THE INFLUENCE OF SPORTS TRAINING ON THE GROWTH AND PUBERTAL DEVELOPMENT IN FEMALE RHYTHMIC GYMNASTS

Abstract

Elite female rhythmic gymnasts represent a selected group of girls exposed to high intensity training in the pre-adolescent period. Constitutive body height of these female athletes is achieved through compensatory "catch up" of growth through which a pattern of longer growth period emerges. At the same time, present puberty delay provides optimal skeletal maturation. Low body fat content is in correlation with late appearance of menarche. On the basis of all these variances there is a primary importance of energy deficiency which directly (reduction of accessibility of circulating energy substrate) or indirectly (effects on growth, bone maturation and body fat accumulation) leads to dysfunction of reproductive hypothalamus. Aiming to preserve normal growth and development, as well as heath of female rhythmic gymnasts and similar sports, it is necessary to monitor them in short-time intervals during pre-pubertal and pubertal age, estimating training volume and diet at the same time.

Key words: RHYTHMIC GYMNASTICS / GROWTH / SEXUAL DEVELOPMENT / NUTRITION

INTRODUCTION

Characteristic somatotype of female rhythmic gymnasts (hereinafter RG) is characterized by low body mass, that implies low body fat, long limbs and relatively high strength compared to body mass (small body) (Klentrou & Plyley, 2003). According to body composition, the majority of these female athletes can be classified in bony morph type. One of the important factors of success in this sport is visual appearance and aesthetics.

Trainings in rhythmic gymnastics begin in pre-adolescent age, in order to achieve good sports results as early as in puberty and during adolescence. Nowadays, in elite RG, trainings last over 20 hours (26-28 hours) a week. During the 70s of 20th century it used to be approximately 15 hours a week, and during the following decades, like in many other sports, the number of hours of trainings was ascending. The demands of RG became especially high in the beginning of the 80s, which is directly connected with the beginning of competitions in the Olympic Games (Theodoropoulou, Markou, Vegenakis, Banardot, Leglise, 2005).

It has been clear for a long time that an intensive physical work influences puberty and in par-
ticular to its initiation, its progression, followed by Tanner's, as well as to the appearance of menarche. Besides, the health effects of sports trainings are conditioned by the specific demands of a sport (training) and individual characteristics of an athlete himself (gender-related differences and constitutional characteristics regarding growth and sexual maturity) (Theodorpoulou et al., 2005; Wiemann, 2002).

The changes of pattern of growth and pubertal development, as well as the appearance of the symptoms of sports triad, can have serious implications to the health (the loss of bone mass), including the failed realization of the genetic maximum of growth and development.

THE INFLUENCE OF SPORTS TRAINING ON THE INCREASE OF BODY HEIGHT IN RHYTHMIC GYMNASTICS

It is generally thought that a fact that should be accepted, that in elite RG, as well in some other sports (sports gymnastics, long track running, ice skating, ballet, tennis and similar), there is a moderate, but a significant retardation in growth and pubertal development.

One of the basic characteristics of growth during puberty is the growth of body height which takes place under the pattern which is specific for each and every individual. When the changes of body height are followed in the case of the female athletes that have been exposed to large and intensive trainings since pre-pubertal period, it is often observed that there is the inconsistency from the usual pattern typical for a certain population.

Researches about the growth of female rhythmic gymnasts and other young persons in similar sports confirmed the fact that constitutional body height is being achieved through compensatory catch up, through which the pattern of longer period of growth is an outcome. In the research Georgopoulos, Markou, Theodorpoulou (2002), the fastest growth in elite female rhythmic gymnasts has been observed between the age of 14-16 (2.8± 2.2cm at the age of 14, 2.6±2.5 cm at the age of 15 and 3.0±2.6 cm at the age of 16), with a peak at the age of 16. It is interesting that non-athlete group of girls, who served as a control group, the fast growth ended with the age of 15, while in the female rhythmic gymnasts the curve of fast growth continued up to the age of 18. In the population of average adolescent girls, the ending of largest growth is expected at the age of 18. Obviously, the pattern of female rhythmic gymnasts that includes so-called catch up of growth should enable to compensate for the body height that has been lost during the earlier phases of puberty. The data (Georgopolous et al., 2002) clearly show that catch up of growth for the elite RG is slow and it comes late. Since it is culminant, there is enough time for the optimal skeletal maturation (Georgopolous et al., 2001). On the contrary, if catch up were in the coincidence with the pubertal growth advancement, the result would be a significant fall of body height because of a rapid skeletal maturation (Georgopolous et al., 2002). In this research the estimated body height was not only achieved, but also surpassed. Genetic factors are those which control the observed catch up of body height growth.

When body height and mass of sub elite female rhythmic gymnasts in Serbia were monitored in the period from 1976-1995, it was observed that these female athletes always had lower values of BH and BM (except the first generation) compared to non athletes. The differences in height are not great and they were distributed in limits of average value for the given age, which could be partly explained by genetic predisposition and sports selection. Greater demands, which mean larger training volume and the specific diet, must be taken into account (Sanader, 2000).

Estimation and monitoring of bone maturation show the covered part on the growth and development path during adolescence, as well as the part that is to follow (Djordjevic-Nikic, 1995). The fact that best confirms the changed scheme of growth and pubertal maturation is moderate, but significant retardation in bone maturity, which is observed in young female rhythmic gymnasts exposed to certain training regime. Georgopoulos, Markou, Theodorpoulou (1999) in their research with RG observed a slow bone maturity of 1.8 years of their chronological age, which was statistically significant (r=0.73; p<0.001).

It is considered that there are more different hormone factors that contribute to such appearance: low concentration of gender steroids, as a consequence of low secretion of gonad stimuli and/or the disturbance in homeostasis IGF-1 (hormone insulin-like growth factor 1). Intensive physical trainings cause chronic psycho-social stress and modify nutritive factors, which is clearly manifested through intolerably low energy intake.
THE INFLUENCE OF SPORTS TRAINING ON THE BODY MASS AND COMPOSITION IN RHYTHMIC GYMNASTICS

The performance score of elite female rhythmic gymnasts is in negative correlation with the fat share in overall body composition.

The low fat content in RG and similar female athletes can represent the protection of premature fusion of epiphysis. In this situation there is a lack of fat that could be the substrate for steroid aromatization in fat tissue (Georgopolous et al. 2002). Fat tissue is a significant extra gonad source of estrogen in which the conversion of androgen into estrogen takes place, so that can be the way to understand the late sex development (breasts and pubic hair), mostly under the influence of low body mass.

It is clear that there is a minimum of body mass for BH and in connection with it, a critical ratio of dry muscular mass compared to the content of body fat, that probably represent the key factors for menarche induction.

The research conducted on World and European Championships in the period from 1997-2004, that comprised 423 elite female rhythmic gymnasts aged 11-23 from 32 countries (from all the continents), provided useful data about the growth of these female athletes. Body mass index was 16.9±1.8kg/m², and body fat percentage of 15.5±4.6%. These values were followed by the delay in skeletal maturation, puberty, as well as late menarche (14.6 years of age) (Theodorpolou et al. 2005).

In the research Stojiljkovic et al. (1995) of sub elite female rhythmic gymnasts of Serbia it was determined that they had 10.5% of fat tissue in body composition, which is statistically significantly less than in non-athletes, while BM was 15% lower compared to the control group, which was on the limit of statistical significance.

THE INFLUENCE OF SPORTS TRAINING ON SEXUAL DEVELOPMENT IN RHYTHMIC GYMNASTICS

It is clear that growth and pubertal development are delayed in the largest number of elite female rhythmic gymnasts, so that the right picture of growth and development is got by determining the bone maturity. Monitoring of this parameter enables highly reliable forecasting of the dynamic of sexual development and the appearance of menarche (Georgopolous et al. 1999).

Genetic factors are important for the appearance of menarche, so this indicator of sexual maturing in female athletes is monitored in comparison to the menarche of mothers and sisters, taking into account their engagement in similar sports during adolescence. The researches show that there is a variance of 37% for menarche and genetics (Klentrou & Plyley, 2003). The late menarche, amenorrhea and oligomenorrhea in female athletes can be observed in 6-79% of cases (Theodorpolou et al., 2005). Nowadays, it is thought that the deviation from the optimal is the lack of signs of secondary sexual characteristics at the age of 14, as well as the absence of menarche at the age of 16.

For a long time it has been considered that there is a correlation between the percentage of fat in body composition and the appearance of menarche and the regularity of menstrual cycles.

Predictive significance of BM, body mass index and the percentage of fat in body composition for the appearance of menarche is clearly observed when all the parameters are compared in pre-menarche and menarche RG.

In researches of sexual maturing of female rhythmic gymnasts it is found that CDs of body mass is the factor that is the most important in development of breasts (Theodorpolou et al., 2005). It is known that the development of breasts and appearance and sustenance of regular menstrual cycle are connected to the level of estrogen, which can be of extra gonad origin (fat tissue). Whenever the female athletes demonstrate: 1) low level of body fat, 2) low BM, 3) low energy intake and 4) high intensity trainings, it is real to expect the delay of menarche (Theodorpolou et al., 2005). Low fat and intensive trainings therefore stay as the most predictable factors of growth and sexual development of female rhythmic gymnasts.

Theodorpolou et al. (2005) in their research of elite FRG determined that the normal growth of breasts of 2-4 phases (according to Tanner) lasted for 1.96±0.93 years, which showed the preserved pattern of sexual maturing progress. Normal development of pubic hairs takes place under the influence of androgens of adrenal gland. In researches it was shown that in female athletes in rhythmic and sports gymnastics pubic hair growth is caused by the age in which
sports trainings begin (Theodoropoulou, 2005). So, ballerinas who start trainings at the age of 8-9, with only 3.5-7.3 hours a week, have pubic hair at the expected age, while female gymnasts who start trainings at the age of 6.5-7.4 with 30 hours a week experience the growth of this sexual characteristic later.

THE IMPORTANCE OF OPTIMAL NUTRITION FOR THE GROWTH OF RHYTHMIC GYMNASTICS FEMALE ATHLETES

There are well-known and universally accepted theories about the primary importance of energy deficiency for the dysfunction of reproductive hypothalamus, in the case of athletes and other young people (Klentrou et al., 2003).

Acute reduction of energy accessibility under 25 Kcal/kg of dry muscle mass causes the reduction of T3 (tri-iodine-thyronine). This adaptation of thyroid hormone causes metabolic changes and deflation of LH (luteinizing hormone)-pulses. Reduction of LH-pulses is more expressed after serious diet restrictions, than after equivalent energy deficiency caused by the increase of energy consumption. Therefore, the changes in LH-pulses in case of female athletes can be prevented by an adequate energy intake. That is the reason why an inadequate energy intake is the primary factor of fertility suppression and more important that the other aspects of intensive exercising (Nemet, Connolly, Pontelo, 2004; Borer, 2003)

There are few researches in which the detailed data about energy-nutrition characteristics of female rhythmic gymnasts are obtained. The data available about this problem are related to the athletes in sports gymnastics, aged 10, that have 15 hours of trainings a week (Filaire & Lac, 2002). In this research female athletes have been in energy balance, i.e. a daily energy intake corresponded to the daily energy consumption. Body height, mass and body fat share have lower values compared to referent values for the given population (France). In the light of these data the importance of constitutional factors and sports selection is confirmed. Nutritional analysis has shown the deficit of vitamins E and B6, diet fibers and poly-unsaturated fat acids. Calcium intake had the limit values. Protein and fat intake surpassed the references, together with less carbohydrates intake values. The acquired data about nutritive values of diet are similar to the values that are often obtained in analyses of young athletes’ nutrition, as well as in general population of children in developed countries, showing the importance of professional monitoring and correction of the young people nutrition. The fact is that 15 hours of training a week, recorded in this research, makes it possible to satisfy the energy demands with the corrections of nutritive intake.

Unreal objectives connected to the body mass and composition in sports in which aesthetics is important, together with exceptionally high volume of trainings, are very often accompanied with significant deviation from energy-nutritive needs of a young organism.

CHANGES IN ENDOCRINE FUNCTIONS IMPORTANT FOR GROWTH AND SEXUAL DEVELOPMENT

Generally speaking, sectional views show that physical exercise of female adolescents is connected with adaptation of growth hormone system – hormone-insulin-like growth factor 1 (GHS – HIGF-1), showing the hormone expression – anabolic condition. As a contribution of this fact there is a positive correlation of sectional view of night level of growth hormone and the level of trainings. Besides, there is a significant correlation of average growth hormone secretion and the peak of body height growth (Elia- kim, Brasel, Mohan, Barstow, 1996, Felsing, Brasel, Cooper, 1992). The raise of insulin-like growth factor 1 in trained examinees is the result of a well known mechanism, when the raise of growth hormone level stimulates the raised production of HIGF-1 in liver. In these conditions there is an expected raise of connecting proteins to the growth hormone (GH – CP). HIGF-1 is a known mitogen in skeletal muscles. A significant correlation between the muscle volume (hypertrophy and hyperplasia) and circulating HIGF-1 was found (Eliakim et al., 1996).

Volume and pattern of growth hormone secretion depends on the intensity and volume of physical exercise. Children and adolescents that are introduced in physical trainings of large volume and intensity are less tall than it is usual for their chronological age; they grow slower and often have low concentration of HIGF-1 in plasma (Borer, 2003; Eliakim et al, 1996, Nemet et al, 2004).
Functional axis of endocrine glands – hypothalamus – hypophysis – gonads can be interrupted by the signals that are the result of inadequate skeletal maturation, the deficiency of energy reserves, reduction of energy accessibility and stress. The change in this axis is manifested in the form of late appearance of menarche (primary amenorrhea), irregular menstrual cycles (oligomenorrhea) or secondary amenorrhea. Reduced frequency of gonadotropin releasing hormone pulses (Gn-RH), dysfunction of adequate number of Gn-RH – receptors on gonadotropin, together with suppressed amplitudes of gonadotropin pulses, they all cause the break in hypothalamus – hypophysis – gonads axis.

Instead of starting at the age of 12.8 (average age for menarche in non-athlete female population), menarche in female athletes occurs often from one to several years late. In the case of female athletes such as runners, gymnasts and ballerinas, the delay in puberty start is 1-2 years. Every year of intensive trainings before the menarche leads to the delay of the same of approximately 5 months, which suggests the suppressive effects of exercise, through factors that initiate puberty – that show cumulative effect (Borer, 2003). In the case of aforesaid female athletes, there is a sustained pre-pubertal pattern (longer than in average population) of low frequency LH-pulses, followed by changed relation of follicular stimulating – luteinizing hormone (FSLH – LH) – in the behalf of FSLH and the absence of oestradiol secretion increase, which is altogether necessary for the normal puberty progression.

Secretion of gonadotropin and pubertal development is re-established again in the case of amenorrhea – anorexic female athletes – female adolescents, when the demands of their trainings are reduced or when their energy intake is increased, even in the case of absence of oestradiol secretion increase, which is altogether necessary for the normal puberty progression. These facts suggest that energy lack can change hormone pattern, which is the cause of the changes of initiation and progression of puberty. Energy deficiency induces it directly through the reduction of accessibility of circulating energy substrate or indirectly through the effects to growth, bone maturation and accumulation of body fat.

Women’s hormone cycle in post pubertal age can be deranged by long lasting trainings defined by high energy demands. In that case it can be shown through the reduction of luteal phase reduction, oligomenorrhea, absence of ovulation and secondary amenorrhea. Incidents of secondary amenorrhea are more frequent in case of younger women, as well as those who have not had a birth. In this case amenorrhea is also followed by insufficient energy intake, low body fat and more expressive psycho physical stress (Borer, 2003).

Primary cause that deranges fertility of female athletes is the suppression of LH-pulses amplitude, caused by the fall of the activity of hypothalamus GnRh-pulse generator. This situation causes the defect of luteal phase or the lack of ovulation and amenorrhea. Shortening of luteal phase is followed by prolonged follicular phase of menstrual cycle. Changed secretion function of the corpus luteum is manifested by inadequate quantity and secretion of progesterone. The mistakes in ovulation and amenorrhea are the consequences of reduced secretion of oestradiol and the lack of oestradiol-positive feedback for gonadotropin secretion. In the lack of fertility that is in connection with severe sports trainings there are usually no changes of hypophysis sensitivity on GnRh (Borer, 2003).

THE SIGNIFICANCE OF LEPTIN FOR NORMAL GROWTH AND SEXUAL DEVELOPMENT

Leptin is a cytokine, discovered in 1994. It is synthesized fully in fat tissue and it is secreted from it depending on fat body mass. It has its effects on hypothalamus, skeletal muscles, fat tissue and liver. It is considered to have an influence on food intake and metabolic energy spending (Borer, 2003). The loss of body fat (insufficient energy intake), especially low fat level in amenorrhea female athletes causes dramatic reduction of leptin concentration in plasma. The fall of leptin influences secretion of LH-releasing hormone and to the level of sex steroids as well, especially through the lack of suppression of appetite-stimulating neuron peptide Y (NPY). Therefore, the reduction of leptin level in serum causes suppressive effect on reproduction axis, which can be renewed by exogenous administration of this substance (Weimann, 2002).

It is postulated that leptin is a connection among fat depots, pubertal development and the secretion of LH-releasing hormone. The secretion of leptin is enlarged in luteal phase of menstrual cycle.
In the case of female athletes with amenorrhea, daily pattern of leptin secretion is absent. Variations of leptin level can influence the development and preservation of reproductive functions, which can be observed in female athletes participating in sports that demand certain aesthetic (Weimann, 2002).

**FEMALE ATHLETE TRIAD**

Female athlete triad is a serious and widespread pathological condition characterized by: derangement in eating habits (especially anorexic neurosis), amenorrhea (the lack of menstruation in the continuous period longer than three months) and premature osteopenia (osteoporosis is only in the case of reduced bone density – BMD (DEXA) for more than 2.5 SD below the average for young adults). The above mentioned triad actually comprises malnutrition, estrogen and calcium deficiency as well as osteopenia (Klentrou & Plyley, 2003). Significant osteopenia (T score = -2.0) in twenty-year-old female can show worse prediction about future bone health than in the case of osteoporosis at 65 year-old female with T score = -2.6 (Benjamin, 2007).

**CONCLUSION**

Elite female rhythmic gymnasts represent a selected group of girls exposed to high intensity training in the pre-adolescent period.

Aiming to preserve and achieve constitutional potential of growth and development, as well as health of female rhythmic gymnasts and similar sports, it is necessary to monitor them in short-time intervals during pre-pubertal and pubertal age, and at the same time, to estimate training volume and diet.

**REFERENCES**


