | Weight mm [kg] | Weight mm [%] | BMI |
|---|---|---|---|---|---|---|---|
| FLB no fall/fall | | | | | | | 0.427 |
| HGR right | | | | | 0.966 | | |
| HGR left | | | | | 0.916 | | |
| SAR | | | | | | | |
| SBJ | | | -0.568 | -0.577 | | 0527 | -0.484 |
| SUP | | -0.562 | -0.699 | -0.700 | | 0.652 | -0.620 |
| PLT | | | | | | | |
| BF | | | | | | | |
| TV | 0.695 | 0.557 | | | 0.785 | | |
| VE | 0.702 | 0.592 | | | 0.778 | | |
| HR | | | | | | | |
| $VO_2max$ [ml/kg/min] | | | -0.443 | -0.381 | | 0.616 | |
| Speedmax [km/h] | | | -0.413 | | 0.481 | 0.692 | |

Legend to Table 3.

Flamingo balance FLB, plate tapping PLT, sit-and-reach SAR, standing broad jump SBJ, handgrip strength HGR, sit-ups SUP. Current minute oxygen consumption ($VO_2$), relative oxygen consumption ($VO_2$/kg), minute pulmonary ventilation (VE), heart rate (HR), respiratory rate (BF) and tidal volume (TV).

An analysis of the correlation of body composition parameters with the resting and post-exercise BDNF concentration showed correlations in non-training boys - negative with obesity, both relative [%]: r = -0.756, p<0.05, as well as absolute [kg]: r = -0.714 , p<0.05 for BDNF resting values and positive for body weight (r = 0.778, p<0.05) and absolute muscle mass (r = 0.906, p<0.05). In contrast, training girls showed a positive correlation of pre- and post-exercise BDNF values with the leg explosive power, which is probably related to the difference in musculature between the training and non-training group of girls. A positive correlation was found between the effort increase in one minute lung ventilation and exercise BDNF concentration only in the group of non-training boys (r = 0.735, p<0.05) and girls (r = 0.607, p<0.05). This correlation has not been demonstrated in the case of training individuals. The analysis of the correlation of other indices of physiological response to physical effort did not show a statistically significant correlation between the heart rate, maximum speed, metabolic equivalent, the value of maximum oxygen consumption and BDNF concentration at rest and after the completed exercise stress test.

## Discussion

Differences in the body composition between the investigated males and females can be a sign of puberty and the significant influence of the generated sex hormones on body composition. It is worth noting that the investigated adolescents classified according to sex did not differ in the BMI value, but the composition of the body differed significantly. We emphasize this fact, because the BMI calculation alone is not enough if the analyzed parameters can directly depend on the content of the adipose tissue. It was shown that higher body fat content in body weight composition may be associated with inflammatory markers, contributing simultaneously to a decrease in BDNF (Pedersen, Bruunsgaard,

Weis, Hendel, Andreassen, Eldrup, et al., 2003; Woods , Wilund, Martin, Kistler,2012). In the conducted studies, a negative correlation was found between the BDNF concentration and the amount of adipose tissue. This correlation was stronger in girls, probably due to the higher proportion of body fat in the body composition. There was no difference in both sex groups due to the level of fitness, between the junior high school group and their peers involved in regular physical training. However, there was a statistically significant difference in the level of aerobic capacity both between individuals of different sexes and between those who exercise and those who did not. Based on the literature data, it can be concluded that a higher level of physical performance promotes neurogenesis and improves brain function. Regular physical exercise reduces inflammation in the body, generated, among others, by adipose tissue, reduces oxidative stress and stimulates the release of endogenous neurotrophins. Adaptation to training in a person with a high oxygen potential of the body consists in the creation of an effective antioxidant barrier and a resting decrease in the concentration of markers of inflammation. Hence, a higher resting BDNF level can be found in individuals with a high $VO_2$max index. In response to the maximum exercise stress test, individuals with lower body oxygen potential, even though they performed less muscular work with a lower cardiopulmonary response to the maximum exercise load, had statistically significantly higher BDNF levels in saliva. This may be due to more significant damage to the muscle cells and a stronger metabolic response to the test physical effort. Physical activity, especially with high intensity above the anaerobic transformation threshold, leads to metabolic acidosis, hyperventilation and disturbance of homeostasis with damage to cell membranes, while stimulating the secretion of the anabolic insulin-like growth factor-1 (IGF-1) into the bloodstream. A high concentration of IGF 1 and BDNF in the hippocampus at the end of an exercise is often described in the literature. Probably the high post-exercise BDNF concentration observed in the non-training group under the study is due to the strong acidity of the body, stimulation of catecholamine secretion by the adrenal glands and IGF 1 in response to a one-time test physical effort. Training individuals, due to better adaptation to physical effort, are characterized by lower hormonal and neurohormonal response to the exercise load. The consequence of the described phenomena is a decrease in the concentration of IGF-1 in the blood of individuals with high oxygen potential of the body and the reduction of BDNF synthesis in response to physical effort.

The concentration of BDNF in saliva was tested using diagnostic kits available on the market, designated for the determination of this substance in various physiological fluids. We have been guided by reports of the possibility of determination, described in several works. There were also suggestions undermining the possibility of obtaining credible results with these kits (Vrijen, Schenk, Hartman, Oldehinkel, 2017), but the article describing these doubts appeared only after conducting this research. In training individuals of both sexes, BDNF was detected in saliva in the first study, but its concentration did not increase significantly in the second study. The change in the concentration of the studied marker did not significantly correlate with the value of maximum oxygen consumption. Its effort-related change in this case did not depend on the level of aerobic capacity of the subjects. It can therefore be assumed that this is an exponent of mobilization (stress in a positive perspective), and not stress as a negative phenomenon. The highest physical effort increase in BDNF concentration was recorded only in the group of non-training girls. This change, although statistically insignificant, may indicate the occurrence of the highest stress level associated with the exercise stress test only in this group of subjects. This differs from the results obtained in Pareja-Galeano et al.( Pareja-Galeano, Brioche, Sanchis-Gomar, Montal, Jovaní, Martínez-Costa et al., 2013). It seems that the concentration of BDNF in saliva in girls depended on the fat content and stress response to physical effort, because the increase was found mainly in non-training junior high school female students (Oztasyonar, 2017).We conclude that regulatory mechanisms leading to an increase in BDNF concentration were slightly different in both sexes, that they might depend on body composition (and higher adipose tissue content promotes this production) and, finally, that they might be a derivative of both stress in the negative sense (worse response to the exercise stress test in non-training girls), as well as stress in the sense of mobilization (better results of performance tests in well-trained boys). BDNF can be considered as an index of CNS mobilization - stress in a positive sense, and its concentration increase also as improved CNS perfusion, which in many studies had been associated with the improvement of intellectual functions and memory (Jeon, Ha, 2017), although we were unable to confirm the thesis about the impact of long-term physical effort. However, there are also reports that in subjects undergoing a one-time exercise stress test rather than regular physical activity, an increase in BDNF concentration in plasma/serum, was a manifestation of a stress response. In the present study, it can be shown that undergoing the same exercise stress test, teenagers who exercise regularly did not show symptoms of a stress response, unlike the group of junior high school students, especially girls ( Oztasyonar, 2017; Miyamoto,Hashimoto, Yanamoto, Ikawa, Nakano, Sekiyama, et al., 2018).

## Conclusions

The concentration of BDNF was significantly dependent on the body composition only in girls and negatively correlated with the content of the adipose tissue. Training and non-training teenagers did not differ in fitness, but in the level of cardiorespiratory fitness. Non-training teenagers showed a higher concentration of BDNF in saliva and further increase after the exercise stress test. In the training individuals, the exercise stress test did not lead to an increase in BDNF concentration.

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