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CHARACTERIZATION OF BIOCHEMICAL HEALTH MARKERS DURING ATHLETIC ACTIVITY IN PUBERTY

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Abstract

Over the past half-century, there has been a steady decrease in the age at which athletes begin to achieve rapid success in competitive sports. Aged-related changes occur in metabolism and its regulation during puberty. To fully understand age-related performance in competitive sports, researchers must study gender-dependent metabolic characteristics of athletes during puberty. The aim of this work was a comparative analysis of metabolic markers in athletes during puberty. The study population included 430 female adolescents (54 - control group, 376 - athletes) and 900 male adolescents (144 - control group, 756 - athletes). Blood serum was collected from the study population, and 24 biochemical markers and 7 coefficients for metabolic characteristics were assessed. The article presents data on constant and variable biochemical biomarkers of blood serum of adolescents of both sexes at puberty. Three categories of biochemical health markers were assessed. To assess the course of puberty without regular physical exertion and during sports, the following biochemical markers should be determined: the first group (independent of gender)- two markers (atherogenic index and Glucose / HDL cholesterol coefficient); the second group (during puberty in males) is the glucose level; the third group (during puberty in females) - 6 markers (the content of triglycerides, calcium, potassium, the value of TIBC, CPK activity and CPK / ALP coefficient). Conclusions: Changes in these markers can indicate negative effects on the most important biochemical and physiological processes in puberty.

INTRODUCTION

Currently, many pediatric laboratory tests are misinterpreted because control intervals are used that are obtained from an adult population, from hospitalized pediatric populations, or obsolete and/or inaccurate technologies. For the development of modern reference intervals for the pubertal period of life, data from 6 international projects are used (Jones & Koetsier, 2014, Tahmasebi et al., 2017): AACB (Australasian Association of Clinical Biochemists, Australia and New Zealand) - Common blood analytes (mostly ions and enzymes), all age groups; CALIPER (Canadian Laboratory Initiative on Paediatric Reference Intervals, Canada) - Common biochemical markers, endocrine markers, tumor markers, vitamins, metabolic disease biomarkers, testosterone indices, age range 0-18;CHILDx (Children's Health Improvement through Laboratory Diagnostics, United States) - Enzymes, coagulation tests, hormones, vitamins, bone markers, age range 0.5-17; COPENHAGEN (The Copenhagen Puberty Study, Denmark) - common blood analytes, age range 5-20; KiGGS (German Health Interview and Examination Survey for Children and Adolescents, Germany) - Nutrient deficiency markers, non-communicable diseases and lipids Immunology markers, thyroid hormone, age range 0-18; LOOK (Lifestyle of Our Kids, Australia) - Cardiac biomarker, common blood analytes, age of examined 8, 10 and 12. In the multicenter European Helena-CSS study (The Healthy Lifestyle by Nutrition in Adolescence Cross-Sectional Study), a study of 3528 adolescents 12.5-17.5

years old in 10 cities of 9 European countries studied cardiometabolic risk. As a result of the studies, it was concluded that physical activity is the most significant way to protect adolescents from cardiometabolic pathology (Castro-Pinero et al., 2019).

Puberty is the process of changes in the body of a teenager, as a result of which he becomes an adult and capable of procreation. Puberty has been defined to begin in girls aged 10-12 and end when the girls reach 15-16 years. In boys, puberty begins from ages 12-14 and ends when boys reach 17-18 years (Negriff & Susman, 2011). In this period, the increase in body weight for male adolescents averages 35 kg with annual growth fluctuations from 6 kg to 12.5 kg, and for female adolescents - 25 kg with annual growth fluctuations from 5.5 kg to 10.5 kg. In the period of puberty, an increase in body length in boys is on average 36 cm with annual fluctuations from 7 cm to 12 cm and slows down by 14 years, and in girls 2 years earlier (growth by 24.5 cm with annual fluctuations from 6 cm to 10.5 cm). However, a plateau of muscle growth and strength occurs in boys about 2 years earlier compared to girls. Exercise accelerates the formation of the musculoskeletal system and can contribute to an increase in lean body mass. It is believed that by the age of 12, most children are physically and cognitively able to solve complex problems that arise when practicing various sports and participating in competitions (Brown K.A. et al., 2017, Julian-Almarcegui. et al., 2015).

Biochemical analysis shows that, during puberty, serum levels of creatinine, total cholesterol, high-density lipoprotein cholesterol, triglycerides, uric acid, urea, and bilirubin increase. In addition, during puberty, there is a decrease in the levels of alkaline phosphatase, lactate dehydrogenase, aspartate aminotransferase and calcium (Adeli et al., 2015).

Less influence is given to biochemical biomarkers that are maintained during puberty, as well as during sports in this age period, at a constant level. In our opinion, the study of such markers is relevant, since the emergence of quantitative age-related dynamics of them may indicate impaired vital metabolic processes in the adolescent during puberty. The aim of this work was a comparative analysis of metabolic markers in athletes during puberty.

MATERIALS AND METHODS

Under the approval of the ethics committee of Vitebsk State University (EC-20.1), a non-personalized (depersonalized) database was created and analyzed, including age, gender, body mass index, sports qualifications and 24 biochemical markers of blood serum. The material was collected during 2011-2019 when examining groups of male and female adolescents according to the program of measures adopted at the Vitebsk Regional Sports Medicine Dispensary (Republic of Belarus). Written consent for the research conducted by children and adolescents was given by parents. Parents/guardians / legal representatives were notified that adolescents participated in the study and did not object to the results of the study being published. All subjects were part of organized groups and examined in the presence of a trainer and doctor and donated blood voluntarily. The study was carried out following the Helsinki declaration of the World Medical Association “Ethical principles for conducting medical research involving a person as a subject” (1964, as amended 1975-2008), taking into account international norms and standards, as well as the Law of the Republic of Belarus “On Health Care” "Dated 06/18/1993, No. 2435-XII, article 46.

In this study 4 groups of female adolescents were observed:girls aged7-11 years old, 12-15 years old, 16-18 years old and 19-20 years old. In addition, 3 groups of male adolescents were observed:boys aged 12-15 years old, 16-18 years old and 19-20 years old. In each of the 7 groups, 2 subgroups were distinguished. The first control subgroup was comprised of people who began to engage in sports but did not receive sports qualifications. The second subgroup included people who received sports qualifications as a result of systematic participation in sports activities. Therefore, criteria for inclusion in the control group included participation in physical exercise which did not lead to sports qualifications. This selection principle reduces the degree of difference with regards to the level of consistent physical activity of examined individuals in a random sample. Besides, this selection principle allowed for the establishment of adequate control groups. This study included 430 female adolescents (54 - control group, 376 - athletes) and 900 male adolescents (144 - control group, 756 - athletes).

Biochemical studies of blood serum of adolescents were carried out based on a certified laboratory of the Vitebsk Regional Diagnostic Center according to the methods described previously (Chirkin A.A. et al., 2019). We used reagent kits from BioSystems S.A. (Spain) developed according to the standards recommended by IFCC following IVD Directive 98/79 EC and ISO 9001/13485 and Biochemical automatic analyzer Mindray BS-200 (China). In the links to each biochemical test, the principle of the determination method is indicated, which is used by the corresponding set of BioSestems S.A.

All examined individuals were evaluated for body mass index (BMI). The content of glucose (Trinder, 1969), total protein (Gornall et al., 1949), total and direct bilirubin (Thaler et al., 2008), albumin (Doumas et al., 1971), uric acid (Sanders et al., 1980), potassium (Tietz, 1986) urea (Taylor &Vadgama, 1992), creatinine (Bartels &Böhmer, 1971), total cholesterol (Allain et al., 1974), high-density lipoprotein cholesterol (Warnick et al., 2001), triglycerides (Fossati&Prencipe, 1982), low-density lipoprotein (Nauck et al., 2002), total iron-binding capacity(Kaplan et al., 1996), iron (Artiss et al., 1981), calcium (Michaylova&Ilkova, 1971), activity of alanine aminotransferase and aspartate aminotransferase (Bergmeyer&Horder, 1986; Bergmeyer et al., 1986), alkaline phosphatase (Tietz et al., 1983), total

alpha amylase (Foo & Bais, 1998), gamma glutamyl transferase (Shaw et al., 2002), and total creatine kinase (Schumann et al., 2002), were determined in the blood serum of adolescents.

The content of glucose, urea, total cholesterol (TC), high density lipoprotein cholesterol (HDL cholesterol), triglycerides, low density lipoproteins (LDL), calcium, potassium was expressed in mmol/L. The content of total bilirubin, direct bilirubin, uric acid, creatinine, iron, total iron-binding activity (TIBC) were expressed in μmol/L, the content of total protein, albumin and globulins were expressed in g/L. The activity of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), creatine phosphokinase (CPK), alpha-amylase, and gamma-glutamyl transferase (GGT) were expressed in IU/L. The atherogenic index (TC – HDL cholesterol) / HDL cholesterol), the albumin/globulin coefficient (A/G), AST/ALT, CPK/AST, glucose/TC(Glu/TC), glucose/HDL cholesterol (Glu/HDL cholesterol), CPK/ALP, glucose/LDL (Glu/LDL) were expressed in arbitrary units, since the numerator and denominator of the ratios had the same dimensions (g/L, IU/L, mmol/L).

Statistical processing of digital material was carried out using nonparametric statistical analysis (Statistica 10.0, StatSoftinc.). Multiple group comparisons were performed using the Kruskal-Wallis test. If differences were detected between groups, then the pairwise comparison of groups was performed using the Mann-Whitney U-test. The differences were considered statistically significant at $p < 0.05$, with a pairwise comparison, and the Bonferroni correction ($p < 0.01$) was taken into account. The results are presented in tables in the form of the median and percentiles (Me (25% - 75%)).

RESULTS

When analyzing the results of the examination of male adolescents in the control subgroups, 4 variants of changes in biochemical markers important for the pubertal period were established (Table 1).

1. In the age group of 12-15 years old, the lowest values of the following indicators were identified: BMI, urea, creatinine, total bilirubin, total protein, globulins, TC, HDL cholesterol, triglycerides, ALT, AST, CPK, GGT, potassium, as well as the values relations CPK/AST, CPK/ALP, Glu/LDL ratios. It can be assumed that these biochemical markers indicate insufficient maturity and / or a physiological strain on important metabolic parameters, which should increase during subsequent ontogenesis.

2. In this regard, the highest values of indicators were identified in the16-18-year-old age group. These indicators were urea, total bilirubin, triglycerides, LDL, ALT, AST, ALP, TIBC, potassium, Glu/TC, Glu/LDL ratios. These are biochemical markers of puberty's end. After 16 tests using the control subgroup with reduced data, 11 indicators increased by the end of puberty.

3. The highest indicators were identified in the 19-20-year-old age group. These indicators are BMI, creatinine, total protein, total cholesterol, HDL cholesterol, LDL, atherogenicity index, activity of CPK, alpha amylases, GGT, and CPK/AST and CPK/ALP ratios. These indicators are present in adult males.

4. We next assessed indicators that should be expected to decrease during puberty. The highest indicators in the 12-15-year-old age group were analyzed. These indicators are content of glucose, uric acid, albumin, LDL, iron and coefficients A/G, AST/ALT, Glu/HDL cholesterol. These are biochemical markers of metabolic dysregulation upon the onset of puberty.

Athletes of the 12- to 15-year-old age group have statistically significantly increased BMI, urea, globulins, triglycerides, potassium, the activity of AST, alpha-amylase, GGT and AST/ALT ratios, as well as decreased albumin, calcium, TIBC and A/G, CPK/AST ratios. Compared with the control subgroup, 8 biochemical parameters increased and 5 decreased. It has been established that 12-15-year-old athletes have similar metabolic parameters for these indicators compared to adolescents in the control subgroup representing subjects who are 16-18 years old. These indicators are the content of urea, globulins, triglycerides, potassium, the activity of AST, GGT and the value of coefficient A/G. This leads to the conclusion that, in athletes, metabolic processes during early puberty are restored faster than the control group. However, an increase in alpha-amylase activity and AST/ALT ratio and decrease in TIBC and a CPK/AST ratio, may indicate signs of amylolytic decomposition of carbohydrates, iron transport and excessive release of AST from the muscle tissue. This effect is probably due to a decrease in the stability of muscle cell membranes.

In 16-18 year- old athletes, the content of urea, uric acid and serum iron increased compared to the control subgroup. The activity of ALT, AST, alkaline phosphatase, CPK and the ratio of CPK/AST decreased. 8biochemical indicators differed between the subject groups.3of these indicators increased and 5 decreased. The following changes were observed in the group of 19- to 20-year-old athletes, the end of puberty. During this age range, only three statistically significant differences were observed in the following biochemical parameters: serum iron content increased and creatine phosphokinase activity and CPK/AST both decreased. Age-dependent biochemical markers in female subjects are presented in Table. 2. Since puberty begins about 1-2 years earlier in girls than in boys, the table shows the data obtained in girls aged 7-11 years.

In 7- to 11-year-old girls, the control group showed lower values of the following biomarkers compared to athletes: the content of urea, globulins, total cholesterol, triglycerides, potassium, the activity of ALT, AST, alpha-

Table 1. The dependence of the values of biochemical markers on the age of the examined male

Indicators	SubjectAge					
	12-15 yearsold		16-18 yearsold		19-20yearsold	
	Control	Sport	Control	Sport	Control	Sport
BMI	19,7 (18,5-20,9)	20,3 (18,8-21,9)*	22,3 (21,2-24,1)	22,7 (21,3-24,3)	23,7 (22,5-25,7)	23,2 (21,3-24,7)
Urea	4,10 (3,60-4,79)	4,51 (3,80-5,30)*	4,60 (3,90-5,59)	5,04 (4,20-5,91)*	4,53 (4,00-6,00)	5,20 (4,50-6,00)
Uricacid	0,29 (0,25-0,31)	0,28 (0,25-0,33)	0,27 (0,25-0,31)	0,31 (0,27-0,36)*	0,29 (0,28-0,35)	0,30 (0,25-0,35)
Albumen	44,0 (41,0-45,0)	41,0 (39,0-44,0)*	43,0 (40,0-45,0)	44,0 (40,0-45,0)	42,0 (40,0-46,0)	44,0 (41,0-45,0)
Globulins	26,0 (24,0-31,0)	30,0 (27,0-33,0)*	31,0 (27,0-34,0)	29,0 (26,0-33,0)	31,0 (30,0-34,0)	30,0 (26,0-34,0)
Triglycerides	0,60 (0,46-0,87)	0,79 (0,56-1,01)*	0,80 (0,50-1,04)	0,76 (0,58-1,00)	0,70 (0,51-0,89)	0,80 (0,60-1,00)
ALT	19,0 (15,0-23,0)	18,0 (15,0-23,0)	32,0 (20,0-41,0)	22,0 (18,0-30,0)*	27,0 (19,0-35,0)	24,0 (18,0-31,0)
AST	25,5 (22,0-32,0)	31,0 (24,8-38,0)*	38,0 (27,0-63,0)	31,0 (25,0-41,0)*	32,0 (28,5-39,5)	33,0 (24,0-43,0)
ALP	307 (140-484)	342 (176-620)	356 (194-440)	191 (111-321)*	171 (100-280)	117 (86-236)
CPK	263 (182-376)	241 (167-420)	511 (346-1740)	334 (209-581)*	608 (463-943)	326 (191-659)*
Alpha-amylase	58,0 (43,0-78,0)	77,0 (49,0-120)*	51,0 (42,0-63,0)	51 (41,0-70,0)	64,0 (50,0-80,0)	52,0 (53,0-71,0)
Calcium	2,50 (2,30-2,56)	2,34 (2,22-2,43)*	2,40 (2,32-2,50)	2,40 (2,26-2,50)	2,43 (2,31-2,48)	2,35 (2,27-2,47)
TIBC	62,5 (54,7-67,0)	53,0 (49,0-57,0)*	69,0 (55,0-69,5)	51,0 (48,0-57,5)	47,0 (42,5-53,0)	49,0 (45,5-55,0)
Potassium	4,10 (3,67-4,60)	4,43 (3,90-5,00)*	4,80 (3,98-5,30)	4,34 (3,90-4,80)	4,42 (4,00-4,97)	4,20 (3,90-4,97)
GGT	13,0 (11,0-15,0)	14,0 (12,0-17,0)*	14,0 (11,3-17,5)	15,0 (13,0-18,0)	18,0 (12,8-23,3)	16,0 (12,0-22,0)
Iron	16,6 (12,4-27,6)	15,6 (10,9-18,8)	14,1 (11,0-16,6)	17,5 (12,5-21,9)*	12,0 (10,9-16,1)	17,6 (14,4-25,1)*
A/G	1,70 (1,40-1,90)	1,40 (1,20-1,60)*	1,40 (1,20-1,60)	1,50 (1,30-1,70)	1,30 (1,30-1,50)	1,50 (1,30-1,80)
AST/ALT	1,30 (1,10-1,90)	1,60 (1,30-2,00)*	1,30 (1,10-1,70)	1,40 (1,20-1,70)	1,20 (1,10-1,80)	1,30 (1,00-1,80)
CPK/AST	10,0 (7,40-14,8)	8,30 (6,10-12,4)*	15,1 (11,2-29,0)	11,3 (7,70-16,1)*	17,8 (13,6-23,8)	10,9 (7,10-16,9)*

Note: * – P <0.05. Glucose, total bilirubin, total protein, total cholesterol, high-density lipoprotein cholesterol, atherogenicity index, low-density lipoproteins, as well as the values of the Glu/TC, Glu/ HDL cholesterol, CPK/ALP and Glu /LDL did not change.

Table 2. The dependence of the values of biochemical markers on the age of the examined female

Indicators	SubjectAge					
	7-11 years old		12-15 years old		16-18 years old	
	Control	Sport	Control	Sport	Control	Sport
BMI	17,2 (16,4-18,4)	16,7 (16,0-19,1)	16,7 (16,0-19,1)	19,6 (18,1-21,6)*	20,8 (20,1-22,5)	21,0 (19,9-22,6)
Glucose	4,95 (4,55-5,17)	4,70 (4,40-5,40)	4,90 (4,76-5,10)	4,70 (4,40-5,10)*	4,39 (4,10-4,75)	4,60 (4,29-4,90)
Urea	4,54 (4,30-5,05)	3,62 (3,11-4,20)*	4,68 (3,49-5,21)	3,97 (3,30-4,68)	5,20 (3,50-6,50)	4,31 (3,70-5,40)
Bilirubin	13,7 (10,8-16,8)	14,8 (10,8-26,5)	14,5 (10,8-16,6)	13,3 (10,6-21,4)	11,8 (10,6-13,0)	14,6 (10,7-21,3)*
Uricacid	0,32 (0,28-0,32)	0,20 (0,18-0,25)*	0,23 (0,18-0,28)	0,23 (0,19-0,27)	0,25 (0,22-0,28)	0,23 (0,19-0,28)
Albumen	45,0 (43,2-46,7)	42,0 (41,0-43,0)*	43,0 (42,0-45,0)	42,0 (40,0-44,0)*	43,0 (41,0-45,0)	43,0 (40,0-45,0)
Globulins	25,5 (23,5-26,0)	30,0 (29,0-33,0)*	30,0 (26,0-33,5)	30,0 (27,0-33,0)	28,0 (27,5-28,5)	29,0 (26,0-33,0)
TC	4,07 (3,72-4,55)	4,00 (3,90-4,50)	4,20 (3,68-5,05)	4,30 (3,80-4,95)	5,04 (5,00-5,30)	4,10 (3,70-4,70)*
LDL	-	2,41 (1,93-2,57)	2,93 (2,36-3,49)	2,38 (1,92-2,80)*	2,90 (2,65-3,10)	2,40 (1,90-2,60)*
AST	18,0 (15,7-19,5)	25,0 (20,0-29,0)*	25,0 (21,2-27,7)	25,0 (21,0-30,0)	22,0 (19,0-23,0)	26,0 (22,0-32,0)*
ALP	239 (200-876)	634 (545-807)	202 (150-396)	156 (98-310)*	174 (112-196)	203 (143-262)
A/G	1,77 (1,68-1,93)	1,38 (1,27-1,45)*	1,46 (1,28-1,58)	1,40 (1,24-1,57)	1,50 (1,43-1,58)	1,48 (1,29-1,64)
AST/ALT	0,84 (0,80-0,91)	1,73 (1,46-2,00)*	1,90 (1,56-2,23)	1,51 (1,27-1,85)*	1,29 (1,19-1,39)	1,44 (1,16-1,72)
Glu/TC	1,15 (1,07-1,31)	1,21 (1,04-1,37)	1,12 (0,96-1,29)	1,11 (0,96-1,29)	0,86 (0,81-0,91)	1,10 (0,94-1,27)*
Glu/LDL	-	2,23 (1,97-2,37)	1,70 (1,50-1,88)	2,03 (1,63-2,45)*	1,49 (1,30-1,80)	1,93 (1,74-2,26)*

Note: * -$p<0.05$. Indicators of creatinine, total protein, high-density lipoprotein cholesterol, atherogenic index, triglycerides, ALT, CPK, alpha-amylase, GGT, calcium, potassium, iron, TIBC, as well as the values of CPK/AST, Glu/HDL cholesterol, CPK/ALPdid not change.

amylase, GGT, and AST/ALT ratio. When boys in early puberty are compared to girls in early puberty, the following biochemical markers had higher values: content of glucose, uric acid, albumin, activity of ALT, ALP, and the values of A/G, Glu/TC ratios. Expectedly, in subsequent ontogenesis, 10 decreased indicators should increase, and 7 increased indicators should decrease.

In the control subgroup of adolescent girls aged 12-15 years, the following biochemical indicators increased compared to athletes: total bilirubin, total protein, globulins, LDL, serum iron, TIBC, AST/ALT, and Glu/HDL. The end of puberty period can be assessed by normalizing indicators in the control subgroups of girls aged 16-18 years old (increasing urea, total cholesterol, HDL cholesterol, potassium, atherogenicity index and CPK/ALP ratios) and age group 19-20 years (increasing creatinine, triglycerides, AST, CPK, GGT activity, CPK/AST and Glu/LDL ratios).
3. To search for indicators that should decrease during puberty, the highest indicators in the age group of 7-11 years were analyzed: the content of glucose, uric acid, albumin, the activity of ALT, alkaline phosphatase, the values of the A/G and Glu/TC coefficients. Some of them coincide with similar indicators of boys in the control subgroup of the age group of 12-15 years old (Tables 1 and 2). These are biochemical markers of metabolic imbalance and dysregulation upon the onset of puberty.

In female athletes aged 7–11 years, globulin content, AST activity, and AST/ALT are statistically significantly increased. Urea, creatinine, uric acid, albumin and A/G are reduced.

Table 3 shows biochemical health markers that do not change during puberty and sports in this period of life. It has been established that, regardless of gender, 2 markers are supported at a constant level in adolescents - the atherogenicity index and the coefficient Glu / HDL cholesterol; in male adolescents, only one marker is preserved - glucose level; in female adolescents, for the course of the normal puberty, the constancy of 6 markers is required - the content of triglycerides, calcium, potassium, total iron-binding activity of blood serum, CPK activity and CPK / ALP coefficient.

Table 3. Permanent biochemical markers at puberty and sports

Group of teenagers	Puberty	Sport
Both sexes,	Index atherogenicity, LDL, alpha-amylase, iron, Glu/HDL cholesterol	Index atherogenicity, total protein, HDL cholesterol, Glu/HDL cholesterol, CPK/ALP
Male	Glucose, albumen, AST/ALT	Glucose, total bilirubin, total cholesterol, LDL, Glu/ total cholesterol
Female	Urea, creatinine, total protein, albumen, HDL cholesterol, triglycerides, LDL, ALT, CPK, calcium, potassium, total iron-binding capacity, CPK/AST, Glu/LDL	creatinine, triglycerides, calcium, potassium, iron, ALT, CPK, GGT, alpha-amylase, total iron-binding capacity, CPK/AST, Glu/HDL cholesterol, CPK/ALP

DISCUSSION

Studies have shown that consistent full-body exercise in male adolescent athletes probably leads to adaptive processes that ensure the maintenance of biochemical health markers within normal limits. This is compared to those subjects who begin physical activity, who have metabolic disorders and an increase in the presence of markers of musculoskeletal system damage and the state of membrane structures in the blood serum (the control subgroup). The greatest perturbations are found during early puberty. Monitoring the effectiveness of physical activity not only requires the help of tests during the training process, but also requires periodic analysis of markers of damage to the musculoskeletal system and lability of membrane structures. During puberty, the above tests did not allow us to detect perturbations in lipid transport, which would reduce the pool of transport molecules that provide the energy supplies for the growing bodies of male adolescents. These energy supplies are glucose and triglycerides.

The results obtained by observing athletes allow us to draw a preliminary conclusion about a possible negative effect of consistent, intense athletic activity performed by girls during early puberty. During early puberty, careful laboratory monitoring of main biochemical health markers should be performed for girls who consistently engage in physical activity.

Athletes aged 12-15 are nearing the end of puberty, when biochemical signs of metabolic tension are observed. However, in athletes aged 16-18, normal lipid transport and energy-intensive molecules are established earlier than in girls of the control subgroup. In athletes aged 19-20 years old, the assayed metabolic parameters mirrored the levels observed in an adult female body, but the body mass index was lower than that of girls in the control group. This is probably due to the more intense expenditure of long-term energy reserves in the form of triglycerides.

Growth during puberty depends on three main factors: heredity, nutritional status and the dynamics of hormonal regulation. Additional sports activities cause increased expenditure of energy resources and can affect the

influence of these three factors on the linear growth rate and the relative proportions of fat-free and fatty body mass (Roemmich et al., 2001). In young football players, increased physical activity accelerates bone maturation, but does not directly affect the ratios of growth hormone, insulin-like growth factor IGF-1,or testosterone in the blood, depending on the intensity of the physical activity (Nebigh et. al, 2009; Hammami et al., 2017; Hammamiet al., 2018). At the same time, it has been observed that the concentration of testosterone and the molar ratio of IGF-1/IGFBP-3 in blood serum are the main determinants of bone mineral density in boys during different stages of puberty (Pomerants et al., 2007). It was shown that the beginning of football lessons during early puberty in boys (11–13 years) leads to faster osteogenesis and mineralization of bones subjected to stress (Zouch et al., 2015). These data confirm the main conclusion of this article, that playing sports in the puberty accelerates age-related metabolic development.

In conclusion, it should be noted that the observed changes in metabolic markers can be explained by constantly improving interdisciplinary analysis. Long-term trends indicate a significant decrease in the age of puberty starts to a greater extent in girls, and to a lesser extent in boys (Nikitina, 2013).To understand the molecular mechanisms of puberty, studies are needed in at least three directions: 1 - Establishing a hierarchical structure of gonad stat activation regulatory genes, the sequential expression of which coordinates intraneuronal and glioneuronal interactions, with the ultimate goal of increasing impulse secretion of gonadotropin-releasing hormone; 2 - Epigenetic mechanisms of action are important (DNA methylation, histone deacetylation), which play a significant role in the transcriptional activity of genes and generally determines the plasticity of the functioning of this network, and 3 - the key role of the system of kisspeptins in the regulation of sexual differentiation of the brain, the synchronization of the processes of sexual development in adolescents and the functioning of the reproductive system throughout life cannot be ruled out.

CONCLUSIONS

The biochemical parameters measured from blood serum presented in the article can be divided into 3 groups of biochemical health markers during sports in puberty. The first group includes 5 biochemical health markers that were independent of gender, age of the subjects, and their relationship to constant physical activity. These markers are total protein, HDL cholesterol, atherogenicity index, Glu /cholesterol HDL and CPK/ALP ratios. The second group includes 5 biochemical health markers that are maintained at a constant level during puberty in males. These markers are glucose, total bilirubin, total cholesterol, LDL and Glu/total cholesterol. The third group includes the content of 13 biochemical health markers that did not change during female puberty. These markers are creatinine, triglycerides, calcium, potassium, iron, the activity of ALT, CPK, GGT, alpha-amylase, TIBC, CPK/AST, Glu/HDL, CPK/ALP ratios. To assess the course of puberty without regular physical exertion and during sports, the following biochemical markers should be determined: the first group - two markers (atherogenic index and Glu / HDL cholesterol coefficient); the second group is the glucose level; the third group - 6 markers (the content of triglycerides, calcium, potassium, the value of TIBC, KFK activity and KFK / ALF coefficient). Changes in these markers can indicate negative effects on the most important biochemical and physiological processes in puberty: changes in the markers of the first group can indicate the ratio of direct and reverse cholesterol transport and energy supply of the body at the stage of enhanced biosynthesis of steroid sex hormones; a marker of the second group - the level of glycemia characterizes the current energy supply of functions in young men; markers of the third group in girls indicate a long-term energy supply of functions, the state of iron homeostasis in connection with the menstrual cycle, and the provision of regular muscle activity in sports that is not characteristic of the female body. These biochemical health markers can be used for medical monitoring throughout puberty, as well as for identifying metabolic disorders in athletes during puberty.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ETHICAL APPROVAL

Institutional board approval for the study was obtained from the Ethics Commission of the Vitebsk State University (ЭК-20.1). All procedures involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Informed consent was obtained from all participants included in the study.

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