A Study of Physical Development Indicators in Children and Adolescents Under the Influence of Hygienic and Ecological Factors

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Abstract: This article examines the impact of environmental pollution, nutritional quality, and daily hygienic conditions on the physical development indicators of children and adolescents. Children aged 7–17 were assessed using anthropometric (height, weight, chest circumference) and physiometric (vital lung capacity, hand strength) methods. It was determined that children living in unfavorable ecological conditions exhibit a lower harmony of physical development and lag behind the norm in their functional indicators.

Keywords: physical development, children and adolescents, hygiene, medical ecology, anthropometry, environmental factors

INTRODUCTION

The physical development of children and adolescents is one of the most crucial integral indicators of the health of any society. Physical development is understood as the age- and gender-appropriate combination of the body's morphological (height, body weight, chest circumference, body proportions) and functional (vital lung capacity, muscle strength, functioning of the respiratory and cardiovascular systems) characteristics. These indicators reflect not only an individual's health status but also the sanitary-hygienic, ecological, socio-economic, and cultural conditions of the environment in which the population lives.

Over the last 20 years, two negative trends in the physical development of children and adolescents have been observed globally: chronic malnutrition and underweight in developing countries, and a sharp decrease in physical activity and overweight/obesity in developed and industrialized countries. The Republic of Uzbekistan is one of the most industrialized countries in the Central Asian region; in cities such as Tashkent, Andijan, Fergana, Namangan, and Almalyk, the level of anthropogenic pollution of air, water, and soil is high. Children's bodies are more sensitive to ecotoxins than those of adults because their respiratory and digestive systems are not yet fully formed, their metabolism is faster, and their defense mechanisms are weaker. Therefore, from a medical ecology perspective, it is extremely important to regularly monitor the physical development of children and adolescents and to analyze the hygienic factors that determine it.

The purpose of this study is to conduct a comprehensive assessment of the physical development indicators of children and adolescents aged 7–17 living in zones

with varying levels of environmental load in Tashkent city, under the influence of hygienic and medical-ecological factors, and to develop preventive measures.

Research objectives:

1. To determine anthropometric indicators by age and gender in various ecological zones and compare them with WHO standards.
2. To assess physiometric indicators (VLC, hand strength).
3. To identify the main pollutants in the air, water, and soil of the environment.
4. To calculate the correlation between hygienic factors (quality of nutrition, school conditions, family income) and physical development.
5. To develop preventive recommendations.

Materials and Methods of the Study

The study was conducted from 2023 to 2024 in three ecological zones of Tashkent city. Zone 1 (unfavorable area) was defined as parts of the Sergeli (sectors 5–7), Yunusobod (blocks 8–9), and Olmazor districts, which are near industrial enterprises, thermal power plants, and major highways. In these areas, the air pollution index (for NO2, SO2, CO, formaldehyde, and PM2.5) was assessed to be between 7.8 and 9.2 (high level). Zone 2 (moderate) was identified as the city center—the Chilonzor, Mirobod, Yakkasaroy, and Shayxontohur districts—where the pollution index ranged from 4.1 to 5.5. Zone 3 (relatively favorable) was designated as the city's outskirts and green spaces—the Bektemir district (garden zone), the remote parts of Qibray, and Yangihayot—where the pollution index was between 2.0 and 3.2 (low).

A total of 1,200 children and adolescents were included in the study: 600 boys and 600 girls, with 400 participants from each zone (200 boys and 200 girls). The participants were divided into the following age groups: 7–10 years (primary school age), 11–14 years (middle school age), and 15–17 years (high school age, adolescence). Each zone and age group consisted of 130–135 children. The study was conducted using a cross-sectional method, and the sample was randomized and formed based on data from the primary healthcare system. The exclusion criteria were: chronic endocrine diseases, congenital defects, and undergoing cytostatic or hormonal therapy.

Anthropometric measurements were performed using standard methods: height was measured with a stadiometer to an accuracy of 0.1 cm early in the morning, with the head in the Frankfurt horizontal plane; body weight was measured with an electronic medical scale to an accuracy of 0.1 kg while wearing light clothing; chest circumference was measured with a measuring tape during quiet breathing, at the nipple line for boys and below the mammary glands for girls. Additionally, the Quetelet index (body weight kg / height m2 × 100) was calculated.

Physiometric measurements included the following: vital capacity of the lungs was measured three times using a portable spirograph (SpiroLife-200), and the highest

value was recorded; handgrip strength was measured for the right and left hands separately using a hand dynamometer (DKD-100), and the average value was calculated; additionally, breath-holding time was assessed (Stange and Genchi tests).

Hygienic and environmental assessments were conducted in the following areas: illuminance (luxmeter), air temperature and relative humidity (psychrometer), CO2 concentration (gas analyzer), and dust content (gravimetric method) were determined in school classrooms. During the 2023–2024 academic year, 10 classrooms were inspected in each school. Drinking water samples were analyzed for lead (Pb), cadmium (Cd), arsenic (As), and nitrates (NO3−) using atomic absorption spectrometry. Nutritional quality was assessed using a 3-day school and home food diary and the "Healthy Eating Score" (HES) —a system ranging from 0 to 10 points that accounted for the consumption of fruits, vegetables, protein, dairy products, sweets, and fast food. The level of physical activity was determined based on the average time spent outdoors per day (in hours), the number of physical education classes per week, and attendance at sports clubs.

Statistical analysis was performed using SPSS 26.0 software. Quantitative variables were expressed as mean ± standard error (M±SE). Differences between groups were tested using the Student's t-test and one-way ANOVA (with post-hoc Tukey test). The relationship between variables was evaluated using the Pearson correlation coefficient (r). The significance level was set at $p<0.05$ (significant) and $p<0.01$ (highly significant).

Results

Anthropometric indicators. The average height of children in Zone 1 (unfavorable) was statistically significantly lower than in Zones 2 and 3 across all age groups ($p<0.05$). The greatest difference was observed among boys aged 15–17: the average height was 164.3 cm in Zone 1, 169.1 cm in Zone 2, and 171.2 cm in Zone 3 ($p<0.01$). The height difference in girls was smaller: 157.5 cm in Zone 1 versus 162.0 cm in Zone 3 for the 15–17 age group ($p<0.05$). In Zone 1, 24% of children aged 7–10 were found to be below the 3rd percentile on the WHO centile charts (i.e., meeting the "short stature" criterion).

Regarding body weight, the prevalence of underweight (below the 10th percentile) in Zone 1 was 35% in the 7–10 age group, 28% in the 11–14 age group, and 20% in the 15–17 age group. Conversely, overweight (above the 85th percentile) was more common among adolescents: in the 15–17 age group in Zone 1, it was 21% (26% among girls). This indicates the "double burden" phenomenon—the coexistence of both underweight and overweight in the same population. The chest circumference of boys in Zone 1 was, on average, 3.1 cm smaller than that of boys in Zone 3 ($p<0.05$). In girls, the difference was 1.8 cm and was not statistically significant ($p>0.05$).

Physiometric indicators. Regarding vital lung capacity (VLC), children in Zone 1 showed significantly lower values than the norm across all age and gender groups. For example, among boys aged 7–10, the average VLC in Zone 1 was 1420 ml, compared to 1670 ml in Zone 3, with the WHO norm being 1650 ml. For boys aged 11–14, the values were 2150 ml in Zone 1 and 2580 ml in Zone 3 (norm: 2600 ml). For boys aged 15–17, this indicator was 3050 ml in Zone 1 and 3720 ml in Zone 3 (norm: 3700 ml). A similar trend was observed in girls: at ages 15–17, the VLC was 2670 ml in Zone 1 and 3150 ml in Zone 3 (norm: 3100 ml). All differences were statistically significant ($p<0.01$). Overall, the VLC of boys in Zone 1 was 11–18% below the norm. Hand grip strength (right hand) in 15–17-year-old boys averaged 30.2 kg in Zone 1 and 38.5 kg in Zone 3 ($p<0.001$). For girls, the figures were 22.4 kg and 27.6 kg, respectively ($p<0.001$). Left-hand grip strength was, on average, 8-10% lower than the right. The Stange test (breath-holding on inhalation) averaged 28.4 seconds for boys in Zone 1 and 38.1 seconds in Zone 3 ($p<0.01$). The Genche test (breath-holding on exhalation) was 18.3 seconds in Zone 1 and 24.2 seconds in Zone 3 ($p<0.01$). This indicates a decrease in the reserve capacity of the respiratory system.

Hygienic and environmental factors. Water analysis results determined that the lead level in Zone 1 water was 0.025 mg/l (Maximum Permissible Concentration – MPC – 0.01 mg/l), and cadmium was 0.007 mg/l (MPC 0.003 mg/l). In Zone 3 water, lead was 0.005 mg/l, while cadmium was not detected.

Regarding school hygiene, in Zone 1 schools, the natural lighting coefficient in classrooms averaged 1.2% (norm 1.5–2.0%), and artificial lighting was 280 lux (norm 400 lux). The CO2 concentration was 0.12–0.15% (norm up to 0.08%). Relative air humidity during the winter season was 32% (norm 40–60%). In Zone 3 schools, all these indicators were within the normal range.

Nutritional quality: The Healthy Eating Score (HES) for children in Zone 1 averaged 4.6 points (out of a maximum of 10), compared to 7.2 points in Zone 3 ($p<0.01$). 65% of children in Zone 1 consumed fruit less than twice a day, and 52% ate processed meat products (sausages, canned goods) daily. In Zone 3, these figures were 28% and 19%, respectively.

Correlation analysis. A moderate negative correlation was found between the lead level in water and height ($r = -0.48$; $p<0.01$). There was a moderate negative correlation between the air pollution index and FVC ($r = -0.52$; $p<0.01$). The Healthy Eating Score had a positive correlation with body weight ($r = +0.43$; $p<0.05$) and hand grip strength ($r = +0.39$; $p<0.05$). A positive correlation was found between daily time spent outdoors (in hours) and hand grip strength ($r = +0.44$; $p<0.01$). A moderate negative correlation was identified between classroom CO2 concentration and the Stange test results ($r = -0.37$; $p<0.05$). A positive correlation was observed between family income and height ($r = +0.31$; $p<0.05$).

Multivariate regression analysis showed that the environmental zone (unfavorable vs. favorable) explains 38% of the variance in physical development indicators ($R^2=0.38$; $p<0.001$).

Discussion

The results obtained demonstrate that environmental pollution and poor hygienic conditions negatively affect children's physical development. Heavy metals such as lead and cadmium accumulate in bone tissue, disrupting the ossification of growth plates, and also reduce the synthesis of thyroid hormones, thereby stunting growth. Airborne PM2.5 particles and NO_2 cause chronic inflammation in the alveoli, which reduces lung elasticity and vital capacity. In children, such changes occur more rapidly than in adults because the barrier function of their respiratory system is not yet fully mature.

The relatively high prevalence of overweight among adolescents in Zone 1 (26% in girls) is explained by low physical activity and high consumption of inexpensive, high-calorie, yet low-nutrition foods. Concurrently, underweight in younger children is linked to chronic malnutrition and micronutrient deficiencies. This "double burden" phenomenon is characteristic of cities in developing countries.

Poor school hygiene (inadequate lighting, air pollution, elevated CO_2) directly leads to general fatigue among students and a decline in their functional state. Consequently, children are less active in physical education classes and spend less time on outdoor games, which causes a decrease in hand grip strength and respiratory system performance indicators.

Correlation analysis shows that the factors affecting physical development are complex: ecology, nutrition, socioeconomic status, and school hygiene reinforce one another. Therefore, a systemic approach that is not only medical but also ecological, sanitary, and social is necessary.

CONCLUSION

1. The anthropometric indicators (height, body weight, chest circumference) of children and adolescents aged 7–17 living in ecologically unfavorable areas of Tashkent (Zone 1) are significantly lower ($p<0.05$) than those of their peers in relatively favorable areas (Zone 3). The height difference was 4–7 cm in boys and 3–4 cm in girls.

2. The harmony of physical development was only 47% in Zone 1, compared to 78% in Zone 3. In the unfavorable zone, dysharmonic and sharply dysharmonic development (imbalance in height-to-weight ratio) accounted for 53%, indicating a risk of impaired carbohydrate and lipid metabolism.

3. Physiometric indicators (vital lung capacity, hand strength, breath-holding time) in unfavorable zones were 11–22% below the norm, with the greatest difference

observed in the adolescent group (15–17 years). This is linked to chronic environmental stress and poor hygienic conditions.

4. Environmental pollution (lead and cadmium in water; NO2, CO, PM2.5 in the air) and violations of school hygiene (insufficient lighting, excess CO2, low humidity) have a moderate to strong negative correlation with physical development indicators (r = -0.37 to -0.52). Low healthy-eating scores and limited time spent outdoors are also contributing negative factors.

5. The "double burden" phenomenon was observed in unfavorable areas: underweight in young children (35%) and overweight in adolescents (21–26%) occur simultaneously. This situation indicates the need to differentiate prevention programs according to age.

6. Regular medical-ecological monitoring of the physical development of children and adolescents, especially in ecologically unfavorable areas, is an important tool for preserving health and fostering a healthy generation.

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