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ОЦЕНКА БИОХИМИЧЕСКИХ ИЗМЕНЕНИЙ У ПОДРОСТКОВ-СПОРТСМЕНОВ В ЗАВИСИМОСТИ ОТ СТАДИИ ПОЛОВОГО СОЗРЕВАНИЯ

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EVALUATION OF BIOCHEMICAL CHANGES IN ADOLESCENT ATHLETES DEPENDING ON THE STAGE OF PUBERTY

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Аннотация. Введение. Спорт играет важную роль в развитии опорно-двигательного аппарата, способствует тому, чтобы организм всегда был здоровым и активным, что отражается на общей работоспособности человека.

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Цель. Установить изменения биохимических показателей у подростков мужского и женского пола на разных стадиях полового созревания, занимающихся физической нагрузкой.

Методы. В исследование принял участие 430 подростков женского пола (54 – контрольная группа, 376 – спортсменки) и 900 подростков мужского пола (144 – контрольная группа, 756 – спортсмены). В сыворотке крови определяли 10 рутинных биохимических маркера для характеристики обмена веществ испытуемых.

Результаты. Были выделены 3 группы биохимических маркеров здоровья. К первой группе были отнесены 2 биохимических маркеров здоровья, которые не зависели от пола, возраста обследуемых и их отношения к постоянным физическим нагрузкам: глюкоза, калий. Во вторую группу были включены 3 биохимических маркеров здоровья, поддерживаемых на неизменном уровне в пубертатном периоде у лиц мужского пола: глюкоза, общий билирубин, калий. В третью группу были включены 6 биохимических маркеров здоровья, не изменяющихся в периоде женского пубертатного периода: глюкоза, триглицериды, ОХС, калий, кальций, железо.

Выводы. Полученные результаты играют важную роль в определении биохимических изменений в подростковом возрасте, а также позволяют использовать их для определения состояния здоровья подростков, регулярно занимающихся спортом.

Ключевые слова: пубертатный период, спорт, обмен веществ, гендерные отличия, адаптация.

Annotation. Introduction. Sport plays an important role in the development of the musculoskeletal system, helps the body to always be healthy and active, which affects the overall performance of a person.

Objective. To establish changes in biochemical parameters in adolescents of both sexes at different stages of puberty who are engaged in physical activity.

Methods. The study involved 430 adolescent girls (54 - control group, 376 - athletes) and 900 adolescent boys (144 - control group, 756 - athletes). In the blood serum, 10 routine biochemical markers were determined to characterize the metabolism of the subjects.

Results. Three groups of biochemical markers of health were identified. The first group included 2 biochemical markers of health that did not depend on the sex, age of the subjects and their attitude to constant physical activity: glucose, potassium. The second group included 3 biochemical markers of health that are maintained at a constant level during puberty in males: glucose, total bilirubin, potassium. The third group included 6 biochemical markers of health that do not change during female puberty: glucose, triglycerides, TC, potassium, calcium, iron.

Conclusions. The results obtained play an important role in determining biochemical changes in adolescence, and also allow them to be used to determine the health status of adolescents who regularly engage in sports.

Keywords: puberty, sports, metabolism, gender differences, adaptation.

Introduction. Puberty is considered one of the most important stages in human life for both males and females, since changes occur in the body at all levels: internal (hormonal background, psychological and emotional spheres) and external (growth, body composition). This is the stage at which an individual becomes capable of reproduction (Bezrukikh, 2003; Chaki, 2019; Dufour, 1988; Kristian, 2017; Bocharin, 2024).

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Sport plays a special role in improving human health, and balanced training contributes to increasing the speed, strength, and endurance of a person engaged in physical activity (Adeli, 2015; Al-Khelaifi, 2018).

Gradually, the athlete's body adapts to the sport, and this adaptation is also reflected in the athlete's biochemical state. These changes vary across different sports and depend on the physical activity performed by the athlete (Adeli, 2015; Asgari, 2019; Chaki, 2019). Undoubtedly, biochemical changes can be proportional to the intensity, endurance, strength, and fatigue experienced by the trainee, in addition to the changes that occur in the increased power of aerobic oxidation processes during training. The changes occurring during training, especially in muscle proteins, represent a particular observable feature (Asgari, 2019; Bergmeyer, 1985; Karbasy, 2015).

A trained person has greater endurance and work capacity than a person who does not engage in sports, and this is also reflected in biochemical parameters (Finaud, 2006; Robert, 2016).

The aim of the research was to establish changes in biochemical parameters in male and female adolescents engaged in physical activity at different stages of puberty.

Organization and research methods. The study involved 1,338 adolescents aged 10–20 years (897 male adolescents: 743 athletes, 155 control group; 441 female adolescents: 376 athletes, 65 control group; the control group included adolescents who had been engaged in sports for 6 to 8 months, 3 times a week for 2 hours, and had not achieved sports qualifications). The participants were divided into 3 groups by age range: 11–13 years, 14–18 years, and 19–20 years for males, and 10–12 years, 14–17 years, and 18–20 years for females. All stages of the study were conducted at the bases of the Vitebsk Regional Dispensary of Sports Medicine and the Vitebsk Regional Diagnostic Center.

Blood serum was analyzed for the content of glucose (Baykeev, 2012; Vlasova, 2011; Ozarda, 2018; Mischenko, 2021), triglycerides and total cholesterol (TC), HDL cholesterol and LDL cholesterol (Vasilenko, 2017; Higgins, 2018), urea (Kristian, 2017), potassium (Pflaum, 1956), calcium (Stefano,1999) (these parameters were expressed in mmol/dm^3); direct bilirubin (Pearlman, 1974), creatinine (Dufour, 1988), uric acid (Karbasy, 2015), serum iron (these parameters were expressed in μmol/dm^3).

The results were processed using the Mann–Whitney U test (Statistica 10.0 software), considered statistically significant at $p < 0.05$.

Research results and discussion. When analyzing the examination results of male and female adolescent athletes, variants of changes in biochemical parameters important for the pubertal period were identified:

In boys aged 11–13 years (pubertal period), only one parameter changes – creatinine. Creatinine is a product of creatine phosphate metabolism (a metabolite of muscle energy metabolism), formed in muscles, and it is known that the level of creatinine in urine and blood depends on various factors (muscle mass and intensity of physical exertion) (Brancaccio, 2007). It was found that during intense physical exertion compared to the control group, the parameters glucose and triglycerides, uric acid, urea, total bilirubin, potassium, calcium, and iron remain at a constant level.

In female adolescents aged 10–12 years, changes were identified in 3 metabolic parameters – uric acid, urea, and creatinine levels are lower compared to the control group, while the biochemical parameters glucose, triglycerides, TC, total bilirubin, potassium, calcium, and iron remain at a constant level.

The variable and invariable metabolic parameters in male subjects aged 11–13 years and female subjects aged 10–12 years are presented in Table 1.

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Table 1

Metabolic parameters in adolescent athletes (boys 11–13 years old, girls 10–12 years old) and the control group

Indicators	*Young men 11–13*		*P*	*Girls 10–12*		*P*
	Control	*Athletes*		*Control*	*Athletes*	
Glucose, mmol/dm3	3,82 4,40–4,80	4,23 4,45–4,80	0,66	4,80 5,00–5,19	4,57 4,90–5,30	0,55
Triglycerides, mmol/dm3	0,50 0,85–1,11	0,47 0,70–0,96	0,40	0,69 0,84–1,00	0,70 0,90–1,10	0,90
TC, mmol/dm3	3,56 3,90–5,07	3,72 4,30–4,70	0,81	3,60 4,08–5,00	3,90 4,50–5,10	0,59
Uric acid, µmol/dm3	157 230–267	197 270–322	0,70	220 250–290	177 ↓ 220 –260	*0,01*
Urea, mmol/dm3	3,34 4,10–4,49	3,72 4,41–4,88	0,50	3,65 4,76–5,16	3,12 ↓ 3,73–4,21	*0,00*
T. bilirubin, µmol/dm3	10,0 12,3–14,7	10,4 12,0–17,8	0,78	10,7 13,4–15,0	11,0 12,6–22,5	0,59
Creatinine, µmol/dm3	80,0 85,0–100	75,0 ↓ 80,0–90,0	*0,04*	80,0 86,0–93,0	60,0 ↓ 70,0–70,0	*0,00*
Potassium, mmol/dm3	3,60 3,80–4,20	4,00 4,38–4,60	0,22	3,66 4,40–4,58	4,0 4,4–4,8	0,50
Calcium, mmol/dm3	2,18 2,30–2,46	2,19 2,32–2,45	0,91	2,18 2,33–2,41	2,27 2,34–2,40	0,50
Iron, µmol/dm3	10,5 10,5–10,5	9,73 12,95–18,13	1,00	14,4 18,2–21,0	11,9 16,5–18,8	0,44
Note: P<0.05 when comparing the control groups “Young men” and “girls”.						

In boys aged 14–18 years, compared to the age of 11–13 years, the number of parameters that remain at a constant level is greater by 5 parameters: glucose, total cholesterol (TC), total bilirubin, potassium, and iron. It was found that the biochemical parameters triglycerides, uric acid, urea, and creatinine are higher compared to the control group, while calcium levels are lower than in the control group. Triglycerides reflect the degree of balance of lipid (fat) energy resources. A triglyceride level of about 1.0 mmol/L indicates high activation of fat metabolism processes during the training activity of athletes (Pearlman, 1974; Stefano,1999). Urea levels allow assessing the adequacy of the total volume and intensity of training loads to the functional capabilities of athletes during enhanced breakdown of tissue proteins (Pflaum, 1956) Calcium plays an important role, especially during puberty, ensuring the synchronized functioning of muscle tissue, the myocardium, the nervous system, and the skin (Stefano,1999; Osipov, 2023).

Ten biochemical parameters (glucose, triglycerides, TC, uric acid, urea, total bilirubin, creatinine, potassium, calcium, and iron) in female adolescents aged 13–17 years did not change compared to the control group. Compared to the age of 10–12 years, the number of parameters is greater, even though puberty also occurs at this age.

The variable and invariable metabolic parameters in male subjects aged 14–18 years and female subjects aged 13–17 years are presented in Table 2.

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Table 2

Metabolic parameters in adolescent athletes (boys 14–18 years old, girls 13–17 years old) and the control group

Indicators	Young men 14–18		*P*	Girls 13–17		*P*
	Control	*Athletes*		*Control*	*Athletes*	
Glucose, mmol/dm3	4,40 4,72–5,12	4,30 4,7–05,10	0,24	4,39 4,80–5,00	4,31 4,65–5,00	0,49
Triglycerides, mmol/dm3	0,48 0,68–0,99	0,57 ↑ 0,77–1,00	*0,05*	0,69 0,80–1,43	0,56 0,72–1,00	0,13
TC, mmol/dm3	3,44 3,86–4,40	3,40 3,90–4,40	0,76	4,12 4,30–5,00	3,60 4,10–4,60	0,08
Uric acid, μmol/dm3	250 280–320	260 ↑ 300–350	*0,01*	170 220–270	170 210–260	0,93
Urea, mmol/dm3	3,67 4,30–5,00	4,10 ↑ 4,90–5,80	*0,00*	3,31 4,53–5,30	3,50 4,20–5,00	0,57
T. bilirubin, μmol/dm3	11,5 14,3–17,9	10,7 13,7–21,0	0,46	10,6 14,0–15,8	10,5 13,5–21,3	0,64
Creatinine, μmol/dm3	80,0 84,0–95,0	85,0 ↑ 90,0–100	*0,00*	70,4 84,0–93,0	70,0 80,0–90,0	0,46
Potassium, mmol/dm3	3,79 4,21–4,88	3,90 4,40–4,89	0,35	3,62 4,00–4,44	3,90 4,30–4,70	0,33
Calcium, mmol/dm3	2,35 2,45–2,53	2,31 2,42–2,52	*0,00*	2,25 2,34–2,40	2,22 2,34–2,44	0,79
Iron, μmol/dm3	11,0 14,5–19,0	12,5 17,6–21,4	0,26	15,3 20,2–29,0	13,0 16,0–22,5	0,19
Note: P<0.05 when comparing the control groups “Young men” and “girls”.						

Five identical biochemical parameters that remain at a constant level in the male group (19–20 years old) and the female group (18–20 years old) are: glucose, triglycerides, uric acid, potassium, and calcium.

In the comparative group of males (19–20 years old) and females (18–20 years old), seven parameters were found to remain at a constant level, while three biochemical parameters changed. In males, total cholesterol (TC) was reduced, whereas creatinine and iron levels were higher compared to the control group. Cholesterol (TC – total cholesterol) is the final molecule of metabolism, and its level can be used to assess the state of metabolism (Allain, 1974). Proteins, fats, and carbohydrates entering the body are converted during metabolism into acetyl-CoA, which 1) is "burned" in the tricarboxylic acid cycle and mitochondrial respiratory chains, providing ATP production; 2) is converted into fatty acids and triglycerides under conditions of reduced energy expenditure; and 3) is converted into cholesterol. The cholesterol molecule forms the basis for membranes (determining membrane rigidity) and mineralocorticoids (maintaining water-salt balance) [17]. Iron in the body is part of porphyrin compounds, mainly hemoglobin, myoglobin, and porphyrin; in small amounts, it is incorporated into cytochromes and certain enzymes. In male adolescents, the level of total bilirubin is elevated, while urea and creatinine levels are reduced.

The dependence of biochemical parameter values on the age of male (19–20 years old) and female (18–20 years old) subjects is presented in Table 3.

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Table 3

Dependence of biochemical marker values on the age of male and female subjects

Indicators	*Young men 19–20*		*P*	*Girls 18–20*		*P*
	Control	*Athletes*		*Control*	*Athletes*	
Glucose, mmol/dm3	3,95 4,66–5,25	4,20 4,70–5,10	0,84	4,40 4,40–4,68	4,30 4,66–4,96	0,29
Triglycerides, mmol/dm3	0,51 0,70–0,89	0,60 0,80–1,00	0,26	0,64 0,78–1,05	0,60 0,80–1,05	0,91
TC, mmol/dm3	3,80 4,65–5,33	3,70 ↓ 4,20–4,65	*0,07*	4,10 4,40–5,04	3,90 4,50–5,10	0,81
Uric acid, μmol/dm3	275 290–350	250 300–350	0,79	182 230–285	190 240–270	0,85
Urea, mmol/dm3	4,00 4,53–6,00	4,51 5,22–6,00	0,16	3,90 6,20–6,50	3,50 ↓ 4,30–5,90	*0,09*
T. bilirubin, μmol/dm3	12,1 15,1–18,7	11,9 14,7–21,7	0,63	10,0 10,4–12,6	11,6 ↑ 13,6–20,1	*0,01*
Creatinine, μmol/dm3	64,0 82,0–90,0	90,0 ↑ 100–110	*0,00*	80,0 90,0–100	75,0 ↓ 80,0–90,0	*0,03*
Potassium, mmol/dm3	4,00 4,42–4,97	3,90 4,20–4,70	0,24	3,98 4,10–4,28	4,08 4,28–4,58	0,33
Calcium, mmol/dm3	2,31 2,43–2,48	2,28 2,37–2,49	0,55	2,23 2,30–2,37	2,22 2,31–2,41	0,67
Iron, μmol/dm3	10,9 11,0–17,2	14,0 ↑ 17,2–25,0	*0,03*	10,5 10,8–14,6	10,6 13,3–16,7	0,70
Note: P<0.05 when comparing the control groups “Young men” and “girls”.						

Table 4

Biochemical parameters maintained at a constant level in adolescents

Indicators	*Young men*			*Girls*		
	11–13	*14–18*	*19–20*	*10–12*	*13–17*	*18–20*
Glucose	+	+	+	+	+	+
Triglycerides	+		+	+	+	+
TC	+	+		+	+	+
Uric acid	+		+		+	+
Urea	+		+		+	
T. bilirubin	+	+	+	+	+	
Creatinine					+	
Potassium	+	+	+	+	+	+
Calcium	+		+	+	+	+
Iron	+	+		+	+	+
Quantity of biochemical indicators	*9*	*5*	*7*	*7*	*10*	*7*

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Conclusion. The metabolic parameters presented in the article can be divided into two groups. Parameters that remain at a constant level—meaning that physical exertion did not affect their status in adolescent boys aged 11–13 years (glucose and triglycerides, uric acid, urea, total bilirubin, potassium, calcium, and iron)—only one parameter changed: creatinine. In girls aged 10–12 years, the parameters glucose, triglycerides, total cholesterol (TC), total bilirubin, potassium, calcium, and iron remain at a constant level. During the pubertal period, it is noticeable that the parameters glucose, triglycerides, total bilirubin, potassium, calcium, and iron are more stable in both boys and girls. In boys aged 14–18 years, there are fewer parameters that remain at a constant level (glucose, TC, total bilirubin, potassium, iron); this may lead to the conclusion that during this period, the body is developing, and intense physical exertion affects the state of biochemical parameters (stress). In girls, all parameters remain at a constant level without changes. In boys aged 19–20 years, seven biochemical parameters remain at a constant level (glucose, triglycerides, uric acid, urea, total bilirubin, potassium, calcium), and in girls, the same number (glucose, triglycerides, TC, uric acid, potassium, calcium, iron).

Biochemical parameters reflect the internal state of the body and the influence of physical exertion. These biochemical health markers can be used for medical monitoring of the pubertal period, as well as for detecting metabolic disorders in athletes during the pubertal stages of life.

REFERENCES

Baykeev, R. F. Identification of athletes of various qualifications by the biochemical method / R. F. Baykeev // Sports medicine: science and practice. – 2012. – No. 4. – P. 25–32.

Bezrukikh, M. M. Age physiology / M. M. Bezrukikh, V. D. Sonkin, D. A. Farber // M.: Publishing center "Academy", 2003. – 416 p.

Vasilenko, V. S. Blood lipids in athletes depending on the focus of the training process / V. S. Vasilenko, E. S. Semenova, Yu. B. Semenova // Pediatrician. – 2017. – No. 8. – P. 10–14.

Vlasova, Yu. A. The relationship between biochemical parameters of blood and lifestyle of adolescents / Yu. A. Vlasova // Pediatrician. – 2011. - No. 2. – P. 32–36.

Grishina, Zh. V. Reference intervals of biochemical parameters of blood and young athletes / Zh. V. Grishina, S. O. Klyuchnikov, V. S. Feshchenko // Issues of practical pediatrics. – 2022. – Vol. 17, No. 1. – P. 71–78.

Korochanskaya, S. P. Biochemical features of metabolism in children: a teaching aid / S. P. Korochanskaya, I. M. Bykov, T. S. Khvostova. – M.: Krasnodar, 2018. – 134 p.

Adeli, K. Biochemical marker reference values across pediatric, adult, and geriatric ages: establishment of robust pediatric and adult reference intervals on the basis of the Canadian health measures survey / K. Adeli, V. Higgins, M. Nieuwesteeg // Clin. Chem. – 2015. – Vol. 43, № 8. – P. 1049–1062.

Al-Khelaifi, F. A. Pilot study comparing the metabolic profiles of elite-level athletes from different sporting disciplines / F. A. Al-Khelaifi, I. Diboun, F. Donati // Sports Med. – 2018. – Vol. 4. – P. 12–18.

Allain, C. C. Enzymatic determination of total serum cholesterol / C. C. Allain // Clin. Chem. – 1974. – Vol. 20, № 4. – P. 470–475.

Asgari, S. Continuous reference intervals for 38 biochemical markers in healthy children and adolescents: Comparisons to traditionally partitioned reference intervals / S. Asgari, V. Higgins, K. Adeli // Clin. Chem. – 2019. – Vol. 73. – P. 82–89.

Bergmeyer, H. U. Approved recommendationon IFCC methods for the measuremtnt of catalytic concentration of enzymes. Part 2. IFCC method for aspartate aminotransferase / H. U. Bergmeyer, M. Horder, R. Rej // Clin. Chim. Acta. – 1985. – Vol. 24, № 7. – P. 497–510.

Brancaccio, P. Creatine kinase monitoring in sport medicine / P. Brancaccio, N. Maffulli, F. M. Limongelli // Br. Med. Bull. – 2007. – Vol. 81. – P. 209–230.

Castro-Pinero, J. Muscle strength-based tests to identify European adolescent at risk of metabolic syndrome: The HELENA study / J. Castro-Pinero, K. R. Laurson, E. G. Artero // J. Sci. Med. Sport. – 2019. – Vol. 22, № 8. – P. 929–934.

Chaki, B. High-intensity exercise-induced oxidative stress in sedentary pre-pubertal and post-pubertal boys: A comparative study / B. Chaki, S. Pal, S. Chattopadhyay // Indian J. Med. Res. – 2019. – Vol. 150, № 2. – P. 167–174.

Dufour, D. R. Creatine kinase: aspartate aminotransferase activity ratio as an indicator of the source of an increased creatine kinase activity / D. R. Dufour // Clin. Chem. – 1988. – Vol. 34. – P. 2506–2510.

Endurance development in Taekwondo according to the Tabata protocol / N. Mischenko, M. Kolokoltsev, A. Gryaznykh [et al.] // Journal of Physical Education and Sport. – 2021. – Vol. 21, No. Suppl. 6. – P. 3162-3167. – DOI 10.7752/jpes.2021.s6421.

Effect of specific balance training on balance performance and technical combat skills of male and female police cadets / A. Yu. Osipov, T. I. Ratmanskaya, V. M. Guralev [et al.] // Journal of Physical Education and Sport. – 2023. – Vol. 23, No. 2. – P. 335-341. – DOI 10.7752/jpes.2023.02040.

Finaud, J. Oxidative stress: Relationship with exercise and training / J. Finaud, G. Lac, E. Filaire // Sports Med. – 2006. – Vol. 36. – P. 327–358.

Higgins, V. Pediatric reference intervals for calculated LDL cholesterol, non-HDL cholesterol, and remnant cholesterol in the healthy CALIPER cohort / V. Higgins, S. Asgari, M. K. Chan // Clin. Chim. Acta. – 2018. – Vol. 486. – P. 129–134.

Individualization of martial arts training based on sensorimotor reaction analysis in students / I. Bocharin, M. Guryanov, A. Vorozheikin [et al.] // Journal of Physical Education and Sport. – 2024. – Vol. 24, No. 6. – P. 1373-1379. – DOI 10.7752/jpes.2024.06155.

Karbasy, K. Advances in pediatric reference intervals for biochemical markers / K. Karbasy, P. Ariadne, S. Gaglione // J. Med. Biochem. – 2015. – Vol. 34, № 6. – P. 23–30.

Kristian, K. The timing of puberty and gender differences in educational achievement / K. Kristian, P. Tuomas. – IZA-Initiated Institute of labor economics, 2017. – 31 p.

Ma, H. M. Pubertal development timing in urban Chinese boys / H. M. Ma, S. K. Chen, F. Xiong // Int. J. Androl. – 2011. – Vol. 5. – P. 435–445.

Ozarda, Y. Verification of reference intervals in routine clinical laboratories: practical challenges and recommendations / Y. Ozarda, V. Higgins, K. Adeli // Clin. Chem. Lab. Med. – 2018 – Vol. 57 – P. 30–37.

DOI:10*https://doi.org/10.14258/zosh(2026)2.10*

Pearlman, F. C. Detection and measurement of total bilirubin in serum, with use of surfactants as solubizing agents / F. C. Pearlman, R. T. Lee // Clin. chem. – 1974. – Vol. 20. – P. 447–453.

Pflaum, R. T. Spectrophotometric determination of potassium with sodium tetraphenylborate / R. T. Pflaum, L. C. Howick // Anal. Chem. – 1956. – Vol. 28, № 10. – P. 1542–1544.

Robert, N. The search for new diagnostic markers of metabolic response to aerobic aerobic exercise: analysis of creatinine, urea, and uric acid levels in football in football players / N. Robert, B. Rafal, K. N. Dorota // Trends Sport Sci. – 2016. – Vol. 4. – P. 167–175.

Stefano, M. Biochemical markers of bone turnover and the volume and the density of bone in children at different stages of sexual development / M. Stefano, P. Pisit, R. K. Francine // J. Bone Miner. Res. – 1999. – Vol. 14, № 10. – P. 1664–1671.