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THE ROLE OF JUDO IN THE BIOMECHANICAL AND NEUROPHYSIOLOGICAL DEVELOPMENT OF SCHOOL-AGE CHILDREN

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Abstract

The growing need for educational approaches that integrate physical, cognitive, and socio-emotional development highlights the relevance of structured martial arts programs in childhood. Aim: To analyze the influence of systematic judo training on the biomechanical, neurophysiological, and social development of primary school-age children. Methodology: A combined research design was applied, including literature analysis, anthropometric assessment, and evaluation of motor and neurophysiological indicators such as SLJ, SRT, 4×10 m speed test, BMI, and variability measures. Descriptive statistics were used to identify age-related trends, sex differences, and intra-group variability. Results: Judo training activated key neurophysiological mechanisms—sensorimotor integration, proprioceptive regulation, vestibular stabilization, and cognitive activation—leading to improved coordination, balance, and motor competence. Explosive strength and flexibility showed the highest variability, while BMI and speed were more homogeneous. The most pronounced increase in explosive strength occurred between ages 10–13, indicating a sensitive period for strength-speed development. Conclusion: Systematic judo practice exerts a multidimensional positive effect on children's physical, motor, and neurophysiological development, emphasizing the importance of age- and sex-adapted training programs and individualized pedagogical approaches.

Keywords: *judo; motor development; neurophysiological mechanisms; children*

Introduction

In contemporary educational settings, there is an increasing need to integrate sports activities that support not only physical development but also the cognitive, social, and emotional growth of students (24, 26). Judo, as a martial art with a clearly structured philosophy and methodology, offers a unique opportunity to combine motor activity with educational and social functions (7, 25). As highlighted in the monographic text, *"judo… shapes a value system, social skills, and psychological resilience"* (2, 6, 14-18), making it a particularly significant tool in the context of digitalisation, reduced physical activity, and increased aggression among children and adolescents (3, 22, 35). At the same time, contemporary research in recreation and health prevention emphasises the importance of integrated models for physical and psychosocial development (1, 11-13). Approaches based on wellness concepts and holistic methods demonstrate high effectiveness in forming healthy habits and sustainable behavior in children and youth (8, 9, 32). In the Bulgarian context, studies on the biomechanical aspects of physical education (10, 34) and on motor development in early childhood (1) further support the need for structured, evidence-based programs. These models align with international concepts of motor development (21, 23, 31) and highlight the role of diverse motor stimuli for optimal growth. Created by Jigoro Kano as a system for physical, intellectual, and moral development, judo is

grounded in the principles of *Seiryoku-Zenyo* (maximum efficiency) and *Jita-Kyoei* (mutual welfare and benefit), which foster self-control, respect, discipline, and social responsibility (30, 33). This philosophical framework positions judo as a pedagogical model that extends beyond sport training and contributes to the holistic personal development of children (19, 27, 29). In this context, there is a clear need to investigate the influence of systematic judo practice on the neurophysiological, motor, and physical development of primary school-age children, which represents the central focus of the present study (5, 20, 28).

Methods

Objective

To analyze the influence of systematic judo training on the biomechanical, neurophysiological, and social development of school-age children.

The methodology of the study applies a combined approach integrating scientific literature analysis, biomechanical measurements, and assessment of motor and neurophysiological indicators in school-age children. Structured observation and testing were conducted to evaluate key anthropometric, coordination, and strength characteristics, including standing long jump (SLJ), sit-and-reach flexibility test (SRT), 4×10 m shuttle run speed test, and body mass index (BMI), as well as variability analysis through standard deviations.

The data were processed using descriptive statistics to identify age-related trends, intra-group differences, and sex-specific patterns. The methodological framework is aligned with the biomechanical and pedagogical principles of judo, with emphasis on evaluating its influence on neurophysiological mechanisms, motor control, and physical development. The study was conducted in accordance with ethical standards for research involving children, ensuring informed parental consent and participant anonymity.

Limitations and Future Research

This study is limited by its cross-sectional design and the narrow age range of participants. Future research should apply longitudinal methods and include broader developmental and biomechanical assessments to deepen understanding of judo's long-term effects.

Results

The obtained data indicate that judo training activates four key neurophysiological mechanisms that play a critical role in the development of motor control and cognitive functions in children (Figure 1).

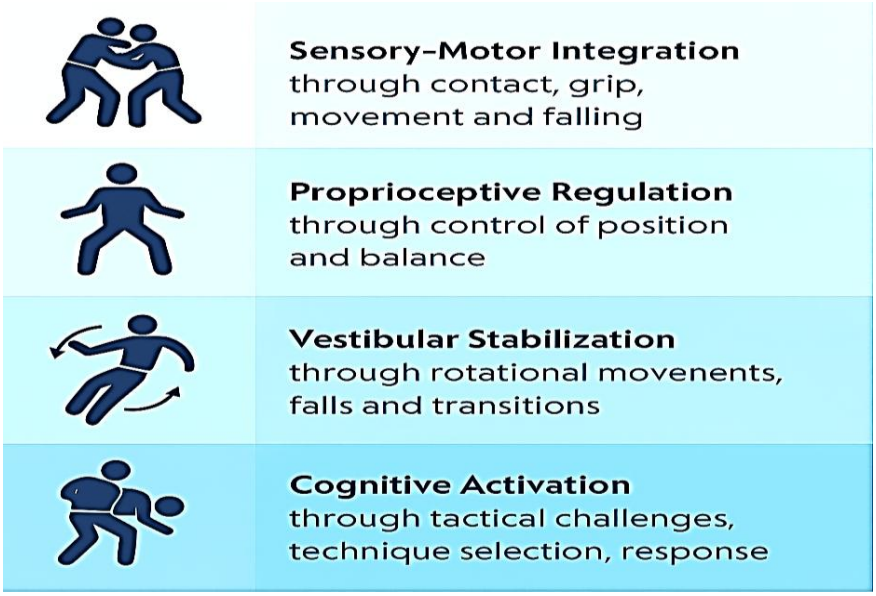


Figure 1. Role of Judo in Neurophysiological Development

Figure 1 illustrates the mechanisms of sensorimotor integration, proprioceptive regulation, vestibular stabilization, and cognitive activation. Motor activity in judo simultaneously engages all these systems, supporting the development of coordination, balance, spatial orientation, and the ability to make rapid tactical decisions. The activation of these processes forms a complex neurophysiological foundation for acquiring motor skills and enhancing overall motor competence. This confirms that judo functions not only as a physical activity but also as an effective means of neurophysiological development in childhood.

Figure 2 ("Motor Development 8–12 years") presents the characteristic age-related curve of motor development and outlines two clearly defined periods. The first is the growth zone (ages 8–10), during which accelerated development of coordination, balance, rhythm, and intermuscular synergy is observed. The second is the stabilization zone (ages 11–13), characterized by the optimization of motor habits and a gradual decrease in the rate of improvement. These trends are fully consistent with biomechanical models of child development and highlight the need for age-adapted training programs that account for sensitive periods in the acquisition of motor skills.

The gradual increase in the motor index within this age range provides a foundation for a more detailed analysis of individual physical qualities. In this context, the following section examines the structure of the physical profile of 7-year-old children, offering a more comprehensive view of strength, coordination, and anthropometric indicators in early school age.

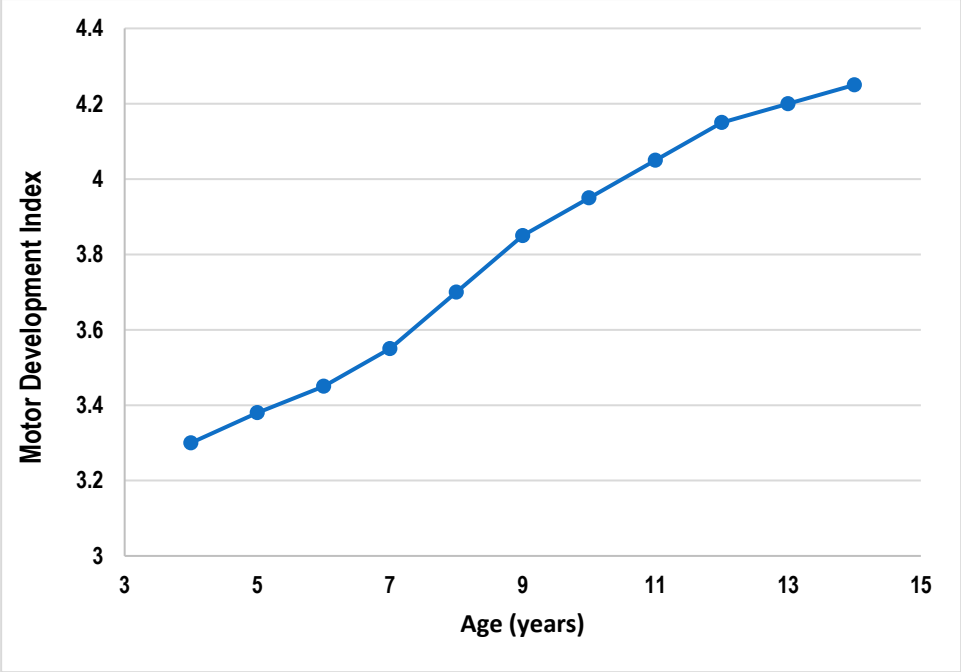


Figure 2. Motor Development (8–12 years)

Figure 3 presents a multidimensional physical profile of 7-year-old boys and girls, assessed through key anthropometric and motor indicators. The analysis shows consistently higher values in boys across most measured parameters, which is characteristic for this age group and reflects early differences in muscular strength and motor activity.

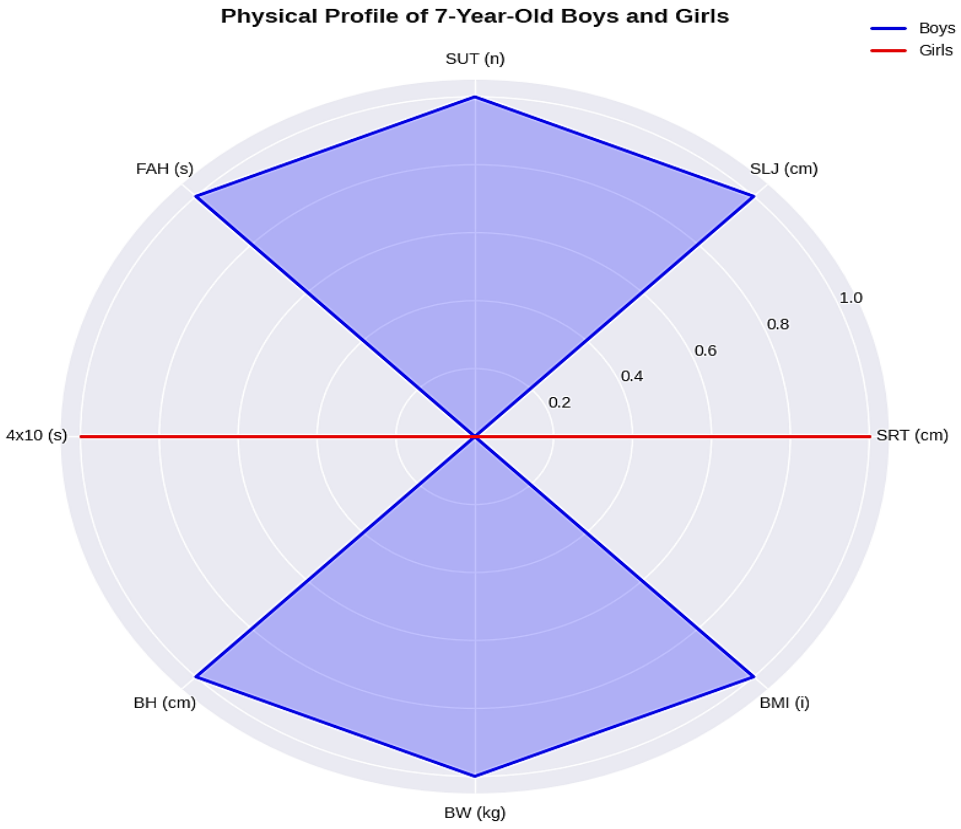


Figure 3. Multidimensional Physical Profile of 7-Year-Old Boys and Girls

Low variability is observed in indicators such as BMI and speed, suggesting a relatively homogeneous body composition and baseline quickness. In contrast, explosive strength (SLJ) and flexibility (SRT) demonstrate high variability, highlighting substantial individual differences in the development of these qualities. These results reveal substantial heterogeneity in the motor development of children in early school age and highlight the need for an individualized approach when planning training tasks in introductory judo education. Understanding this structure of the physical profile is essential for determining optimal training load and selecting exercises that correspond to the children's biological and functional readiness.

A smooth transition to the next stage of the analysis requires examining not only mean values but also the dispersion of results, which provides deeper insight into intra-group differences.

In this regard, the following section analyzes the variability of physical indicators, presented in Figure 4. The standard deviations of key physical and anthropometric indicators in 7-year-old boys and girls. The highest variability is observed in SLJ (explosive strength) and SRT (flexibility), reflecting considerable individual differences in the development of these qualities. In contrast, BMI and the 4×10 m speed test show the lowest variability, suggesting a more homogeneous group structure in terms of body composition and baseline speed. These findings indicate that strength and coordination abilities are the most individually differentiated at this age, whereas anthropometric characteristics and speed are more stable and uniformly developed.

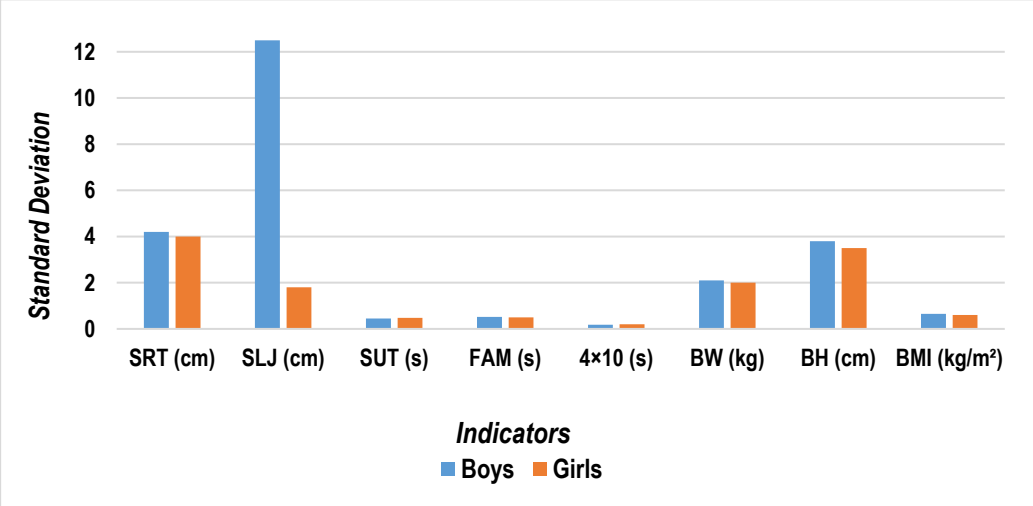


Figure 4. Variability of Physical and Anthropometric Indicators in 7-Year-Old Children

Figure 5 ("Horizontal Jump Distance by Age and Gender") presents the age-related dynamics of explosive strength in boys and girls, assessed through the standing long jump. The data show a stable and consistent increase in both sexes, with the most pronounced improvement occurring between the ages of 10 and 13. This interval coincides with accelerated biological maturation and increased neuromuscular plasticity, identifying it as a critical window for the development of strength-speed qualities.

This period is particularly suitable for teaching and refining dynamic techniques, controlled falls, rotational movements, transitions between stances, and techniques requiring impulse generation and stabilization.

Figure 5 clearly demonstrates that explosive strength not only increases with age but also develops at different rates in boys and girls, underscoring the need for sex- and age-adapted training programs.

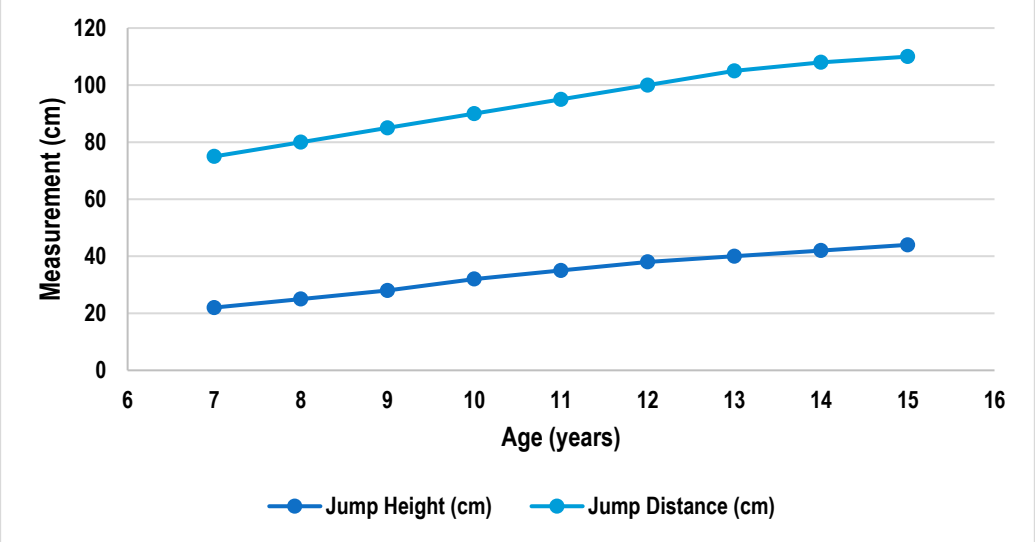


Figure 5. Horizontal Jump Distance by Age and Gender

The statistical analysis reveals clearly defined age-related trends and sex differences in the main physical and anthropometric indicators. A stable increase in explosive strength and coordination abilities is observed with advancing age, with the most intensive development occurring between 10 and 13 years. Comparisons between boys and girls show higher mean values in boys across most indicators, particularly in explosive strength (SLJ) and flexibility (SRT). The variability analysis indicates that strength and coordination qualities are the most individually differentiated, whereas body composition (BMI) and speed (4×10 m test) are more homogeneous. This pattern of dispersion suggests that, in early school age, children differ most strongly in abilities related to neuromuscular control and explosiveness, which has direct implications for planning training tasks. The summarized results outline a clear structure of neurophysiological, motor, and physical development in primary school-age children, emphasizing the role of judo as a complex stimulator of motor and cognitive functions. The observed trends in mean values, variability, and the age-related dynamics of explosive strength provide a solid foundation for interpreting the mechanisms underlying these changes.

Discussion

The results obtained confirm that systematic judo training exerts a multidimensional influence on children's development by simultaneously stimulating neurophysiological, motor, and physical components. The activation of sensorimotor, proprioceptive, and vestibular

mechanisms, as demonstrated in Figure 1, aligns with contemporary models of integrated motor learning, which emphasize that coordination and balance develop most effectively through complex, multi-layered motor tasks. The age-related dynamics presented in Figure 2 and Figure 5 highlight the presence of sensitive periods during which explosive strength and coordination abilities develop at an accelerated rate. This corresponds to the biological patterns of growth and maturation described in the literature and reinforces the need for targeted planning of training loads during the ages of 10–13.

Conclusion

The obtained results confirm that systematic judo training exerts a multidimensional and significant influence on the development of children in early school age. The activation of key neurophysiological mechanisms—sensorimotor integration, proprioceptive regulation, vestibular stabilization, and cognitive activation—creates a foundation for accelerated acquisition of motor skills and improved motor competence.

The analysis of the physical profile reveals clear differences between boys and girls, as well as substantial intra-group variability, particularly in strength and coordination indicators. This highlights the need for an individualized approach when planning training tasks and for adapting the training load to each child's biological and functional readiness.

The age-related dynamics of explosive strength reveal a clearly defined sensitive period between 10 and 13 years, during which strength-speed qualities develop most intensively. This interval should be purposefully utilized for teaching techniques that require impulse generation, stabilization, rotational movements, and controlled falls.

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