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Correlation of Sports Training with Biological and Psychomotor Development in Children and Juniors

Victoria LEŞCO [1*]
Volodymyr PLATONOV [2]
Viorel DORGAN [3]
Gheorghe BRANIŞTE [4]

[1] PhD, Associate Professor, Moldova State University, Physical Education and Sport Institute, Chisinau, Republic of Moldova; victorialesco18@gmail.com; ORCID: https://orcid.org/0000-0001-8718-8525;
[2] Dr. hab., University Professor, Moldova State University, Physical Education and Sport Institute, Chisinau, Republic of Moldova; dr.v.platonov@gmail.com; ORCID: https://orcid.org/0000-0002-6994-9084;
[3] Dr. hab., University Professor, Moldova State University, Physical Education and Sport Institute, Chisinau, Republic of Moldova; dorganv@gmail.com; ORCID: https://orcid.org/0000-0002-4649-4734;
[4] PhD, University Professor, Moldova State University, Physical Education and Sport Institute; Chisinau, Republic of Moldova; branistegheorghe3@gmail.com; ORCID: https://orcid.org/0000-0003-1995-2442
**corresponding author: victorialesco18@gmail.com;*

Abstract: *The motor and biological development of young athletes is a complex process influenced by genetic, hormonal, nutritional, and environmental factors. During puberty, a child's body undergoes disproportionate changes in bone, muscle, and fat mass, with limbs growing more rapidly than the torso and with differentiated development of muscle fibers. These transformations affect coordination, strength, endurance, and the ability to adapt to intense physical effort. Cognitive functions such as attention, memory, and thinking develop simultaneously, influencing self-assessment and motivation for performance. Individual differences in the pace of biological maturation and physical preparedness lead to significant variations in performance parameters, such as maximal oxygen consumption and anaerobic power. Training plans must be tailored to each child's stage of development, avoiding overload and supporting harmonious progress. Group motor activities, games, and competitions contribute to psychological, social, and cognitive development, fostering cooperation, communication, and respect for rules. An integrated understanding of biological, motor, and psychological development is an essential tool for effective sports education and the long-term performance of children. The article presents a theoretical analysis based on current scientific literature on the motor and biological development of young athletes.*

Keywords: *sports training; biological development; psychomotor development; children and juniors.*

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Introduction

The harmonious development of children and juniors is one of the main priorities of modern physical education and sports. In a society where physical activity plays an increasingly important role in maintaining health and shaping personality, aligning sports training with the biological and psychomotor characteristics of young individuals becomes a necessity.

Childhood and adolescence are periods marked by rapid changes at the biological, cognitive, and emotional levels. The disproportionate growth of bones, the development of muscle mass, endocrine changes, and the evolution of psychomotor abilities directly influence how children and juniors respond to physical exertion and the demands of sports training. Ignoring these specific characteristics can lead to overtraining, injuries, or the inadequate development of motor potential.

In this context, the specialized literature emphasizes the importance of a differentiated approach that considers each athlete's biological age and stage of psychomotor maturation. Adapting sports training to these variables not only optimizes performance but also supports the balance between health, education, and social integration.Therefore, this article aims to theoretically analyze the relationship between sports training and the biological and psychomotor development processes in children and juniors, providing guidance for structuring training programs adapted to age-specific characteristics and maturation levels. In this regard, the research pursues the following objectives: to analyze the correlations between sports training and biological development in children and juniors; to investigate the impact of sports training on psychomotor development.

Methodology

The methodology of this study is a theoretical one, being based on the critical analysis and synthesis of existing scientific literature on the biological and psychomotor development of children and young athletes. The literature was selected through a systematic search of international scientific databases, including PubMed, Scopus, and Web of Science, using keywords related to motor, biological, and psychomotor development in young athletes. Inclusion and exclusion criteria were applied to ensure the relevance, currency, and quality of the sources; in total, 34 works were analyzed, including scientific articles and specialized books. The extracted data were synthesized and critically evaluated to identify trends, conclusions, and gaps in the literature, highlighting the relationships between growth rates, sensitive periods, and genetic and environmental factors.

Results and discussions

Sport for children and juniors corresponds to a stage of human life marked by exceptional complexity and dynamism in biological, psychological, and social processes. These processes unfold under conditions of diversity, non-uniformity, heterochrony, and mutual interdependence, closely linked to hereditary factors and the surrounding environment. Therefore, the training system for young athletes can only be effective if it is designed in alignment with ontogenetic development, making the most of each developmental stage to optimize athletic formation. At the same time, it provides opportunities for the holistic development of the individual by harnessing their natural potential and personal inclinations in the process of personality formation.

Age range for children's and junior sports

Even in the most authoritative textbooks and specialized works on children's and junior sports, there is a lack of a clear age range that defines the "children and juniors sports" category. This can be explained by the historical development of sports schools for children, along with their curricular and normative support, which have evolved in accordance with the traditions and approaches of the general education system, typically covering the age range of approximately 6–7 to 17–18 years. As a result, these boundaries have implicitly defined the age limits for children's and juniors' sports.

Setting the age of 18 as the threshold for adulthood also has a social justification. At this age, general education is usually completed, and young people enter adult life with all its responsibilities and challenges. Moreover, sexual maturation is typically completed, and the conditions are established for expanding personal life, starting a family, and shaping prospects for specialized education and professional activity. As a reference point, the UN Convention on the Rights of the Child (adopted by the UN General Assembly in 1989) also sets the threshold of 18 years.

However, this age limit (18 years) contradicts the periodization of human development as recognized in biology and psychology, where an intense pace of development continues until the age of 20–21, or even 22–23 years. This reality is reflected in numerous findings related to the development of the skeletal and muscular systems, energy and endocrine systems, as well as in key psychological processes essential to sports performance, cognitive development, the formation of fundamental life skills, and individual socialization. In this context, the age range of 18–20/22 years is classified as late adolescence, while the ages of 15–17 correspond to early adolescence.

In recent decades, a trend has emerged involving the participation of very young children aged 4–5 years, and even as early as 2–5 years in organized sports. However, early specialization at such a young age can have predominantly negative effectson their long-term sports prospects. The situation is different when a diverse repertoire of motor activities is used, aimed at enhancing the effectiveness of both physical and psychological development and at acquiring essential life skills. In this sense, attention should be given not only to preschool-aged children but also to those in early childhood, i.e., between 1 and 3 years of age.

Therefore, in the context of children's and juniors' sports, the relevant age span extends from birth to approximately 21–22 years. This range must be aligned with the periodization of human development and the governing principles that shape it, as these directly influence the structure and content of the youth training process.

Knowledge of age-specific human development and its periodization has a long history and is marked by notable diversity. It encompasses biological, psychological, intellectual, educational, professional, athletic, and health-related aspects, among others. A significant portion of this knowledge can be leveraged to optimize the multi-year training process for young athletes, to identify children with potential, to capitalize on their natural abilities, and to guide them toward achieving higher levels of athletic performance.

Table 1. Periodization of Biological and Educational Development in Children and Juniors

Developmental Stage	Biological-Psychological Age (Youth Sports)	Educational System Age / Youth Sports
Early Childhood / Young Preschool Age	1–3 years	1–3 years
Early Childhood / Preschool	4–6 years	3–6/7 years
Middle Childhood / Lower Primary School Age	7–11 years girls, 7–12 years boys	6/7–10 years
Puberty / Middle School Age	11–14 years girls, 12–15 years boys	11–14 years
Early Adolescence / Upper Secondary School Age	15–17 years girls, 16–18 years boys	15–18 years
Late Adolescence / University Age	18–21 years girls, 19–22 years boys	18–23 years

There are multiple approaches to the periodization of human ontogenetic development, each based on different criteria—biological, psychological, pedagogical, social, and so on. When it comes to youth sports, it is logical to use an integrative model of age-based periodization, one that focuses on the biological and psychological dimensions of development.

This periodization, however, is incomplete, as it does not encompass the entire lifespan but only the segment related to children's and juniors' sports. When analyzing the correlation between youth sports and high-performance sports, the age range must be extended to also include young adulthood (approximately 22–23 to 30 years) and adulthood (30–45 years).

The effectiveness of long-term athletic training for young athletes largely depends on how well the periodization aligns with models that address the full biological, psychological, and social development of the individual. It also depends on creating favorable conditions for sports, educational, developmental, cultural, and social activities.

Age and age-related development

Chronological age, determined by the number of years lived, forms the foundation for organizing youth sports, structuring youth competitions, admitting athletes into competition, and evaluating training efficiency and competitive performance. Chronological age is particularly important in determining the optimal age to begin sports, the required training duration to reach peak performance, planning the longevity of athletic careers across various sports disciplines, and managing numerous time-dependent processes that influence training and competition. Various types of conditional age derive from the processes of age-related individual development. These reflect the dynamics of biological, psychological, motor, and social development, identifying specific developmental periods, the nature of these processes, and the interdependence between hereditary and environmental factors.

The long-term training process in youth sports runs in parallel with these developmental processes and must be organically aligned with the athlete's biological, psychological, social, and motor development. This requires careful consideration of the complexity of interactions, the heterochrony and non-uniformity of processes, the existence of sensitive periods and critical zones, and the presence of risk factors that can impact health and training effectiveness. The degree to which long-term training periodization—including its duration and content at each stage—aligns with age-specific developmental stages and the biological, psychological, social, and motor processes involved will determine the effectiveness of youth athletic development, the success of the athlete, and the longevity of their high-performance career.

In the specialized literature (Bammess, 1982; Leşco et al., 2021), the structure and content of multi-year training programs are closely analyzed in relation to the characteristics of biological development, such as body growth and composition, the capacities of various organs and systems, energy supply specific to muscular activity, and the existence of sensitive periods for developing motor qualities. Also considered are the psychological functions directly involved in the training process, including sensations, perceptions, emotional responses, and various types of memory.

Thus, age-related developmental processes across different dimensions of an individual's life are often analyzed exclusively through the lens of sports training and competitive activity. In this approach, comprehensive psychological development—particularly cognitive and creative potential—as well as cultural and personal development, are regarded as secondary or, at best, complementary. The same applies to social development, which is often reduced to forming attitudes and life skills directly related to training and competition content. Such limitations ultimately restrict the overall physical, psychological, and social development of young athletes, negatively impacting both the quality of their trainingand their social lives.

Given the considerable amount of time dedicated to practicing sports and the natural restrictions it imposes on lifestyle, social interaction, education, and cultural development, it becomes necessary within the youth sports system to identify and utilize resources that enable the expansion of education, cultural and personal development, and the formation of essential life competencies.

Table 2. Types of Age and Their Relevance in Children's and Juniors' Sports

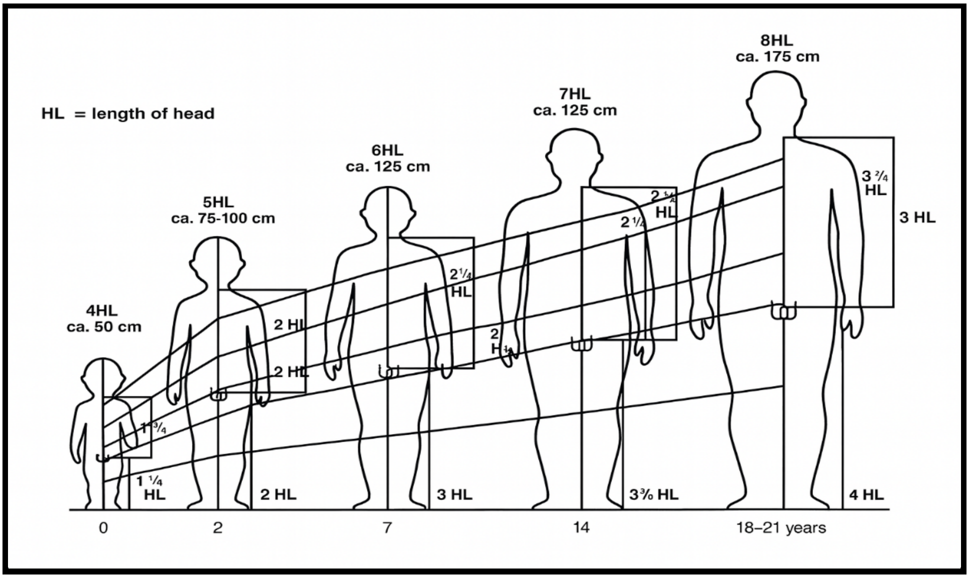
Type of Age	Definition / Description	Key Characteristics	Relevance for Sport
Biological Age	Reflects the growth and maturation process of the body, linked to ontogeny	- Development of the musculoskeletal and nervous systems - Functioning of oxygen transport and endocrine systems - Metabolic characteristics and energy supply	Determines physical capacity, training adaptation, and rate of progress.
Psychological Age	Represents the level of development of cognitive and regulatory processes.	- Cognitive processes: perception, memory, thinking, attention - Regulatory processes: motivation, emotions, willpower, stress resistance	Influences motor skill learning and resilience in competition
Social Age	Defines the individual in relation to social norms and interaction skills.	- Communication abilities - Cooperation and conflict avoidance - Positive attitude, asking for and offering help	Supports team integration and a collaborative sports environment.
Motor Age	Represents the level of development of motor abilities and skills.	- Coordination and movement control - Development of speed, strength, endurance, flexibility - Level of motor skills and competencies	Direct indicator of sports performance and training progress.

These resources can be significantly harnessed if the training system is not confined to the narrow goal of achieving athletic success, but rather approached as a comprehensive field of individual development, focused on humanistic education and the formation of human values. Within this framework, athletic training and competitive activity represent the main type of activity, the central factor, and the core around which the system of well-rounded personality development for young athletes is structured and cultivated.

Physical growth and development

The biological maturation of the human being unfolds over an extended period, beginning at birth and continuing up to approximately 18–20 years in females and 20–22 years in males, at which point bodily growth is completed, and the skeleton and internal organs reach their definitive form. Biological maturation is a non-uniform, heterochronic process, a fact that becomes evident when analyzing the differentiated development of various body components. For example, a comparison of growth rates of the head and legs from birth to adulthood shows that while head length doubles, the length of the legs increases approximately fivefold (see Figure 1).

Figure 1. Alterations in body proportions during growth (from Bammes, 2011)



During the pubertal period, significant and disproportionate changes occur in the structure of bone, muscle, and adipose tissue. Different body segments develop at varying rates: growth in arm and leg length precedes trunk development, and muscle tissue development lags behind bone growth (Michely & Mountjoy, 2009).

In the first year of life, a child's body length increases by 22–26 cm; between ages 1 and 2, the annual growth rate is around 10–12 cm, and then it gradually declines to 5–6 cm per year. However, at the age of 6–7 years, the first growth spurt occurs, with a body ngth increase of 7–8 cm per year.

This growth spurt, along with simultaneous changes in the muscular system and neuromotor regulation, negatively affects specialized motor skills developed through early sports involvement at ages 4–5. Thus, attempts to develop sport-specific motor competencies at this age are often ineffective and can even be harmful to later motor development and refinement. Between the ages of 8 and 11, the annual growth rate decreases again to 5–6 cm, followed by a second growth spurt during puberty, when annual height increases can reach 7–10 cm in girls and 8–12 cm in boys (see Table 3, **Figure 2**). Figure 3 presents the annual body length growth curve in children, highlighting the two main growth spurts: the first, around 6–7 years of age, and the second, during puberty, typically between 12–14 years.

Table 3. Annual Growth in Body Length and Its Impact on Motor Development in Children

Child's Age	Annual Growth in Body Length	Observations on Motor Development
0–1 year	22–26 cm	Rapid growth; intense general development
1–2 years	10–12 cm	Moderate growth; development of general motor abilities begins
2–5 years	5–6 cm	Steady, slow growth; fine motor development begins
6–7 years	7–8 cm (first growth spurt)	Negatively affects specialized motor skills developed at ages 4–5; complex motor competencies become difficult to refine
8–11 years	5–6 cm	Stable growth; continued multilateral motor development
11–14 year girls	7–10 cm (second/pubertal growth spurt)	Rapid growth; motor skills influenced by hormonal and muscular changes
12–15 years boys	8–12 cm (second/pubertal growth spurt)	Rapid growth; motor development may be affected by temporary imbalances

Figure 2. Growth velocity in girls and boys by age (Stratton & Oliver, 2014)

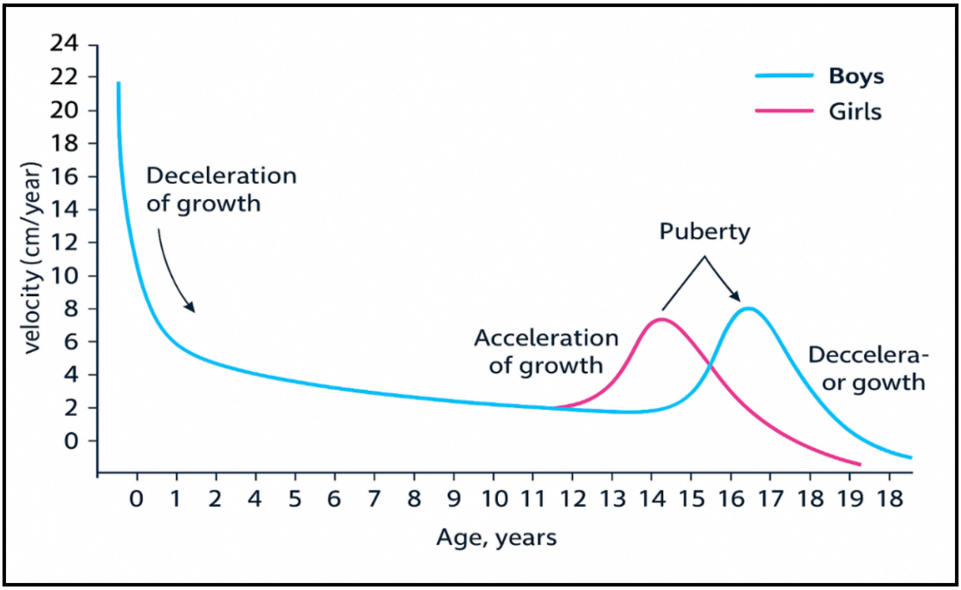
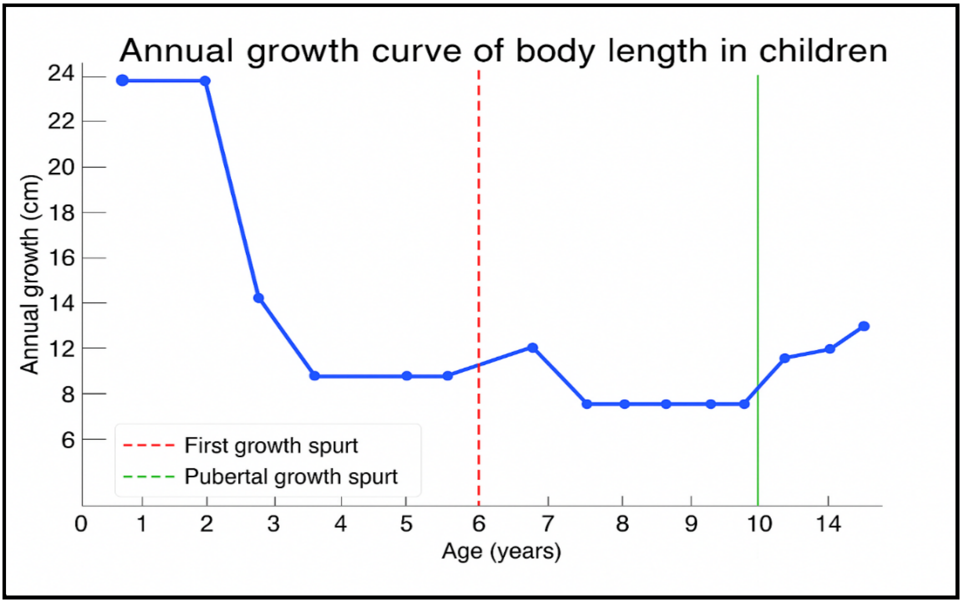


Figure 3. Annual Growth in Body Length Among Children and Adolescents, Highlighting Growth Spurts (from Michely & Mountjoy, 2009)



Starting around the ages of 13–14 in girls and 15–16 in boys, the rate of physical growth begins to slow down, with final height typically reached by 15–16 years in girls and 17–18 years in boys. This growth does not occur uniformly across all body segments: prior to puberty, the length of the upper and lower limbs increases more rapidly, while during the final stages of puberty, the trunk length grows more significantly. Overall growth occurs primarily through bone elongation, while the development of muscles and tendons progresses more slowly.

At 1 year of age, a child's body weight is approximately 10 kg, nearly three times the weight at birth. Between the ages of 2 and 5, the rate of body mass gain slows to about 1.5–2 kg per year. During the first growth spurt, body mass can increase by 3–4 kg annually, while during puberty, annual gains reach up to 5 kg in girls and 6–7 kg in boys. From age 12 onward, boys who engage in sports tend to gain body mass primarily through lean body mass, whereas non-athletic children generally accumulate more adipose tissue. In young athletes, body fat percentage remains relatively stable and can even decrease during the spring–summer period, while total body mass continues to grow. In adult male athletes, fat mass typically accounts for 6–12% of total body mass, compared to 15–22% in sedentary individuals. For females, fat mass percentages are generally about double those of males.

There are significant individual differences in the pace of biological maturation, which can lead to discrepancies of up to 5–6 years between chronological age and biological age (Astrand, 1992). For boys, the pubertal growth spurt in height usually occurs around 13–14 years, although it may happen as early as 11–12 or as late as 16–17 years. Early sexual maturation, along with rapid increases in body mass, muscle mass, and internal organ development, often leads to quick improvements in sports performance, creating misleading impressions among coaches and parents regarding a child's long-term potential.

Studies have shown that boys with accelerated biological development tend to have taller stature, greater body mass, and superior strength capacity, which correlates with higher self-confidence and a preference for speed- and strength-based sports, such as team sports or martial arts.

However, research also highlights that the advantages of early maturation come with certain vulnerabilities, including: disruption of motor coordination, imbalances between functional development and technical skills (Lloyd et al., 2018), increased risk of injury (Kemper et al., 2015). Moreover, these advantages tend to diminish as athletes reach full maturity, with differences between early and average or late developers becoming less significant over time (Lloyd et al., 2018).

At the age of 13, there is a very wide range in physical and physiological parameters among both boys and girls: height: Boys –135–185 cm; Girls – 140–180 cm, Body weight: Boys – 30–85 kg; Girls – 30–80 kg, Maximum oxygen consumption (VO_2max): Boys –46–80 $ml•kg^{-1}•min^{-1}$; Girls –38–70 $ml•kg^{-1}•min^{-1}$. Significant variations are also observed in strength, endurance, and speed capabilities. These differences are largely determined by the individual pace of biological maturation, which complicates not only the selection and guidance of young athletes, but also the optimal planning of their training programs.

Bone and joint development

In the early years of life, children's bones are light and flexible, making them susceptible to deformations and curvatures when exposed to repetitive physical effort or improper body posture. By the end of the third year, the structure of bones begins to resemble that of an adult. The growth and development of bones in toddlers and preschoolers, as well as the degree of mineralization and organic content of bone tissue, depend on a nutritious diet that provides sufficient protein, calcium, phosphorus, and vitamins, particularly vitamin D, as well as on diverse physical activity.

Bones and joints develop intensively between the ages of 6 and the end of puberty, extending into early adolescence. This period supports the growth of bone and cartilage tissue, strengthening of ligaments, and development of joint mobility, especially when physical effort is rationally planned and supported by nutrition that stimulates the developmentof bone, cartilage, and connective tissue. A chronic deficiency of nutrients, combined with intense strength-type physical effort, poses a significant risk to the health and development of bones and joints.

Joint formation and the development of articular surfaces are generally completed by the age of 18–20, while complete bone development may continue until 23–26 years. By 18–20 years, the connective structuresof the musculoskeletal system (fascia, aponeuroses, ligaments) are fully developed, significantly increasing their tensile strength. For example, the Achilles tendon's resistance to rupture increases from about 300 kg in adolescents aged 13–14 years to over 400 kg by age 18 (Fomin & Filin, 1986).

Changes in bone tissue during development and maturation are marked by increases in size, density, and mineral content. In the prepubertal phase, bone development is similar in boys and girls, but during puberty, it intensifies for both sexes, with more pronounced progression in boys. After puberty ends, the rate of bone growth slows down, and peak bone mineral density (BMD) is typically reached between the ages of 23 and 26.

Specialized literature confirms the key role of nutritional, hormonal, and functional factors in the development of bone, cartilage, and fibrous connective tissue. Adequate intake of minerals and vitamins supports the mineralization process and the increase in bone density (Stone, 1992). Some studies also indicate that hormonal interventions, such as anabolic steroid use, can influence the structure of connective tissue (Wood et al., 1988). However, physical activity is recognized as the central factor in the adaptation of bone and connective tissue, being directly dependent on the type and direction of physical stress (Brewer, 2017).

Evidence suggests that physical exercise is a key determinant of bone mass development in children and adolescents. The degree of adaptation is influenced by the intensity and magnitude of mechanical loads, within the limits set by genetic potential (Lanyon, 1987). Under the influence of exercise, bone tissue improves its mechanical resistance through: increase in size, changes in external shape and internal architecture of compact and spongy bone, higher mineral density (Solodkov & Sudzilovski, 1996; Williams et al., 1984).

Recent studies also highlight structural and functional differences between bones of the dominant and non-dominant limbs, with notable adaptations in areas subjected to greater mechanical stress (Solodkov & Sologub, 2017). These findings support the theory that skeletal adaptation to exercise is specific, localized, and intensity-dependent, confirming that mechanical loads are essential stimuli for bone remodeling and strengthening.

The nature of motor activity significantly impacts the development of bone, connective tissue, and joints. Exercises that promote strength and speed-strength are especially effective at increasing bone density, reinforcing connective tissue, and enhancing joint development. Young bones are particularly receptive to mechanical stress, responding with increases in mineral density (Lanyon, 1987). However, excessive strength training volumes can impair the growth of long tubular bones and negatively affect the mechanical properties of bones, tendons, and ligaments.

Sports involving high gravitational loads stimulate bone tissue development more effectively than those with low gravitational demands. For instance, bone mineral density is significantly lower in swimmers compared to sprinters, jumpers, or hammer throwers. A sudden reduction in training volume can lead to bone mass atrophy. The most significant bone mass loss occurs during immobilization, such as bed rest or plaster casting. Injuries requiring immobilization can result in up to 15–20% loss of bone mass (Bar-Or & Rowland, 2009).

When analyzing bone tissue adaptation, one must consider age- and sex-specific characteristics of athletes as well as nutritional factors. During childhood, adolescence, and youth — periods characterized by active skeletal formation —bone mass growth is strongly influenced by a balanced diet, which must provide not only sufficient calcium, but also adequate amounts of protein, phosphorus, and vitamins, especially vitamin D. Such a diet optimizes calcium metabolism and promotes normal skeletal development.

Proper nutrition is particularly important for young female athletes undergoing intense physical effort during menstrual and postmenstrual phases, due to the increased risk of bone demineralization and osteoporosis onset (Brukner, 2002).

Development of muscular and connective tissue

In the early years of life, tonic musculaturedevelops intensively, ensuring the maintenance of the child's body posture. The muscles of the upper limbs form early on, supporting fine motor skills, along with the muscles involved in elbow and wrist flexion and extension.

As the nervous centers responsible for motor control mature, the child's motor activity becomes more diversified between the ages of 3 and 6. This diversification stimulates the development of muscle fibers, tendons, and ligaments, and facilitates the planned growth of strength in various muscle groups, contributing to static body stability and to the efficient execution of motor tasks involving physical effort.

Between the ages of 7 and 11, the natural development process, supported by varied motor activity, leads to the continued development of muscle fibers, tendons, ligaments, fasciae, and muscles, as well as the refinement of intra- and intermuscular coordination. At this age, no significant differences in muscular strength are observed between boys and girls.

During puberty, under the influence of testosterone, boys experience much more intense muscle hypertrophy and connective tissue development compared to girls. By the end of this stage, boys may surpass girls by 25–35% in their capacity to exert strength. However, the rapid body growthoccurring during this period can temporarily impair coordination and affect the regulation of muscular activity. The restoration of coordination between the ages of 14 and 16 is essential for optimizing strength development in both boys and girls. By the age of 18–20, the anatomical diameter of muscles reaches adult values, and muscle mass growth typically stops, representing approximately 40–45% of total body mass. However, the functional and structural differentiation of certain muscle groups continues up to the age of 24–28 (De Vries & Houch, 1994). During this same period, individuals reach peak muscular strength (see Figures 3 and 4). It is important to note that the development of muscle groups does not occur simultaneously: the muscles of the lower limbs grow the fastest, the muscles of the upper limbs develop more slowly, and extensor musclesdevelop faster than flexor muscles (Kots, 1986).

Figure 4. Evolution of Hand Strength by Age: 1 – Males; 2 – Females (De Vries & Houch, 1994)

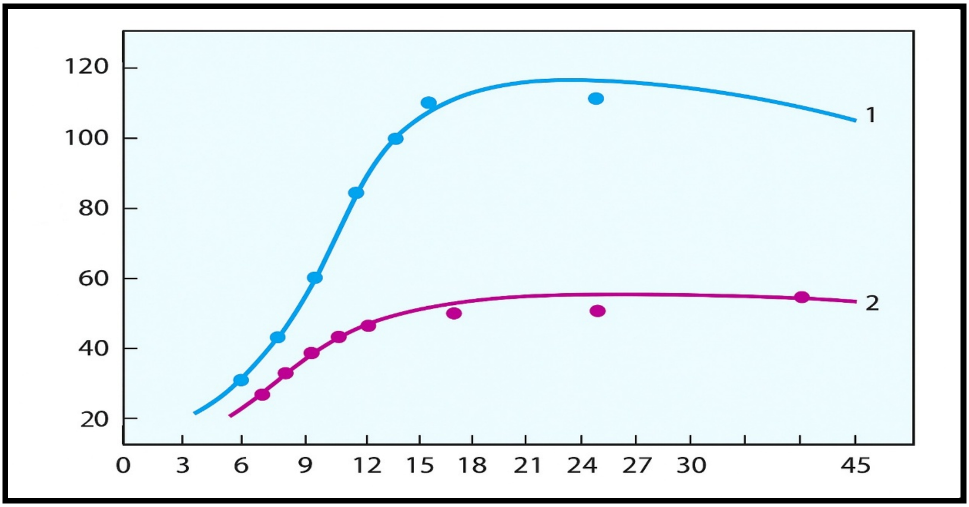
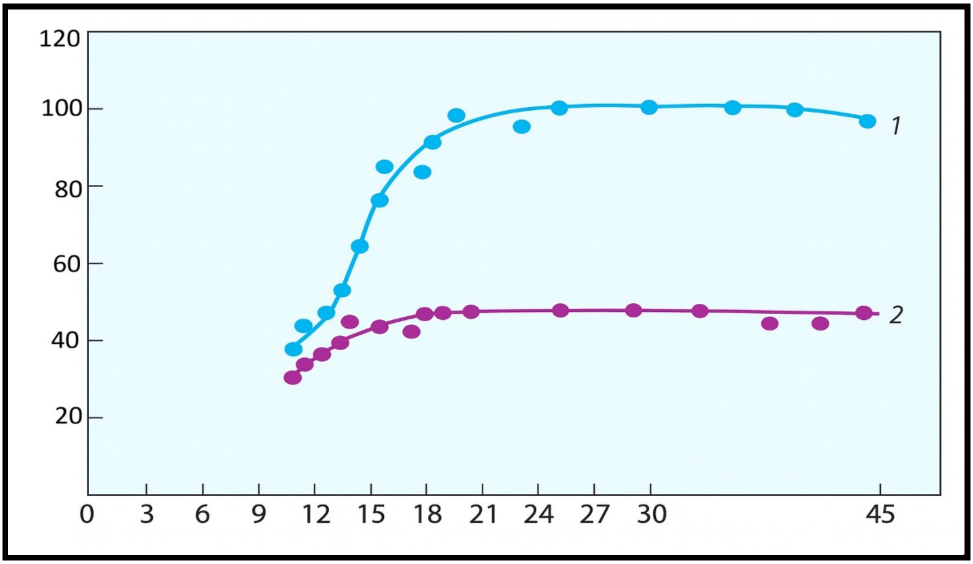


Figure 5. Evolution of Arm Strength by Age: 1 – Males; 2 – Females (De Vries & Housh, 1994)



The distribution of slow-twitch (ST) and fast-twitch (FT) muscle fibers in adults are established during biological development and remains relatively constant thereafter. At birth, a child has a high number of FT-a and FT-b fibers and a low number of ST fibers. After birth, the number of ST fibers gradually increases, which is essential for maintaining trunk stability and ensuring the effective functioning of the limb muscles. During early childhood, a relatively balanced ratio between ST and FT fibers is formed, after which the number of fibers no longer changes only their size increases.

Muscle development and the regulation of muscular activity, stimulated by physical effort especially during puberty are accompanied by an intense development of connective tissue. Specifically, aerobic exercises contribute to increased collagen synthesis in tendons (Stone, 1992), while strength training stimulates the increase of collagen content in ligaments and the total amount of collagen in muscle sheaths. These connective structures transmit the force generated by muscles to tendons and bones, directly influencing the strength of muscular contraction (Fleck & Falkel, 1986).

The application of these exercises leads to an increase in the breaking resistance limit of tendons and the transition elements "bone–tendon," "bone–ligament," and "muscle–tendon" (Stone, 1992). Strength exercises performed with maximum amplitude, which simultaneously develop strength and flexibility, are effective in increasing the length and elasticity of tendons, as well as in optimizing strength by utilizing the elastic properties of tendons and the connective tissue of muscle sheaths.

Particularities of psychological development

Psychological development represents the process of accumulating quantitative and qualitative characteristics of the psyche, as well as maturation and evolution under the influence of hereditary and social factors. It manifests in cognitive processes and phenomena, in psycho-emotional expressions, and in behavioral reactions. It is closely linked to fundamental psychological traits such as temperament, character, abilities, self-awareness, knowledge and experience, thinking, memory, and emotions.

Psychological development occurs through the interaction of heredity and environment. Traits such as temperament, aggressiveness, memory, attention, and reaction speed are significantly influenced by heredity. This influence is more clearly manifested in simple reactions, while complex behaviors are more determined by the environment in which the individual develops.

The environment's influence on psychological development depends on how well environmental factors align with the characteristics of the child's age and the stage of nervous system development. Each stage of development is associated with a primary activity, which represents the most effective way to stimulate psychological development (Leontiev, 2020). Thus, for a child aged 1–2 years, the primary activities promoting psychological development are communication with adults and exploration of surrounding objects and phenomena. For children aged 7–8 years, the central activities are learning and participating in various games, especially self-organized ones. For adolescents aged 13–14 years, the main focus is on peer communication and engagement in self-affirming and passion-driven activities, including high-performance sports.

A well-chosen and organized primary activity becomes the source for developing qualities such as motivation, interest, and a constant need for action. The effectiveness of this activity increases when motivation and the need for action are driven by internal stimuli (joy, pleasure, self-esteem, satisfaction from results) and external stimuli (attention, rewards, and social recognition).

An age-inappropriate primary activity or one mismatched with the child's development level may inhibit natural psychological development and trigger negative reactions such as insecurity, indecision, or withdrawal. Therefore, it is useful to analyze the characteristics of psychological expression and development in children of different ages.

By the age of one, as the child enters early childhood, they already possess qualities that enable diverse motor activity: they can walk or attempt to walk, manipulate various objects, and their actions and perceptions can be organized through language. At this stage, the child begins to speak, and their communication abilities continuously expand, stimulating cognitive and emotional development (Kulagina & Koliutsky, 2015).

This creates the necessary framework for adults to apply development methods and tools adapted to the child's age and abilities, which are essential for the effectiveness of education and instruction. The emotional-psychological atmosphere of interaction with the child is also important. When this atmosphere is pleasant and engaging, it generates active interest and positive emotions, facilitating both physical and intellectual development and turning child–adult communication into an effective cognitive process.

At early ages, speech develops intensively, along with fundamental psychological functions such as perception, attention, memory, and thinking. Sometimes, elements of anticipation also appear. The development of these functions is closely connected with object-based activity and is based on perceptions accompanied by corresponding actions. Diversity and freedom of actions are most clearly expressed through toy manipulation, drawing, and simple games. The volume and variety of objects and action types determine the development of attention and perception, shape the child's attitude toward them, and stimulate thinking and memory development.

Initially, the child's actions are strictly regulated by adult intervention. Gradually, however, the child begins to coordinate their own actions*with those of adults, and over time, these become independent, logical, and deliberate. Between 1–2 years, children largely manipulate objects or toys unconsciously. By the third year of life, their actions become more conscious, including the perception and analysis of the situation, characteristics, and requirements of the play activity. Object-directed motor activity becomes accompanied by conscious decisions, intentional actions, autonomy, and adaptive responses to environmental changes.

However, at this age, the child's actions remain emotionally charged, unstable, and variable. Their ability for emotional self-regulation and independent decision-making in relation to tasks or situations is still limited. Therefore, collaboration with adults and their support in motor activities remain essential.

At the age of 3, the child demonstrates a growing autonomyand a desire to assert their viewpoint, which may lead to opposition toward adults' or peers' wishes. Their actions and decisions become more complex and unpredictable often based on stubbornness, excessive insistence, conflict, jealousy, or dominance tendencies. In group activities, children may be egocentric, lack empathy, and be unable to align their actions with others' interests, sometimes showing aggression.

Between 3 and 6 years, children's activities rely mainly on sensory perceptions and visual demonstrations, rather than on detailed explanations. They understand instructions stated in simple language, applicable to concrete tasks that don't require analysis or alternative decision-making. Their information processing speed, reaction time, and precision are still low, increasing the likelihood of inadequate actions. Coordination of movements, spatial and temporal perception, and effort evaluation are not yet fully developed. Children cannot self-assess their abilities and often show egocentric behavior, demanding constant attention and showing discomfort with restrictions or difficulty internalizing rules (Crain, 2016; Rongen et al., 2023).

At the same time, they develop significant cognitive abilities and communication skills with adults. This requires involving children in group activities, participating in peer games, and demonstrating both competitiveness and cooperation, thereby stimulating psychological and cognitive development. These experiences diversify influences on neuroregulation processes and help form interpersonal communication skills and teamwork competencies.

Ages 7–8 mark a turning point when the social environment becomes decisive in the child's intellectual development and socialization. This is supported by the refinement of the nervous system, especially in brain areas involved in sensation, perception, thinking, and memory, as well as motor activity coordinated by the central and peripheral nervous systems. At this age, children develop logical reasoning, the ability to analyze their own actions, and the ability to act based on memory, guidance, and feedback. Attention, memory, information processing, and motor self-regulation improve. However, these changes occur in immediate contexts and are still weakly correlated with long-term memory (Kipp, 2018).

At 9–10 years, children show a greater need to expand their social circle, especially within peer groups. This is significantly encouraged by organized sports activities, where children gather in groups homogeneous in age, physical abilities, emotional level, and neuroregulatory functions. Such environments foster communication, peer comparison, and objective self-assessment. In this context, egocentric behaviors and overestimations decrease, and development involves a growing desire for collaboration and engagement in training and competitions. Interaction with parents, teachers, and coaches becomes more important, and children become more receptive to feedback and evaluations.

Participation in competitions becomes conscious, and children develop the desire to compete and achieve positive outcomes. This requires parents and coaches to continuously identify strategies for helping children perceive progress and experience satisfaction from their activities. It is essential to avoid negative evaluations and comparisons with peers at the same development stage, focusing instead on individual achievements and progress. Also, collaboration should be encouraged among participants, promoting interaction through mutual evaluations and feedback, and guiding children toward conscious adherence to rules and behavioral norms, as well as active involvement in solving individual and group tasks (Crain, 2016).

The psychological and cognitive development of the child is closely connected to motor activity, involving an evolutionary dynamic across age stages. Table 4 presents the main characteristics of child development and motor activity features, highlighting the role of adultsin this process.

Table 4. Psychological and Cognitive Development of Children in Relation to Motor Activity

Age	Main Characteristics	Particularities of Motor Activity and Game	Role of Adults
1–2 years	Unconscious actions, object manipulation	Toy manipulation without awareness	Direct intervention, constant guidance
3 years	Autonomy, opposition, emotional instability	Games with elements of awareness and simple analysis	Emotional support, behavioral regulation
3–6 years	Egocentrism, difficulties with self-regulation, low attention span	Activities based on sensory perceptions and visual demonstrations	Simple explanations, clear rules, participation in group games
7–8 years	Logical development, emerging analysis and self-evaluation	Activities based on recommendations and evaluations	Guidance in self-regulation, stimulation of memory and attention
9–10 years	Peer group socialization, reduced egocentrism	Organized sports activities, competitions	Support in perceiving progress, avoidance of negative comparisons
11–14 years	Development of cognitive functions (attention, memory, thinking)	Training and competitions with a formative role	Motivation, reflection, support in decision-making and interpersonal relationships
15–16 years	Autonomy, behavioral principles, desire for self-assertion	Active participation in the sports training process	Respect, collaboration, and behavioral correction
15–18 years	Psycho-emotional instability, psychological vulnerability	Intensified training and competitions	Support in stress management and maintaining educational balance

The analysis of the data presented in Table 4 highlights the transition from unconscious actions and adult dependence (ages 1–2) to the expression of autonomy and conscious involvement in group activities (up to age 10). In parallel, the involvement of adults remains essential, but it gradually shifts from direct guidance to support for self-regulation and independent decision-making.

Starting from around age 11 and throughout early adolescence, children begin to intensively develop cognitive functions that reflect the efficiency of the central nervous system, such as attention, thinking, memory, and sensory perception. These functions, combined with previously acquired experience and knowledge, significantly influence both the content and effectiveness of sports training. Among children involved in sports, analytical skills begin to emerge, allowing for a realistic assessment of personal abilities, development of motivation for improvement, and reflection oriented toward finding solutions in specific tasks. The ability to perform retrospective and prospective analysis supports socialization, creativity, and the broadening of thought processes, contributing to innovative approaches in sports activities and their integration with other areas of life (Kulikov, 2017).

At this age, there is a noticeable desire for autonomy and self-development, as well as the formation of deep interest in specific fields—particularly in sports, athletic training, and personal achievement. Simultaneously, young people begin to define their life stance and establish a set of behavioral principles, accompanied by confidence in their own judgments and active engagement in defending their viewpoints. In this context, training and competition activities, along with interaction with coaches, teachers, parents, and peers, contribute to the development of brain functions involved in perceiving and processing complex information, neuropsychological regulation, and modulating motivations and behavioral responses.

The accelerated development of the central nervous system, combined with puberty-specific influences, gives rise to psycho-emotional instability, increased need for independence, conflictual tendencies, insecurity, and exaggerated self-assessment. These manifestations, in correlation with cognitive preparedness, information acquisition, and expansion of the social circle, require coaches, parents, and other adults involved in the lives of young athletes to adopt a careful and responsible attitude toward their psychological well-being, which is highly susceptible to inappropriate reactions and hasty decisions (Rongen et al., 2023).

As children and young athletes grow older, the factors influencing their development become more diverse. Table 5 summarizes the main positive influences and risks associated with the family, school, sports, and social environments.

Table 5. Determining Factors in the Development of the Child and Young Athlete

Domain	Positive Influences	Risks / Difficulties
Family	Emotional support, collaboration, positive evaluations	Excessive pressure, comparisons, lack of understanding
Peer Group	Socialization, cooperation, healthy competitiveness	Egocentrism, jealousy, conflict
School	Development of logical thinking, theoretical knowledge	Overload, imbalance between sports and education
Sport / Training	Motivation, discipline, self-regulation, performance	Competitive stress, perfectionism, anxiety
Society	Recognition, educational and professional opportunities	Social pressures, post-sports career maladjustment

The data presented in Table 5 shows that while the family and peer group are major resources for socio-emotional and motivational development, they can also become sources of pressure or conflict. Likewise, although sport provides opportunities for discipline and self-regulation, it can expose children to risks such as overload and competitive anxiety.

Together, these characteristics define a complex and challenging environment for young athletes and those around them especially coaches, parents, and educators. Harnessing the strengths of this environment while minimizing the impact of negative factors is essential for both the personal development of young athletes and the effectiveness of their training process.

Respect for the adolescent's personality, their opinions and beliefs, combined with careful behavioral correction and the ongoing accumulation of knowledge and experience, helps ensure that by ages 15–16, as they transition into early adulthood, athletes become active partners with their coaches in pursuing a creative and effective approach to sports training.

During early adolescence and the 15–18 age period, both the opportunities and vulnerabilities associated with high-performance sport intensify. Table 6 presents the main psychological risks, possible manifestations, and their consequences.

The findings summarized in Table 6 indicate that between 50% and 75% of adolescent athletes are vulnerable to mental health disorders, mainly due to performance pressure and the imbalance between sport and education. Thus, psychological support and attention to emotional self-regulationbecome essential conditions for maintaining both psycho-emotional balance and long-term athletic performance.

Table 6. Evolution of Psychological Risks in High-Performance Young Athletes (15–18 Years Old)

Risk Factor	Possible Manifestations	Consequences
Sports Overload	Chronic fatigue, stress, anxiety	Decreased motivation, inconsistent performance
Emotional instability specific to puberty	Conflictual behavior, insecurity, inflated self-image	Tense relationships with parents, coaches, and peers
Performance Pressure	Perfectionism, fear of failure	Vulnerability to mental health disorders
Educational Imbalance	Low general education level	Difficult post-sports career adaptation
Lack of Psychological Support	Tendency to hide problems	Undiagnosed mental disorders (in 50–75% of cases)

The nervous system and motor activity.

The nerve cells of a newborn have a single axon, but lack dendrites and myelin sheaths. The development of neurons including axon elongation, growth and branching of dendrites, synapse formation, and myelination—occurs most intensely during the first three to four years of life and is largely completed by the age of 7–8 years.

The functions of interneurons, responsible for establishing inter-neuronal connections, become fully active around the age of 9–10 years, while pyramidal neurons—the brain's main excitatory neurons—reach their functional maturity later, around 12–14 years of age (Esakov, 2010). For a clearer understanding of the maturation stages, the process is summarized in Table 7.

Table 7. Stages of Neuronal Development in Children

Approximate Age	Main Process	Specific Characteristics
At birth	Immature neuron	Single axon, no dendrites, no myelin sheath
0–3/4 years	Axon elongation, dendritogenesis, synaptogenesis	Rapid growth, intense myelination
7–8 years	Maturation of neuronal networks	Completion of main connections and myelination
9–10 years	Development of interneurons	Efficient inter-neuronal connections

12–14 years	Maturity of pyramidal neurons	Full functioning of the brain's main excitatory neurons

The myelination of nerve fibers, essential for ensuring the speed and accuracy of nerve impulse transmission, occurs intensively during the first 2–3 years of life, and continues for several more years depending on the type of nerve fibers. The motor analyzer nucleus, responsible for processing kinesthetic stimuli from skeletal muscles, tendons, and joints, undergoes rapid development in the first three to four years, and becomes fully differentiated, depending on muscle groups, by the ages of 7 to 10. This enables the execution of targeted and coordinated movements. In parallel with the development of the motor analyzer nucleus, the formation and maturation of neuron groups that make up the ascending and descending pathways takes place. These pathways connect the brain with the spinal cord, muscle tissue, joints, and tendons. Starting from 2–3 years of age, processes such as neuron differentiation, specialization, inter-neuronal integration, and the formation of horizontal and vertical neural connections are actively occurring. As cortical functions differentiate and vertical connections develop, various types of sensitivity are consolidated.

In early childhood, reflex arcs that develop in response to motor activity are located primarily at the spinal cord and thalamus levels, without direct involvement of higher brain structures. The development of the motor cortex, cerebellum, basal ganglia, and limbic system only takes place around the age of 7–8, at which point the child acquires the ability for goal-directed motor coordination.

Table 8. Nervous structures involved in movement control

Nervous Structure	Role in Movement Regulation
Limbic System	Motivation for movement
Cerebral Cortex	Movement planning
Basal Ganglia	Movement programming
Cerebellum	Adjustment and coordination
Brainstem and Spinal Cord	Control of motor execution

All these aspects require careful analysis and consideration when designing various types of motor activities for children aged 1 to 6, especially in the context of early sport specialization and the content of such programs.

Attempts to specialize and formally train children aged 4–6 in sport-specific motor skills can generate significant issues, both in terms of psychological development and the refinement of technical mastery.

Specifically, during the learning process, the main structures of the central nervous systemresponsible for motor regulation are still largely isolated and at various stages of development. As a result, the acquisition of motor skills occurs approximately 3 to 4 times slower than it would if training were introduced at 8–12 years of age (Ford & Williams, 2017).

Secondly, motor skills acquired at very young ages are weakly correlated with higher-level CNS structures and with the ascending and descending pathways, which are also still maturing. This prevents children from effectively engaging in motor activity and taking an active role in skill acquisition and consolidation. As a consequence, not only is the quality of motor skills reduced, but there is also an increased risk of forming motor stereotypes, which can undermine the role of central nervous structures in regulating voluntary motor actions.

Thirdly, in young children, the connections and interactions between the central nervous system and both the somatic and autonomic components of the peripheral nervous system, which are generally considered relatively autonomous, are not yet fully developed. The somatic nervous system consists of the afferent and efferent fibers that innervate the skeletal muscles, ensuring motor control and the manifestation of motor qualities. The afferent (sensory) component transmits electrical signals (action potentials) from sensory nerve endings to the CNS, while the efferent (motor) component transmits action potentials from the CNS to effector organs, muscles and glands.

The content of motor activity for children aged 1 to 6 must primarily support ontogenetic development, with special emphasis on the maturation of the central nervous system. Diverse motor experiences, aimed at developing a broad spectrum of motor skills rather than early specialization in a single sport discipline, are crucial for building a healthy nervous system, for early identification of talent, and for laying the foundation for long-term technical refinement.

At the age of 7–8, children begin to process and analyze instructions provided by a coach, provided the communication is clear, concise, and simple. However, their short attention spans and difficulty concentrating on essential aspects require continuous supervision, complemented by brief reminders, observations, and instructions.At this age, children show initial abilities to perceive and analyze the spatial, temporal, and dynamic characteristics of movement, but these are still underdeveloped for effective technique acquisition. They can perform only relatively gross movements, have limited control over speed and body segment positioning, and struggle with complex instructions related to sports technique. Moreover, they lack a full understanding of tactical principles, show low predisposition for teamwork in sports games, and have difficulty making optimal decisions in unexpected situations.

Training should emphasize varied and simple exercises that aim to teach fundamental technical elements across different sports, using motor games and competitions based on elementary actions such as: movement in various directions, rotations and jumps, basic acrobatic movements, manifestations of speed and strength, use of diverse equipment – balls of various sizes and weights, rackets, sticks, etc. A broad range of instructional tools, engaging various abilities, efficiently contributes to the development of kinesthetic and perceptual potential, visual and motor memory, and multiple forms of sensitivity—spatial, temporal, force-related, rhythmic, and object-specific (ball, racket, water, etc.).

Between the ages of 8 and 11, the level of neurological development allows for efficient integration between CNS activity, the musculoskeletal system, and autonomic systems. Cognitive development at this stage enables children to understand tasks aimed at technical improvement and motor skill development. Their attention span and ability to solve complex motor tasks (involving varying and shifting actions) improve significantly (Michely & Mountjoy, 2009).

Thanks to the plasticity of the nervous system, a variety of relatively complex exercises can be used to develop coordination, cognitive capacity, pattern recognition, and sensorimotor coordination (Moody et al., 2014). However, children at this age tend to overestimate their abilities, often without understanding the consequences of their actions, increasing the risk of injuries. Their strong desire for self-affirmation and lack of critical thinking may hinder teamwork and the assimilation of basic tactical elements (Patel & Pratt, 2009).

From 9 to 11 years, children are well positioned to deepen their understanding of sports techniques due to advanced cognitive development, enhanced kinesthetic and perceptual sensitivity, and improved visual and motor memory. This is supported by a relatively high level of language development, enabling them to analyze and follow more complex instructions and respond appropriately to technical feedback.

All these aspects contribute to the formation of an extensive and effective motor memory, which underlies the synchronized and balanced coordination of the spatial, temporal, and dynamic characteristics of a wide range of movements. Research indicates that the prepubertal period, marked by accelerated nervous system maturation, is particularly favorable for developing multiple motor skills, with significantly higher efficiency than during puberty (Behringer et al., 2011). The variety of training methods that exert a complex influence on motor function create essential prerequisites for technical mastery in later stages (Myer et al., 2013).

Thus, varied motor activity during this critical phase of neurological development ensures general motor competence, contributing to career longevity, a higher likelihood of performance across disciplines (Lloyd & Oliver, 2014) and reduced injury risk (Larsen et al., 2017).

Conclusions

The biological and psychomotor development of children and youth athletes is a complex process, marked by asynchronous growth rhythms, and by ongoing interactions between genetic and environmental factors. As such, effective sports training must consider not only chronological age but also biological, psychological, and social age, to avoid overtraining, injuries, and the negative outcomes of early specialization.

The effectiveness of athletic training depends on adherence to the principles of ontogenetic periodization and on adapting the training process to the specific characteristics of each developmental stage, from early childhood to late adolescence. Integrating physical effort with cognitive, emotional, and social development contributes to the comprehensive formation of young athletes' personalities and to the long-term optimization of performance. At the same time, organized sport should be designed to harness each child's natural potential, prevent risks associated with premature maturation or inappropriate training, and support the healthy development of the skeletal, muscular, and psychological systems. Consequently, the age range relevant for youth sports can extend from 0 to 21–22 years, and the long-term training process must be organically aligned with individual growth rhythms, sensitive periods, and the specific features of biological and psychological development, in order to ensure both athletic performance and the harmonious development of the individual.

Based on the analysis conducted, several essential recommendations emerge for educational and sports practice. First, training programs should be tailored to the biological, psychological, and social characteristics of children and adolescents, avoiding standardization based solely on chronological age. Second, early sport specialization should be postponed to allow for well-rounded development, reducing the risk of injuries and overtraining. Additionally, close monitoring of progress, maintaining a healthy balance between effort and recovery, and active collaboration with parents are indispensable for creating a safe and motivating environment. Finally, physical activity should be integrated into a broader educational process, in which sport contributes not only to performance, but also to personality development, as well as cultural and social growth of young people.

Statement on the Use of AI Tools | *The authors declare that no generative artificial intelligence (AI) tools were used in the research, data analysis, or writing process of this manuscript. The entire content of the paper represents the authors' original contribution, produced solely through human effort, in accordance with the principles of research ethics and LUMEN's editorial policy on AI use.*

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