Original Article

Adaptation to physical loads of the osseous tissue of highly skilled female athletes specializing in artistic gymnastics

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Published online: March 25, 2016

(Accepted for publication March 06, 2016)

DOI:10.7752/jpes.2016.01030

Abstract:

The results of densitometric studies of the osseous tissue of highly skilled female athletes specialized in artistic gymnastics have been presented. From the standpoint of “female athlete triad” syndrome that includes disordered eating (neurotic anorexia), amenorrhea and osteoporosis, the high percentage of sports medicine representatives refers female athletes to risk group due to their predisposition to the development of osteoporosis and increased risk of fractures. It should be outlined; however, that osteoporosis associated with its diagnostic manifestation – bone fracture – is not developed in all female athletes subjected to high physical loads even in case of hypogonadism.

Objective of studies – to determine the impact of physical loads on the osseous tissue adaptation in highly skilled female athletes specialized in artistic gymnastics.

Methods of studies. Special questionnaire surveys along with anthropometric studies were carried out. Structural and functional status of the osseous tissue was determined by the method of ultrasound densitometry using “Achilles+” (USA) device and the method of the dual energy X-ray densitometer “Prodigy” (USA). Obtained results demonstrated higher elasticity and strength of the osseous tissue in highly skilled female gymnasts as compared to the indices of average statistical standard of Ukrainian females of the same age.

Keywords: osseous tissue, densitometry, artistic gymnastics.

Introduction

Of all body systems, the locomotorium, being the biological system with complex pattern of skeleton osseous structures that constantly experience mechanical tensions due to weight bearing (body mass), muscle tone and activity, is subjected to the greatest loads during regular sports activities (Brusko, Omelchuk & Haiko, 1998). Therefore, it may serve as a reliable indicator of favorable and unfavorable impacts of physical culture and sports engagement.

Development of elite sport, increase of the number of sports participants, intensive and continuous physical loads, enhanced and specific requirements imposed by each sports event on athlete's body increase the risk of injuries.

Analysis of the causes of sports traumatism in Ukraine in 1997-2002 performed by V.N. Levenets indicates that according to data of the Statistical Office of the Ministry of Public Health of Ukraine sports traumatism of adults, adolescents and children shows the tendency to increase. The level of sports traumatism in Ukraine in 2002 among adults and adolescents has increased by 8,82 %, whereas that among children – by 5,88 % as compared to 2001 (Levenets, 2004). Continuous increase of the number of sports injuries assumes rather menacing proportions.

Locomotorium injuries may be caused by internal and external factors. The first ones mainly involve sports event specifics including conditions of training sessions and sports competition venues, violation of training principles and methods, in particular, inadequacy of exercise complexity to the level of athlete fitness, quality of nutrition (Zetterberg, 2002, Platonov, 2006). Extreme and continuous stress of the body systems during physical loads, microtraumas, diseases, age and sex as well as structural and functional disorders of the osseous tissue may be referred to the second ones (Kannus, 2002, Jackson, 2003).

Osseous tissue is a metabolically active structure of the body, which is continuously developed and renovated. It is subjected to continuous process of mature bone tissue removal – resorption and new bone tissue formation. This process is called bone remodeling (Podrushnyak, 1994, Rozhinskaya, 2000, Tsygan, Deyev, 2007).

In adults up to 10 % of skeleton bone tissue is remodeled annually. Bone formation prevails over bone resorption before the age of 20. The peak of human bone mass is formed by 25 years (Rozhinskaya, 2000, Tsygan, Deyev, 2007). According to Ukrainian scientists (Povoroznyuk, 2004, Povoroznyuk, Vovk, Orlyk et al., 2004), the peak of bone mass among females of Ukraine is achieved at 23-24 years with the major increase at the age of 10-15 years, i.e. during the puberty. The main structure of the osseous tissue is inherited. Meanwhile, its

mass and structure mainly depend on the following major factors – balanced nutrition, character of physical loads, sex hormone homeostasis (Povoroznyuk, Grigoryeva (2000).

While comparing structural and functional differences between male and female body, one should bear in mind that biological cyclic character of female body hormonal status and, thus, cyclic changes of the body system functions, characterize specificity of its adaptation to all types of activity and to high physical and psycho-emotional loads of the modern elite sport, in particular (Shakhlina, 2001).

Morphofunctional reorganization of female athlete body in the process of adaptation to the long-term training and competitive loads introduces specific changes in the functions of their body systems, including reproductive one, both during active sports career and after retirement (Shakhlina, 2001, Shakhlina, Litisevich, 2007).

Professionalization and commercialization of the modern sport further contribute to increase of training loads. Lack of proper qualified medical control for the tolerance of high volumes of work by female athletes does not contribute to their health; therefore, sports activities are usually associated with acute and chronic overstrain of body systems with preferential disorder of one or several functional systems (Medik, Yuryev, 2001).

Physical loads in sport require reliable mechanical support of athlete body, i.e., proper structural and functional state of skeleton bone tissue. It is known that the bone tissue performs three major functions in the body: mechanical (strength of the osseous tissue within the locomotorium is the main condition of locomotion); protective – protection of vital viscera's (bones of thoracic cage and pelvis) and metabolic – the osseous tissue represents calcium and phosphorus depot in the body maintaining their homeostasis (Rozhinskaya, 1994; Rozhinskaya, 2000).

Bone tissue is subjected to constantly changing loads and adapts to them by alteration of bone mass and skeleton geometry.

In 1892 J. Wolff determined that under the influence of mechanical load the bone structure is changed by means of enhancing bone formation in the area of the highest load and increasing resorption in the opposite area. The impact of this principle upon bone modeling and resorption is known as the Wolff's Law (Lawrence, Melton, 2000, p. 472). His studies demonstrated that motor activity has positive effect on the bone tissue preventing the reduction of bone mass, whereas the decrease of weight bearing function of skeleton results in negative impact on the bone.

Optimum physical loads may probably induce an increase of bone tissue formation or reduce its resorption, thus, resulting in bone mass increase while adapting bone structure to suggested physical impacts (Lindsay, 2000). Hypodynamia, extremity immobilization, paralyses accompanied with fast and massive loss of bone mass (Lindsay, 2000), the reduction of which represents significant potential problem for long duration space missions, produce the opposite impact upon bone tissue structure (Berezovskyi, Litovka, 2004; Gyulmazarova, 2004).

More than 100 years ago after the series of clinical studies, F. Albright reached the conclusion that among various causes of osteoporosis development sex hormones deficiency played the leading role.

According to several scientists (Rozhinskaya, 2000; Tsygan, Deyev, 2007; Mehrsheed, 2000), despite insufficient understanding of the remodeling process and mechanisms of its regulation, there are sufficient data allowing to consider the important role of sex hormones in maintenance of structural and functional state of skeleton bone tissue, which is, probably, achieved by means of regulation of remodeling cycle frequency, establishment of balance between resorption and modeling within each remodeling cycle (Lawrence, Melton, 2000).

After reaching the peak of bone mass at the age of 25, a zero balance, i.e., the period of relative balance of bone mass structure is maintained at the age of 35-40 years (Kannus, 2002; Povoroznyuk, Vovk, Orlyk et al. 2004; Tsygan, E. N., Deyev, R. V. (2007). The age loss of bone mass is observed after 40 years constituting 0,5-2,0 % and 2,0-3,0 % per year in males and females, respectively. This loss tends to accelerate significantly within 5-10 years after menopause (Povoroznyuk, Grigoryeva, 2004; Tsygan, Deyev, 2007).

It has been determined (Roos, 1996) that throughout life females lose up to 35 % of cortical and up to 50 % of trabecular bone, as compared to 20 % and 30 % losses in males.

These changes of bone mass are considered as age atrophy that is manifested in decrease of thickness and increase of porosity of cortical bone and trabecular thinning and perforation, which reduce trabecular construction strength, thus increasing the risk of fractures (Rozhinskaya, L. V. (1994; Rozhinskaya, 1994; Tsygan, Deyev, 2007).

Sex hormones play an important role in skeleton formation and prevention of bone mass losses. Androgens and estrogens provide the achievement of bone mass peak and are involved in maintenance of bone balance, mineral homeostasis, i.e., the development of sexual dimorphism of skeleton during reproductive age (Povoroznyuk, 2004; Rozhinskaya, 2000).

Estrogen receptors (Eriksen, Colvard, Berg et al., 1988) have been found in bone tissue (in osteoclasts and osteoblasts); it is noteworthy that osteoblasts possess greater amount of estrogen, progesterone and parathormone receptors as compared to osteoclasts (Zetterberg, 2002). Available data are indicative of the key role of estrogens

in bone tissue metabolism – they suppress the activity of osteoclasts preventing the process of bone resorption as well as have the direct effect on osteoblasts stimulating the processes of bone tissue modeling (Lawrence, Melton, 2000; Rozhinskaya, 2000). For this very reason estrogen deficiency during hypogonadism (ovarian dysfunction) in females of reproductive age and during menopause is the key factor of osteopenia development (Povoroznyuk, 2004; Povoroznyuk, Grigoryeva, 2004; Rozhinskaya, 2000).

Female sex and elderly age are the main factors of osteopenia development followed by osteoporosis (postmenopausal osteoporosis) (Povoroznyuk, 2004; Povoroznyuk, Grigoryeva, 2004; Lindsay, 2000).

Osteoporosis is the most common type of metabolic diseases of skeleton that is characterized by progressive decrease of bone mass in the unit of bone volume relative to standard index in persons of respective sex and age (Rozhinskaya, 2000; Tsygan, Deyev, 2007). Impaired structure of osseous tissue leads to increased brittleness of bones and increased risk of fractures as a result of minimal injury or even without injury (Lawrence, Melton, 2000; Roos, 1996).

Sports medicine specialists took note of frequent combination of disordered eating (neurotic anorexia), amenorrhea and osteoporosis in female athletes (Niauri, Yevdokimova, & Kurganova, 2003; Povoroznyuk, Vovk, Orlyk, et al., 2004). The given syndrome was called “female athlete triad” in 1992. It is noteworthy, however, that in modern elite sport osteoporosis associated with its diagnostic manifestation – bone fracture – is not developed in all female athletes subjected to strenuous physical loads even in case of hypogonadism (Shakhlina, Povoroznyuk, 2004).

Objective of study – to examine structural and functional state of the osseous tissue of highly skilled female athletes specialized in artistic gymnastics.

Methods

Fourteen highly skilled athletes, members of the national team of Ukraine in artistic gymnastics, participated in the study. Special questionnaire survey along with measurements of body length and mass were made preliminary. Structural and functional state of the osseous tissue was determined at the Department of Clinical Physiology and Pathology of the Locomotorium of the Institute of Gerontology of the AMS of Ukraine together with Professor V.V. Povoroznyuk. Qualitative and quantitative estimation of spongy bone tissue of calcaneus was made by the method of ultrasound densitometry using “Achilles+” device of Lunar Corp. (USA) Company. The following parameters were determined: speed of ultrasound propagation through the bone (SUP, m•s⁻¹), which depends on its density and elasticity; wide-band ultrasound attenuation (WUA, dB/MHz), which reflects trabecular number and size. Ultimately, the index of bone density (ID, %) was determined on the basis of indices calculated by means of densitometer according to formula. Usage of more advanced method of osteodensitometry - the dual energy X-ray densitometer “Prodigy” (USA) - allowed to examine structural and functional state of different segments of skeleton in two views and, in particular, the lumbar spine and the whole body.

Computer software of densitometer contained the programs of standard indices according to age and gender identity allowing automatic comparison of the results of each study and calculation of differences in percentage ratio (T and Z criteria). Statistical processing of obtained results was performed by means of standard programs of statistical analysis Microsoft Office Excel 2000 and the package of applied statistical programs “Statistica”. The results were compared with reference indices of young females of Ukrainian population of respective age.

Results and their discussion.

Table 1 presents the results of questionnaire survey and anthropometric studies. The age of subjects ranged from 14 to 21 years. Sports qualification: master of sport (MS) – 8; merited master of sport (MMS) – 2; international master of sport (IMS) – 4. Sports experience – 9-15 years depending on age and sports qualification. Age of beginning regular artistic gymnastics training: 3 – 7,13 %, 4 – 28,5 %, 5 – 42,8 %, 6 – 14,25 %, 7 – 7,13 %. Body mass – 36,0-55,0 kg, body length – 146,0-166,5 cm. Age of menarche (the first menses) is the most important indicator of the onset of sexual maturity of a girl. Analysis of questionnaire details has shown menstrual function in 9 athletes (64,2 %) with menarche onset at the age of 15 in 33,3 %, at the age of 16 in 33,3 %, at the age of 17 in 11,1 % and at the age of 19 in 11,1 %. The length of menstrual phase (bleeding) constituted about 5 days. It should be noted that all 9 athletes reported irregular menstrual cycles with delay of up to 2 months and even more. Menstrual function was absent in 5 of 14 athletes.

In our opinion, the fact concerning sports injuries is very important. According to available data (Platonov, 2006; Smolevskiy, Gaverdovskiy, 1999; William, Garron, 2003) gymnasts are subjected to both acute and chronic (stress) injuries such as fractures, sprains of ligaments and muscles, bruises. The most common are sprains.

According to specialists of China, where gymnastics is highly developed, 66,7 % of female and 33,3 % of male gymnasts are exposed to complex combined injuries; fractures in gymnasts aged 8-16 years have been observed in 52,8 % of cases (Li Guiving, Gang, Jimei, Wang, Linglin-Join, 2008). Analysis of the character of

traumas in highly skilled Ukrainian female gymnasts has demonstrated fracture occurrence in 9 of 14 surveyed athletes (64,2 %). They were localized in the area of forearm, elbow and ankle joints, foot (instep bone), fingers and toes, nose. It is noteworthy that 5 athletes (35,8 %) have not suffered any fractures during 9-13 years of active sports activities. All subjects reported occasional exacerbations of chronic traumas – sprain of ligaments mainly in the area of ankle, knee and radiocarpal joints.

Table 1. Results of analysis of questionnaire survey data of female athletes specialized in artistic gymnastics

№ п/п	Name	Age, years	Qualification	Sports experience,	Body length, cm	Body mass, kg	Age of menarche,
1	S.	14	MS	10	152	38,5	—
2	K.	14	MS	9	151	41	—
3	G.	15	MS	10	148	36	—
4	S.	15	MS	10	159	52,5	—
5	I.	16	MS	11	159	47	15
6	V.	16	MS	12	160	51	16
7	Z.	17	IMS	13	160	51,5	—
8	K.	17	IMS	12	150	42,5	17
9	K.	18	MS	12	165	51	16
10	M.	19	MS	15	156	46,5	15
11	I.	19	IMS	12	150	43,2	16
12	K.	19	MMS	15	161	51	15
13	K.	19	MMS	14	154,5	49	18
14	K.	21	IMS	18	167	55	19
х		17,071			155,32	46,6	
м		0,5786			1,573	1,54	

While analyzing obtained results and accentuating that artistic gymnastics is one of the most high-injury sports events, one may suppose that the cause of such acute injuries as the bone fractures may be related to continuous increase of technical complexity of gymnastic elements and combinations or disordered structure of bone tissue.

Table 2. Anthropometric data and indices of structural and functional state of bone tissue of highly skilled female athletes specialized in artistic gymnastics

Subjects	Age, years	Body length, cm	Body mass, kg	SUP, m•s ⁻¹	WUA, dB/MHz	ID, %
Athletes	17,071 ± 0,58	155,32 ± 1,57	46,64 ± 1,54	1606,0 ± 6,76	128,86 ± 2,67	115,5 ± 2,96
Population of the same age & sex возраста и пола	17,0	170,0 ± 0,11	60,3 ± 11,1	1575,0 ± 33,3	113,0 ± 12,0	96,0 ± 16,0
Differences, %		8,64	22,70	1,93	12,31	16,88

The results of studies of structural and functional state of highly skilled gymnasts' osseous tissue (Table 2), carried out by means of "Achilles+" ultrasound densitometer on calcaneus, which was represented by trabecular (spongy) bone tissue, demonstrated that speed of ultrasound propagation (SUP, m•s⁻¹) through the osseous tissue of athletes, depending on its density and elasticity, was 1,93 % higher than in females of Ukrainian population of respective age group. The wide-band ultrasound attenuation (WUA, dB/MHz) and the index of density (ID, %) were 12,31 % and 16,88 % higher in athletes, which is indicative of not only the higher bone density but the greater number and size of spongy bone trabecules. Presented results indicate higher elasticity and strength of bone tissue of female athletes of the given specialization as compared to indices of average statistical standard of Ukrainian girls of the same age. Advanced method of osteodensitometry - the dual energy X-ray densitometer "Prodigy" (USA) – was used to study the bone mineral density (BMD).

Fig. 1. Histogram of distribution of examined gymnasts depending on indices of BMD of lumbar spine.
Fig. 2. Histogram of distribution of examined gymnasts according to indices of BMD of the whole body

The results of studies (Fig.1) demonstrated that bone mineral density of lumbar spine of all examined gymnasts was within normal range, which was further confirmed by histogram of Z-criterion indices in the values of standard deviation SD having being within normal range for the given age and sex. According to diagnostic criteria of the WHO (1994), SD deviation in T-criterion from -1,0 to -2,5 and from -2,5 and more is indicative of osteopenia and osteoporosis, respectively (Berezovskyi, Litovka, 2004; Shakhlina, Litisevich, 2007). Application of Z-criterion provides estimation of deviation of the results of measuring bone mineral density with account for gender and age standards.

Figure 2 illustrates the results of examining BMD of the whole body of highly skilled female athletes specialized in artistic gymnastics.

The results of histogram show that the average index of BMD of the whole body of 14 female gymnasts constituted $1,09 \text{ g}\cdot\text{cm}^{-2}$, with maximal and minimal values being equal to $1,16 \text{ g}\cdot\text{cm}^{-2}$ and $1,02 \text{ g}\cdot\text{cm}^{-2}$, i.e., BMD of the whole body was within normal range. However, estimation of the results according to Z-criterion (Fig.3) has revealed a tendency to decrease of BMD of the whole body in one athlete as compared to the reference group of the same age.

Fig. 3. Histogram of distribution of examined gymnasts according to indices of BMD of the whole body.

Further studies of structural and functional state of the osseous tissue by means of “Prodigy” (USA) densitometer have permitted to reveal the differences in bone mineral density (BMD) and bone mineral concentration (BMC) of the upper and the lower extremities of subjects.

These data are indicative of higher mineral density and concentration of bone tissue of the lower extremities of athletes as compared to the upper ones. These differences may be associated with load specifics peculiar for artistic gymnastics, in which the lower extremities are subjected to higher specific weight of load – jumps, run-up, landings, and acrobatic elements.

The results of a few studies demonstrate that BMD and BMC of the upper extremities of tennis players (Berezovskyi, Litovka, 2004; Shakhlina, Litisevich, 2007) exceed examined indices of dominant hand. Some researchers (Kannus, Haapasalo, Sankelo, et al. 1995) believe that physical load impact upon bone mineral density of dominant hand of female tennis players resulted in twofold predominance of bone mineral content

increase in those female athletes who had begun regular training before the onset of menarche as compared to those who had started training after the first menses.

The same conclusion was reached by C. Cheng et al. (Cheng, Maffulli, Leung, et al., 1999). In their opinion, optimum increase of bone mass is impossible without physical activity of the growing body well before the puberty.

At the same time, uncontrolled and excessive physical loads may have a negative effect on the body of immature girls. According to V.V. Povoroznyuk et al. (Povoroznyuk, Vovk, Orlyk, et al., 2004) unbalanced nutrition, amenorrhea and high physical loads have negative effect on structural and functional state of bone tissue of female athletes, especially during the period of bone mass accumulation, which may negatively influence osteogenesis.

Studies of structural and functional state of the osseous tissue of highly skilled female athletes specialized in artistic gymnastics have revealed that systematic physical loads contribute to statistically significant increase of the index of bone tissue density in young girls engaged in volleyball and handball as compared to reference group (Povoroznyuk, Shakhlina, Orlyk, et al 2003). It has been also demonstrated that structural and functional state of the osseous tissue in female water polo players was lower than in female athletes specialized in handball and basketball. Such direction of the differences in the results of the subjects is peculiar for girls of juvenile age (14-15) and female athletes aged twenty. Differences in the results that characterize structural and functional state of calcaneus trabecular tissue have been attributed by the authors to slightly higher physical load upon the lower extremities, and calcaneus, in particular, of female basketball and handball players as compared to specific loads in water polo, in which gravity forces acting on the body in the water are lesser (Povoroznyuk, Shakhlina, Orlyk, et al, 2003).

Several researchers (Povoroznyuk, Shakhlina & Novokhatskyi, 2000), who have revealed in the course of examining the national team of Ukraine in artistic gymnastics, that in most of the girls aged 12-17 years the ultrasound characteristics of bone tissue exceeded the indices of average statistical standard for Ukrainian girls and adolescents, have the same view on this issue. It should be noted that at the time of studies neither of them experienced menstrual function. The above may be indicative of the low level of sex hormones – estrogens – in their body.

It has been established that osteoblasts are the target structure for estrogens, progesterone and parathormone (Zetterberg, 2002). Available data show that in the female body they serve as the protectors of bone tissue, activating formation and function of osteoblasts, enhancing calcium mobilization by bone tissue, decreasing bone tissue resorption by osteocytes (Lawrence, Melton, 2000; Rozhinskaya, 2000; Tsygan, Deyev, 2007). Therefore, high physical loads upon female body in the modern elite sport, having disturbed menstrual function and sex hormone status, may cause bone mass reduction not only in the future but in active athletes as well (Povoroznyuk, Vovk, Orlyk, et al., 2004; Shakhlina, Litisevich, 2007; Lindsay, 2000).

Several authors (Povoroznyuk, 2004; Povoroznyuk, Grigoryeva, 2004; Mehrsheed, 2000) believe that the character of load, the number of repetitions, the speed of displacement of skeleton segments and anthropometric data are the factors that distinguish the character of motions in different sports events. These peculiarities may probably impose specific loads on bone tissue, as soon as the development of skeletal muscles in the course of training is an important factor of bone mass development.

According to A.T. Brusko et al. (Brusko, Omelchuk, Haiko, 1998), during walking the human bone is subjected to varied loads of longitudinal compression accompanied by elastic deformation and induces physiological changes of microcirculatory provision of trophism and metabolic processes in bone tissue.

Physical loads specific to artistic gymnastics contribute to increase of the index of bone tissue density, which characterizes exceeding bone mass peak as compared to its formation in female-nonathletes of the same age. This positive effect of artistic gymnastics training may explain the fact that the upward change of the stereotype of functional load of girls enhances hydrodynamic impact of elastic deformations upon bone blood supply and trophism (Brusko, Omelchuk & Haiko, 1998). According to V.V. Povoroznyuk et al. (Povoroznyuk, Grigoryeva, 2000), despite the fact that menstrual function of examined gymnasts is characterized by deviations from the norm for the given age group, the influence of hormonal deviations and delay of menarche in highly skilled and experienced gymnasts may be levelled off by constant specific loads (of jumping character, with constant pushing offs and landings requiring equilibrium maintenance), which contribute to increase of the number and the size of trabecules and bone tissue strength.

Nevertheless, artistic gymnastics is one of the high-injury sports events. While examining the character of traumas (bone fractures) in subjects, conspicuous is the fact of the absence of tubular bone fractures and localization of fractures in typical areas only (radiocarpal, elbow and ankle joints as well as fingers, toes and metatarsal bones). Taking into account an adequate structural and functional state of the osseous tissue, confirmed by our results, the above may indicate that traumatism in the given sports event is most frequently caused by increased complexity of gymnastic elements, breach of principles and methods of training along with discrepancy between exercise complexity and the level of fitness of gymnasts (especially young), number of

repetitions, inadequate warming-up. The above causes of traumatism are commonly reported by specialists in the theory and methods of training of highly skilled gymnasts (Smolevskiy, Gaverdovskiy, 1999; Roos, 1996).

Conclusions

1. Indices of densitometric studies of highly skilled female gymnasts indicate higher elasticity and strength of the osseous tissue of athletes of the given specialization as compared to indices of average statistical standard for Ukrainian females of the same age.

2. Significantly higher values of bone mineral density and concentration of athletes' lower extremities as compared to the upper ones have been noted, which may reflect specific character of physical loads peculiar for artistic gymnastics (jumps, run-up, landings, acrobatic elements with greater specific load imposed on the lower extremities).

Similar results were observed in our experimental animal studies.

3. One may assume that positive influence of physical loads on structural and functional state of bone tissue of highly skilled gymnasts in the face of estrogen deficiency is not the risk factor of the development of osteopenic syndrome and osteoporosis within the given age period. Further studies are required.

4. Well-balanced nutrition of female athletes specialized in artistic gymnastics should be considered as preventive and curative method for maintaining overall health, optimum conditions for provision of an adequate structural and functional state of bone tissue.

5. Regular special medical control for young female athletes should be provided from the angle of their biological development in accordance with real age; besides, the health status of female athletes, their ability to tolerate physical and psycho-emotional training and competitive loads, nutrition behavior and rest should be monitored regularly.

The above listed conditions and high professional level of a coach will permit female athletes, and gymnasts, in particular, to achieve high performances and preserve their health.

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