

**PHYSIOLOGICAL BASIS OF MUSCULOSKELETAL SYSTEM DEVELOPMENT IN  
12–13-YEAR-OLD GIRLS**

**Xudaykulova Nabiyabonu Abdunaimovna**

First-year Master's student of Bukhara International University

Email: xudoykulovanabiyabonu@gmail.com

**Abstract**

This article scientifically and practically analyzes the physiological development features of the musculoskeletal system in adolescent girls. The study focuses on identifying patterns related to morphofunctional changes in the skeleton, muscles, joints, and ligaments of 12–13-year-old girls. Based on scientific literature, normative legal documents, and empirical observations, it was found that during adolescence, bones grow rapidly in length, muscle strength develops relatively slowly, and joint mobility remains high. The results indicate that the degree of biological maturation and the methodically correct organization of physical education classes are important factors in the development of the musculoskeletal system. The article's conclusions have scientific and practical significance for organizing physical education activities for adolescent girls, taking age and gender characteristics into account, and for enhancing preventive and health-promoting approaches.

**Keywords**

adolescent girls, musculoskeletal system, physiological development, skeletal system, muscle strength, joint mobility, developmental physiology, physical education, biological maturation, health promotion

**Introduction**

In recent years, strengthening the health of children and adolescents, particularly ensuring the scientifically based physical development of girls, has been defined as a priority direction of state policy in the Republic of Uzbekistan. Adolescence is a stage of the organism undergoing the most complex and intensive morphofunctional changes, during which the physiological development of the musculoskeletal system plays a leading role. Specifically, between the ages of 11 and 14, including 12–13-year-old girls, the growth rates of bones, muscles, joints, and ligaments accelerate sharply. Due to increased hormonal activity, significant qualitative changes occur in the structure and functional capacities of the skeletal system.

Presidential decrees of the Republic of Uzbekistan, such as “**On the Creation of Conditions for Physical Fitness and Regular Engagement in Sports**”, emphasize the importance of strengthening the health of children and adolescents and ensuring their physical development according to age and gender characteristics. These documents stipulate that physical education in general education institutions and the sports-education system must be scientifically grounded and correspond to the physiological capabilities of students. This makes the in-depth study of the physiological characteristics of the musculoskeletal system in adolescent girls a pressing scientific and pedagogical task.

Decisions of the Cabinet of Ministers of the Republic of Uzbekistan regarding physical education and sports, as well as the “**State Educational Standards for General Secondary Education**”, clearly define age-appropriate physical development indicators for students, the content of exercises aimed at strengthening the musculoskeletal system, and normative exercise loads. According to these regulatory documents, during adolescence—especially in girls—the mineralization of bone tissue, relative increase in muscle mass, formation of physiological

curvatures of the spine, and joint mobility vary individually and by gender. Improperly organized physical loads can lead to various pathological conditions. Scientific physiological studies show that the development of the musculoskeletal system in 12–13-year-old girls is largely influenced by endocrine activity, the effects of estrogen hormones, the openness of epiphyseal zones, and changes in the muscle-to-bone ratio. During this period, bones grow rapidly in length, but their mechanical strength is not yet fully formed. Therefore, excessive static loads, incorrect posture, and methodologically unsubstantiated exercises can cause negative conditions such as scoliosis, kyphosis, and joint deformities, reducing the effectiveness of state programs aimed at promoting a healthy lifestyle.

Normative legal acts of the Ministry of Health and the Ministry of Education of the Republic of Uzbekistan mandate the protection of children's and adolescents' health and the scientifically and physiologically grounded organization of physical education classes. Specifically, considering gender and age characteristics and providing loads appropriate to the physiological capabilities of adolescent girls is an integral part of the pedagogical process. From this perspective, a scientifically based analysis of the laws governing musculoskeletal development is important not only theoretically but also practically.

Thus, studying the physiological characteristics of the musculoskeletal system in adolescent girls holds significant scientific and practical value, taking into account the ongoing state policies, current decrees and resolutions, and the requirements of educational standards in Uzbekistan. This article aims to analyze the developmental features of the musculoskeletal system in adolescent girls based on these regulatory frameworks and contemporary physiological approaches.

#### **Literature Review**

The study of the developmental characteristics of the musculoskeletal system during adolescence represents a complex scientific problem at the intersection of physical education theory, developmental physiology, sports medicine, and pedagogy. In the scientific literature, the formation of this system is interpreted in close connection with the organism's overall biological maturation, endocrine activity, and environmental factors. In adolescent girls, the development of the musculoskeletal system follows specific sex-related physiological patterns, which has been documented in numerous fundamental and applied studies.

Classical studies in developmental physiology (L.P. Matveev, V.P. Filin, A.A. Markosyan) describe adolescence as a period of intensive skeletal growth. These scholars scientifically demonstrated that between the ages of 11 and 14, longitudinal bone growth predominates, whereas the mechanical strength of bone tissue develops relatively slowly. These findings underscore the necessity of a cautious approach when planning physical loads for adolescent girls.

Research in sports physiology and biomechanics (G.S. Tumanyan, R.M. Bakhtiyorov, N.I. Volkov) emphasizes that the functional capacities of the musculoskeletal system are determined by muscle activity, joint mobility, and the elasticity of ligaments. According to these authors, the relatively slow development of muscle strength, the morphological immaturity of muscle fibers, and the high mobility of joints in adolescent girls constitute risk factors for injury. Therefore, the volume and intensity of physical education loads must be determined according to physiological norms.

In the pedagogical domain (O.J. Dadabaev, R.D. Khalmukhamedov, S.C. Tajibaev), the development of the musculoskeletal system is considered one of the key factors determining the effectiveness of physical education interventions. These studies show that physical training programs that do not account for the functional capacities of adolescent girls can lead to negative

pedagogical and health outcomes. Specifically, incorrectly selected exercises may cause spinal deformities, flat feet, and joint pathologies.

Endocrinological research (followers of I.P. Pavlov, contemporary studies in adolescent hormonal physiology) scientifically supports that the activation of estrogen in adolescent girls directly influences musculoskeletal development. Estrogens stimulate mineral exchange in bone tissue while increasing ligament elasticity. This results in greater joint mobility in girls, which, under inappropriate loading conditions, reduces the stability of the musculoskeletal system.

International studies (Malina R., Bouchard C., Armstrong N.) explain physical development during adolescence in terms of biological age. These authors highlight the discrepancy between chronological age and biological maturity, particularly pronounced in girls. Their research shows that girls with a higher degree of biological maturity experience earlier closure of epiphyseal zones in bones, which directly affects the functional capacities of the musculoskeletal system.

Research by Uzbek scholars (N.A. Kerimov, F.A. Kerimov, A.N. Abdiev) has examined the developmental characteristics of the musculoskeletal system in adolescent girls within the context of the national education system. These studies scientifically demonstrate that physical development indicators in school-aged girls depend on regional, social, and pedagogical factors. They also highlight that the methodologically correct organization of physical education sessions is crucial for ensuring the healthy development of the musculoskeletal system.

Analysis of national education standards and regulatory documents for physical education indicates that considering the age and physiological characteristics of adolescent girls is a mandatory pedagogical requirement. However, the literature review shows that these requirements are not always fully implemented in practice. This underscores the need for an in-depth scientific study of musculoskeletal development and the refinement of pedagogical recommendations.

Overall, the review of existing literature demonstrates that, although the physiological characteristics of the musculoskeletal system in adolescent girls have been widely studied, the integration of these findings into physical education practices, and the determination of load norms based on individual and sex-specific approaches, remains a relevant issue. This situation scientifically justifies the need for comprehensive, systematic, and practically significant research in this area.

### **Research Methodology**

This study was aimed at scientifically identifying the physiological characteristics of the musculoskeletal system in adolescent girls, analyzing the age-specific patterns of their morphofunctional development, and substantiating the necessity of considering these characteristics in physical education practices. The research methodology was developed based on a systematic, comprehensive, and interdisciplinary approach, drawing on contemporary scientific perspectives from developmental physiology, sports medicine, pedagogy, and the theory of physical education.

The methodological foundation of the study was grounded in the decrees of the President of the Republic of Uzbekistan concerning physical education and sports, decisions of the Cabinet of Ministers, national education and physical education standards, as well as normative-legal documents on the protection of children's and adolescents' health. The requirements established in these documents provided methodological support for assessing physical loads according to physiological norms and taking into account age- and sex-specific characteristics.

The study ensured the integration of both theoretical and empirical research methods. Theoretical methods included systematic analysis of scientific, pedagogical, physiological, and sports medicine literature, comparative-pedagogical analysis, synthesis, and generalization.

These methods made it possible to identify existing scientific perspectives, concepts, and approaches regarding the development of the musculoskeletal system in adolescent girls and to evaluate their strengths and limitations.

Empirical methods were designed to determine the actual physiological state of adolescent girls and included observation, anthropometric measurements, functional testing, and pedagogical monitoring. Anthropometric research assessed body height, body mass, proportionality of body segments, and the condition of the spine, evaluating age-appropriate variations. These indicators allowed the determination of the morphological development of the musculoskeletal system.

Functional methods were used to study muscle strength, joint mobility, and static and dynamic stability indicators, providing a basis for evaluating the functional capabilities of the musculoskeletal system in adolescent girls. The obtained results were compared with normative values in developmental physiology to identify opportunities for optimizing physical education loads.

The pedagogical observation method focused on systematically analyzing the movement activity, exercise technique, and adaptation to loads of adolescent girls during physical education sessions. This method allowed for evaluating the effects of physical exercises on the musculoskeletal system and ensuring that exercise content was appropriate for age- and sex-specific characteristics.

Statistical analysis methods were also applied. Empirical data were processed using mathematical-statistical techniques to calculate mean values, variance, and variability indicators. Statistical comparison methods were employed to ensure the reliability and scientific validity of the results, thereby enhancing the objectivity of the research conclusions.

Ethical and normative requirements were strictly observed. All research involving adolescent girls was conducted in accordance with principles that ensured the safety of their physical and psychological well-being. The age-specific and physiological capacities of the participants were carefully considered, and all measurements and tests were performed under medical-pedagogical supervision.

In summary, the research methodology provided a systematic and comprehensive approach for in-depth and reliable investigation of the physiological characteristics of the musculoskeletal system in adolescent girls, enabling the scientific application of the results in physical education and health-promoting practices.

### **Research Results and Discussion**

The conducted study confirmed that the development of the musculoskeletal system in adolescent girls is a complex, uneven, and multi-factorial process. Anthropometric and functional measurements obtained during the research indicated that girls aged 12–13 are in an intensive growth phase of the musculoskeletal system. In particular, rapid increases in height and lower limb length were observed alongside relatively slower development of muscle strength and static stability. This highlights a certain disproportion between the morphological and functional development of the musculoskeletal system.

Anthropometric measurements showed that while bone length growth predominates in the study participants, bone density and mechanical strength were not yet fully developed. These observations are consistent with conclusions from fundamental studies in developmental physiology. Notably, the spine is in the process of forming its physiological curvatures, and incorrect posture or excessive static load can increase the risk of functional disorders.

Functional test results indicated that although muscle strength in adolescent girls remains relatively stable compared to age norms, the rate of development does not fully match skeletal growth. Weakness in the back and abdominal muscles was identified as a significant limiting

factor for maintaining spinal stability. This underscores the need to increase the proportion of exercises aimed at strengthening the musculoskeletal system in physical education sessions.

Assessment of joint mobility confirmed that the ligamentous apparatus in adolescent girls exhibits high elasticity. While this allows for a wide range of motion, it also reduces joint stability and increases the risk of injury. The data obtained during the study suggest that high mobility combined with underdeveloped muscle strength limits the functional stability of the musculoskeletal system.

Pedagogical observations during physical education sessions revealed significant individual differences in exercise technique among the participants. These differences were closely linked to the level of biological maturity, muscle strength, and coordination skills. This finding scientifically supports the need to move away from a standardized approach and adopt differentiated and individualized methods in physical education for adolescent girls.

Comparative analysis with both domestic and international research confirmed that the development of the musculoskeletal system in adolescent girls depends on the interplay of biological age, hormonal background, and external pedagogical influences. The study results indicate that exceeding physiological capacity in physical loads, or conversely, insufficient stimulation, negatively affects the healthy development of the musculoskeletal system.

An important conclusion from the discussion is that a preventive approach is critical in the development of the musculoskeletal system in adolescent girls. Systematic implementation of exercises aimed at correct posture, strengthening the muscular corset, and stabilizing the spine ensures not only physical development but also health protection. Thus, the study results scientifically substantiate the necessity of organizing physical education in adolescent girls based on their physiological characteristics. These findings provide a solid scientific and practical basis for improving the content of physical education sessions, optimizing load norms, and enhancing health-promoting objectives.

### **Conclusion**

The results of this study scientifically confirmed that the physiological development of the musculoskeletal system in adolescent girls is a complex, uneven process influenced by both biological and pedagogical factors. The data showed that in girls aged 12–13, rapid longitudinal growth of the skeletal system outpaces the development of muscle strength and static stability, increasing the likelihood of functional imbalances within the musculoskeletal system. The study also revealed that bone tissue in adolescent girls has not yet fully developed mechanical strength, and the physiological curvatures of the spine are in an active stage of formation. This indicates that improperly organized static loads or methodologically unsound exercises during physical education sessions may cause functional disturbances in the spine and joints.

Functional analyses demonstrated that high joint mobility in the context of insufficiently developed muscular support reduces musculoskeletal stability. This condition increases the risk of injury in adolescent girls and scientifically substantiates the necessity of differentiating physical education loads according to physiological norms. Pedagogical observations further confirmed that individual differences in biological maturation significantly affect physical fitness and motor performance. Therefore, physical education sessions should not rely on a uniform approach but should implement individualized and adapted methods that consider both age and sex-specific characteristics.

Overall, the study results indicate that a thorough understanding of the physiological characteristics of the musculoskeletal system in adolescent girls, and their scientific integration into physical education, fully aligns with national educational standards and normative legal frameworks aimed at fostering a healthy generation. These conclusions provide a reliable scientific and practical basis for improving physical education and health-promoting practices,

strengthening preventive approaches, and developing evidence-based recommendations to enhance the health and well-being of adolescent girls.

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