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AGE-RELATED FEATURES, GROWTH DYNAMICS, AND CENTILE CHARACTERISTICS OF LOWER LIMB LENGTH IN PRESCHOOL CHILDREN LIVING IN TASHKENT

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✓ ***Resume***

The article presents the results of an anthropometric study of lower limb length in preschool children (aged 2–7 years) living in Tashkent. The study analyzed the age-related dynamics, centile characteristics, and gender differences in growth patterns. It was found that the most intensive increase in lower limb length occurs between the ages of 2 and 6, followed by gradual stabilization by the age of seven. The data indicate heterochronic development of body segments and the establishment of proportional body structure by this age. The results can be applied to the development of regional standards for physical growth and Z-score norms for the child population of Uzbekistan.

Keywords: physical development, anthropometry, lower limb length, preschool children, centile tables, growth, Tashkent.

TOSHKENTDA YASHAYDIGAN MAKTABGACHA YOSHDAGI BOLALARDA PASTIKI OYOQ-QO'L UZUNLIGINI YOSHGA BOG'LIQ XUSUSIYATLARI, O'SISH DINAMIKASI VA SENTIL XUSUSIYATLARI

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✓ ***Rezyume***

Maqolada Toshkentda yashovchi maktabgacha yoshdagi bolalarda (2-7 yosh) pastki oyoq-qo'l uzunligini antropometrik o'rganish natijalari keltirilgan. Tadqiqotda yoshga bog'liq dinamika, sentil xususiyatlari va o'sish naqshlaridagi gender farqlari tahlil qilingan. Pastki oyoq-qo'l uzunligining eng intensiv o'sishi 2 yoshdan 6 yoshgacha bo'lgan davrda sodir bo'lishi, so'ngra yetti yoshga kelib asta-sekin barqarorlashishi aniqlangan. Ma'lumotlar tana segmentlarining geteroxron rivojlanishini va bu yoshga kelib proporsional tana tuzilishining shakllanishini ko'rsatadi. Natijalar O'zbekiston bolalar populyatsiyasi uchun jismoniy o'sish bo'yicha mintaqaviy standartlar va Z-ball normalarini ishlab chiqishda qo'llanilishi mumkin.

Kalit so'zlar: jismoniy rivojlanish, antropometriya, pastki oyoq-qo'l uzunligi, maktabgacha yoshdagi bolalar, santil jadvallari, o'sish, Toshkent.

Relevance

The physical development of young children is regarded by modern science as one of the key integral indicators of health, reflecting the combined influence of biological, social, environmental, and behavioral factors. It serves as an important indicator of the organism's adaptive potential and reflects the overall level of societal well-being.

It should be emphasized that the level of physical development is closely associated with the child's biological age, the state of the endocrine system, the nature of nutrition, the quality of sleep, the level of physical activity, and environmental conditions. According to several authors, harmonious

physical development reflects a balanced interaction between the processes of growth and tissue differentiation, as well as the functional maturation of organs and systems.

During early childhood, rapid growth in body length, the formation of body proportions, and the development of the musculoskeletal system occur. At this stage, the body shows the greatest sensitivity to external factors — climatic conditions, environmental status, childcare practices, nutrition patterns, and levels of motor activity. Therefore, anthropometric indicators are not only quantitative measures of growth but also diagnostic tools that allow assessing the quality of life and a child's adaptation capacity.

Moreover, physical development serves as an important criterion for evaluating the effectiveness of preventive health, nutrition, and educational programs. It provides the basis for early detection of developmental deviations, assessment of biological age, and prediction of a child's physical and intellectual potential.

Modern research emphasizes the need for a differentiated approach to the assessment of physical development, taking into account ethnic, regional, and socio-economic characteristics. In this context, the development of national standards based on local data becomes a crucial task, allowing objective evaluation of children's health and the planning of targeted programs for its improvement.

According to researchers, longitudinal and circumferential anthropometric parameters in children during the first years of life exhibit a clear age-related dynamic, reflecting the regular formation of body proportions and somatic growth rates. The obtained results confirm that early childhood is a critical period of morphofunctional development, during which even minor deviations in nutrition or environmental conditions can lead to long-term consequences in physical and mental development.

Regional and gender differences in children's physical development were noted in study. Scientists established that climatic, geographical, and socio-economic factors significantly influence growth harmony as well as the relationship between body mass and length. Similar patterns were found by in Andijan region children — the rate of increase in body mass and linear dimensions varied by sex and age, highlighting the need to develop regional standards for physical development.

A study based on the Siberian population showed that the use of unified standards and consistent statistical criteria during large-scale examinations plays a key role in the early detection of deviations. Researchers emphasized that the analysis of parameter variation (σ and Z-score) is an essential tool for identifying both individual and population differences.

In recent years, there has been a trend in international science toward an interdisciplinary analysis of factors determining physical development. Researchers have revealed a strong correlation between the level of physical activity, the development of fundamental motor skills, and body mass index in preschool children. Insufficient physical activity (hypodynamia) and lifestyle changes in urbanized settings lead to growth retardation and altered body proportions, which are considered one of the causes of early-onset metabolic syndrome.

A significant contribution to improving methods for assessing physical development was made by authors who proposed advanced algorithms for calculating Z-scores. These techniques enhance the accuracy of diagnostic assessments, minimize systematic errors, and allow for more objective health monitoring of the pediatric population. Mei and Grummer-Strawn justified the use of the standard deviation of Z-scores as a data quality control tool, forming the foundation of modern WHO international standards.

Research has also drawn attention to the impact of chronic stress, urbanization, and social inequality on children's growth and endocrine development. It has been demonstrated that psycho-emotional overload and sleep deprivation in children reduce somatic growth rates and can cause imbalances in growth hormone and cortisol.

Long-term studies conducted in the Voronezh region revealed clear secular trends — a gradual increase in body length and mass over 15 years, reflecting improved living standards and nutrition. However, a concurrent rise in overweight children indicates the need for comprehensive monitoring of nutrition and physical activity factors.

A global forecast published in *The Lancet* indicates a steady increase in the prevalence of obesity and overweight among both children and adults. These data highlight the importance of revising national approaches to assessing physical development in light of global epidemiological trends.

The WHO Child Growth Standards (2006) and the updated 2021 version *Child Growth Standards: Methods and Development* have become a universal methodological foundation for forming national assessment systems. Their implementation ensures data comparability, identification of morphological patterns, and accurate determination of Z-scores for different age and sex groups.

In domestic science, a significant contribution was made by Shamirzaev N.Kh. and co-authors (1998), who developed an anthropometric methodology for assessing children's physical development based on comprehensive body length and circumference measurements. These studies formed the basis of the national morphological school, which accounts for the ethnic and natural-climatic features of Uzbekistan's child population.

Modern international studies emphasize the need for integrating morphological, biomechanical, and genetic approaches in the assessment of physical development. Such systemic analysis provides a deeper understanding of growth regularities and enables the development of differentiated health improvement and correction programs.

Thus, literature analysis shows that children's physical development results from the complex interaction of multiple factors — nutrition, motor activity, socio-economic conditions, and emotional environment. Contemporary international standards and national studies form the basis for objective evaluation of physical condition, early detection of abnormalities, determination of biological age, and creation of preventive programs. The findings have strategic importance for the healthcare system, demographic policy, and human capital development in Uzbekistan, as the harmonious growth of children determines the nation's health and future intellectual potential.

The study aimed to identify regularities of physical growth and the formation of body proportions in preschool children.

Materials and Methods

The study aimed to identify regularities of physical growth and the formation of body proportions in preschool children. Anthropometric research combined longitudinal and cross-sectional designs following the methods developed by N. Kh. Shamirzaev and colleagues.

A total of 678 children aged 2 to 7 years, attending preschool institutions in Tashkent, were examined. All participants were born to healthy mothers and had no chronic diseases.

Measurements were performed in dedicated medical rooms in accordance with standard methodological requirements. Cross-sectional assessments captured physical development at a specific time point, whereas longitudinal observations enabled tracking individual growth dynamics over a defined period.

The data were processed statistically; result reliability was evaluated at $p < 0.05$. A sex-specific analysis identified differences between boys and girls. Correlation analysis was used to assess the influence of nutrition, physical activity, environmental conditions, and heredity on physical development.

Result and discussions

Analysis of the data (Table 1) shows a pronounced age-related increase in lower limb length among boys from 2 to 7 years. The indicators demonstrate a steady trend of linear growth, with varying intensity across age intervals.

Mean lower limb length is 40.3 cm at age 2, 45.9 cm at 3, and 46.9 cm at 4, reflecting active establishment of body proportions and the alignment of trunk–limb relationships. At age 5, the mean reaches 49.8 cm, at 6 — 56.5 cm, and at 7 — 57.9 cm. Thus, the overall increase from 2 to 7 years is about 17.6 cm (43.7%), indicating intensive development of the locomotor system in this period.

Table 1. Age dynamics and centile characteristics of lower limb length in boys aged 2–7 years (cm)

Centile	2	3	4	5	6	7
3%	34.2	36.7	39.1	41.0	49.26	47.00
10%	36.0	40.0	41.0	41.2	52.0	49.75
25%	37.4	41.7	42.9	45.1	53.0	54.25
50%	41.0	45.0	45.3	50.0	55.0	61.00
75%	42.3	50.3	50.6	54.0	60.75	63.43
90%	45.0	53.0	54.0	57.0	62.4	64.50
93%	46.0	54.7	56.3	60.3	63.3	65.28
Mean	40.3	45.9	46.9	49.8	56.53	57.89

Note: Values are in centimeters. Centile ranges (3–93%) reflect variations in lower limb length; the "Mean" row shows arithmetic means by age.

The most pronounced increment is observed between 5 and 6 years (≈ +6.7 cm), indicating a phase of maximal osteogenesis and accelerated somatic growth. By age 7, elongation slows, evidencing a transition toward functional refinement and stabilization of body proportions.

Centile distributions confirm marked individual variability: Lower centiles (3–10%): from 34.2 cm at 2 years to ≈49.7–50.0 cm by 7 years, with a stable positive trajectory. Middle range (25–75%): median (50th) rises from 41.0 to 61.0 cm, consistent with physiologically harmonious development. Upper centiles (90–93%): increase from 45.0–46.0 to 63.3–65.3 cm, exceeding the mean by ≈7–8 cm.

The wide spread (up to ≈31 cm between extreme centiles) points to substantial individual and hereditary contributions to boys' linear growth. Accelerated growth is typically seen in children with higher physical activity, balanced nutrition, and favorable health backgrounds.

Overall, ages 2–6 comprise a critical window for shaping morphofunctional body proportions (rapid growth of femur and tibia, strengthening of joints and ligaments, and postural stabilization). By 7 years, trunk–limb proportions level out, supporting functional readiness for school age.

Comparisons with international studies [6, 7] show greater amplitude of limb-length variation in boys than in girls during preschool years, associated with androgenic regulation of long-bone growth and a higher sensitivity to environmental factors.

Analysis of the data (Table 2) demonstrates steady, patterned age-related increases in lower limb length among girls aged 2–7. The increments are progressive and relatively uniform, reflecting harmonious morpho functional development characteristic of the female body in early childhood.

Mean lower limb length increases from 41.4 cm (2 years) to 45.0 cm (3) and 47.2 cm (4). By 5 it reaches 50.4 cm, at 6 — 56.7 cm, and at 7 — 58.2 cm. Thus, from 2 to 7 years the mean increase is ≈16.8 cm (≈40.5%).

The most intensive growth occurs between 4 and 6 years (≈ +9.5–10 cm), coinciding with rapid femoral and tibial growth, ligamentous strengthening, and postural stabilization. After 6, the linear growth rate declines, indicating transition to functional maturation and consolidation of the locomotor system.

Table 2. Age dynamics and centile characteristics of lower limb length in girls aged 2–7 years (cm)

Centile	2	3	4	5	6	7
3%	32.4	36.0	40.0	40.3	50.0	47.0
10%	35.8	38.0	41.5	42.1	51.0	50.0
25%	39.0	41.0	43.4	47.0	53.0	55.8
50%	41.5	44.0	46.5	51.5	56.0	61.0
75%	45.0	48.0	51.0	54.5	60.0	63.1
90%	47.0	53.0	52.9	57.8	62.9	64.5
93%	49.0	55.0	55.0	60.0	64.0	65.8
Mean	41.4	45.0	47.2	50.4	56.7	58.2

Note: Values are in centimeters. Centile ranges (3–93%) reflect variations in lower limb length; the "Mean" row shows arithmetic means by age.

Centile patterns show moderate variability and a stable developmental rhythm: Lower centiles (3–10%): 32.4–35.8 cm at 2 years to 47.0–50.0 cm at 7, consistent with physiologically slower growth. Middle range (25–75%): median rises 41.5 → 61.0 cm; the 75th centile 45.0 → 63.1 cm, indicating smooth, sustained dynamics. Upper centiles (90–93%): 47.0–49.0 → 64.5–65.8 cm by 7 years, about 7–8 cm above the mean.

The inter-centile span approaches ≈33 cm (32.4–65.8 cm), reflecting moderate individual variability and relatively stable growth in girls compared with boys, which supports the notion of earlier and more uniform morpho functional maturation in females.

In preschool girls, elongation of the lower limbs is harmonious and gradual, with early stabilization of body proportions and absence of sharp spurts typical of boys. The most active musculoskeletal formation occurs at 4–6 years (peak mineralization and muscular strengthening). The findings justify the development of regional centile norms and Z-score scales for girls in Uzbekistan's diverse climatic regions.

A sex comparison shows that at equal ages, girls have slightly higher means at 2–4 years, but these differences diminish by 6–7 years. Girls reach a growth plateau earlier, whereas boys retain potential for further limb elongation and overall stature increase. International data [6, 7] likewise indicate that girls display greater symmetry, smoothness, and predictability of growth with smaller fluctuations, and a tighter coupling between lower limb length and overall stature — markers of harmonious somatotype formation.

Analysis and Discussion

Across both sexes, lower limb length demonstrates a substantial linear increase exceeding 40% over the 2–7-year developmental interval. In boys, the mean values rise from 40.3 cm at 2 years to 57.9 cm at 7 years (overall gain ≈ 17.6 cm), while in girls the increase spans from 41.4 cm to 58.2 cm (overall gain ≈ 16.8 cm). These changes underscore the high growth plasticity of the lower limb segments in early childhood and the critical role of this period in establishing the foundations of locomotor morphology.

The most pronounced acceleration occurs between 4 and 6 years, where boys increase from 46.9 to 56.5 cm and girls from 47.2 to 56.7 cm. This interval represents a biologically sensitive window during which rapid osteogenesis, strengthening of the ligamentous apparatus, maturation of neuromuscular coordination, and refinement of postural control occur. By 7 years, both sexes exhibit a marked deceleration in linear growth, reflecting a shift toward functional maturation, redistribution of metabolic resources, and increasing emphasis on muscular hypertrophy and motor refinement rather than on skeletal elongation alone.

Early childhood displays small but consistent sex differences. At ages 2–4, girls slightly exceed boys in mean lower limb length (e.g., 41.4 vs. 40.3 cm at age 2; 47.2 vs. 46.9 cm at age 4). These differences are attributable to earlier morphofunctional maturation in girls, characterized by more synchronized endocrine regulation and earlier stabilization of segmental proportions.

By 6–7 years, these differences diminish, with girls reaching 56.7–58.2 cm and boys 56.5–57.9 cm, indicating convergence toward a common morphological baseline. Nevertheless, upper centiles diverge more clearly: boys extend up to ≈65.3 cm, while girls reach ≈65.8 cm, though with lower frequency. This pattern reflects a subset of boys with accelerated somatic potential, likely associated with delayed but more intense androgen-mediated stimulation of long-bone growth during later childhood.

Girls display greater growth harmony and bilateral symmetry across all centiles, whereas boys exhibit more pronounced spurts and higher variability, especially between 3 and 6 years. These findings are consistent with international data showing that male growth trajectories are more sensitive to exogenous modulators—nutrition quality, physical activity, psychosocial stress—and that girls' growth is governed predominantly by consistent endogenous mechanisms (genetic regulation, metabolic stability, hormonal constancy).

The 3rd–93rd centile span reaches approximately 33 cm, illustrating significant individual diversity. Boys present a wider centile spread, confirming that their growth patterns are more heterogeneous and context-dependent. Girls, in contrast, maintain narrower variability, emphasizing greater physiological predictability and stable developmental rhythms.

Both sexes exhibit heterochronous growth, with the femoral segment achieving its peak velocity earlier than the tibial segment. This sequential elongation contributes to: progressive optimization of body proportions, improvement of pelvic–lower limb alignment, enhancement of gait biomechanics, and stabilization of posture and balance.

By age 7, girls typically demonstrate well-established morphological symmetry, whereas boys retain reserve potential for continued linear elongation into middle childhood.

The observed dynamics align with the broader concept of morphofunctional heterochrony, reflecting the naturally asynchronous maturation of skeletal, muscular, and neural subsystems. These findings carry important practical implications for morphology, pediatrics, physical anthropology, and child health monitoring: development of regional centile norms and Z-score standards, assessment of individual conformity to age- and sex-specific reference ranges, timely identification of delayed, accelerated, or disharmonious somatic development, optimization of preventive interventions, nutrition

policies, and physical activity programs, more precise estimation of somatotype formation trajectories in early childhood.

These results are especially relevant for large urban centers—such as those in Uzbekistan—where the influence of diverse social, environmental, nutritional, and climatic factors contributes to high variability in child growth patterns.

Conclusion

The period from 2 to 7 years represents a pivotal stage in shaping the child's morphofunctional organization. During these years, fundamental body proportions, locomotor biomechanics, and segmental relationships are established, forming the structural basis for future somatotype development, motor coordination, and functional performance.

Understanding the specific laws of lower limb growth, along with associated sex differences and heterochronous developmental trends, enhances the precision of diagnostics and contributes to early detection of developmental deviations. These insights support the design of evidence-based strategies aimed at promoting healthy physical development through balanced nutrition, optimal physical activity, and routine anthropometric monitoring.

Continued research in this domain will enable the refinement of national growth standards tailored to Uzbekistan's climatic, geographic, and ethnocultural conditions. Such efforts represent a strategic priority for strengthening pediatric health, improving population-based monitoring, and maximizing children's morphofunctional potential across diverse regions of the country.

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