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Cross-scoring of cardiovascular and somatometric ratios at normal and elevated values in schoolchildren (15–17 years)

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The work was carried out on the basis of the Azerbaijan Medical University and secondary schools in Baku. Correlation of blood pressure (BP), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), myocardial indicator dispersion (MI), heart rhythm indicator (RI) with somatometric indexes - body mass index (BMI) in schoolchildren aged 15-17 are investigated; a combined change in blood pressure (BP) with a myocardial indicator (MI) is shown: Percentile tables were used. It has been established that the increased values of these indicators are mainly formed in overweight groups with selective distribution of the skin-fat layer (SFL) in certain areas of the body. Cross-correlation analysis of hemodynamic parameters (SBP, DBP, MI) with somatometric (BMI, SFL) revealed the presence of selective functional relationships between them and their increase with an increase in the values of the BMI and the SFL. Complex shifts of the analyzed indicators indicate the formation of cardiometabolic risk in schoolchildren.

Keywords: *Blood pressure (BP), myocardial indicator (MI), body mass index (BMI), skin-fat layer (SFL), correlation*

ABBREVIATIONS

MI – myocardial indicator
BP - blood pressure
SBP - systolic blood pressure
DBP - diastolic blood pressure
HR - heart rate
IR - rhythm index
BMI - body mass index
SFL - skin-fat layer
Elevat. – elevation

INTRODUCTION

In accordance with the theory of systemogenesis of functional systems (Anokhin, 1968; Sudakov, 2012) and principles of heterochronous development of the organism (Butrova, 2001; Dudnik et al., 2005; Sudakov, 2012) in the formation of functional systems, a growing organism, unequal growth rate of different systems and body structures of children and adolescents leads to their disproportionate development, reflected in the formation of neuroendocrine and neurochemical regulatory mechanisms (Babenko et al., 2019; Dedov, 2004). All this disrupts vital physiological processes, including various indicators of the cardiovascular system: blood pressure, blood supply to the heart, which are aggravated by overweight, adynamia, emotional stress, etc. (Arshavsky, 1982; Dedov, 2004; Beisbekova et al., 2017; Netrebenko, 2017; Suder, 2017; Babenko et al., 2019).

According to WHO, more than 200 million school-age children and adolescents in the world currently suffer from overweight, accompanied by a violation of the indicators of the cardiovascular system (BO3, 2012, 2018; WHO, 2018).

In this regard, comprehensive studies of various indicators, blood pressure (BP) and indicators of the myocardium (MI) were conducted for the first time in this work, which allows judging early dispersion disorders of myocardial blood supply

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that is, about "transient" ischemia on the background of somatometric measurements, within normal and overweight schoolchildren (15-17 years old) (Mammedov et al., 2015, 2017).

The main goal of this research is the study of cardiovascular and somatometric ratios at normal and elevated values in schoolchildren (15-17 years old).

MATERIALS AND METHODS

This investigation was carried out on the basis of the Azerbaijan Medical University and secondary schools in Baku. The research was conducted with a contingent of schoolchildren aged 15-17, of both sexes. Investigated such indicators of the functional state of the cardiovascular system as SBP, DBP (mm Hg), and HR (bpm). The level of blood pressure with a set of cuffs for children measured by N.S.Korotkov's tonometer was considered elevated if SBP or DBP was equal to or exceeded the value of the 90th percentile of the scale of distribution of indicators for a given age, gender, and height. Heart rate was assessed by counting the pulsation of the radial artery for 1 minute.

The myocardial indicator was also researched for changes in the dispersion of low-amplitude ECG oscillations reflecting early manifestations of "transient" myocardial ischemia. Wherein, if the dispersion index of the myocardial indicator was within MI≤14%, then it was evaluated as a norm, and at elevated values of MI> 14%, it testified to the formation of "transient" myocardial ischemia (Mammedov et al., 2017). At the same time, the rhythm indicator (IR) was calculated, which is due to the presence of arrhythmia on the ECG, indicating the emotional stress of the body. Dispersion assessment of MI and IR was carried out by a non-invasive method, according to ECG, on the analyzer "Cardiovisor - 06C".

Somatometric, anthropometric measurements were carried out according to the generally accepted methodology: the body length, and then the body weight were determined (Babenko et al., 2019; Beisbekova et al., 2017; Dudnik et al., 2005). The size of the skin-fat layer (SFL) was also recorded in various parts of the body (shoulder blades, abdomen, forearm, thigh).

The measurements were carried out non-invasively, with an electronic digital Caliper (KEC-100) with a measurement discreteness of 1 mm (Babenko et al., 2019; Gerasimchuk and Girsh, 2019).

The determination of the nutritional status was based on the study of the body mass index - BMI (kg/m^2).

The results obtained in the studies were subjected to statistical processing using variational (U-Mann-Whitney) and correlation (Rho-Spearman) methods of analysis on a statistical package SPSS-22 (Arbackle, 2012; Gapanovich-Kaidalov et al., 2020).

RESULTS AND DISCUSSION

Investigated indicators of blood pressure and myocardial indicator in the age group of 15-17-year-old schoolchildren. In general, it was found that out of the analyzed 125 boys, it was revealed that 31 (24.8%) had high blood pressure (BP). With a normal body mass index, an increase in blood pressure was noted in 14.4% of cases, i.e. out of 104 people, 15. With elevated values of the body mass index, elevated blood pressure occurs in 79.2%, i.e. 16 out of 21 people. As regards the 128 girls we researched, 39 of them in 30.5% of cases, at normal body mass index values, and elevated blood pressure was found in 23.8% of cases (out of 101 people in 24). At elevated values of the body mass index, increased blood pressure was registered in 55.56% of cases or in 15 out of 27 people.

In this way, among schoolchildren aged 15-17 years of both sexes, compared to the normal values of this indicator elevated blood pressure values were mainly registered with elevated body mass index values.

In addition, based on the dispersion analysis of low-amplitude ECG oscillations, by means of a "Cardiovisor", the myocardial indicator (MI) and the heart rhythm index (IR) were also determined (Fig., A, B).

Depending on the quantitative values of the dispersion indicators of the myocardial indicator (MI) in 15-17-year-old schoolchildren the portrait of the heart in figure 1 (A, B) shows the "color" changes: A is the variance of IM within ≤14% and green color prevails, which indicates a normal blood supply (while blood pressure is normal); B - dispersion of MI>14%, the green color decreased, and gray, yellow, and red increased, which indicates the formation of "transient" ischemia (with

increased blood pressure).In this case, as well, these changes were accompanied by an increase in the values of IR ≥40% (In normal IR≥20)%.

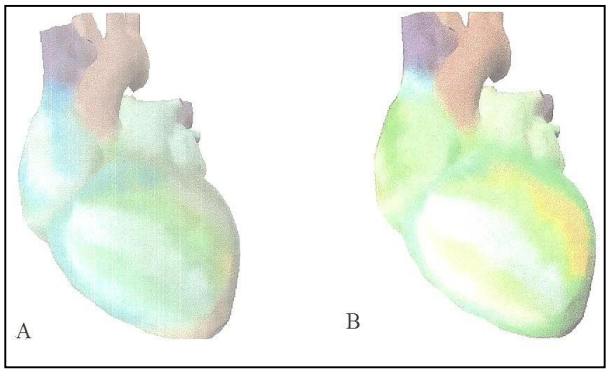

Fig. Comparison of heart portraits in children aged 15-17 in terms of MI.

At the same time, in our previous works, it was shown that (Mammadov et al., 2017) the increased values of MI(>14%) among boys with elevated blood pressure and BMI is 86.7% out of 31 people in 26, compared with 21.3% of cases (out of 94 people in 20) with increased MI, identified in the group with normal blood pressure values, as well as BMI (Table 1). Among 15-17-year-old schoolchildren of both sexes, statistically significant, combined and unidirectional changes in the values of MI with AT were revealed (in 80.7% of cases), mainly with elevated values (BMI, BP, MI).

As can be seen from Table 1, 15-17-year-old boys with overweight and elevated values of BMI, BP and MI, compared with the group with normal values, the indicators of IR, SBP, DBP and heart rate were respectively higher, specifically: 41.3%, 148.7+12.31 mm Hg, 97.7 mm Hg±3.17и 87.2 bpm±2.75. In girls, these changes were observed in the same percentage ratios and were higher in magnitude compared to normal indicators. Gender differences are shown in more detail in Table 1.

It is important to note that (Table 1) elevated values of BMI, BP and MI in boys, are accompanied by a selective increase in the values of the skin-fat layer (SFL) distributed over various parts of the body (shoulder blades-21.2±1.97, forearm-12.9±0.67, with the highest values of fat folds in the abdomen (26.8±1.88) and hip (28.8±2.52). In girls, due to gender characteristics, these indicators increase, respectively, reaching 24.6±1.92 and 31.8±1.31, and the adipose tissue in the area of the shoulder blades up to 26.9±2.38 they exceeding similar values in boys. The question arises whether are there and what are the functional relationships between hemodynamic and somatometric parameters?

Table 1. Values of SBP, DBP, heart rate, IR, as well as with SFL (shoulder blades, abdomen, forearm and hip) with normal and elevated BP, MI and BMI in schoolchildren aged 15-17 years of both sexes

BMI / Indicators	Normal body mass index (BMI)				Elevated body mass index (BMI)			
Gender differences	**Boys**		**Girls**		**Boys**		**Girls**	
BP, mm Hg	norm.	elevated	norm.	elevated	norm.	Elevated	norm.	elevated
Number of examined	n=89	n=15	n=77	n=24	n=5	n=16	n=12	n=15
MI, %	norm.	elevated	norm.	elevated	norm.	Elevated	norm.	elevated
Number of examined	n=72	n=12	n=59	n=19	n=2	n=14	n=5	n=13
Compatibility BP with MI, %	80.9	80.0	76.6	79.2	40.0	87.5	41.7	86.7
RI,%	≤26.2	≤27.0	≤26.4	≤28.1	≤35.7	≤41.3	≤36.3	≤44.7
SBP, mm. Hg	114.6±1.72	141.1±3.17***	110.7±1.03	137.5±1.03	116.2±2.64	148.7±2.31***	112.3±1.76	139.5±1.33
DBP, mm Hg	73.4±2.63	93.3±1.77***	71.7±1.22	81.6±2.23	78.1±2.36	97.7±3.16	68.6±0.94	85.8±2.67
HR, bpm	68.9±0.72	76.8±1.93***	74.9±1.01	86.8±2.11	70.8±1.54	87.2±2.75	69.7±2.04	84.2±2.58
SFL (mm) Shoulder blades	13.1±0.27	13.5±1.28	12.8±0.46	18.7±1.12	15.2±1.86	21.2±1.97*	22.3±1.17	26.9±2.38
Abdomen	13.5±0.34	24.4±1.56***	18.2±0.49	25.1±1.52***	19.1±1.47	26.8±1.88*	24.1±1.53	24.6±1.92
Forearm	5.4±0.28	8.3±0.66***	9.9±0.40	10.0±0.78	7.1±1.15	12.9±0.67***	12.2±0.87	12.4±1.18
Hip	16.9±0.42	19.1±1.84	22.1±0.67	27.0±1.47**	19.9±1.98	28.8±2.52*	31.1±2.49	31.8±1.31

Note: there are significant differences between indicators with normal or elevated BP and MI: *-p<0.05; **-p<0.01; ***-p<0.001.

Table 2. Correlation coefficients (R) of indicators SBP, DBP, MI and RI in relation to somatometric indicators (height, weight, BMI), and also SFL (shoulder blades, abdomen, forearm and hip), with normal and elevated values of BMI, BP and MI in 15-17 year-olds of both sexes.

			Boys							
			Indicators BMI, BP and MI, norma, n=72				Indicators BMI, BP and MI elevated, n=14			
			SBP	DBP	RI	MI	SBP	DBP	RI	MI
Spearman's rho	Height sm	R	0.180	0.166	0.044	0.112	0.278	0.201	-0.087	0.270
		Sig.	0.067	0.093	0.658	0.257	0.223	0.381	0.707	0.237
	Weight kq	R	0.514**	0.519**	0.485**	0.407**	0.569**	0.479*	0.091	0.431
		Sig.	0.000	0.000	0.000	0.000	0.007	0.028	0.696	0.051
	BMI Kq/sm^2	R	0.471**	0.468**	0.503**	0.348**	0.891**	0.705**	0.285	0.517*
		Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.210	0.016
	SFL: shoulder blades	R	0.511**	0.523**	0.518**	0.364**	0.712**	0.582**	0.314	0.546*
		Sig.	0.000	0.000	0.000	0.000	0.000	0.006	0.166	0.011
	Abdom.	R	0.534**	0.576**	0.506**	0.469**	0.620**	0.507*	0.164	0.480*
		Sig.	0.000	0.000	0.000	0.000	0.003	0.019	0.477	0.028
	Forearm	R	0.550**	0.558**	0.597**	0.376**	0.588**	0.481*	0.075	0.525*
		Sig.	0.000	0.000	0.000	0.000	0.005	0.027	0.747	0.015
	Hip	R	0.359**	0.400**	0.483**	0.545**	0.461*	0.338	-0.118	0.306
		Sig.	0.000	0.000	0.000	0.000	0.035	0.134	0.611	0.178
			Girls							
			Indicators BMI, BP and MI, norma, n=103				Indicators BMI, BP and MI elevated, n=14			
			SBP	DBP	RI	MI	SBP	DBP	RI	MI
Spearman's rho	Height sm	R	0.302**	0.293**	0.187	0.223*	0.240	0.216	0.010	0.162
		Sig.	0.002	0.003	0.061	0.025	0.227	0.279	0.962	0.419
	Weight kq	R	0.517**	0.493**	0.470**	0.409**	0.703**	0.656**	0.402*	0.582**
		Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.001
	BMI Kq/sm^2	R	0.545**	0.516**	0.534**	0.453**	0.867**	0.821**	0.570**	0.759**
		Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
	SFL: Should. blades	R	0.530**	0.508**	0.409**	0.563**	0.605**	0.563**	0.662**	0.695**
		Sig.	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
	Abdom.	R	0.463**	0.445**	0.426**	0.535**	0.562**	0.505**	0.712**	0.635**
		Sig.	0.000	0.000	0.000	0.000	0.002	0.007	0.000	0.000
	Forearm	R	0.557**	0.546**	0.544**	0.568**	0.399*	0.321	0.539**	0.500**
		Sig.	0.000	0.000	0.000	0.000	0.039	0.103	0.004	0.008
	Hip	R	0.363**	0.324**	0.397**	0.462**	0.453*	0.348	0.603**	0.507**
		Sig.	0.000	0.001	0.000	0.000	0.018	0.075	0.001	0.007

Note: R - correlation coefficient by Spearman.
Sig. - statistical significance of the correlation coefficient: * - $p<0.05$; ** - $p<0.01$;

The results of the cross-correlation analysis showed, how functional connections between the analyzed structures change with changes in weight and redistribution of adipose tissue in different parts of the body (Table 2).

Increases in cross-correlation coefficients, (R) between hemodynamic parameters (SBP, DBP, MI) and weight indicators, BMI, and also distribution of the thickness of the skin-fat layer (SFL) in various parts of the body (shoulder blades, abdomen, forearm, and thigh)against the background of increased values of the latter, indicate an increased influence of somatometric indicators on the increase in blood pressure(BP) and"transient" ischemia is assessed by the myocardial indicator (MI). At the same time, in girls, the increase in cross-correlation coefficients is more significant than in boys.

All this may be related to the gender characteristics of girls in this period of development. It was further revealed that cross-correlation relationships of weight values, BMI and SFL with hemodynamic parameters (SBP, DBP, MI), increased and were higher than the links with height and IR indicators, which also confirms the greater dependence of increases in blood pressure and MI on the increase in body weight and the distribution of the

skin-fat layer in it. It is known that these changes stimulate an increase in the level of cortisol and catecholamines, which in turn leads to an increase in BP and MI (Dedov, 2004; Babenko et al., 2019).

Summarizing the results obtained in groups of 15-17-year-old schoolchildren of both sexes, we note that, symbiosis of elevated comorbid parameters and features of changes having common pathogenetic bases, evidence of the formation of cardiometabolic risk in schoolchildren during the period of growth and development (Butrova, 2001; Bekasbekova et al., 2017; Babenko et al., 2019).

CONCLUSIONS

1. A high combination of unidirectional changes in BP values with MI values was revealed.
2. Overweight and high BMI, hemodynamic parameters of BP, (SBP, DBP) and IR, MI were elevated compared with the group with normal weight and BMI. At the same time, the result also depended on the selective redistribution of the thickness of the SFL in individual parts of the body.
3. The increase in cross-correlation coefficients of the functional relationship between hemodynamic and somatometric parameters is accompanied by increases in BP and MI. All of this testifies to the complex effect of somatometric indicators on increases in blood pressure and ischemic manifestations of the myocardium.
4. In accordance with the theory of the functional systems of the body, the process of teaching schoolchildren aged 15-17 is accompanied by an increased “physiological price”, considered a cardiometabolic risk in achieving the final beneficial result.

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Məktəblilərin (15-17 yaş) normal və yüksəlmiş ürək-damar və somatometrik göstəricilərinin krosskorrelyasiya əlaqələrinin tədqiqi

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İş Azərbaycan Tibb Universitetinin və Bakı şəhər orta təhsil məktəblərinin bazasında görülüb. Tədqiqatlar, 15-17 yaşlarında olan məktəblilərin sistolik arterial təzyiqi (SAT), diastolic arterial təzyiqi (DAT), miokard indikatorun (Mİ) dispersiyası və ürəyin ritm indeksi (Rİ) göstəriciləri ilə somatometrik göstəriciləri (bədən kütləsi-BK, bədən kütləsi indeksi-BKİ, Dəri Piy Qatının –DPQ qalınlığı) əlaqələrin tədqiqi aparılmışdır. Müəyyən olunmuşdur ki, BKİ normal olan 104 nəfərdən, yalnız 15-də, (14.4%) arterial təzyiqin (AT) yüksəlməsi qeydə alınmışdır. Lakin BKİ yüksək olan 21 nəfərdən isə, 16-da (79.2%) AT yüksək olmuşdur və risk qrupunu təşkil etmişdir. Ilk dəfə olaraq arterial təzyiqlə (AT) və Mİ dispersiyasının eyni vaxtda birgə tədqiqi aparılmışdır. Göstərilmişdir ki, bu göstəricilərin dəyişikliyi bir biri ilə əlaqəli və eyni istiqamətli olmuşdur. Müəyyən olunmuşdur ki, tədqiq olunan ürək-damar sistemi göstəricilərin yüksəlməsi əsasən artıq bədən kütləsi olan qruplarda və onların DPQ qalınlığının bədənin ayrı-ayrı nahiyyələrində müxtəlif olaraq paylanması ilə əlaqədardır. Kardiogöstəricilər və somatometrik göstəriciləri ilə aparılan krosskorrelyasiya təhlili əsasında aşkarlanmışdır ki, onların arasında seçici funksional əlaqələri mövcuddur və bu isə somatometrik göstəricilərin kəmiyyətcə artması ilə əlaqəlidir. Beləliklə, somatometrik komponentlərin krosskorrelyasiya təsirinin artması kardiogöstəricilərin yüksəlməsinə gətirib çıxarır. Təhlil olunan kompleks göstəricilərin artması, kardiometabolik riskin formalaşmasını göstərir və həmin qrup məktəblilərdə tədris prosesinin yüksək fizioloji dəyər hesabına başa gəlməsini göstərir.

Açar sözlər: *Arterial təzyiq (AT), miokard indikatoru (MI), bədən kütləsi indeksi (BKI), dərialti piy qatı (DPQ), korrelyasiya*

Кросскорреляционные исследования сердечно-сосудистых и соматометрических соотношений при нормальных и повышенных их значениях у школьников (15-17 лет)

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Работа выполнена на базах Азербайджанского Медицинского Университета и средних школ г. Баку.
Исследованы взаимоотношения систолического артериального давления (САД), диастолического артериального давления (ДАД), дисперсий индикатора миокарда (ИМ), индикатора ритма (ИР) сердца с соматометрическими показателями, с индексом массы тела (ИМТ) и распределением кожно-жирового слоя (КЖС) на отдельных частях тела у школьников 15-17 лет. Выявлено, что при нормальном ИМТ, повышение АД было отмечено в 14.4% случаев, т.е. у 15 из 104 человек. При повышенных значениях ИМТ, АД увеличивается в 79.2% случаях, т.е. у 16 из 21 человек этот показатель был выше нормы и составлял группу риска. Впервые проведены одновременные исследования артериального давления (АД) с дисперсией ИМ. Показаны сочетанные, однонаправленные изменения этих показателей. Установлено, что повышенные значения указанных показателей, в основном формируются в группах с избыточном весом и в связи с избирательным распределением величин кожно-жирового слоя (КЖС) на отдельных участках тела. Кросскорреляционный анализ, кардиопоказателей (САД, ДАД, ИМ) с соматометрическими (ИМТ, КЖС) показателями выявил наличие между ними избирательных функциональных связей и их увеличение при повышении значений ИМТ, КЖС. Таким образом, эти данные свидетельствуют о возрастании кросскорреляционного влияния соматометрических компонентов на формирование повышенных значений кардиопоказателей. Комплексные сдвиги анализируемых показателей и их увеличение указывают на формирование кардиометаболического риска, рассматриваемого, как повышение «физиологической цены» учебного процесса у школьников.

Ключевые слова: *Артериальное давление (АД), индикатор миокарда (ИМ), индекс массы тела (ИМТ), кожно-жировой слой (КЖС), корреляция*