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Professional paper

THE EVALUATION OF BIOLOGICAL MATURITY IN SPORT

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Abstract: The aim of the paper is to present various methods for the evaluation of biological maturity which can define the differences between chronological age and biological maturity in young athletes. Biological maturation is a non-linear process, taking place at all organic levels, differing from the flow of time after birth. From this point of view, there is a need to determine the differences in the rate of biological maturation within the chronological period. Defining the biological maturity of athletes has a multidimensional significance, the evaluation of youth's maturity in comparison with the chronological age has an implicit value, the selection and prediction of sports achievement at the individual level is crucial for the planning and programming of the training process. Maturity evaluation feedback has a function in preventing and restraining injuries of athletes who are behind their peers. Athletes who are advanced in comparison to their chronological generation, in younger selections, reach a plateau of sports performance early, which can negatively affect success in the senior period. The paper presents the basic methods of evaluation of biological matrices used in the diagnosis of young athletes. Biological maturity can be determined by means of radiography, anthropometric measurements, and sex-based indicators.

Keywords: *radiography, sex-based indicators of maturity, peak height velocity, young athletes*

INTRODUCTION

Human development is a complex and discontinuous process that takes place under the influence of external and internal factors. The influence of genetic potential, geographical area, race, sex, social status, nutrition, lifestyle and pathological conditions can influence the dynamics and quality of human development (Ehrlich, 2000). From ontogenetic point of view, one is strongly influenced by the laws of nature which determine the order, orientation and

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direction of development with three fundamental components, tissue differentiation, functional maturation and growth (Ugarković, 2001). Over time, man goes through developmental stages that are anthropologically clearly defined. The duration of each stage is determined by a time interval, although there are individual differences in the speed of development.

The maturity of young athletes can be observed chronologically and biologically. Chronological maturity is the observed period from birth to a given point in time (Prieto, 2005). Chronologically observed age involves the use of astrological parameters for determining the age. Such an approach perceives human development unilaterally, without taking into account numerous influences that can lead to misconception when considering the biological potential of systems of organs. Developmental progress is based on the physiological characteristics of the human organism, the level of biological and chronological maturity can often not coincide, especially in the period of pre-adolescence and adolescence (Choen, 1979). Biological maturity is defined according to the model of functional, morphological, anatomical and biochemical status of the organism, characteristic for a given chronological period, the imbalance of the biological and chronological maturity is seen in the rate of changes that characterize developmental phases. Some people mature faster and are quicker to reach biological parameters that are characteristic of the population that is at the higher chronological age. Literature lists three groups of biological maturity in relation to chronological age, the young who are behind their peers in terms of biological development, those who mature in line with the chronological determiner and a group of people who have reached a higher level of biological maturity (accelerants) compared to their chronological age (Avsiyevich, 2016). The differences of biological parameters may be latent, but from the morphological and anthropometric aspect they are clearly observed between the groups. In terms of functional features, a higher increase in power in accelerants is noticeable as a result of a higher degree of muscle maturation, which reflects on better performance of motor skills and superiority in sports performance (Avsiyevich, 2016). Primary somatic indicators that the biological assessment of maturity is based on include measures of cartilage ossification, primary and secondary sexual maturation, dental maturity, morphological status, biochemical hormone markers (Beunen et al., 2006).

The assessment of the biological maturity of young athletes is an important segment of diagnostics, the observed phenomenon of individual human development represents the need to define and determine the biological basis of each individual. Performance in sports activity in most sports is predominantly related to morphological structure, anthropometric characteristics and motor skills (Jakovljević et al., 2016). Differences in biological potential within the same generation of athletes are precisely differentiated in these details, which can present a discriminatory factor for achieving sports results. In cases of greater biological maturity variations than the chronological standard of biological markers, an adequate approach in training should be applied. Acceleration currently contributes to better sports results in younger categories,

but due to the achievement of the maximum developmental level, the performance in senior categories is under question. Coaches often select players who were born in the first half of the year or who are biologically more mature in order to achieve success in a competition (Müller, 2017). It often happens that athletes who develop in accordance with their age or those who are late in developing, achieve better sports results in the senior age group than accelerants who experienced success in competitions for younger categories. For the purpose of selection, the level of biological maturity of athletes, especially during the training process, should be taken into account and appreciated when making decisions. Also, determining the position in the team, in case of team sports, based on current physical characteristics and physical abilities can lead to early specialization which leads to unilateral development of skills. Athletes whose biological maturity is consistent with chronological age, especially during adolescence, can experience emotional crises, anxiety states caused by failure in competitions against other teams where biologically more mature peers have achieved better results. It is necessary to educate young players so that they understand the biological processes of maturation and the significance of human developmental biology in the training process. The biological maturity assessment comprises three sets of methods, based on the estimation of skeletal maturity, sexual development and the proportional relation of certain dimensions of body parts. Skeletal maturation is a reliable parameter for the evaluation of biological maturity and prediction of the peak height which is important for selection in some sports (Baxter-Jones, 2005). Skeletal maturity is assessed on the basis of an X-ray image of the joints, the distance of the proximal bone edge from the medial or distal margin defines a development stage of skeletal ossification on the basis of which biological maturity is determined. Sex-based indicators that can determine the degree of physical maturity are observed through the primary and secondary characteristics of men and women. In men, sex-based are the development of genitals, while in women maturity is observed through the development of breasts, facial, pubic and axillary hair, menarche, and vocal frequency (Malina et al., 2015). An estimate of biological maturity based on the growth rate and proportional dimensions of the body parts (sitting height, length of the lower extremities, etc.) indicate that the rate of physical growth, which is non-linear, provides information concerning maturity (Loyd et al., 2014).

METHODS FOR BIOLOGICAL ASSESSMENT

The complexity of methods for assessing biological maturity is reflected in the techniques used. The invasiveness of techniques may influence an athlete's consent to undergo testing. Certain methods involve x-ray radiation or intimate examinations. On the other hand, the level of validity of the obtained data and the importance of feedback influences the selection of an appropriate method for assessing biological maturity. When assessing maturity in children, methods that may affect the personality of the respondents require a consent of the respondents or their parents, while for the research and scientific checks the consent of an ethics committee must be obtained (Puri, 2009).

Radiography

Radiography is a method used in medicine to observe internal organs. The X-ray device has electromagnetic properties, it performs differentiation of soft and hard tissues, and during the process, X-rays identify the bone structures that are displayed on the radiogram (X-ray). Radiography is an invasive technique because X-rays penetrate the tissues, exposing them to non-harmful radiation. By treating bone and joint sites with X-rays provides data on the dimensions, structure and distance between the bones based on which the biological maturity analysis is performed (Bešenski i Škegro, 2012). The assessment of biological maturity by means of radiography is based on the degree of cartilage ossification and the approximation of proximal and distal bone epiphyses. The maturation of the skeleton is affected by the endocrine system, the rate of changes affecting the skeletal system determines the level of maturity (Rai et al., 2012). Complete ossification of joints in the human body signifies the completion of physical growth. Skeletal maturation has an individual character, as the skeletal status can vary significantly within the same chronological age (Beunen et al., 2006).

Modern diagnostics by radiographic method involves the use of specialized computer programs that detect and analyze parameters from radiographs, and such an approach allows obtaining precise results that are independent of the subjective assessment of the expert. In scientific practice, a different approach is used in the calculation of biological age, which is determined by bone maturity. Since 1896, assessment has been made based on the footage of the left hand of the respondent (Hojreh et al., 2018). The Greulich-Pyle technique estimates bone maturation based on Todd's Atlas, which makes a collection of 100 radiographic images for each chronological age from birth to the age of 19 (Todd, 1937). The average value of the size and arrangement of the bones of the left hand contained in Todd's Atlas represent a value that is compared with the parameters of radiographs of subjects (Roche et al., 1975). The FELS technique determines the skeletal maturity based on the diameter of the radius, ulna, carpals, metacarpals and finger bones (Nahhas et al., 2013). The *Tanner-Whitehouse* technique had three versions over time before the latest *Tanner-Whitehouse III* technique was established (Tanner et al., 2001). Bone maturity diagnostics is done on the basis of an individual estimate of 20 bones of the left hand whose scale was based on a large sample of children from different continents (Beunen et al., 2006). Computer Skeletal Diagnostics, an automated approach to determining results provides a reliable and easy way to evaluate biological maturity in relation to chronological age. *BoneXpert* is a multidimensional modeling tool for assessing skeletal maturity based on the reconstruction of 15 bones of the left hand. *BoneXpert* estimates bone maturity based on the *Greulich-Pyle* and *Tanner-Whitehouse III* technique (Thodberg et al., 2009). Figure 1 shows the reference data in two different approaches to skeletal maturity estimation, as well as standard deviations with the *Bone Health Index* (BHI).

Figure 1. *Results of the skeletal biological maturity assessment in the BoneXpert program* (https://www.bonexpert.com/products/bonexpert-server)

Modern tendencies in the diagnostics of biological maturity based on skeletal maturation are directed at the validation of MRI and ultrasound assessments, bearing in mind the development of diagnostic medical equipment (Hojreh et al., 2017; Mughal et al., 2014). The radiographic method can provide an assumption about the final height of the examinee with the help of predictive formulas for both sexes (Gilsanz & Ratib, 2005).

Anthropometric method

Anthropometric parameters of the body have a predictive function in determining the biological maturity of young people. The method is based on the phenomenon of peak height velocity, which represents a somatic determinant, the point of approaching complete maturity (Tanner et al., 1966). Topographically observed, the growth rate of different body parts does not occur linearly in all areas. Science has confirmed that it is possible, on the basis of certain body proportions, to determine the point in which biological development is currently taking place (Moore et al., 2015). Anthropometric assessment of biological maturity is a non-invasive method, covering several body variables, body height, sitting height, leg length and body mass. It is also necessary to define the sex and chronological age of the respondents (Gil et al., 2013). The protocol involves two measurements, the measures used are the mean, if the difference between the obtained results between the first and the second measurement is 4 mm in height / length and 0.4 kg in mass assessment, it is necessary to conduct re-measuring (Sherar et al., 2005). The accuracy of the obtained measures is important for prediction, so even the smallest deviations can significantly affect the final assessment of biological maturity.

Regression analyses in several different longitudinal studies, which encompassed continuous measurements of young people aged 8 to 16, provided predictive parameters for two different formulas, separately for female and male sex (Mirwald et al., 2002.; Koziet & Malina, 2018.; Moore et al., 2015):

1. Males:

Biological maturity (years) = - 9.236 + ((0.0002708 x (length of leg x sitting height)) + (- 0.001663 x (age x length of lower limb)) + (0.007216 x (age x sitting height)) + (0.02292 x ((body weight / body height) x 100)), or

Biological maturity (years) = -7.999994 + (0.0036124 x (age x body height))

2. Females:

Biological maturity (years) = - 9.376 + ((0.0001882 x (length of leg x sitting height)) + (0.0022 x (age x length of lower limb)) + (0.005841 x (age x sitting height)) + (- 0.02658 x (age x body weight)) + (0.07693 x (body weight / body height) x 100)), or

Biological maturity (years) = -7.709133 + (0.0042232 x (age x body height))

The anthropometric method is widely accepted as a simple diagnostic procedure for assessing the biological maturity of adolescents of both sexes. Also, this method can be used to estimate the final height of the respondent (Sherar et al., 2005).

Sex-based characteristics method

Maturation of primary and secondary sex-based characteristics takes place through the mechanism of biological development until complete reproductive functionality. Sex-based indicators represent a method used in many studies for the assessment of the biological maturity of athletes, that is, the degree of differentiation from their chronological age (Brooks-Gunn et al., 1987; Susman et al., 2010; Malina et al., 2007; Baxter-Jones et al., 1995). The development of breasts and pubic hair in girls, as well as the development of genitals and body hair in boys determines the degree of biological maturity. Comparing the obtained measures with the values that are characteristic of a particular chronological age can lead to conclusions that indicate whether the respondent deviates from their age cohort and to what extent. Also, in girls, it is possible to take into account earlier menarche which is interpreted as faster biological maturation, but this may be due to other factors, so this type of prediction is taken only as an additional parameter (Marshall & De Limongi, 1976).

The method of sex-based characteristics requires the engagement of medical professionals who are the only ones who can carry out examination and have a final say on the degree of maturity (Malina et al., 2004). The examination involves palpatory examination as well as photographing target body parts in order to form an archive. According to Tanner's classification, there are five phases (TS1-TS5) of full maturation. The examination involves determining the sex-based development stage of the penis, testicles, pubic hair and breasts (Tanner, 1962). Tanner's diagnostic technique has a reduced sensitivity, the range of the stages is not precisely specified, two children can fall into the same stage, but one closer to the beginning of the development stage and the other at the end of sex development in the same stage (Lloyd, 2014). The main disadvantage of this method lies in the fact that it can be applied only in the period of puberty, and that the dynamics of maturation can't be determined. Experts recommend looking at multiple sex-based characteristics at the same time, so that the assessment is supported by multiple arguments describing

biological maturity. Evaluation is done by allocating the number of years above or below the respondent's age category, usually up to 3 years. The respondent can also get zero, which means that he develops according to his chronological age. The most common sign of biological maturity in a boy is the volume of testicles while in girls, it's breast circumference and the appearance of pubic hair (Johnston et al., 1980).

CONCLUSION

Determining the quality and speed of the biological development of young athletes should definitely be included in the training process, regardless of whether it is the selection of players for top-level ranges or amateur sport. From the competitive aspect it is necessary to look at all the effects and disadvantages that result from the deviation of biological maturity from chronological age. Rapid development, the heterogeneity of the training group, in terms of many anthropological dimensions, imposes additional responsibility on coaches. They inevitably need to customize the content, intensity and volume of training units. Particular imbalance is observed in children who mature earlier and those who are late in development. The sensitivity of musculature can lead to injuries during training if the possibility of having physical differences in the same age group is ignored. Long-term planning athletes' sports life is conditioned by the potential of biological development.

When biological maturity is assessed, it is desirable to use methods that are non-invasive and which can't cause discomfort to the respondents. In this regard, it is most desirable to apply the anthropometric method that is based on the longitudinal dimension of the skeleton. It is simple to apply and it represents all ethical principles. For the purposes of more precise determination, it is more desirable to evaluate biological maturity by means of radiography, which is invasive to a lesser extent, but in turn provides a high level of predictive assessments. Sex-based features can be used in scientific studies and in situations where it is not possible to act differently.

In addition to the biological maturity assessment methods outlined in this paper, methods based on tooth development rate and quality (by developing an orthopan), as well as voice characteristics (the specificity of voice mutations) can be used. The important criteria when choosing the method are the age group (pre-puberty or puberty), the categories of respondents (children selected for top-level sports or recreational development), equipment and human resources, the material status of the club. Certainly methods can be combined, especially if research is done for scientific purposes, descriptive or epidemiological studies.

Determining the prevalence of biological differences in relation to chronological parameters is the beginning of research for scientific purposes. It is necessary to focus the research lines on looking for the causes of the dynamics of the initiation of biological development mechanisms, the influence of external and internal factors. Also, the knowledge about the characteristics and abilities of children who are biologically advanced or behind their peers will contribute

to the formation of adequate training treatments that would be stimulating and have a reduced risk of injuries. The obtained results, with adequate diagnostic methods for assessing biological maturity, can contribute to the creation of a competitive environment that is based on biological qualities in relation to the chronological categorization of athletes.

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