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ORIGINAL PAPER

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Analysis of the correlation between body composition, construction and aerobic capacity in teenage team sport training

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ABSTRACT

Introduction. Research results indicate that a low level of physical fitness is associated with a high percentage of fat in the body and low levels of physical activity. The aim of this work was to assess the relationships between selected morphological indicators, and the level of aerobic capacity in adolescents attending the schools with team sports.

Material and methods. The studies covered students participating in sports in middle school and high school; the study group included 90 boys aged 13-19 years.

Body height and weight were measured as well as waist and hip circumference. Body weight components were assessed by using a Tanita Body Composition Analyzer. A Fitnessgram® test battery was used to assess physical fitness.

Results. Research results indicates systematic increase of somatic characteristics such as weight, body height and waist and hips circuits with age. Taking into account the results obtained with the PACER test indicate a very good aerobic capacity of tested boys.

Conclusions. Age is a factor that improves motor fitness of physically active adolescents. There is no linear relationship between BMI and fitness among the boys who regularly train team sports, but both lower and higher BMI values seem to be connected with lower physical fitness.

Keywords. fitnessgram, adolescents, cardio respiratory fitness

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Introduction

Research results indicate that a low level of physical fitness is associated with a high percentage of fat in the body with low levels of physical activity.[1–5] In the most highly developed countries, for the last 20 years, there is an epidemic of sedentary lifestyle.[6] The results of the observation of changes in physical activity in studies of Polish teenagers conducted in the 90s of the last century leads one to believe that levels of physical activity decreases with age and is constantly lower than recommended.[7] One can estimate that only 30% of children and adolescents, and 10% of adults practices physical forms of activity in which the intensity of the load effort meets the physiological needs of the organism. Moreover, it is reported that cardiopulmonary efficiency is more strongly associated with cardiovascular risk factors than objectively measured physical activity components in children and adolescents.[8] As physical fitness is an important part of metabolic health as well as a strong independent predictor of premature mortality, identification of changes level of physical fitness among children in the age of "the obesity and sedentary lifestyle epidemic" may indicate the need for implementation of actions aimed at improving physical fitness in this group.[9–14]

Aim of this study

The aim of this work was to assess the prevalence of the relationships between selected morphological indicators, and the level of aerobic capacity in adolescents attending the schools with a sport profile.

Materials and methods

Studies were carried out within the framework of the project of the Student Research Society of Diagnostics in Sport and Health Training titled "Sport talented children and teenager assessement of the Podkarpacie region" in Secondary School number 2 in Rzeszów. The study group included 90 boys aged 13-19 years who are students of Middle and High Schools that participate in sports. Most participants trained football (85.7%), and rest of the group trained in handball. The criteria for inclusion to the test group were: being a student of V High School named of Krzysztof Kamil Baczyński, Sports Championship School or the Sports Gymnasium in Rzeszów and a valid sports medical examination. Exclusion criteria were: lack of a valid medical sport result or injury precluding performance of fitness tests and a lack of mentors or coach consent for student testing.

The first anthropometric assessment was carried out in accordance with the protocol recommended by the International Society for the Advancement of Kinanthropometry (ISAK).[15] Body height (BH) was measured using a Martin type Anthropometer; body weight (BW) and its components was assessed by using a Tanita Body Composition Analyzer type TBF 300. It is a tool recommended for this purpose by The Cooper Institute which developed the Fitnessgram® test battery. In addition, waist circumference (WC) of the subjects was measured at half the distance between the last touchable rib and the top edge of the iliac crest; hip circumference (HC) was measured at the most rearward points of the buttocks (at the widest point of the hips). Measurement circuits were made with the help of Gulick anthropometric tape to the nearest 1 mm.

Next, a physical fitness assessment was performed in accordance with the protocol described in the guide to the Fitnessgram® test battery.[16] Evaluation of aerobic capacity was carried out using a standardized 20 meter shuttle run (Progressive Aerobic Cardiovascular Endurance Run - PACER) with progressive intensity for indirect assessment of maximal oxygen consumption (VO_2 max [ml/min/kg]). The test was carried out in a gym and was based on shuttle 20 meters running distances with increasing rate of the signal generated by computer program "beep test ver. 4_1", up to the denial (fatigue) of the test, or the decline in pace in accordance with given signal.[17] The test enabled the participation of a higher number of people, and the coefficients of reliability and repeatability of results make it a recommended and used tool in population studies of children and adolescents ($r = 0.89$).[18] Muscular strength and endurance was rated by three tests: Curl Up, Trunk Lift and Push Up. Curl Up test is based on performing at the same rate (according to the sound file playing by teacher) the largest number of curl-ups in order to lie back with knees flexed and feet unanchored. The maximum number of sits predicted by the authors of the test was 75 assays. The result of assays is the number of full cycles. A trunk Lift test was performed from prone lying position with arms along the body (hands slipped under the hips). The mattress includes a point that should be addressed by sight during time of the test. The tested person slowly lifts the body as high as possible and keeps it in order to measure distances of chin from the floor. The result is given in centimeters. In the 90° Push Up, the student being tested assumes a prone position on the mat with hands placed under or slightly wider than the shoulders, fingers stretched out, legs straight and slightly apart, and toes tucked under. In this way tries to perform as many repetitions as possible. The pace of implementation is served by a teacher playing an audio file. The result of the assay is the number of complete motor cycles made until, when the tested person after the second time does not maintain the recommended speed. Flexibility was assessed using the Sit-and-reach test where the student removes his or her shoes and sits down at the test apparatus. One leg is fully extended with the foot flat against the face of a box. The other knee is bent with the sole of the foot flat on the floor. Tested person performs this four times with progressively deeper slope. The result of the trial is to measure the distance from the point of the seat back of the foot of the platform given in centimeters. The test is performed twice with a straight right foot, followed by the left.

On the basis of the measurements, waist to hip ratio was calculated (WHR) as waist circumference divided by the hip circumference and waist to height ratio (WHtR) as waist circumference divided by height, where all variables are expressed in centimeters. Body mass index (BMI) was also calculated by dividing body weight in kilograms by the square of the body height in meters and the Rohrer Indicator (RI) by multiplying by 100 the result of dividing the body weight in grams by body height, expressed in centimeters and raised to the power of three. The value of VO_2max was calculated on the basis of the model proposed by Boiarskaia.[19]

$$\mathbf{VO_2max = 32.57 + (laps \times 0.27) + (3.25 \times (sex)) + + (0.03 \times (age))}$$

Statistical analysis was performed with the use of SPSS statistical analysis software. The normality of the distribution of the analyzed variables were evaluated using the Shapiro-Wilk test. The differences between the group characteristics of somatic and physical fitness due to age have been assessed using Kruskal-Wallis test due to failure to comply with the assumptions of a normal distribution of the analyzed features. In all analyses, statistically significant results were found with $p < 0.05$.

Results

Research results indicates a systematic increase of the somatic characteristics such as weight, body height, waist and hip circumference with subject age. The results obtained with the PACER test indicate a very good aerobic capacity of the boys in the study group. The biggest intra-group variation of these parameters was observed in the youngest study group. This dependency has been shown by statistical significance (Tab. 1). By analyzing the WHR, it was concluded all age groups had an average value of 0.8 level. WHtR had values between 0.42 and 0.44. According to the BMI analysis, one can note that the results of the study group fall within the limits of 19.2 and 22.2. The Rohrer indicator in all age groups accepted the value of 1.2. As in the case of indicators: WHR, WHtR and BMI, so in Rohrer indicator, the largest intra-group variation was observed in the youngest study group. Taking into account the calculated anthropometric indicators, statistical significance was noted only in the case of BMI. Body weight composition analysis showed that the highest content of fat in the body, at 12.1%, was found in boys at the age of 16 years. A similar level of body fat (11.8%) was noticed at the age of 17 years. The smallest percentage of the test parameter was noted among 15 year-olds. Results of the study shows that the value of fat free mass and total body water increases with subjects age. The value of the variation coefficient for each body composition param-

Table 1. Differences in the structure and composition of the body weight in different age groups

Age		The structure and composition of the body											
		BH [kg]	BW [cm]	WC [cm]	HC [cm]	WHR	WHtR	RI	BMI	FAT [%]	FAT [kg]	FFM [kg]	TBW [kg]
14 years (N=17)	*M*	53.5	165.7	73.3	86.5	0.8	44.3	1.2	19.2	10.8	6.2	47.3	34.6
	sd	14.3	10.8	7.9	8.3	0	4.4	0.2	3.2	5	4.6	10.8	7.9
	V	26.8	6.5	10.7	9.6	4.6	9.9	14.3	16.5	46.1	73.7	22.8	22.8
15 years (N=15)	*M*	59.6	172.6	72.9	90.2	0.8	42.2	1.2	20	9.9	6.1	53.5	39.2
	sd	7.4	4.9	4.6	5.7	0	2.3	0.1	1.7	3.1	2.5	5.5	4
	V	12.4	2.9	6.4	6.4	4.9	5.5	7.7	8.6	30.8	40.7	10.2	10.3
16 years (N=22)	*M*	68.8	178.5	76.3	93.7	0.8	42.8	1.2	21.6	12.1	8.6	60.3	44.1
	sd	8.5	6.1	5.3	5.2	0	2.7	0.1	2	3.8	3.5	6.2	4.5
	V	12.3	3.4	6.9	5.5	4.6	6.4	9.2	9.3	31.5	40.4	10.3	10.3
17 years (N=28)	*M*	72.1	180.3	78.1	94.7	0.8	43.3	1.2	22.2	11.8	8.9	63.1	46.2
	sd	11.7	6.2	6.8	6.3	0.1	3.7	0.2	3	4.8	4.8	7.8	5.7
	V	16.2	3.5	8.7	6.7	6.4	8.6	13.7	13.6	40.9	53.3	12.4	12.4
18 years (N=23)	*M*	73.2	181.5	78.3	95.2	0.8	43.1	1.2	22.2	10.8	8.2	65	47.6
	sd	10.1	6.2	5.5	5.5	0	2.5	0.1	2.2	3.3	3.6	7.3	5.3
	V	13.8	3.4	7.1	5.8	5.1	5.9	9.4	10	30.5	43.7	11.3	11.2
Test K-W	p	**0.0001**	**0.0001**	**0.0053**	**0.0004**	0.1129	0.6695	0.1823	**0.0004**	0.3807	**0.014**	**0.0001**	**0.0001**

M – arithmetic average, *sd* – standard deviation, v – coefficient of variation [%], BH – body height, BW – body weight, WC – waist circumference, HC – hip circumference, WHR – waist to hip ratio, WHtR – waist to height ratio, RI - Rohrer indicator, BMI – body mass index, FFM – fat free mass, TBW – total body water eter indicate that the biggest intra-group variation was noted in group 14-year olds. At the same time, it has been observed statistical significance between the age of the study group and the mass of the body fat, fat free mass and total body water (Tab. 1).

Table 2 shows the numeric characteristics of individual tests that comprise the assessment of physical fitness of study group in terms of age. Analysis showed that the largest number of 20 meter distances (LAPS) in the PACER test of was noted in the group of the oldest tested participants (M = 93.0). A similar high score, at the level of 92.5 distances, was noted among the age of 16 years participants. The weakest result during this attempt was recorded in the group of 14-year boys (M=68.5). At the same time in this age group it was observed the biggest variety in terms of intra-group test parameter. In addition, there was noted statistical significance between the age of the study group and the number of distances according to PACER test (Table 2).

After analyzing the strength and endurance of the abdominal muscles, it is concluded that the results recorded in the group of 18-year-olds and men at the age of 15 years are at a similar level with a small advantage in the oldest group. The results obtained by 16- and 17-year-olds are also similar (16 years - 66.2; 17 years - 66.4). Studies have also shown that the smallest strength of ab-

Table 2. The differences of individual components of physical fitness in different age groups

Age		Physical Fitness						
		PACER Laps [n]	Curl Up [n]	Trunk Lift [cm]	Push Up [n]	Sit-and-reach R[cm]	Sit-and-reach L [cm]	VO2max
14 years (N=17)	*M*	68.5	57.7	23.6	20.9	24.2	23.8	54.7
	sd	17.6	21.7	6.9	7.6	4.3	3.9	4.7
	V	25.6	37.5	29.3	36.1	17.6	16.4	8.7
15 years (N=15)	*M*	84.7	70.5	22.1	22.6	29.8	28.6	59.1
	sd	19.8	9.6	3.7	6.5	6.4	7.6	5.4
	V	23.4	13.6	16.9	29	21.6	26.4	9.1
16 years (N=22)	*M*	92.5	66.2	22.9	26	28.7	28	61.3
	sd	17.9	18.1	8	13.4	7.7	7.6	4.8
	V	19.4	27.4	34.9	51.4	26.9	27	7.9
17 years (N=28)	*M*	89.4	66.4	24.1	26.4	30.6	30.9	60.4
	sd	20.6	16	6.7	7.7	4.9	5.1	5.6
	V	23	24.1	27.8	29	16	16.5	9.1
18 years (N=23)	*M*	93	71.2	27	27.7	31.7	31.3	61.5
	sd	20.9	10.3	5.1	8.9	5	5.4	5.7
	V	22.5	14.5	18.8	32.3	15.8	17.4	9.2
Test K-W	p	**0.0013**	0.2416	**0.0107**	0.0605	**0.0018**	**0.0015**	**0.001**

M – arithmetic average, *sd* – standard deviation, v – coefficient of variation [%]

Table 3. The differences of individual components of physical fitness in terms of quartile BMI groups

Age		Physical Fitness						
		PACER LAPS [n]	Curl Up [n]	Trunk Lift [cm]	Push Up [n]	Sit-and-reach R [cm]	Sit-and-reach L [cm]	VO2max
Q1 (N=28)	*M*	80.8	64.8	21.8	21.9	25.6	25.2	58.1
	sd	22.4	17.3	6.6	6.7	6.2	6	6.1
	V	27.8	26.8	30.1	30.6	24.3	24	10.5
Q2 (N=26)	*M*	95.8	66.7	23.9	25.6	30.4	30.4	62.2
	sd	18	18	5.3	9.4	5.7	6.1	4.9
	V	18.8	27	22.2	36.7	18.8	20.1	7.8
Q3 (N=25)	*M*	88.9	73.4	23.9	28	30.6	30.1	60.3
	sd	18.6	6.9	6.5	10.7	4.7	5.8	5.1
	V	21	9.4	27.1	38.2	15.3	19.3	8.4
Q4 (N=26)	*M*	82.1	61.9	26.9	25.5	31	30.3	58.5
	sd	21.9	17.7	6.8	10.1	6.4	6.4	5.9
	V	26.7	28.6	25.1	39.4	20.7	21.3	10.1
Test K-W	p	**0.027**	**0.025**	**0.0619**	0.134	**0.0063**	**0.007**	**0.027**

dominal muscles have men at the age of 14 years (M = 57.7). In this case, the greatest stability in terms of this parameter was noted among 15 year-olds (V = 13.6%). In the next stage of the research, results of the Trunk Lift test were analyzed as an assessment of back muscle strength. As is apparent from the figures contained in Table 2, the highest values of the test parameter again were presented by men at the age of 18 years (27.0 cm).

The results recorded in the other age groups are on similar levels with a small margin 17- year olds (24.1 cm). As in the case of distance, there was reported statistical significance between the strength of the spine muscles and the age of study group. Analyzing the value of the coefficient variation of the attempts results in the Push Up test, it is noted that the largest variety is characterized by a group of 16-year-olds (V = 51.4%). While the greatest stability in terms of the test parameter has been among 15 to 17-year olds. At the same time, it is noted that the youngest group recorded the weakest results of Push Up, and a group of 18-year-olds had marked the highest level of the test parameter (M = 27.7). In addition, a correlation between age of study group members and number of Push Up attempts (Tab. 2) has not been demonstrated. Research shows that the best test result of Sit-and-reach for the right and left leg were reported among 18-year-olds (right leg 31.7 cm; left leg 31.3 cm). Similar results, although slightly lower, were found in men about a year younger (30.6 cm; left 30.9 cm). The results of a similar level during the Sit-and-reach test for both legs were also noted in a group of 15-and 16-year-olds with a slight predominance of group at the age of 15 years. The average value of the Sit-and-reach test for the right and left legs was 29.8 cm and 28.6 cm among 15- olds and 28.7 cm and 28.0 cm in the test group at the age of 16 years. As is apparent from the figures included in Table 2, there is statistical significance between the age of the study group and the value of the Sit-and-reach test for both the right and the left leg (Tab. 2). The last analyzed parameter was VO_2max. As is apparent from the data contained in Table 2, average result of VO_2max in a group of 15-, 16-, 17-and 18 year olds are similar in value. The highest level of endurance was noted among the oldest test group (VO_2max = 61.5 ml/kg/min) and the lowest VO_2max was noted among a group of 14-year-olds (VO_2max = 54.7 ml/kg/min). In addition, it is noted that the biggest intra-group variations in terms of the test parameter represent the men at the age of 17 and 18 years of age. The greatest stability of VO_2max is observed among 16-year-olds. In addition, statistical significance was found between age of subjects and the value of the VO_2max (Tab. 2).

For further analysis, the study group was divided into four equal quartile parts. For the criterion of allocation, body mass index was taken into account, marking them appropriately Q1, Q2, Q3 and Q4. The Q1 group included persons with the lowest, while Q4 with the highest value index BMI. Analyzing the physical fitness of tested men, taking into consideration quartile BMI groups, it is concluded that the greatest amount of 20 meters distance recorded the study group belonging to the Q2 (M = 95.8). The second in order of the best result reached the men of the group Q3 (M = 88.9). The worst result recorded Q1 group at the level of 80.8. In this group was observed the largest diversity of intra-group in terms of the test parameter. In addition, the study showed that there is a statistically significant difference between groups of Q1 and Q2 (Tab. 3).

From the data contained in Table 3, it is also clear that the group belonging to the Q3 have the greatest strength of the abdominal muscles (M=73.4). Results in the remaining quatrain BMI group are at similar levels with a clear predominance of group from Q2, who recorded during the test result on the level of 66.7. During this test, the worst result reached group Q4 (M=61.9). At the same time the greatest stability in terms of the test parameter was noted in group Q3. Another analyzed sample was the Trunk Lift. As it is clear from the research results that Q2 and Q3 groups during the trunk raise attempts have adopted the same values (23.9 cm). The members of group Q1 reached a similar result - 21.8 cm, however, the best one was Q4, whose members reached the result at 26.9 cm. For each group of quartile BMI, there has been high coefficients of variation, but the biggest variation in intra-group is evident among Group Q1. In addition, between Q1 and Q4 there was statistical significance. Analyzing the test of Push Up, it is concluded that the biggest amount of repetitions were done by quatrain Group Q3 (M = 28.0). Results of Q4 groups (M = 25.0) and Q2 (M = 25.6) are on the same level with a slight predominance of study group Q2. The worst result during this attempt belonged to the men of the Group Q1 (M = 21.9). The biggest intra-group variations in terms of test parameter is observed in the Group Q4 (V= 39.4%). Further analysis showed that there is a statistically significant variation between Q1 and Q3 and Q4 during the Sit-and-reach test for the right and left legs. The results recorded in this test in group Q2 (M=30.4 cm), Q3 (M=30.6 cm) and Q4 (M=31.0 cm) adopt similar values, with a slight predominance of test group belonging to the Q4 Group. In this case, the largest intra-group variety is characterized by group Q1. A similar phenomenon has been observed during the Sit-and-reach test for the left leg. Also group Q1 was characterized with a great high coefficient of variation (V=24.0%). As with previous attempts, the results in groups Q2, Q3 and Q4 are on similar levels with a small margin of the group Q2 (M=30.4 cm). In addition, as is apparent from the figures contained in Table 3, recorded results showed statistical significance between Q1 and Q2, Q3 and Q4. The last parameter to be analyzed in terms of quartile groups BMI is VO_2max. The analysis show that the greatest stability in terms of the test parameter is characterized by group Q2, which recorded the lowest coefficient of variation (V=7.8%). The best VO_2max have the study group Q2 (VO_2max=62,2 ml/kg/min). The second best result was VO_2max at level of 60.3 ml/kg/min, which obtained the men from Group Q3. Statistical significance was noted only between groups of Q1 and Q2 (Table 3).

Discussion

Analysis of the research carried out indicates a systematic increase with age of somatic characteristics such as weight, body height, waist and hip circumference, which can be justified in the natural physical development of children in this age range. The average body weight and height and calculated on this basis BMI among tested boys in all age groups was between 50 and 75 centile according to growth chart, based on data representative for the population of children and youth in Poland, prepared within the framework of the OLAF project and centile charts developed by Dobosz.[20–23] The value of BMI among tested boys also point to the standard according to International Obesity Task Force.[24] Average waist and hip circumference among tested boys similar to BMI, was between 50 and 75 centile according to OLAF growth chart.[22] In the same centile range there were counted values calculated on the basis of the above measurements indicators WHR and WHTR both for Polish and Greek standards.[25,26] Analysis of Rohrer's indicator allows to pass the test group to those with slim body structure (classification according to Wanke). The percentage of body fat in all study groups of boys significantly deviates from the above classification. Referring to international standards (FAT% value in the study group) there are some with less than the 2 centile and this indicates at the same time less than the correct fat percentage in study group.[27,28] So low fat content in the body may be associated with high physical activity of group, who attended the school with sport profiles.

Taking into account the results obtained with the PACER test indicates a very good aerobic capacity of tested boys. According to the international standards for this test, average results obtained for 14 year olds are between 70 and 80 centile. The best results were reported in a group of 16 year olds and place them between 90 and 95 centile, other age groups ranged between 80 and 90 centile of the above standards.[29] Due to the lack of international or Polish standards relating to other physical fitness tests, the obtained results can only refer to the standards for the American population elaborated by Cooper Institute. The creators of the test to assess the physical fitness of study group refer the individual test results to the so called Healthy Fitness Zone (HFZ). According to this classification, the strength and endurance of the abdominal, back and shoulder griddle muscles and the flexibility of the surveyed boys are located in standard known as the HFZ.[30] Statistically significant differences in fitness between age groups, such as in somatic characteristics, one can explain by the process of physical development that can directly influence the results in fitness assays. Similar results were presented by Migasiewicz and Milanese who carried out an assessment of selected anthropometric characteristics and physical fitness in 152 children aged 6-12 years.[31,32] Also in the work of Mota et al., there was demonstrated a correlation between the status of sexual maturity and fitness on the basis of test covering 494 children aged 8-16 years.[33]

A linear correlation between body construction and fitness among the boys who regularly train team sports has not been demonstrated. In study group with the lowest value of BMI, there was found the weakest results from almost all fitness tests; the exception was Curl Up test, in which the weakest results were recorded in Q4 group and thus people with the highest BMI. The best results of the aerobic capacity reported in Q2 group, while the greatest strength of the abdominal muscles and the shoulder girdle in the Q3 group. These results seem to confirm the idea that not only the potential obesity, but also underweight can adversely affect physical performance. The lack of a linear relationship between BMI and cardiorespiratory fitness was also recorded in work by De Araujo et al, who tested 288 students aged 10 to 14 years old using the fitnessgram® test battery.[34] The lack of reliance between BMI and fitness was also noted in the work of Milanese et al. Authors of that work suggest that subcutaneous fat is a better predictor of physical fitness than BMI or waist circumference.[31] Also in work by Ortega et al., a correlation between waist circumference and the level of cardio respiratory fitness was shown.[35] Similar results were obtained Tomaszewski et al., who carried out an assessment of selected anthropometric characteristics and International Fitness Test among 308 boys at the age of 9 years. The results of their work have shown significant difference in body weight, waist circumference and the size of the body in groups of different physical fitness.[36]

Conclusions

Motor fitness of physically active adolescents tends to improve with the subjects age. There is no linear relationship between BMI and fitness among the boys who regularly train team sports, but both lower and higher BMI values seem to be connected with lower physical fitness.

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