

Comprehensive evaluation of the functional state in senior schoolchildren with varying levels of daily motor activity

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Abstract:

The study of human motor activity continues to be a relevant area in the field of physical education. **Purpose.** The aim of this study is to evaluate the relationship between functional body indicators in senior schoolchildren, considering their health status and daily cyclic motor activity. **Materials and methods.** A comprehensive examination was performed on 255 senior schoolchildren in the 10th grade from schools in Nizhny Novgorod, Russia. The assessment included a pediatrician's evaluation, life history collection, and various instrumental methods such as pedometry, anthropometry, bioimpedance analysis, and hemodynamic parameter assessment. Daily locomotion counts were recorded using an electronic pedometer over seven consecutive days. Non-invasive functional testing of the body was performed using the "MedicalSoft" Sports Testing System (MS FIT-01). **Results.** We classified the schoolchildren into three groups based on their average daily step count. The first group consisted of those who walked fewer than 5,000 steps per day, the second included those taking 5,000–10,000 steps daily, and the third comprised those exceeding 10,000 steps per day. The study revealed that 54.7% of adolescents had physical activity levels between 5,000 and 10,000 steps per day, while a quarter were categorized as "low-active," walking fewer than 5,000 steps daily. An evaluation of the impact of health status on locomotor activity showed that students in the first health group exhibited the highest levels of physical activity, while those in the third functional health group had the lowest. Increased physical activity was associated with enhanced cardiac reserves, as indicated by the cardiac index and minute blood circulation volume. Additionally, schoolchildren with higher physical activity levels had the lowest fat mass and the highest muscle mass in their body composition. **Conclusions.** The results of the study can be used to plan and adjust work programs for the physical training of senior schoolchildren, as well as to promote physical activity among young people.

Keywords: physical education, physical training, physical activity, pedometry, bioimpedancemetry, hemodynamics

Introduction

Effective education for children and adolescents in educational institutions requires a high level of health, strong cognitive abilities, and physical fitness. However, numerous studies have reported a decline in the health of young people, primarily attributed to the rising prevalence of physical inactivity (Eksterowicz et al., 2020; Raghuveer et al., 2020; Lv et al., 2024). Concurrently, a negative perception of physical education and diminishing motivation to participate in it have been observed (Liu et al., 2023; Johannes et al., 2024). Researchers have linked low physical activity (Zhang et al., 2018) to the heavy academic workload faced by

students in educational institutions. Additionally, the digitalization of education and the pervasive use of electronic devices (Wang et al., 2024), coupled with the psychological stress induced by assessments and examinations, have detrimental effects on physical well-being. These factors contribute to the development of various health issues and the onset of multisystem pathology in young individuals, hindering their ability to engage fully in physical activity. The decline in physical activity among children and adolescents has resulted in an increase in musculoskeletal disorders (Metelnikov et al., 2024), frequently linked to connective tissue dysplasia, which exacerbates the progression and prognosis of the underlying condition. During their school years, children's health begins to decline considerably (Krasnozhen et al., 2017), with over 50% of children developing various health conditions by the time they complete their studies (Gerber et al., 2017; Hollis et al., 2017). According to V.N. Dolich et al. (2022), the number of schoolchildren in Russia classified in health group III, indicating restrictions on physical activity, has increased by 10% over the past decade. Additionally, the proportion of students recommended for therapeutic physical education (health group IV) has increased by 4.6%. As they continue their education, the health of these children and adolescents continues to decline (Glazkova et al., 2020).

Regular physical activity is essential for a child's proper physical and mental development, as well as the optimal functioning of their organs and systems (Novytskyi et al., 2024; Rebryna et al., 2024). Notably, younger children require longer durations of daily physical activity. Numerous studies have highlighted the significance of physical activity in maintaining good health and promoting normal physical development in young individuals. A strong correlation has been established between physical activity levels and body weight in children (Yan et al., 2024).

Research has demonstrated the efficacy of physical exercise in preventing and treating mental health disorders, enhancing cognitive development and attention, and showing promise in the management of attention deficit hyperactivity disorder in children (Barbosa et al., 2024; Mehren et al., 2024). Furthermore, physical activity is essential in the development of non-cognitive functions in children, as evidenced by studies such as that conducted by Yuan et al. (2022). Their findings revealed a positive impact on six key child abilities: social behavior, communication skills, persistence, school adaptation, educational aspirations, and creative thinking. The health benefits of physical activity can be realized through engaging in regular physical activity of sufficient volume and intensity (Rebryna et al., 2024). Regular exercise enhances aerobic capacity and muscular strength, promotes recovery from concurrent illnesses, and reduces the risk of metabolic disorders, type 2 diabetes (Gulyaeva et al., 2019), and cardiovascular diseases (Qiao & Zhang, 2024; Wu et al., 2024). Spanish researchers Rodríguez-Martín et al. (2024) found that in children aged 7–12, obesity was directly linked to their level of physical activity. This relationship should be considered when developing strategies to improve the health of these children.

To support the rational and scientifically based standardization of physical activity, researchers continue to refine activity level recommendations. Various methods are used to determine the appropriate levels of physical activity for individuals. Globally, the widely accepted standards for physical activity, tailored to different age groups, are outlined in the World Health Organization (WHO) Guidelines on Physical Activity and Sedentary Behavior (2020). However, these guidelines do not account for a person's gender, health status, or functional capabilities, which may adversely affect their body's response to physical activity. Therefore, it is essential to personalize physical activity recommendations. This approach to standardizing physical activity should consider the unique physical development and functional characteristics of individuals, particularly children (Liu et al., 2023). The pedometer method can be used for this purpose. Research has shown that using a pedometer in the workplace effectively increases physical activity. However, sustaining adherence to an active routine over time can be challenging because it is often hindered by a decline in motivation for regular physical exercise (Rinaldi-Miles et al., 2019). Contemporary research highlights the relevance of using devices to monitor physical activity. In physical education, there is a growing interest in exploring the relationships between the functional systems of the body and individuals' physical fitness and health status (Kolokoltsev et al., 2022; Bocharin et al., 2022). Accelerometers provide a valuable tool to delineate patterns of physical activity and sedentary behavior (Macdonald et al., 2023; Evenson et al., 2024). Despite the growing body of research, the scientific literature lacks sufficient exploration of the correlation between daily physical activity levels, as measured by pedometer data, and the health status of schoolchildren based on annual medical examinations and the condition of their functional systems. Investigating this relationship is crucial for refining the physical activity recommendations for students, potentially leading to a positive effect on their health.

Purpose. The aim of this study is to evaluate the relationship between functional body indicators in senior schoolchildren based on their health status and daily cyclic physical activity.

Materials and methods

We performed an extensive survey involving 255 high school students aged 16–17 years (mean age: 16.3 ± 1.3 years) enrolled in the 10th grade of schools in Nizhny Novgorod, Russia. The inclusion criteria were

the written voluntary informed consent of one parent or legal guardian for the child's participation in the study, as well as a doctor's assessment confirming the child's functional health group for physical education.

The comprehensive examination of the adolescents encompassed a pediatrician's assessment, detailed medical history, anthropometric measurements, and instrumental investigations, including pedometry, bioimpedance analysis, and hemodynamic parameter evaluation. Daily step counts during everyday activities were recorded using the Omron HJ-325 electronic pedometer (Omron Dalian Co. Ltd., China), which was securely attached to the participants' belts. Measurements were collected continuously throughout the day for seven consecutive days.

Non-invasive functional testing of the schoolchildren's bodies was performed using the MedicalSoft Sports Testing System (MS FIT-01, Russia). The testing protocol included four methods (Bocharin et al., 2023), of which the following were used in this study:

1) Bioimpedance analysis of body composition. This method measures electrical conductivity (electrical impedance) and evaluates two components: R-active resistance, which represents the extracellular and intracellular fluids, and Xc reactive resistance, the dielectric component of impedance, which corresponds to cell membranes. This technique provides estimates of both absolute and relative values of muscle and fat mass.

2) Analysis of hemodynamic parameters. The hardware method was used to determine the cardiac index and minute blood volume. The cardiac index is calculated as $CI = CO / BSA$, where CI is the cardiac index ($L/min \times m^2$), CO is cardiac output (L/min), and BSA is body surface area (m^2). The minute blood volume is calculated as $IOC = HR \times CO$, where IOC is the minute blood volume (L/min), HR is heart rate (beats/min), and CO is cardiac output (L/min).

The study was performed in accordance with the ethical principles outlined in the Helsinki Declaration of 2008, the World Medical Association (2013 version), and the National Standard GOST 52379-2005 "Good Clinical Practice" of the Russian Federation. Ethical approval for the study was granted by the Local Ethics Committee of the "Volga Region Research Medical University" of the Ministry of Health of Russia (Protocol No. 5, dated 03.31.2023).

Statistical analysis was performed using the Statistica 6.0 and IBM SPSS 24 software packages. The normality of data distribution was assessed using the Shapiro–Wilk test and QQ-plot graphs. Descriptive statistics included the calculation of the arithmetic mean (M), standard deviation (σ), and the standard error of the mean (m). The statistical significance of differences was evaluated using nonparametric tests: the Mann–Whitney U test, the Wald–Wolfowitz runs test, and Pearson's χ^2 test. A p-value ≤ 0.05 was considered statistically significant.

Results

In accordance with the WOS recommendations for grading daily physical activity (WHO Guidelines on Physical Activity and Sedentary Behavior, 2020), we categorized the schoolchildren into three groups based on their average daily step count.

The first group consisted of high school students who walked fewer than 5,000 steps per day, the second group included those walking between 5,000 and 10,000 steps daily, and the third group comprised students taking more than 10,000 steps per day. In a large cohort of randomly selected schoolchildren from educational institutions in Nizhny Novgorod, the majority (54.7%) belonged to the second group (5,000–10,000 steps per day). Meanwhile, 23.3% were classified as "low-active," and 22.0% as "highly active." It was of scientific and practical interest to examine potential gender differences in the locomotor activity of high school students. The results revealed that a higher proportion of boys (25.3%) than girls (20.1%) take more than 10,000 steps daily. However, there were also more "low-active" boys (26.9%) compared to girls (19.9%, $p \leq 0.05$). For this age group, the daily physical activity recommended by WHO exceeds 15,000 steps. The pedometry results from our study highlight the issue of physical inactivity among the adolescents examined.

We also analyzed the physical activity of schoolchildren assigned to different functional health groups for physical education classes. Schoolchildren without any health issues were assigned to the first functional health group. Schoolchildren with functional health deviations or disharmonious physical development and poor physical fitness were assigned to the second functional group, while those with various somatic diseases were assigned to the third group.

Among tenth-graders in the healthiest group I, the largest proportion of adolescents (72.7%) had an average level of physical activity (5,000–10,000 steps), which was significantly higher than the proportion of students in other health groups ($p \leq 0.05$). Among schoolchildren in group I, the lowest proportion of "highly active" individuals (9.1%) was observed ($p \leq 0.05$). Additionally, the lowest proportion (18.2%) of adolescents with a minimum level of activity was found in group I, compared to the proportion of adolescents with this level of activity in other functional health groups (Figure 1).

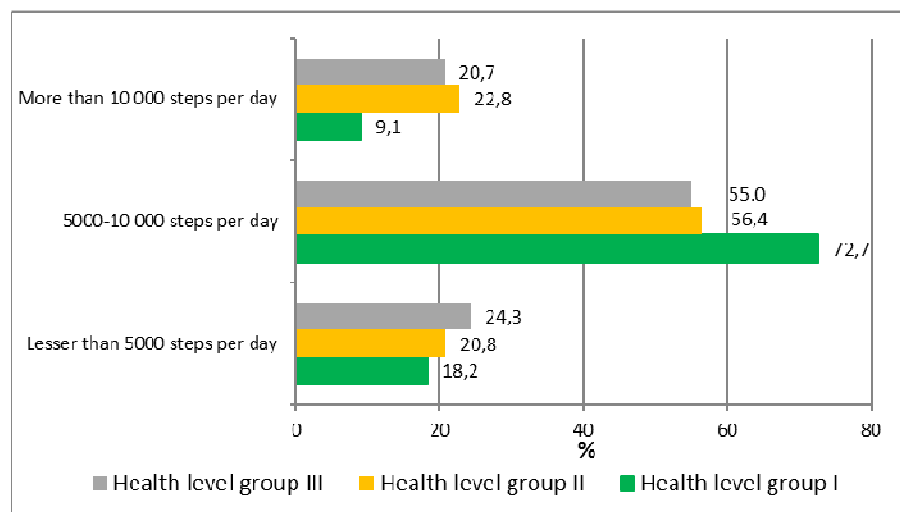


Fig. 1 Distribution of schoolchildren by physical activity levels and health status

Schoolchildren assigned to functional health groups II and III exhibited a more uniform quantitative distribution across the levels of daily locomotion. Notably, a higher proportion of schoolchildren in these groups took more than 10,000 steps per day (Figure 1). In functional health groups II and III, the proportion of such schoolchildren was 22.8% and 20.7%, respectively.

It is noteworthy that the highest percentage of "low-active" schoolchildren (24.3%) was found among students assigned to the third health group, which had the most unfavorable health status based on the medical examination results. This is likely attributed to the presence of somatic diseases that restrict the physical activity of these schoolchildren.

In addition to gender characteristics, general health, functional systems, and physical development, body composition, particularly the proportion of fat and muscle mass, is an important parameter related to the physical activity of schoolchildren (Figure 2).

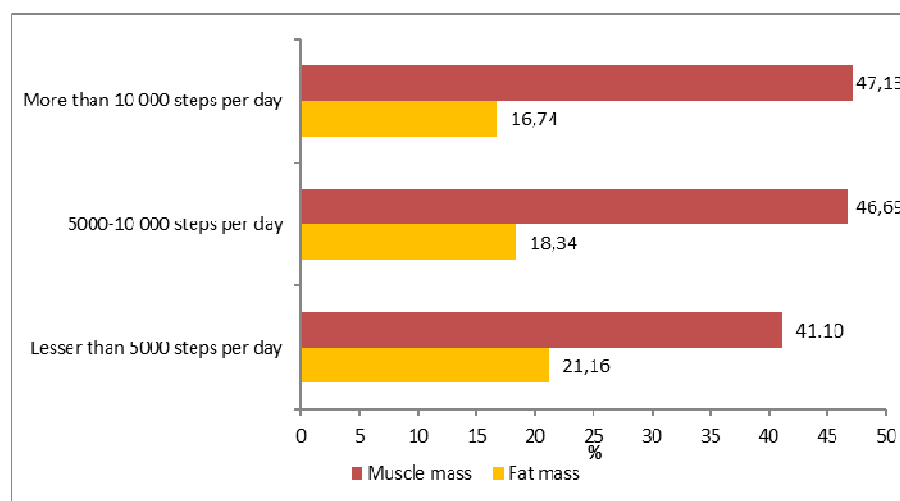


Fig. 2 Bioimpedance analysis of body composition in schoolchildren with different levels of physical activity

Bioimpedance analysis results demonstrated that the proportion of fat mass decreased as the level of daily physical activity increased. In schoolchildren with average physical activity (5,000–10,000 steps per day), the percentage of fat mass was 15.4% lower than in their "low-active" counterparts. In those with maximum physical activity (a daily distance greater than 10,000 steps), the percentage of fat mass was 26.4% lower ($p < 0.05$ for both cases). Conversely, the proportion of muscle mass in the body composition of adolescents increases proportionally with increasing physical activity. For average and high levels of physical activity, the proportion of muscle mass was 13.6% and 14.7% higher, respectively, compared to low levels of physical activity ($p < 0.05$).

for both cases). This further suggests a positive impact of physical activity on the body composition of high school students.

An important component of the analysis is the assessment of certain hemodynamic characteristics in schoolchildren, as shown in Figure 3.

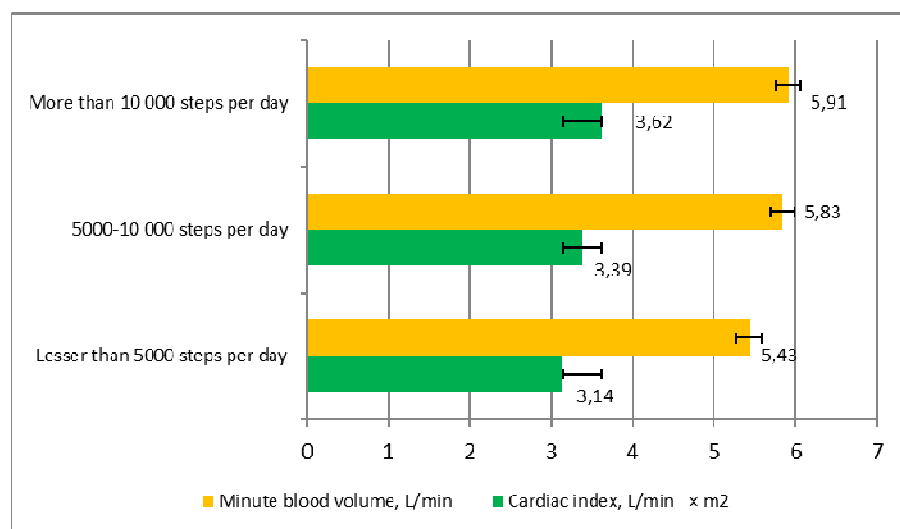


Fig. 3 Hemodynamic parameters in schoolchildren with varying levels of motor activity

Our findings revealed that the CI, which represents the pumping function of the heart, increased with increasing levels of daily physical activity in high school students.

While no statistically significant differences were observed between the CI of "low-active" students and those with average motor activity, significant differences were observed between "low-active" and "highly active" schoolchildren ($p < 0.05$). Specifically, the CI increased by 13.2%, and the IOC increased by 8.8% with increasing levels of physical activity ($p < 0.05$ for both indicators).

These results indicate a relationship between the health of schoolchildren, their daily physical activity, body composition, and key hemodynamic indicators.

Dicussion

It is generally recognized that one of the effective means of improving the health of children, adolescents and young people, and preventing serious psychosomatic diseases is regular physical activity (Novytskyi et al., 2024; Rebryna et al., 2024 b; Barbosa et al., 2024; Mehren et al., 2024). At the same time, numerous observations by scientists indicate a serious deterioration in the health of the younger generation on almost all continents of the planet. Thus, modern data are provided on the deterioration of the health of young people in the United States (Raghuveer et al., 2020), Europe (Rodríguez-Martin et al., 2024), the African continent (Johannes et al., 2024), and in Asia (Liu et al., 2023).

Despite the existing rich and comprehensive experience of research work on issues of physical activity, many of them require further clarification and some rethinking (Liu et al., 2023). This concerns, for example, a deeper study of the relationship between physical activity and the health of children and adolescents. In recent decades, there have been profound negative trends in the health of the population, including young people (Eksterowicz et al., 2020; Raghuveer et al., 2020; Lv et al., 2024). This fact causes concern among scientists, health workers, educators, sociologists, and government officials for the demographic situation in a number of regions and individual countries (Wang et al., 2024). Therefore, a comprehensive study of physical activity as an important means of improving the level of physical, mental and somatic health seems relevant and timely. One of the important areas of studying regular human physical activity is to identify the relationship between the required number of steps in daily physical activity depending on gender, the level of health of schoolchildren, their functional parameters, anthropometric indicators, body composition and other characteristics. In world practice, recommendations for physical activity of the population proposed by WHO (WHO Guidelines on Physical Activity and Sedentary Behavior, 2020) are widely used. However, these standard parameters of physical activity do not take into account the features of the factors listed above. Therefore, the use of physical activity within the framework of these standards does not always achieve the set goals in improving the health of those involved.

Our studies confirm the findings of other scientists about the different levels of human physical activity depending on their gender (Novytskyi et al., 2024). According to our data, it was found that daily physical

activity is higher among young men who take more than 10,000 steps daily, but there are also more “low-active” people among them compared to girls. At the same time, most of the young men and women we examined had fewer steps than the WHO recommendation of 15,000 steps. This allows us to classify a significant part of the adolescents we examined as at risk for physical inactivity.

We have established differences in physical activity among schoolchildren depending on their health group. Similar studies were conducted among university students (Kopeikina, 2023). We confirmed the author’s data that adolescents who are assigned to the first functional health group have the highest physical activity in the form of walking. The lowest physical activity is recorded among schoolchildren of the third functional health group. Thus, low physical activity of schoolchildren in this group is further worsened by physical inactivity. We propose to identify schoolchildren with low physical activity as a risk group for physical inactivity. This allows us to conduct targeted physical education and health work among them.

According to the study of body component composition, we have found that schoolchildren with a sufficient level of cyclic physical activity in the form of walking have the lowest fat mass content and the largest proportion of muscle tissue. These data are consistent with the results of studies by other scientists (Gulyaeva et al., 2019; Yan et al., 2024), who found that obesity and overweight are closely related to the level of physical activity. Therefore, the obtained data can be used to popularize physical education and sports among young people in the context of weight loss.

According to our data, a study of some hemodynamic indicators shows that the value of the cardiac index and minute volume of blood circulation, which reflect the pumping function of the heart, naturally increase as the level of daily physical activity increases. Schoolchildren with low physical activity have lower hemodynamic parameters. This indicates a direct dependence of the cardiovascular system on the level of physical activity. Increasing the tolerance of this functional system to physical activity increases the body's reserve capacity and is aimed at preventing the development of cardiovascular diseases. Many researchers report the importance of preventing diseases of this functional system (Qiao, & Zhang, 2024; Wu et al., 2024).

Thus, a relationship has been established between physical activity and the health level of schoolchildren, their body composition and hemodynamic parameters.

Conclusions

Our study revealed that over half of the tenth-grade students surveyed (54.7%) engaged in physical activity ranging from 5,000 to 10,000 steps per day, while a quarter of the schoolchildren could be categorized as "low-active" (less than 5,000 steps daily). Notably, young men exhibited higher levels of activity compared to young women. Furthermore, our assessment of the impact of the health group on physical activity demonstrated that individuals in the first health group had the highest levels of physical activity, while those in the third health group had the lowest. Our study additionally revealed that the increased motor activity of high school students was associated with increased reserves of the heart's pumping function, as indicated by the analysis of the CI and IOC. Furthermore, pedometer data showed that schoolchildren with the highest levels of physical activity had the lowest percentage of fat mass in their body composition and the highest percentage of muscle tissue.

The results of this study can be applied in planning and adjusting physical education curricula for senior schoolchildren. Additionally, the findings can be used to promote physical activity among modern youth.

Conflicts of interest. The authors declare no conflict of interest.

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