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DIFFERENCES IN THE DEVELOPMENTAL RATES OF VENTILATION CAPABILITIES BETWEEN BOYS WHO PLAY FOOTBALL AND BOYS WHO DO NOT PLAY FOOTBALL

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Abstract
The aim of this research was to determine the differences in the rate of development of ventilation capabilities in 12 to 15-year-old boys who systematically train football, and boys in the same age group who are not involved in any sports. The research included 40 football players and 40 non-players, divided into chronological age groups U12, U13, U14, and U15. Ventilation capabilities are represented with 10 parameters: forced vital capacity, forced vital capacity in percentage predicted, volume of air exhaled during the first second, volume of air exhaled during the first second in percentage predicted, Tiffeneau index, percentage of the predicted Tiffeneau index, forced expiratory flow, forced expiratory flow 25-75% of FVC, forced expiratory flow 75-85% of FVC, and maximum expiratory flow. The difference between the arithmetic mean of groups and the development rate of the variables is determined by one-way analysis of variance (ANOVA). Non-players have a higher and faster growth in value for most variables until the age of 13, followed by a gradual stagnation and decline in values, while football players have a more balanced growth in values until the age of 13, and they experience the maximum in development at 14 years of age, after which it begins to decline slightly. The obtained values confirm that boys who are participating in systematic sport training have a continuous rate of development of pulmonary ventilation, and have greater capacity values, as well as better airway patency.

Key words: **spirometry, football, growth and development, training**

Introduction

Developmental changes at the age of 12-15 are heterogeneous, and the development of organ systems does not follow a homogenous pattern either, as this is a period of rapid growth and development, with an increased sensitivity to all types of stimuli. Unlike the mature age, childhood and adolescence are periods of the most rapid development of the lungs and lung capacities, as well as the pulmonary ventilation. At this stage of development, the increase in lung capacity, the number of alveoli, their size, as well as the volume of the chest and muscle strength are significant (Gautlier & Zinman, 1983; Grivas, Burwell, & Purdue, 1991; Quanjer et al., 2010).

During this period of child development, the inability to rapidly adapt to the specific functions of certain organ systems becomes prominent, and this developmental period is susceptible and sensitive to changes which may occur under the influence of adequate training process and thus move in a positive direction.

Active children of both sexes involved in physical activity and sports training generally have a higher aerobic endurance and higher levels of a number of functional motor skills, especially endurance and running speed. This finding is supported by many studies comparing active and inactive children (Beunen et al.,1992; Mirwald et al., 1981). Muscle activity is related to the transformation of chemical energy into mechanical energy and heat, while the energy for muscle contraction is delivered by the transport system, which means that the increased activity of the locomotor system is directly associated with an increased activity of the internal organs. Lung activity is increased due to an increased need for oxygen, and the increase in blood circulation is necessary for the increased transport of oxygen, so the heart must work faster and with more power.

The lungs are developing rapidly, rate of respiration decreases and it becomes deeper, while the frequentional ability of the respiratory apparatus is gradually approaching adult capabilities. As part of the further development of the respiratory system, its functions are changing as well. The vital lung capacity increases, and the value of maximum pulmonary ventilation increases more rapidly in girls, so that at the age of 12-13 it amounts to 69.8 - 80 l/min in girls, and around 74.5 - 83.6 l/min in boys (Mišigoj--Duraković, 2008; Medved et al. 1989).

Absolute oxygen uptake (VO_{2max}) in girls ranges from 0.97 l/min at the age of 8, and has a constant upward trend until the age of 18, when it reaches the value of 2.15 l/min. In boys, these values range from 1.12 l/min at the age of 8, with a constant upward trend until the age of 18, when they reach the value of 3.32 l/min (Medved et al., 1989). More effective ventilation is observed in people who are much better adapted to physical effort through systematic exercise. Various sports differently affect the development of respiratory function. Aerobic training has the greatest influence on the increase in vital capacity, while the anaerobic stimuli most significantly affect the increase in velocity of the air (Diniz Da Silva, Bloomfield, & João, 2008).

The role of the respiratory system in sports activities is related to the increased transport of oxygen and carbon dioxide, as well as the maintenance of acid-base balance by controlling the concentration of carbon dioxide. Ventilation increases and accelerates in order to facilitate a faster exchange of gases during physical activity, both pulmonary and alveolar. Similarly, the flow of blood through the lesser circulatory system accelerates, which leads to a faster exchange of gases. This change and the response of the respiratory system to the appropriate load is the same in children and adult athletes, with the only difference being in the level of quantitative expression.

Absolute values of ventilation parameters and their growth rate from the ages of eight to eighteen continuously increase in value (Mišigoj-Duraković, 2008; *Stanojevic et al., 2008)*. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) in boys have a tendency to increase continuously up to the age of 18 when they reach three times the value they had at the age of 8. Tiffeneau index in boys has a continuing decline between the ages of 8 and 18. Forced flow in the middle of expiration, between 25% and 75% of forced vital capacity, and forced flow between 200ml and 1200ml, gradually increase throughout the years, which is consistent with their sensitivity to changes in the greater airways and dependence on the effort exerted during exhalation (Mišigoj-Duraković, 2008; Medved et al., 1989; *Stanojevic et al., 2008)*. Physical strains that require high respiratory minute volume stimulate the growth and development of the chest wall in young athletes, thus making the chest wider, longer, and increasing its capacity. This is the manner of developing "sport lungs" with greater air volume, as well as greater blood volume and increased surface of the alveoli.

Sport activity, including football practice, strengthens and leads to hypertrophy of the respiratory muscles, and to a more cost-effective breathing at lower frequencies, which results in an increase in the patency of the airways, and an increase in the ventilation function of the lungs. The aim of this study is to determine the difference in the rate of development of ventilation in boys who are involved in systematic football training and boys who are not.

Methods

Participants

Participants sample consisted of 80 participants from a population of boys aged 12-15 from the city of Mostar (Bosnia and Herzegovina). Participants were football players (junior football players of FC Velež Mostar, who trained for at least three years), comprising four age categories U12 (n = 10), U13 (n = 10), U14 (n = 10), U15 (n = 10), and non-players of the same age (n = 40) who did not engage in systematic sport activities, but have regularly attended physical education classes at school: U12 (n = 10), U13 (n = 10), U14 (n = 10), U15 (n = 10).

Variables

Variables were represented by 10 parameters for assessing the capability of ventilation and airway patency: FVC (litre) - forced vital capacity, FVC% - forced vital capacity in percentage predicted, FEV1(litre) - volume of air exhaled during the first second, FEV1% - volume of air exhaled during the first second in percentage predicted, FEV1/FVC - Tiffeneau index, FEV1/FVC% - percentage of the predicted Tiffeneau index, FEF (l/min) - forced expiratory flow, FEF_{25-75} - forced expiratory flow 25-75% of FVC, FEF_{75-85}- forced expiratory flow 75-85% of FVC, and PEF (l/min) - maximum expiratory flow.

Procedures

Ventilation parameters were assessed using a spirometer SPIROVIT SP1 (Schiller AG, Switzerland). Data on age, height, and weight was collected in order to compare the results with individual predictive values. Calibration of the spirometer was performed based on external factors (room temperature, air pressure, relative humidity), in order to apply the correction of the measured volume with regards to standard conditions (BTPS standard) (Miller et al., 2005).

Statistical analysis

The results were processed using the software package IBM SPSS 21.0 for Windows. One-way analysis of variance (ANOVA) was used to determine the difference between arithmetic means of groups, as well as the rate of development of the observed variables. The development rate of certain variables is shown graphically.

Results

Height and weight variables were assessed in order to determine whether the sample of participants falls within the parameters for the chronological age group, as well as to compare the results with individual standards (predictive values for age, body height, and weight of the participants). Both groups have similar values, except for the finding that, on average, children who are involved in the process of training are taller and lighter (Table 1). In boys who are not football players, the growth in height is accelerated starting at the age of 12-13. After the age of 13, there is a slight stagnation of growth, while the mass constantly increases until the age of 14, when it starts decreasing in value. In football players, the increase in height is continuous until the age of 14, when it rapidly increases by about 10 cm until the age of 15. Body mass in this group of boys experiences a slight decline until the age of 13, when it gradually increases until the age of 15. The height and weight of all boys who participated in this study is at a level that corresponds to their chronological age.

By comparing the values of arithmetic means of these variables with the values of previous research (Malina, 1993; Mišigoj-Duraković, 2008), Čolakhodžić, Skender, & Pistotnik, 2011; Śliwowski et al., 2011), we see that these boys have similar values of arithmetic means of both variables, with slightly increased values of body height in football players. The values of basic descriptive parameters of ventilation capabilities shown in Table 1 (FVC, FVC%,FVC1, FVC1%, Tiffeneau index, FEF_{25-75}, FEF_{75-85}, and PEF)) show that both groups of boys experience an increase in values of ventilation parameters until 13 years of age, with non-players having a somewhat greater value of the arithmetic means of ventilation parameters in comparison to football players. After the age of 13, there is a mild stagnation in the values of parameters in the group of non-players, and a sharp increase in these values in the group of football players, when the latter experience a continued increase in ventilation capacity of up to 117% of the predicted value of FVC in the 14th year of life. After the age of 14, FVC% of non-players declines to 98% of the predicted value for this age, while it reaches the value of 109.40% in the group of football players. The value of the Tiffeneau index decreases continuously from the age 12-15 in non-players, and amounts to 103% of the predicted value at the age of 15. This value is stable in the group of football players, ranging from 105.20%, to 109% it measures at the age of 15. Similar values for 15-year-old football players (Erceg, Jelaska, & Maleš, 2011). The values of the variables FEF (forced expiratory flow) and PEF (peak expiratory flow) showed a constant increase starting at the age of 12-15 for both groups of subjects, but with higher values in the group of players (FEF = 7.26 and = 8.40 PEF at the age of 15).

Table 1. Descriptive parameters of variables

Variables	Group	Footballers			Non footballers		
		N	Mean	Std.Dev.	N	Mean	Std.Dev.
AVIS	U 12	10	156.10	6.78	10	158.80	8.67
	U 13	10	166.40	8.59	10	163.70	9.20
	U 14	10	165.50	13.12	10	167.20	8.14
	U 15	10	173.10	7.78	10	176.60	6.25
AMAS	U 12	10	42.70	8.16	10	47.30	7.36
	U 13	10	54.10	10.69	10	46.20	8.03
	U 14	10	61.40	15.49	10	54.50	9.21
	U 15	10	59.50	12.28	10	59.70	5.65
FVC	U 12	10	2.90	.52	10	2.98	.71
	U 13	10	4.05	1.38	10	3.38	.83
	U 14	10	4.26	1.25	10	4.67	1.18
	U 15	10	4.47	1.11	10	5.18	1.04
FVC%	U 12	10	92.90	15.68	10	91.10	17.38
	U 13	10	103.70	23.42	10	93.10	15.15
	U 14	10	104.10	20.93	10	117.50	24.95
	U 15	10	98.00	14.61	10	109.40	21.55
FEV1	U 12	10	2.75	.51	10	2.83	.69
	U 13	10	3.84	1.43	10	3.15	.82
	U 14	10	3.92	1.27	10	4.47	1.06
	U 15	10	4.03	.91	10	4.94	.98
FEV1%	U 12	10	98.40	18.41	10	95.00	15.17
	U 13	10	110.50	29.20	10	97.50	16.82
	U 14	10	109.20	25.08	10	126.10	25.91
	U 15	10	100.80	15.61	10	118.60	23.26

FEV1/FVC	U 12	10	94.52	5.22	10	95.21	6.69
	U 13	10	93.96	7.55	10	93.20	4.65
	U 14	10	92.01	7.93	10	95.00	3.36
	U 15	10	91.10	6.13	10	95.44	4.30
FEV1/FVC%	U 12	10	106.00	5.90	10	106.30	7.70
	U 13	10	106.00	8.47	10	105.20	5.49
	U 14	10	104.30	8.69	10	107.60	3.86
	U 15	10	103.50	7.09	10	109.00	4.98
FEF	U 12	10	4.71	1.29	10	4.48	1.23
	U 13	10	6.20	2.02	10	4.97	1.14
	U 14	10	6.11	1.60	10	7.54	2.52
	U 15	10	6.07	1.03	10	7.26	1.54
FEF_{25-75}	U 12	10	4.18	1.26	10	3.45	.99
	U 13	10	5.03	1.70	10	3.95	.86
	U 14	10	4.87	2.05	10	6.12	1.78
	U 15	10	4.72	1.02	10	6.08	1.36
FEF_{75-85}	U 12	10	2.87	1.11	10	2.04	.72
	U 13	10	3.01	.99	10	2.42	.66
	U 14	10	2.84	1.11	10	3.40	1.35
	U 15	10	2.79	.72	10	3.60	.90
PEF	U 12	10	5.16	1.42	10	5.03	1.28
	U 13	10	6.86	2.68	10	5.37	1.21
	U 14	10	6.89	2.14	10	8.64	2.95
	U 15	10	6.83	1.36	10	8.40	1.84

Analysis of variance (Table 2) tested whether groups of participants belong to the same population, the F-test examined the statistical significance of differences between groups of variables and variables within the group, i.e. the significance of the difference between intergroup and intragroup variance, and the growth rate of certain variables was shown in graphs. If we examine the values of the F-test and their statistical significance among non-players, we can see that most of the variables (FVC%, FEV1%, FEV1/FVC, FEV1/FVC%, FEF, FEF_{25-75}, FEF_{75-85}, PEF) do not have a statistically significant F-test value. These results clearly show that there is no statistically significant difference in the arithmetic means of these variables, i.e. that the participants in the group practically belong to the same population.

Significantly different variables between the groups are: body height (AVIS), body weight (AMAS), forced vital capacity (FVC), and forced vital capacity in the first second (FVC1). In the group of football players, we notice that only two variables, Tiffeneau index (FEV1/FVC) and percentage of the predicted Tiffeneau index for this age group (FEV1/FVC%), do not have a statistically significant F-test value; all other variables have the level of significance of $p=.01$ or $p=.05$.

These results clearly show that there is a statistically significant difference in the arithmetic means of these variables by groups of participants, i.e. that the groups of participants do not belong to the same population. Comparing the results of the groups, a clear difference is observed in the growth rate of the majority of variables, from which we can conclude that playing football inevitably leads to the development of functional or ventilation capabilities in boys.

Rates of growth and development of certain variables in both groups, demonstrate that forced vital capacity (FVC) in non-players has a growth curve slope with the highest rate of increase from the age of 12-13, after which there is a mild stagnation of this variable. The FEV1 variable, which represents the forced expiratory volume of the participant measured in the first second and shown in litres (l), also has a positive growth trend, especially in the period of 12-13 years of age, when the rate of increase is the highest ad amounts to 1.1 litres. After the age of 13, there is a sudden decrease in this value and the curve has a gentler slope until 15 years of age.

This is reflected in the percentage value of the variable in relation to the predicted value, and therefore the curve for FEV1% experiences a sudden drop after the age of 14.

Tiffeneau index (FEV_1/FVC) in boys who do not play football has a constant relationship between the obtained and predicted value from the age of 12-13, followed by a slight decline in value until the age of 15, when it reaches 103% of the predicted value. In the group of football players, these values decrease between the ages of 12 and 13, after which they steadily increase until the age of 15, when they reach 109% of the predicted value for that age group.

Forced expiratory flow (FEF) variable has the highest value growth from the age of 12-13 in the group of non-players, followed by a gradual decline in the value until 15 years of age, while the largest growth in football players occurs between 13 and 14 years of age (2.57), when it reaches the maximum value (7.54).

This is followed by a mild stagnation of growth. These results clearly show that reduced sport activity or inactivity

Table 2. One-way analysis of variance (ANOVA)

Variables	Footballers				Non footballers			
	df	Mean Square	F	Sig.	df	Mean Square	F	Sig.
AVIS	3	489.09	5.54	.003	3	565.35	8.51	.000
	36	88.18			36	66.38		
	39				39			
AMAS	3	706.62	4.94	.006	3	404.15	6.85	.001
	36	142.99			36	58.95		
	39				39			
FVC	3	4.91	3.92	.016	3	10.88	11.74	.000
	36	1.25			36	.92		
	39				39			
FVC%	3	281.62	.77	.514	3	1635.42	4.04	.014
	36	361.60			36	404.85		
	39				39			
FEV1	3	3.53	2.95	.045	3	10,27	12.50	.000
	36	1.19			36	.82		
	39				39			
FEV1%	3	362.62	.70	.557	3	2374.86	5.50	.003
	36	516.33			36	431.55		
	39				39			
FEV1/FVC	3	25.93	.56	.644	3	10.49	.43	.729
	36	46.24			36	24.10		
	39				39			
FEV1/FVC%	3	15.76	.27	.846	3	26.95	.83	.484
	36	58.12			36	32.33		
	39				39			
FEF	3	5.04	2.14	.112	3	24.40	8.43	.000
	36	2.35			36	2.89		
	39				39			
FEF_{25-75}	3	1.36	.55	.646	3	19.59	11.51	.000
	36	2.44			36	1.70		
	39				39			
FEF_{75-85}	3	.08	.08	.968	3	5.72	6.32	.001
	36	.99			36	.90		
	39				39			
PEF	3	7.17	1.83	.159	3	37.02	9.69	.000
	36	3.91			36	3.81		
	39				39			

leads to a decline in the air flow during expiration. Figure 8. shows the growth rate of the variable that represents maximum expiratory flow (PEF). Predicted value of this variable should have a continuous flow from the age of 12-15.
However, with regards to this variable as well, a positive trend is observed only from the age of 12-13 in non-players, and 13-14 in football players, after which it begins to stagnate and decline in value until the age of 15 (6.83 vs. 8.40).

Discussion

Results of this research show that participants have no obstructions in airway patency, as the indicators of ventilation capabilities vary within a normal range. The development rate of the main ventilation parameters for boys at this age demonstrates a clear difference between the groups, which is in favour of boys who play football and can certainly be attributed to the sports activities and improved ventilation capacity through systematic training. The difference is evident in nearly all variables, which undoubtedly proves that, as children grow and develop, functional capabilities of inactive children experience a gradual stagnation in comparison to children who practice football. If we compare the values of the basic variables of ventilation - FVC, FVC1, Tiffeneau index and FEF_{25-75} - with the results of previous research (Mišigoj-Duraković, 2008; Ziaee et al., 2007), we will see that our participants have increased values in the group of players, while the boys who are not involved in any sports activities have reduced values, but they fall within the normal range for that age group.
The development trend of forced vital capacity (FVC) variable in boys who play football has a different growth curve slope compared to boys who do not play football. In the group of football players, the highest growth occurs from the age of 13-14, while the highest increase in value in the group of non-players was between the ages of 12 and 13. At the age of 14, we observe the highest value of the forced

vital capacity in percentage predicted (FVC%) variable in the group of football players, in the amount of 117% of the predicted value, followed by a slight decline in the value from the age 14 -15. Similar results were obtained by (Medved et al., 1989); Erceg, Jelaska, & Maleš, 2011) for the population of boys in Croatia, on a sample of senior players. Slightly lower values were obtained for the sample of 274 boys, aged from 11 to 16, taken from a population of primary and secondary school students from Benin (Messan et al., 2013). A similar look and slope of the curve is observed for variables that determine forced vital capacity in the first second (FEV1, FEV1%), which clearly shows that boys who systematically train, develop their ventilation skills in a more consistent manner, achieve maximum ventilation later than their counterparts, and have a higher value of these parameters. The FEV1 (volume of air exhaled during the first second) variable has a positive growth trend in the group of football players, especially in the period from the age of 13-14, when the growth rate is the highest and amounts to 1.3 litres, after which the curve has a somewhat gentler slope until the age of 15. In the group of non-players, the highest growth is observed from the age of 12 to 13, after which the value stagnates.

This is reflected in the percentage values of this variable in relation to the predicted value, and therefore the curve of FEV% has the highest growth rate from the age of 13-14, and experiences a sudden drop starting at the age of 14, until the age of 15.

In terms of these variables as well, football players have higher observed values and achieve the highest growth slightly later than the boys who do not play football. Tiffeneau index (FEV1/FVC, FEV1/FVC%) in this group of participants shows that participants who are 12-13 of age have a constant ratio of the obtained and predicted value, followed by a slight decline in value until the age of 15 when it amounts to 103% of the predicted value.

Unlike non-players, who have a sudden increase in the value from the age of 12-13, football players experience a continuous growth rate with the largest increase in value from the age of 13-14. After the age of 14, there is a slight reduction in the curve slope of growth and decline of value until the age of 15.

The growth curve slope of variables that define forced expiratory and maximum expiratory flow, i.e. the speed of exhalation (FEF, PEF) shows similar inclinations as the previous variables, with the highest growth rate from the age of 12-13 in non-players, and 13-14 for football players.

Conclusion

Based on the obtained results, it was determined that boys who play football have a different rate of growth and development of ventilation capabilities compared to boys who do not play football. By comparing the value of the arithmetic means and the growth curves of variables, we noticed a significantly different slope and position of the point of flection of the curve. It was determined that non-players have higher values and a faster growth of ventilation capabilities until 13 years of age, followed by a gradual stagnation and decline in value below 100% of the predicted value. Football players have a balanced growth in values between the ages of 12 and 15, with a steady slope of the growth and development curve that is practically similar to the slope of the curve of predicted development of the participants in this age group, and achieves its maximum percentage during the 14^{th} year, after which it begins to gradually decline to a value of 110% of the predicted value. It is evident that both groups have values above 100%, which indicates that they do not have obstructive disorders of pulmonary ventilation. These values confirm the aim that there are differences in the rate of growth and development of pulmonary ventilation between boys who play sports and boys who do not, and that these differences are in favour of the former group. It is evident that boys who are engaged in systematic sports activities have higher average values of forced vital capacity, maximum speed exhalation, and total pulmonary ventilation. These results can be attributed to technology of training, because both groups belong to the same population, and live in the same area, affected by the same external factors.

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