nificantly changed, with the FD diagnosis prevailing (due to the inclusion of PDS for diagnosis), and the IBS incidence rate decreasing threefold (due to the new limiting criteria).

5. Particular attention should be paid to the high prevalence of PDS among children observed in almost half of children with RAP in-school sample (44.4 (27.5-62.8) and in 66.7 (53.3-77.8)% of cases of RAP in hospital, since it is the PDS that indicates an evacuation disorder from the stomach, congestion in the intestine, thereby encouraging the development of peptic ulcer disease and GERD.

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PHYSICAL AND SEXUAL DEVELOPMENT OF BOYS WITH LATENT IRON DEFICIENCY WITHOUT ANEMIA

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УДК: 616.155.194.8:616-095

The aim of the study was to analyze the possible impact of iron deficiency (ID) without anemia on physical and sexual development of adolescent boys

Materials and methods. 46 adolescent boys with ID without anemia (serum ferritin (SF) level <15 μg/l in the absence of inflammation defined by normal level of C-reactive protein) and 99 healthy peers were recruited in the study. All the participants were without underlining chronic illness. Average age was 14.8±0.9 years.

Results. Physical development of adolescent boys with ID without anemia did not differ from that of their healthy peers. We found no correlation between anthropometric indicators and SF level. The SF level was significantly higher in overweight or obese children as determined by bioelectrical impedance then in normal weight children (35.15 (20.8; 48.6) vs. 18.8 (16,4; 20,0), p<0.001) and more so in obese children (40.8 (19.4; 56.3) vs. 18.8 (16.4; 20.0), p=0.012). Body fat (rs = 0.210 p = 0.013), visceral fat (rs = 0.208 p = 0.014) and body fat percentage (rs = 0.239 p = 0.005) correlated with SF level. Sexual development of boys with ID without anemia was within the age norm, but it was generally on the earlier stage then in the control group and correlated with the level of SF: for pubic hair rs = 0.186, p = 0.028 and for genitalia development rs = 0.224, p = 0.008.

Conclusion. ID without anemia did not altered physical development of adolescent boys. Obesity or excess weight is associated with a higher level of SF, which should be considered when diagnosing ID. ID is associated with sower sexual development in boys.

Keywords: bioelectrical impedance, iron deficiency, adolescents, sexual development, physical development

Introduction. Iron deficiency (ID) is one of the most common metabolic disorders. Results of the meta-analysis have shown a global rate of 16.42% of iron deficiency anemia and 17.95% of iron deficiency without anemia among children under the age of five, who are at the highest risk of this condition [15]. The frequency of iron deficiency (ID) in adolescents is significantly lower and subjected to gender differences. For example, according to Zakharova I.N., iron deficiency in adolescent girls occurs 1.6 times more often than in boys [8]. Another study in the Stavropol Region has shown that in the age group of 12-18 years, 70% of patients who received inpatient treatment for IDA were girls [7]. However, some studies suggest a relatively high incidence of ID without anemia in adolescent boys. For example, according to Sharuko G.V., the frequency of ID without anemia is 20.6% in boys under 14 years and increases to 32.1% in adolescence [2].

ID developing during the first 1000 days of life, that is, from conception and up to 2 years of age, has multiple detrimental effects on children's health, including changes in immunological reactivity and increased infectious morbidity [19], delayed cognitive [12] and psychomotor development [26], as well as a delay in linear growth and body weight [10]. At the same time, the effects of ID, especially without anemia, developing later in life

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during adolescence, are less understood. The impact of ID on reproductive health has been studied quite comprehensively in girls. Even ID without anemia promotes a decrease in ovarian reserve [4], and up to 43% of women with infertility suffer from ID [6]. Studies of sexual development and reproductive function in males are predominantly focused on iron overload but not ID [16, 22].

The aim of this study was to analyze the possible impact of ID without anemia on the physical and sexual development of adolescent boys.

Methods. The study was held out in Samara Cadet Corps as a part of a routine annual examination.

Inclusion criteria: age at the time of the study from 12 to 15 full years, consent of parents or legal representatives to participate in the study.

Exclusion criteria: refusal to participate in the study, acute infectious diseases with hyperthermia during the entire study period, diarrhea within 7 days before the laboratory analysis, routine medication of any kind, severe swelling of the extremities, failed complete blood count and/or biochemical blood test at the recruitment (clot formation, hemolysis, insufficient volume of material), significant limbs' edema.

Anthropometric measurements (head, chest, hips, and shoulder circumference) were measured with a soft centimeter tape [16]. Standing height was measured by a stadiometer and weight - by electronic floor scales with an accuracy of 100 grams. Skin-fat folds thickness at 4 points was measured with a plastic caliper and the results were rounded to the nearest 0.5 cm [17]. Overweight was defined as body mass index (BMI) exceeding 1 SD, obesity - > +2SD, and underweight < -2 SD. Bioelectrical impedance analysis was carried out in the morning 2.5-3 hours after breakfast using ABC-02 "Medass" (Russia) analyzer at a probing current frequency of 50 kHz according to the eight-pole circuit [17]. The fat mass percentage was evaluated per body fat reference curves by McCarthy H. et al. [18], the excess adipose tissue was defined as above the 85th centile for the corresponding age, obesity - above the 95th centile, adipose tissue deficiency - below the 2nd centile. Sexual development was assessed by the Tanner method by a trained pediatric endocrinologist [19].

Laboratory assays were performed as follows: automated complete blood examination (Sysmex XT-2000i, Sysmex, Japan), serum ferritin and C-reactive protein (fluorescent flow cytometry, Integra 400 plus, Roche, Switzerland). Anemia was defined as hemoglobin level below 120 g/l, ID was defined as serum ferritin level less than 15 µg/l in the absence of inflammation (C-reactive protein <5mg/L) [2]. IDA was diagnosed when anemia and ID were concomitant, latent ID or ID without anemia - in the presence of iron deficiency and the absence of anemia.

Statistic analysis. Accumulation, correction, systematization of initial information, and visualization of the obtained results were carried out in Microsoft Office Excel 2016 spreadsheets. Statistical analysis was carried out using the STATISTICA 13.3 program (StatSoft. Inc). Quantitative indicators were evaluated for distribution using the Kolmogorov-Smirnov criterion, as well as indicators of asymmetry and kurtosis. Quantitative indicators with a normal distribution were presented as mean (M) and standard deviation (SD), and quantitative indicators with a distribution that differs from normal were described as median (Me) and the lower and upper quartiles (Q1;Q3). Comparison of quantitative data was done by calculating Student's t-test for normally distributed data and The Mann-Whitney U-test for data whose distribution differed from normal. The relationship between quantitative data was assessed by the calculation of the Spearman rank correlation coefficient.

Results and discussion. Due to the limited number of children in the cadet corps and the low ID rate identified during the initial examination, we enrolled adolescents in the study in two steps: from 18.03.2021 to 30.04.2021 and from 08.11.2022 to 16.12.2022 by continuous sampling as part of a routine examination. We assessed iron storage levels in 265 adolescents. 51 (19.2% of examined) boys had ID, 5 of them - in the form of IDA. Due to the small number of children with IDA, we excluded them from further analysis. The ID group consisted of 46 adolescents with ID without anemia. The healthy control group included 99 adolescents with adequate iron stores and normal values of complete blood count. The average age of adolescents

Table 1

Anthropometric indicators in the comparison groups

Indicator	ID, n=46	Healthy control, n=99	p
*Height, cm	166.4 (8.0)	166.3 (9.4)	0.978
*BMI	21.6 (2.1)	21.3 (3.1)	0.464
*Weight, kg	59.6 (8.0)	59.2 (11.0)	0.781
**Waist circumference, cm	71.0 (70.0; 76.0)	71.0 (65.0; 75.0)	0.196
*Hip circumference, cm	90.5 (4.9)	89.7 (6.3)	0.389
**Wrist circumference, cm	16.4 (16.0; 17.0)	16.0 (15.5; 16.5)	0.128
**Chest circumference at maximum exhalation, cm	89.2 (7.4)	87.9 (7.4)	0.331
*Chest circumference at maximum inhalation, cm	82.1 (6.2)	81.3 (6.9)	0.485
*Shoulder circumference at maximum muscle tension, cm	28.7 (3.1)	27.9 (3.2)	0.200
* Shoulder circumference in a relaxed state, cm	25.7 (2.3)	25.4 (2.7)	0.373
*Head circumference, cm	55.5 (1.5)	55.4 (1.6)	0.829

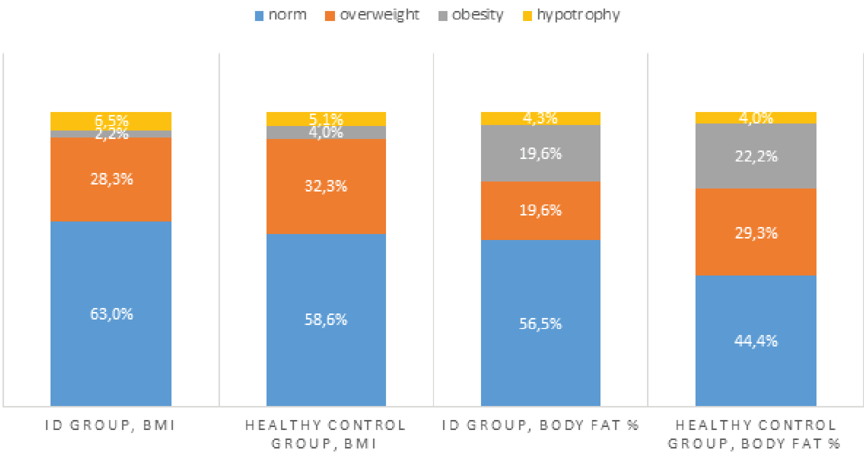
* - normal distribution, M (m). Welch's t-test
** - non-normal distribution, Me (Q1; Q3). Mann-Whitney U-test

Table 2

Results of anthropometry in the comparison groups

Fold thickness, mm	ID, n=46	Healthy control, n=99	p
over the biceps	8.0 (4.0; 9.0)	7.0 (4.0; 9.0)	0.625
over the triceps	10.0 (8.0; 12.0)	10.0 (6.0; 11.0)	0.703
over the scapula angle	10.0 (8.0; 12.0)	10.0 (8.0; 12.0)	0.885
over the inguinal fold	8.0 (7.0; 10.0)	8.0 (7.0; 10.0)	0.409

non-normal distribution, Me (Q1; Q3). Mann-Whitney U-test



Body weight assessment in the comparison groups by BMI and body fat percentage

was 14.8 (0.9) years, age in the comparison groups did not differ: 14.6 (0.9) years in the main group and 14.8 (0.7) years in the control group (p=0.278).

Main anthropometric indicators in the comparison groups did not differ (Table 1).

BMI of most adolescents was within the normal range: 63.0% (29) in the ID group and 58.6% (58) in the control group (p=0.609). The percentage of overweight children was 28.3% (13) and 32.3% (32), respectively. One adolescent in the ID group (2.2%) and four in the healthy control group (4.0%) were obese. Additionally, we found that 6.5% (3) in the ID group and 5.1% (5) in the healthy control group were underweight.

The thickness of the subcutaneous fat fold as measured by a caliper also did not differ between the groups (Table 2): the mean value of skinfold thickness was 7.5 mm (6; 9.5) in the ID group and 9.0 mm (6.75; 10.5) in the healthy control group (p=0.228).

Results of biological impedance have shown that the average body fat, body fat %, and visceral fat in the groups did not differ. The body fat in the ID group was 12.7 (3.4), while in the healthy control group - 13.0 (4.8) (p=0.675), body fat percentage 21.4 (5.4) and 21.5 (5.8), respectively (p=0.874).

The proportion of children diagnosed as overweight and obese by BMI significantly changes when using body fat percentage determined by bioelectrical impedance analysis (Figure). The differences between groups remain insignificant (p=0.534).

Other parameters of bioelectrical impedance analysis, such as active cell mass and skeletal muscle mass in comparison groups, did not differ (Table 3).

The SF level is significantly higher in children who are overweight and, especially, obese as determined by body fat percentage.

Data on the relationship between obesity and ID is inconclusive. Some studies did not reveal any association between these conditions [23,24]. On the other hand, a meta-analysis has found an association between IDA and obesity in children (OR 2.1, 95% CI 1.4-3.2) [25]. The possible mechanism of association of ID and obesity is through chronic inflammation and subsequent modulation of hepcidin level and reduction of iron absorption in the intestine [18]. Coexisting inflammation could mask ID. Therefore, the use of inflammation-independent parameters of iron stores, such as soluble transferrin receptors, or SF cut-off val-

Table 3

Comparison of bioelectrical impedance analysis parameters in the comparison groups

Parameter	ID, n=46	Healthy control, n=99	p
Active cell mass	25.4 (4.8)	25.2 (5.3)	0.826
Active cell mass percentage	53.9 (3.2)	54.4 (3.2)	0.415
Skeletal muscle mass	27.3 (4.1)	26.8 (4.1)	0.494
Skeletal muscle mass percentage	58.0 (1.9)	58.3 (4.2)	0.619

normal distribution, M (m)

Table 4

Serum ferritin level and body mass correlation

Obesity and overweight as defined by BMI			
	Obesity and overweight, n=50	Normal body weight, n=87	p
Serum ferritin, µg/l	30.7 (19.3; 45.7)	28.7 (17.2; 43.3)	0.617
	Obesity. n=5	Normal body weight. n=72	p
Serum ferritin, µg/l	40.6 (36.7; 50.0)	28.7 (17.2; 43.3)	0.247
Obesity and overweight as defined by body fat percentage			
	Obesity and overweight. n=69	Normal body weight. n=70	p
Serum ferritin, µg/l	35.15 (20.8; 48.6)	18.8 (16.4; 20.0)	<0.001
	Obesity. n=31	Normal body weight. n=53	p
Serum ferritin, µg/l	40.8 (19.4; 56.3)	18.8 (16.4; 20.0)	0.012

Примечание. Распределение, отличное от нормального, Me (Q1; Q3). U критерий Манна-Уитни

Table 5

Correlation of the level of SF, mcg/l, with body weight and individual bioimpedance parameters characterizing fat metabolism

Body weight, kg	BMI	Fat mass	Visceral fat	% of fat mass	% skeletal muscle mass
r_s = 0.118 p = 0.165	r_s = 0.037 p = 0.665	r_s = 0.210 p = 0.013	r_s = 0.208 p = 0.014	r_s = 0.239 p = 0.005	r_s = -0.136 p = 0.111

Note. Spearman's Rho coefficient, significant differences at p< 0.05.

ues corrected for inflammation, can give more reliable results [23]. Bioelectrical impedance analysis is a preferable method in overweight and obesity diagnostics.

Further analysis showed a correlation between SF and adiposity indicators of bioelectrical impedance but not between SF and BMI (Table 5).

Our results are similar to other studies, which also did not reveal a relationship between BMI or anthropometric parameters and ID [17].

The sexual development of all boys was within the age norm, which is partially explained by the wide age limits for puberty onset in boys: from 9 to 14 years [3]. Nevertheless, in the ID group, sexual development was slower than in the control group. Pubic hair development in the ID group was rated at 2.5 (2; 3), while in the healthy control group - at 3 (3; 4) points ($p = 0.009$), and genital development at 3 (2; 4) and 4 (3; 5) scores, respectively ($p=0.022$). There were no significant differences in axillary hair growth ($p=0.296$). We also found a correlation between the sexual development level of adolescent boys and SF: for pubic hair growth rs = 0.186, p (2-tailed) = 0.028, for genitals development rs = 0.224, p (2-tailed) = 0.008.

Existing studies of iron storage and sexual development relationship are primarily focused on severe iron overload. The negative impact of infusion-dependent thalassemia and hereditary hemochromatosis on sexual development and reproductive function is known [14]. At the same time, iron plays a critical role in spermatogenesis and sperm motility [13, 20], and testosterone is a natural regulator of iron metabolism through hepcidin synthesis inhibition [14]. Thus, ID may be a result of puberty delay in boys and the absence of testosterone effect on iron absorption.

Conclusion. The physical development of children with ID, assessed by anthropometric measurements, does not differ from healthy controls and does not correlate with SF level. Overweight and obesity determined by body fat percentage are associated with higher SF levels, probably due to mild chronic inflammation. In cases of visceral obesity, higher cut-off values of 30 µg/l for SF can improve the accuracy of diagnosing ID. Further studies of iron metabolism in obese children and adolescents are necessary to develop practical guidelines for their management. The association of ID with slower sexual development in boys determines the need for ID screening and subsequent prophylactics in pubescent boys.

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Conflict of interests. The authors declare no conflict of interest.

Informed consent. Informed consent was obtained from patients or their parents or legal representatives.

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DIAGNOSTIC AND TREATMENT METHODS

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RESULTS OF CLINICAL APPLICATION OF DYNAMIC PNEUMOAPPLANATION METHODS OF THE CORNEA IN MYOPIA

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The introduction into clinical practice of research methods based on dynamic corneal pneumoapplanation significantly expanded the possibilities of clinical (in vivo) assessment of the "biomechanics" of eye structures in myopia. This review summarizes the results of using pneumoapplanation methods to assess biomechanical indices in initial myopia and after its laser correction.

Keywords: cornea, biomechanical properties, pneumoapplanation methods, myopia.

The size and shape of the fibrous (corneoscleral) envelope of the eye are the main components of refractive disorders formation. Myopic defocus can be associated primarily with an increase in the anteroposterior axis (APA) as well as an increase in corneal refraction. According to the three-factor theory of myopia pathogenesis by E.S. Avetisov, APA instability with a tendency to increase due to impaired mechanical properties of the sclera is an anatomical cause of progressive myopia [1]. On this basis, the main focus of biomechanical studies of the ocular fibrous membrane in myopia is related to the evaluation of various sclera parameters. On the basis of a set of studies (in vitro mechanical tests, measurement of eyeball stiffness, determination of the deformation coefficient and acoustic density of the sclera, ophthalmomechanography), it was established "that the range of elastic deformations of the sclera decreases and the contribution of the viscous component ..... increases with progressing myopia, resulting in irreversible stretching of the sclera and in an increase in the OPC" [2]. In high myopia, the sclera is characterized by a decrease in strength and elastic modulus predominantly in the equatorial and posterior regions, with these changes occurring first in the equatorial zone, followed by changes in the posterior part of the sclera.

The introduction into clinical practice of research methods based on dynamic corneal pneumoapplanation significantly expanded the possibilities of clinical (in vivo) assessment of the "biomechanics" of eye structures in myopia. This review summarizes the results of pneumoapplanation techniques application for biomechanical evaluation in initial myopia and after its laser correction.

Modern techniques of bidirectional pneumoapplanation of the cornea. The first device to use the effect of an air jet for dynamic corneal deformation was the ORA (Oclaur Response Analyzer, USA). Biomechanical parameters generated by standard ORA software are corneal hysteresis (CH) and corneal resistance factor (CRF). CH is a conventional value reflecting visco-elastic properties of the cornea, while CRF characterizes the resistance of corneal tissue itself which would exist at zero ophthalmotonus [6, 39, 45-46].

Corvis ST technology (Oculus, Germany) belongs to an alternative method of biomechanical characteristics measurement using corneal pneumoapplanation. This device uses high-speed Scheimpflug camera to fix transverse section of cornea (4330 frames per second) during deformation in real time followed by program analysis to obtain different biomechanical indices, the most used ones according to literature data are as follows [2, 4, 17, 22-23, 35, 40, 42]:

- Applanation-1 Time (A1T), ms - time of the first applanation;
- Applanation-2 Time (A2T), ms - time of the second applanation;
- Applanation-1 Lenght (A1L), mm - diameter of the "flattened" corneal area during the first applanation;
- Applanation-2 Length (A2L), mm - diameter of the "flattened" cornea during the second applanation;
- Applanation-1 Velocity (A1V), m/s - inner corneal velocity during the first applanation (it indirectly reflects corneal viscosity);
- Applanation-2 Velocity (A2V), m/s - speed of corneal outward movement to the initial position at the second applanation (the higher the value, the higher the degree of corneal elasticity);
- Highest Concavity Peak Distance (HCPD), mm - diameter of maximum concavity, i.e. the distance between the two highest points of the cornea at its greatest concavity (it indirectly reflects corneal stiffness);
- Highest Concavity Radius (HCR), mm - radius of curvature of the concavity of the cornea at the greatest deformation;
- Deformation amplitude (DA), mm - amplitude of deformation, the value of displacement of the corneal apex at its maximum "indentation" relative to the original shape (MDA - maximum amplitude of deformation);
- Central corneal thickness (CCT), µm - thickness of the cornea in the central zone;
- Deformation Amplitude Ratio (DA Ratio) - ratio between the deformation amplitude at the corneal apex and the

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