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Original Article

Intercorrelation between adolescent' physical status and aerobic capacity level

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Abstract
Introduction. Insufficient level of schoolchildren physical fitness and physical health determines the relevance of studying of physical qualities development in relation to adolescents' body aerobic capacity. **Purpose**: to investigate the correlation between the components of physical state (physical development, fitness, physiological state) of adolescents and levels of aerobic capacity. **Methods**: Assessment of schoolchildren physical fitness; aerobic capacity determination step-ergometry method. Physical development assessment was carried out with the help of strength indexes, body mass index and Kettle's, Pignet's, Hirata's and Rohrer's indexes. Matejko's method was used to determine body composition. The functional state was estimated by using Robinson index, vital capacity index та strength indexes. State of cardiovascular system was discribed using haemodynamic indicators (cardiac output, stroke index, cardiac index, total peripheral resistance, specific peripheral resistance and functional blood circulation indices). Spectral heart rate analysis was performed on the basis of veloergometry results. The study involved 423 adolescents, 211 of them were females and 212 were males. **Results.** The relationship between body mass index, body fat, all body circumferences and aerobic capacity level in our experiment are directly proportional regardless gender and aerobic capacity level, but need to point our attention on the fact that VO_{2max} is directly proportional to absolute body fat and inversely proportional to body fat % for boys and positive correlations were found between absolute body fat, body fat % and VO_{2max} in girls. It was established that with the increase in the aerobic capacity level, the number of correlations with hemodynamics and functional status indicators of adolescents, both male and female, increases. Our studies have shown that with a decrease of physical performance level, the values of stress index, autonomic rhythm indicator, autonomic balance index, regulation process adequacy ratio increase, which reflects regulatory systems tension increase. In girls, with a decrease in physical performance level, the total heart rate spectrum power decreases, which indicates a decrease in the reserves of regulation. It should be noted that in young men, regardless of aerobic capacity level, heart rate variability indicies did not correlate with VO_{2max}. **Conclusions.** Physical development indicators, physical fitness, heart rate variability, hemodynamics of adolescents have certain pecularities due to both gender factors and their aerobic performance level. The obtained results can be used to develop differentiated approaches in physical education of students with different aerobic capacity levels.
Key words: physical fitness, physical development, aerobic capacity, adolescents.

Introduction

Aerobic and anaerobic organism capacity is considered as integral indicators of functional preparedness of person. There is scientifically based information on the relationship between human physical health and aerobic and anaerobic body capacity (Ekelund et al., 2001; Lemak et al., 2018; Biletskaya, et al., 2017; Diachenko-Bohun et al., 2019; Kashuba et al., 2021).

It is known that physical education classes, conducted according to general secondary education program, do not improve aerobic or anaerobic body capacity, as, in our opinion, the physical work dosage does not take into account individual functional capabilities of students (Omelyanenko, 2017).

Training-induced adaptations in aerobic fitness have been widely studied in adults (Mondal& Mishra, 2017), and another scientists have applied these and similar training programmes for young generation (Kashuba et al., 2017) and sportsmen (Shete et al., 2014; Pogodyna, 2017). It should be noted, the subject of the adaptation to aerobic loading of children and adolescents is controversial and than debatable (Landgraff et al., 2021; Sheridan et al., 2021; Wong et al., 2021). At the age of 8–10 years, the energy supply of muscular work is due to increased aerobic capacity (Rowlands et al., 1999). At the age of 12th a decrease in aerobic capacity took place, which is associated with the puberty period, as well as with an increase of anaerobic energy mechanisms (Armstrong&Welsman, 2019). Some scientists noted the largest increasing in aerobic capacity in boys aged 13–14 and girls aged 12–13 (Landgraff et al., 2021). According to other data, the obvious increasing of the absolute

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value of aerobic capacity is observed in boys aged 15–16 and stabilization – after 16 years, and in girls – after 14 years (Tomkinson, 2011). It can be partly explained by different training designs, which make comparisons between studies very problematic.

At the same time, the functional preparedness structure and the presence of all its components (regulatory, energetic and motor) are mandatory for all activity types. However, the role, significance of certain components, regulatory mechanisms perfection, functional properties and characteristics development level, as well as their combination and interdependence can be very specific for each specific activity type and different at certain stages of adaptation to it (Bassett & Howley, 2000; Wilmore & Costil, 2004; Gavrilova, 2015).

Thus, the establishment of correlations between aerobic capacity level and morpho-functional state indicators, cardiovascular system state and physical preparedness remains insufficiently studied.

Material & methods.

Participants

The study was conducted on the basis of Yamnytsya, Dzvynyach secondary schools of Ivano-Frankivsk region, secondary schools No 1, 18, 24, gymnasium No3, boarding lyceum for gifted children in rural areas, lyceum school No23 in Ivano-Frankivsk. 423 school students (male: 212, 50.12%, age: 13–16 years; female: 211, 49,88%; age: 12–15 years) were recruited for the study. Informed consent was obtained from all participants. The necessary sample size which would have adequate power was determined using Cochran formula (Thompson, 2012).

The division into experimental groups was carried out depending on the MAC value determined during veloergometry loading: adolescents with "high level" of aerobic capacity, adolescents with "moderate level" of aerobic capacity, adolescents with "low level" of aerobic capacity (Table 1).

Table 1. **Distribution of the studied contingent by aerobic capacity and age level**

Age, years	Aerobic capacity level						Total	
	high		moderate		low			
	♂	♀	♂	♀	♂	♀	♂	♀
12	–	28	–	22	–	6	–	56
13	15	10	27	22	11	12	53	44
14	10	11	32	25	9	13	51	49
15	9	5	38	31	12	26	59	62
16	7	–	20	–	22	–	49	–
Total	41	54	117	100	54	57	212	211

Task and apparatus

HRV assessment technology was performed using the CardioLab + electrocardiographic diagnostic complex, which meets the requirements of the working group of the European Society of Cardiology and the North American Community of Stimulation and Electrophysiology (European Heart Journal) (Task Force…, 1996).

Analysis of respiratory system functional state was performed using SpiroCom diagnostic complex (HAI-medic); blood pressure (BP) was measured by a mechanical tonometer Microlife BP AG 1–30, heart rate (HR) - using a Polar 800 RS heart rate monitor.

Anthropometric examination of studied contingent was performed with standard tools according to the generally accepted unified method described in (48, 56). Anthropometric methods included body length measurement (DT) using a height meter (Δ = ± 0.5 cm), body weight (VT) - electronic scales (Δ = ± 0.05 kg), chest girth was performed using a measuring tape (Δ = ± 0.5 mm) in two states: at maximum inspiration and at maximum exhalation; skinfolds were measured using a Lange® adipometer (Bloomington, Minnesota, MN, USA) with a precision of 0.2 mm, and a constant pressure of 10 g/mm^2, maximum hand grip strength was measured using a digital Takei Hand Grip Dynamometer (range 5–100 kg, precision of 100 g), through two attempts per every hand; maximum back strength was measured using a digital Takei Back and Leg Dynamometer, which has a measurement range from 20.0 to 300.0 kg and a precision of 0.5 kg.

Measurements

Based on somatometric, physiometric characteristics and body structure, a comprehensive assessment of physical development was made. Somatometric study included such indicators as body height (BH), body weight (BW), body circumferences and physical development indices: body mass index (BMI), Kettle's, Pignet's, Hirata's and Rohrer's indexes (Makarova, 2002). A three-component model was used to determine a body composition (Martirosov et al., 2006). For this purpose, the absolute and relative masses of skeletal, fat and muscle components were calculated using J. Matiegka's formula.

The functional state was estimated by using Robinson's index, which indicates myocardial coronary reserve, vital capacity index (VCI), which reflects respiratory system reserves and strength indexes (SI), determined by hand and posture dynamometer (Makarova, 2002).

The main hemodynamic parameters: cardiac output, total peripheral resistance (TPR) and specific peripheral resistance (SVR) and functional blood circulation indices were calculated. Baevsky adaptive capacity, stroke index (UI), cardiac index (SI) were also determined (Klabunde, 2012).

Spectral heart rate analysis was performed based on the evaluation of indicators: statistical (mode (Mo), mode amplitude (AMo), variational range or difference between the maximum and minimum cardio-intervals (MxDMn), standard deviation of all NN intervals (SDNN), square root of the mean of the squares of differences between adjacent NN intervals (RMSSD), percentage of differences between adjacent NN intervals that are greater than 50 ms (pNN50), stress index (SI), regulation process adequacy ratio (IARP), triangular index (HRV TI), autonomic rhythm indicator (ARI); autonomic balance index (IAB), centralization index (IC)); spectral (total power (TP); ultra low frequency (ULF); very low frequency (VLF); low frequency (LF); high frequency (HF) powers; normalised low frequency (LF_{norm}) and high frequency (HF_{norm}); low frequency to high frequency ratio (LF/HF) and geometric (width of the scatterogram (W), length of the scatterogram (L), length-to- width ratio (L/W), scatterogram square (S), histogram width at the 1% (WN_1) and 5% (WN_5) level of the total number of elements, histogram width at the 5% (WAM_5) and 10% (WAM_{10}) level of the mode amplitude) (Ardashev& Loskutov, 2011).

Aerobic body capacity was assessed using a functional test PWC_{170}, which was performed by veloergometry (Karpman, 1988), taking into account the recommendations for age-specific loads dosage, then calculated VO_{2max} ($ml \cdot min^{-1}$) value, which reflects the aerobic body performance.

The following test exercises were used to assess physical fitness: push-up test, pull-ur test, modified pull-up test (brockport) (female), straight arm-hang test, standing long jump test, 30 s sit-up test, sit -and-reach test (Sergienko, 2010). In order to level anthropometric indicators influence, the AF indices were determined: SIstraigh arm-hang - strength index on basis of straight arm-hang indicators; SIpush-up - strength index on basis of push-up test indicators; SIstanding long jump - strength index on basis of standing long jump test; SIpull-ur - force index on basis of pull-ur test indicators; SIsit-up test - strength index on basis of sit-up test (Lemak et al., 2018).

Data analysis

We examined the Pearson product-moment correlations between aerobic performance and morphofunctional state indicators, hemodynamics, heart rate variability and physical fitness. The magnitude of the correlations was defined according to the Hopkins's scale (Schober et al., 2018): trivial ($r < 0.1$); small (0.1–0.3); moderate (> 0.3–0.5); large (> 0.5–0.7); very large (> 0.7–0.9); nearly perfect (>0.9) and perfect (1). Statistical significance was set at $p \leq .05$. Totaly 94 indicators were correlated.

Results

Statistically significant correlations between aerobic capacity values and all morphometric parameters, except triceps, biceps, forearm, hand, thing, calf skinfolds and body fat (BF%) were found in male adolescents aged 13–16 years with a high level of aerobic capacity. (Fig. 1).

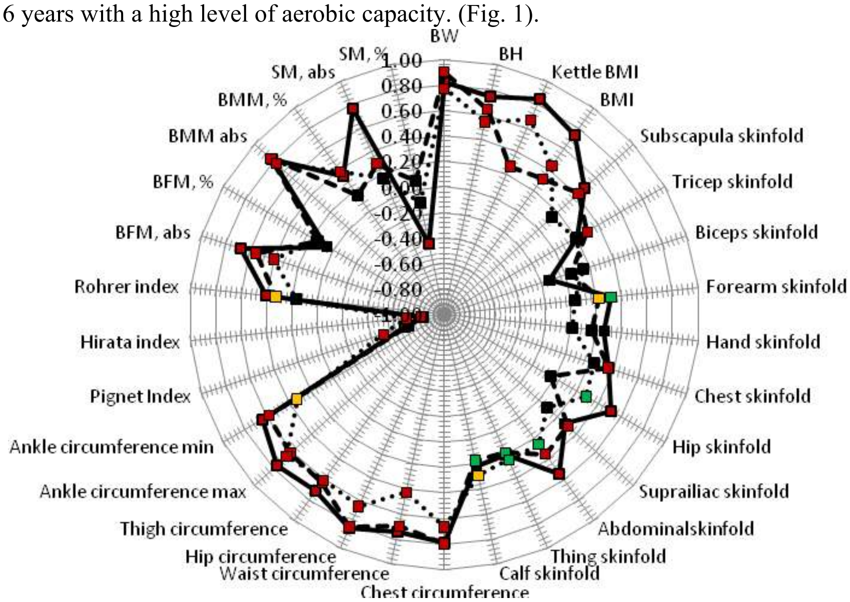

Figure 1. Correlations between aerobic capacity values and morphometric parameters in male adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – medium aerobic capacity; ..... – low aerobic capacity; ■ –p>0,10; ■ – p<0,10; ■ –p<0,05; ■ –p<0,01

In male adolescents with medium aerobic capacity, very large statistically significant correlations were found between aerobic capacity values and the following morphometric parameters: BW (r=0.902; p<0.01), chest circumference (r=0.803; p<0.01), hip circumference (r=0.822; p<0.01), waist circumference (r=0.700; p<0.01), Pignet's index (r=-0.714; p<0.01), Hirata's index (r=-0.819; p<0.01) and absolute muscle mass (BMM_{abs}) (r=0.828; p<0.01).

Statistically significant large correlations were established with BH (r=0.640; p<0.01), thigh circumference (r=0.630; p<0.01), ankle circumference (r_{max}=0.619; r_{min}=0.582; p<0.01) and absolute body fat (BF_{abs}) (r=0.550; p<0.01).

Statistically significant moderate correlations were seen with BMI (r=0.319; p<0.01), subscapula skinfold (r=0.420; p<0.01), chest skinfold (r=0.351; p<0.01), suprailiac skinfold (r=0.311; p<0.01), abdominal skinfold (r=0.348; p<0.01), skeletal mass (SM_{abs}) (r=0.303; p<0.01) and Rohrer's index (r=0.330; p<0.01).

Statistically significant small correlations were seen between aerobic capacity and triceps (r=0.30; p<0.01), forearm (r=0.223; p<0.05) skinfolds.

In male adolescents with low aerobic capacity statistically significant very large correlations were found between aerobic capacity values and the such morphometric parameters as BW (r=0.770; p<0.01), Hirata's index (r=-0.710; p<0.05) and BMM_{abs} (r=0.769; p<0.01).

Statistically significant large correlations were established between aerobic capacity values and BH (r=0.542; p<0.01), Kettel's BMI (r=0.670; p<0.01), chest circumference (r=0.670; p<0.01), hip circumference (r=0.651; p<0.01), thigh circumference (r=0.612; p<0.01), ankle circumference (r_{max}=0.660; r_{min}=0.332; p<0.01) and Pignet's index (r=-0.501; p<0.01).

Statistically significant moderate correlations were established between aerobic capacity та BMI (r=0.440; p<0.05), BF_{abs} (r=0.410; p<0.01), waist circumference (r=0.431; p<0.01), hip skinfold (r=0.291; p<0.05), calf skinfold (r=0.290; p<0.05).

To determine the relationship between physical fitness indicators and high aerobic capacity in male adolescents, the correlation coefficient of motor test results with aerobic capacity was also determined (Fig. 2).

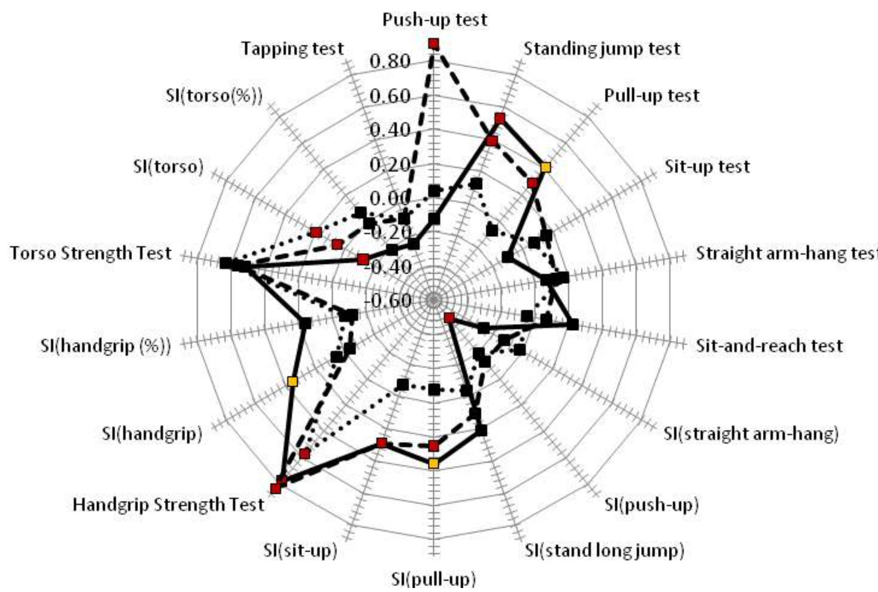

Figure 2. Correlations between aerobic capacity values and physical fitness indicators in male adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ –p<0.05; ■ –p<0.01

Thus, in male adolescents with a high aerobic capacity statistically significant very large and large correlations was found with maximum isometric strength of the hand and forearm muscles (handgrip dynamometry) (r=0.780; p<0.01), maximum isometric strength of the back (torso dynamometry) (r=0.522; p<0.01), explosive leg power indicators (r=0.530; p<0.01); moderate correlation was found with upper body strength and endurance (r=0.421; p<0.05), it's relevant indexes ($SI_{pull-up}$) (r=0.360; p<0.05), $SI_{push-up}$ (r=-0.461; p<0.01), relevant strength index ($SI_{handgrip}$) (r=0.350; p<0.05). At statistical tendency level were established correlations with strength index of the abdominal and hip flexor muscles (SI_{sit-up}) (r=0.330; p<0.05).

In male adolescents with moderate aerobic capacity statistically significant very large correlations were established with upper body strength and endurance indicators (r=0.901; p<0.01 (according push-up test) and r=0.304; p<0.01 (according to the pull-up test), $SI_{handgrip}$ (r=0.840; p<0.01); statistically significant moderate correlations were established with strength of a patients back (r=0.560; p< 0.01) and explosive leg power (r=0.392; p<0.01); small – with SI_{sit-up}) (r=0.290; p<0.01) and $SI_{pull-up}$ (r=0.253; p<0.01).

In male adolescents with low aerobic capacity statistically significant correlations were established with handgrip (r=0.570; p<0.01) and torso dynamometry (r=0.642; p<0.01) indicators.

As for functional state indicators, male adolescents aged 13–16 years with high aerobic capacity had significant correlations with such indicators as systolic blood pressure (SBP) (r=0.360; p<0.05), diastolic blood pressure (DBP). (r=0.441; p<0.01), vital capacity (r=0.523; p<0.01), vital capacity index (VCI) (r=-0.370; p<0.05), Bayevsky' adaptive capacity (r=0.361; p<0.05), cardiac output (r=-0.380; p<0.05), cardiac index (r=-0.610; p<0.01), stroke volume (r=-0.610; p<0.01), SVR (r=0.329; p< 0.05) and Martines test indicator (r=0.310; p<0.1) at statistical trend level (Fig. 3).

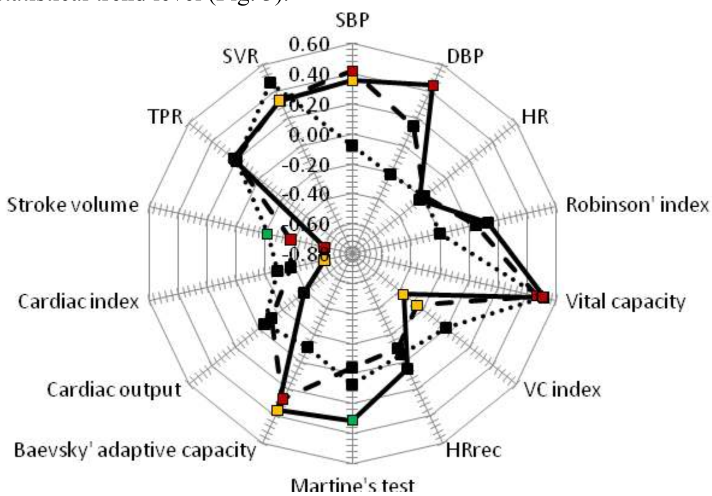

Figure 3. Correlation between aerobic capacity and functional state indicators of male adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ –p<0.05; ■ –p<0.01

In male adolescents with moderate aerobic capacity statistically significant correlations were established with SBP indicators (r=0.421; p<0.01), vital capacity (r=0.470; p<0.01), VCI (r=-0.250; p<0.05), Baevsky' adaptive capacity (r=0.282; p<0.05), cardiac index (r=-0.371; p<0.01), stroke volume (r=-0.380; p<0.01), TPR (r=0.212; p<0.05), SVR (r=0.330; p<0.01) and HR (r=-0.184; p<0.10) at statistical trend level.

In male adolescents aged 13-16 with low aerobic capacity statistically significant correlations were seen with vital capacity (r=0.510; p<0.01), SVR (r=0.472; p<0.01) and with cardiac index (r=-0.280; p<0.1) at statistical trend level.

There were also statistically significant correlations between aerobic capacity level and heart rate variability indicators (HRV) (Fig. 4).

In male adolescents aged 13–16 years with both high and low aerobic capacity, no significant correlations with HRV values were found, while in adolescents with medium aerobic capacity, significant correlations with such indicators as mRR (r=0.211; p<0.05), X_{min} (r=0.230; p<0.05) and at statistical trend level with Mo (r=0.183; p<0.10) were established.

We established statistically significant very large correlations in female adolescents with its high aerobic capacity with BW (r=0.930; p<0.01), Kettle BMI (r=0.911; p<0.01), thing circumference (r=0.910; p<0.01), ankle circumference (r=0.591–0.880; p<0.01), BH (r=0.858; p<0.01), BMI (r=0.801; p<0.01), BF_{abs} (r=0.744; p<0.01), BMM_{abs} (r=0.860; p<0.01) and SM_{abs} (r=0.732; p<0.01); large correlation with hip skinfold (r=0.720; p<0.01), abdominal skinfold (r=0.680; p<0.01), suprailiac skinfold (r=0.532; p<0.01), subscapula skinfold (r=0.520; p<0.01), triceps skinfold (r=0.521; p<0.01) and moderate correlation with forearm skinfold (r=0.312; p<0.05) and Rohrer's index (r=0.380; p<0.01) (Fig. 5).

In female adolescents with moderate aerobic capacity, statistically significant correlations were found between aerobic capacity indicators and morphometric parameters such as BW (r=0.920; p<0.01), Kettle's BMI (r=0.880; p<0.01), BMI (r=0.732; p<0.01), BMM_{abs} (r=0.840; p<0.01), BF_{abs} (r=0.712; p<0.01), SM_{abs} (r=0.610; p<0.01), BH (r=0.592; p<0.01); skinfolds: subscapula (r=0.419; p<0.01), triceps (r=0.490; p<0.01), biceps (r=0.401; p<0.01), hand (r=0.282; p<0.01), hip (r=0.403; p<0.01), suprailiac (r=0.300; p<0.01), abdominal (r=0.441; p<0.01), forearm (r=0.403; p<0.01), thing (r=0.390; p<0.01), calf (r=0.402; p<0.01); circumferences: waist (r=0.680; p<0.01), thing (r=0.909; p<0.01), ankle (r_{min}=0.460; r_{max}=0.632; p<0.01) and Rohrer's index (r=0.420; p<0.01).

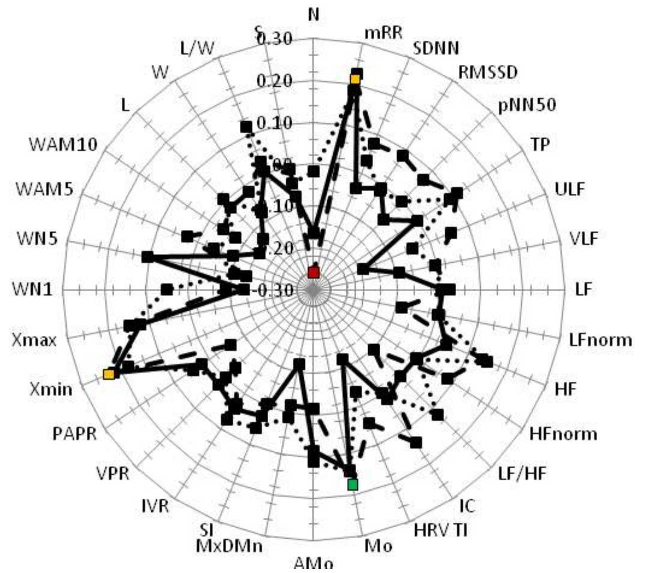

Figure 4. Correlation between aerobic capacity and HRV indicators of male adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ – p<0.05; ■ –p<0.01

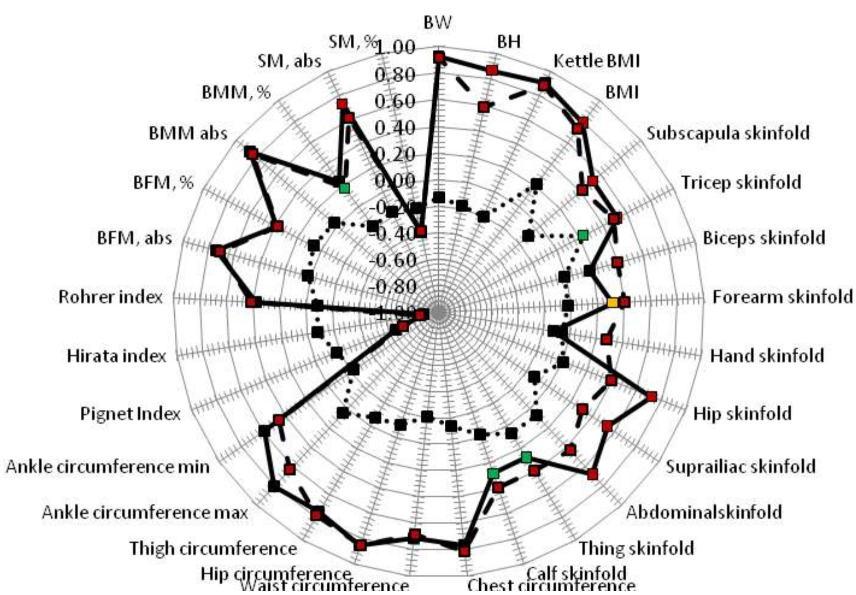

Figure 5. Correlation between aerobic capacity and morphometric indicators of female adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ –p<0.05; ■ –p<0.01

Statistically significant moderate negative correlations were found between aerobic capacity and Pignet's index (r=-0.710; p<0.01), Hirata's index (r=-0.851; p<0.01).

No statistically significant correlations with morphometric indicators were found in female adolescents with low aerobic capacity, except for triceps skinfold (r=0.230; p<0.10) and ankle circumference (r=-0.231; p<0.10) at the statistical trend level.

Thus, in female adolescents with a high aerobic capacity statistically significant correlations were seen with upper body strength and endurance indicators (r=-0.330; p<0.05) and relevant indexes $SI_{straight\ arm\text{-}hang}$ (r=-0.410; p<0.01), $SI_{pull\text{-}up}$ (r=-0.403; p<0.01), $SI_{sit\text{-}up}$ (r=-0.332; p<0.05), handgrip dynamometry (r=0.502; p<0.01) та torso dynamometry (r=0.350; p<0.05). At the statistical trend level correlations are found with upper body endurance (r=-0.290; p<0.10), tapping test (r=-0.251; p<0.10), $SI_{push\text{-}up}$ (r=-0.239; p<0.10), $SI_{stand\ long\ jump}$ (r=-0.250; p<0.10), SI_{torso}, % (r=-0.282; p<0.1) (Fig. 6).

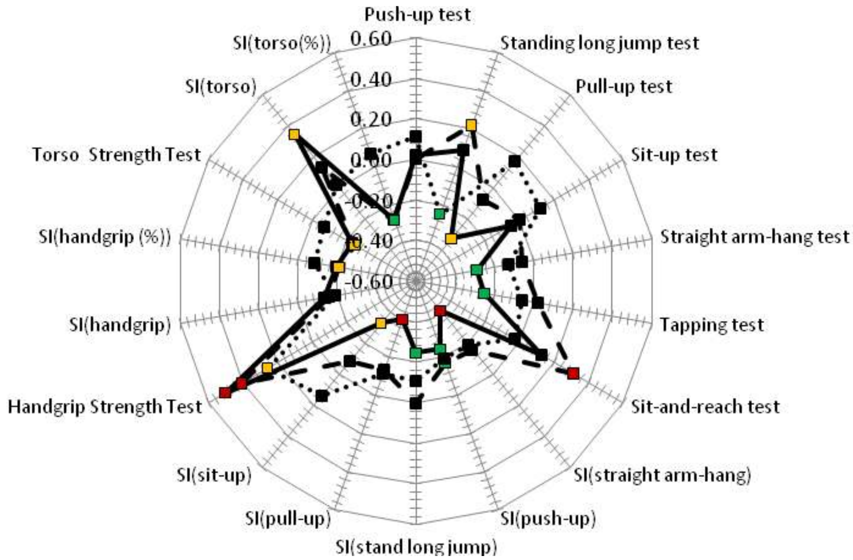

Figure 6. Correlations between aerobic capacity values and physical fitness indicators in female adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ –p<0.05; ■ –p<0.01

For female adolescents with moderate aerobic capacity statistically significant correlations was seen with explosive leg power indicators (r=0.220; p<0.05), flexibility (r=0.312; p<0.01), maximum isometric strength of the hand and forearm muscles (r=0.410; p<0.01), it's relevant index $SI_{handgrip}$ (r=-0.213; p<0.05) and maximum isometric strength of the back (r=-0.250; p<0.05) and it's relevant index SI_{torso} (r=-0.282; p<0.05).

For female adolescents with its low aerobic capacity, statistically significant correlations was found only with the indicator explosive leg power (r=-0.250; p<0.05) and maximum isometric strength of the back (r=0.261; p<0.10) at statistical trend level.

As for functional state indicators, in adolescents aged 12–15 years with high aerobic capacity there were found significant correlations with such indicators as SBP (r=0.302; p<0.05), vital capacity (r=0.590; p<0.01), VCI (r=-0.332; p<0.05), cardiac index (r=-0.430; p<0.01), stroke volume (r=-0.663; p<0.01), SVR (r=0.470; p<0.05) and Bayevsky adaptive capacity (r=0.272; p<0.07) at statistical trend level (Fig. 7).

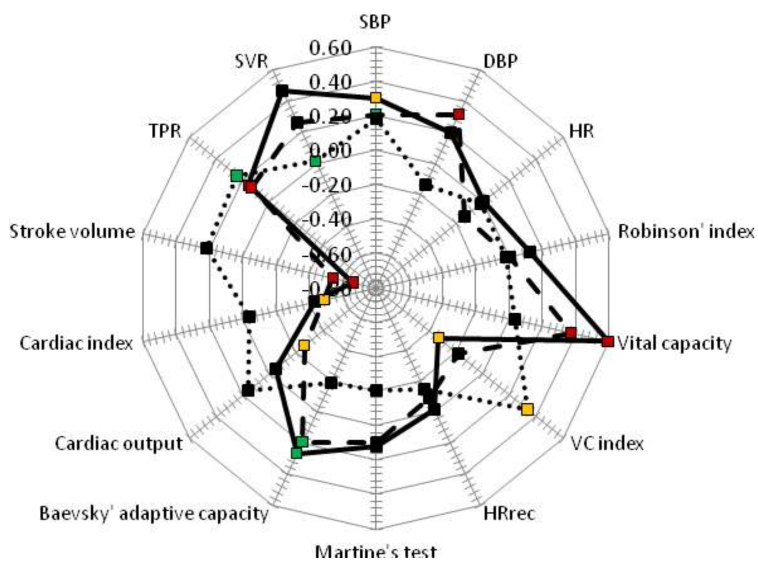

Figure 7. Correlation between aerobic capacity and functional state indicators of female adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ..... – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ –p<0.05; ■ –p<0.01

In female adolescents aged 12–15 years with moderate aerobic capacity, significant correlations were found with such indicators as DBP (r=0.320; p<0.01), vital capacity (r=0.373; p<0.01), cardiac output (r=-0.263; p<0.05), cardiac index (r=-0.488; p<0.01), stroke volume (r=-0.539; p<0.01), SVR (r=0.270; p<0.01) and VCI (r=-0.192; p<0.08), Bayevsky' adaptive capacity (r=0.203; p<0.06) at the level of statistical trend.

Female adolescents aged 12–15 years with low aerobic capacity were found significant correlations with such indicators as VCI (r=0.340; p<0.05), TPR (r=0.244; p<0.07) and stroke volume (r=0.223; p<0.10) at statistical trend level.

There were also found significant correlations between aerobic capacity level and heart rate variability indicators (HRV) (Fig. 8).

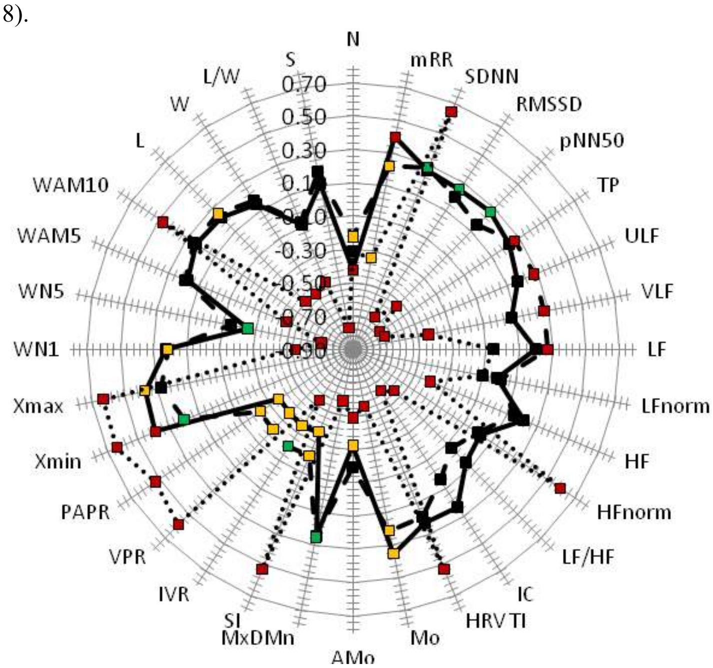

Figure 8. Correlation between aerobic capacity and SBP indicators of female adolescents: ▬▬ – high aerobic capacity; ▬ ▬ – moderate aerobic capacity; ….. – low aerobic capacity; ■ –p>0.10; ■ – p<0.10; ■ –p<0.05; ■ –p<0.01

In female adolescents aged 12–15 years with high aerobic capacity significant correlations were found with N (r=-0.422; p<0.01), mRR (r=0.402; p<0.01), Mo (r=0.350; p<0.02), AMo (r=-0.321; p<0.01), SI (r=-0.370; p<0.01), IVR (r=-0.352; p<0.02), VPR (r=-0.360; p<0.05), PAPR (r=-0.359; p<0.01), X_{min} (r=0.390; p<0.01), X_{max} (r=0.382; p<0.01).

At statistical trend level, correlations are found with such indicators as SDNN (r=0.270; p<0.08), RMSSD (r=0.251; p<0.09), pNN_{50} (r=0.270; p<0.07), WN_5 (r=-0.262; p<0.09).

In female adolescents aged 12–15 years with medium aerobic capacity significant correlations were found with N (r=-0.221; p<0.03), mRR (r=0.220; p<0.03), SDNN (r=0.280; p<0.01), TP (r=0.269; p<0.01), ULF (r=0.280; p<0.01), VLF (r=0.272; p<0.01), LF (r=0.270; p<0.01), Mo (r=0.213; p<0.04), MxDMn (r=0.250; p<0.02), SI (r=-0.212; p<0.05), VPR (r=-0.220; p<0.04), PAPR (r=-0.232; p<0.03), X_{max} (r=0.270; p<0.01), WN_1 (r=0.211; p<0.04), WAM_5 (r=0.250; p<0.02), WAM_{10} (r=0.249; p<0.02), L (r=0.248; p<0.02).

At statistical trend level, correlations are found with such indicators as RMSSD (r=0.202; p<0.06), HRV TI (r=0.192; p<0.08), AMo (r=-0.190; p<0.07), IVR (r=-0.200; p<0.06), X_{min} (r=0.201; p<0.06), S (r=0.180; p<0.08).

In female adolescents aged 12–15 years with low aerobic capacity, significant correlations were found with all BCP indicators excepr LF and LF_{norm}.

Discussion

Body composition and VO_{2max} are essential indicators of good physical fitness (de Andrade Goncalves, 2017). Early studies have shown that such components as muscle mass (Maciejczyk et al., 2014) and body fat (BF%) (Goran et al., 2000; Ekelund et al., 2001) are correlated with VO_{2max}, that was improved in our investigations regadless the gender. The relationship between body mass index (BMI), BMM_{abs}, BMM%, all body circumferences and VO_{2max} in our experiment are directly proportional regardless gender and aerobic capacity level that agreed with result obtained by another scientists (León-Ariza, Botero-Rosas, & ZeaRobles, 2017). Also similar results were found in a previous study of León-Ariza et al. (2017), which demonstrated that muscle mass exhibited a stronger positive correlation with VO_{2max} (r=0.61) and Mondal & Mishra (2017) where significant correlation between FFM and VO_{2max} was found only in the total sample (r=0.31). Similar results were also found by Minasian et al. (2014) reported stronger negative correlation coefficients (r=-0.58) for the girls and (r=-64) boys.

Need to point our attention on the fact that VO_{2max} is directly proportional to BFM_{abs} and inversely proportional to BFM% for boys and positive correlations were found between BFM_{abs}, BFM% and VO_{2max} in girls. This data agreed with results were only found in the study by Ara, Moreno, Leiva, Gutin, & Casajús (2007) (r=0.48) but in contrary to data de Andrade Goncalves et al. (2017) who found correlation coefficients between BFM% and VO_{2max} r=-0.45 for the girls and boys.

The mechanism of significant strong positive influence BFM_{abs} on VO_{2max} for the girls and boys is not yet clear. Chattarjee& Bandyopadhyay (2005) assumed that body fat helped to increase O_2 uptake capacity for its own aerobic metabolism. Fat has no augmenting action towards cardiorespiratory responses or towards muscle oxygen extraction capacity. However, adipose tissue starts to breakdown during exhaustive work to yield energy by oxidative metabolism and this demand of O_2 is association between body composition and cardiorespiratory fitness of adolescents fulfilled by a higher uptake of O_2 that is solely because of the fat. Therefore, fat might not be dead weight, rather it might have enough mobility to influence VO_{2max} (Landgraff et al., 2021).

Studies León-Ariza et al. (2017), Shete et al. (2014) shown no significant correlation between body fat percent and VO_{2max} (r=0.16; r=-0.10) that we noticed for boys and girls with low aerobic capacity.

We can make a conclusion that improvement in some body composition components such as the BMM and BFM% as result by the exercise can improve VO_{2max}.

We didn't find a significant correlation between HR and VO_{2max} nor for girls, nor for boys. This fact agrees with Armstrong&Welsman (2019), Dilenian (2016) and Rowland (2013) data. Moreover, they have been consistently reported VO_{2max} to be independent of age, body size, body composition, and sex during childhood and early adolescence. Rowland et al. (2000a; 2013), Wilmore&Costil (2004) proved that stroke volume is the only cardiovascular factor differentiating peak VO_2 in girls and boys. In our case we received the correlation in both girls and boys having high and medium levels of aerobic capacity. It should be noted that statistically significant correlations between these indicators in adolescents with low aerobic capacity were not found.

For both female and male adolescents with high and medium aerobic capacity levels, a direct correlations was established between VO2max and SBP and TPR with a decrease in stroke volume and cardiac index, indicating the economization of cardiac output at rest (Huang et al., 2020).

Unexpectedly, we have not found correlations between aerobic capacity level and HRV indicators for 13–16-year-old male adolescents, except mRR and x_{min} for adolescents with high levels. We have not found an explanation of this fact in the scientific literature.

Comparing with boys, girls presented significant correlations VO_{2max} with all time-domain and spectral HRV parameters, especially girls having low aerobic capacity.

In female adolescents with low aerobic capacity the heart rate variation parametres monitoring and spectral analysis of HRV showed signs of autonomic balance shift towards sympathicotonia, as evidenced by a decrease in mRR, MxDMn, TP, ULF, VLF, LF, HF and LF/HF with increasing indicators of SI, IAB, IARP, indicating of constantly expressed autonomic regulation tension. The group of adolescents with medium aerobic capacity significantly differed in spectral parameters and stress index values. Significant differences in the heart rate spectral components power indicators (TP, ULF, VLF, LF) were noted. Inverse correlations with SI, VPR, PAPR indicates a decrease in the autonomic regulation tension. In female adolescents with high aerobic capacity the last is inversely correlated only with indicators of heart rhythm regulation reserves (SI, IVR, VPR, PAPR). The obtained results correlate well with Lisovskiy & Sultanov data (2011), Sharma et al. (2015), Bosenko et al. (2017), according to which the heart rhythm structure changes more significantly in adolescents with an extended motor regime that is the extended regime accelerates circulatory system maturation and its regulatory mechanisms

These complementary findings indicate the need to account for genderas well as age-related differences in heart rate dynamics.

Conclusions

The relationship between body mass index (BMI), BMM_{abs}, BMM%, all body circumferences and VO_{2max} in our experiment are directly proportional regardless gender and aerobic capacity level, but need to point our attention on the fact that VO_{2max} is directly proportional to BFM_{abs} and inversely proportional to BFM% for boys and positive correlations were found between BFM_{abs}, BFM% and VO_{2max} in girls.

It has been established that with the aerobic capacity level increase, the number of correlative links with hemodynamics and functional state indicators of both female and male adolescents.

Our studies have shown that with a decrease in physical performance level, the values of SI, IVR, VPR, PAPR increase, which reflects regulatory systems tension increase. In girls, with a decrease in physical performance level, the total power of heart rate spectrum decreases, which indicates a decrease in regulation reserves. It should be noted that in male adolescents, regardless of physical performance level, HRV values did not correlate with VO_{2max}.

Conflict of Interest. The authors declare that there is no conflict of interest that could be perceived as interfering with publication of the article.

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