ASSESSMENT OF PHYSIOLOGICAL RESERVES IN PHYSICAL EDUCATION STUDENTS BASED ON BIOIMPEDANCE INDICATORS: THE CASE OF THE REPUBLIC OF KARAKALPAKSTAN

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ABSTRACT

This study examines the formation of physiological reserves in physical education students based on bioimpedance indicators in the Republic of Karakalpakstan. It emphasizes that physiological reserves reflect the adaptive capacity of the organism and are closely linked with body composition, hydration status, and cellular integrity. Bioelectrical impedance analysis is presented as a practical method for evaluating fat mass, muscle mass, body water, and phase angle. The study highlights the influence of ecological conditions of the Aral Sea region on students' functional potential. It is concluded that bioimpedance-based assessment provides an effective tool for monitoring health, improving physical training, and optimizing adaptive readiness.

In the contemporary scientific landscape, the issue of maintaining and strengthening students' health has become increasingly significant, particularly in the context of higher education institutions where both intellectual and physical demands are continuously intensifying. In this regard, special attention should be paid to students enrolled in physical education programs, since their professional competence is directly connected with physical performance, endurance, and functional readiness. Therefore, the concept of physiological reserves emerges as a central category, as it reflects the organism's ability to adapt to external influences, sustain homeostasis, and effectively mobilize internal resources under conditions of physical and environmental stress. At the same time, physiological reserves cannot be reduced to a single measurable parameter; rather, they represent a complex, multidimensional system that integrates morphological, metabolic, and functional components.

Against this background, bioelectrical impedance analysis has gained considerable importance as a method for assessing body composition and indirectly evaluating physiological potential. On the one hand, this method is characterized by its non-invasive nature, relative simplicity, and applicability in field conditions. On the other hand, it provides access to a wide range of physiologically meaningful indicators, including fat mass, fat-free mass, skeletal muscle mass, total body water, and the distribution of intracellular and extracellular fluids. Furthermore, one of the most informative parameters derived from bioimpedance is the phase angle, which is increasingly interpreted as a marker of cellular integrity, membrane functionality, and overall adaptive capacity. Consequently, bioimpedance analysis makes it possible to move beyond purely descriptive anthropometric measurements and to approach a more integrative understanding of the organism's functional reserves [4, 165-172].

Moreover, the relevance of this methodological approach becomes even more pronounced when it is applied in specific regional contexts characterized by environmental challenges. In particular, the Republic of Karakalpakstan represents a unique ecological zone, where long-term exposure to the consequences of the Aral Sea crisis has created a complex set of environmental stressors, including arid climate conditions, increased salinity, and dust-aerosol pollution. As a result, the organism of individuals living in this region may experience additional adaptive pressure, which in turn affects the formation and realization of physiological reserves. Therefore, the study of body composition and functional potential in students from this region cannot be limited to general physiological norms; instead, it requires a context-sensitive approach that takes into account ecological, climatic, and lifestyle factors [3].

In this connection, it is important to emphasize that physiological reserves are formed through the interaction of several interrelated systems. First of all, the structural basis of these reserves is determined by the ratio between active and inactive body tissues. For instance, a higher proportion of skeletal muscle mass and fat-free mass is associated with greater metabolic activity, improved strength characteristics, and enhanced capacity for physical work. Conversely, an excessive accumulation of adipose tissue, particularly visceral fat, may reduce movement efficiency and negatively influence cardiovascular and metabolic functions. Therefore, the qualitative composition of body mass plays a decisive role in shaping the organism's reserve potential.

In addition to structural factors, hydration status constitutes another crucial component of physiological reserves. Since bioimpedance measurements are based on the electrical conductivity of body tissues, they are highly sensitive to changes in fluid distribution. In particular, intracellular water is closely related to metabolically active cell mass and reflects the functional readiness of tissues. By contrast, an increased proportion of extracellular fluid may indicate imbalance, reduced tissue quality, or insufficient adaptation. Thus, the ratio between intracellular and extracellular water can serve as an important indicator of the organism's internal equilibrium and its ability to respond to physical нагрузка. Consequently, students with a more balanced hydration profile are likely to demonstrate better recovery processes and greater tolerance to training loads [2, 379-387].

Furthermore, the role of phase angle deserves special consideration, since it integrates several aspects of physiological functioning. From a biophysical perspective, phase angle reflects the relationship between resistance and reactance, which are influenced by fluid distribution and cell membrane properties. However, from a physiological standpoint, it is increasingly interpreted as a global marker of cellular health and adaptive capacity. Accordingly, higher phase angle values are generally associated with better tissue integrity, more favorable nutritional status, and greater functional readiness, whereas lower values may indicate reduced physiological reserves. Therefore, within the framework of this study, phase angle can be regarded as one of the key indicators linking body composition with functional potential.

At the same time, it should be noted that the interpretation of bioimpedance indicators requires methodological caution. Since the results are influenced by hydration status, recent physical activity, nutritional intake, and even circadian factors, standardized measurement conditions are essential for ensuring reliability. For example, measurements should ideally be conducted under similar conditions of hydration and rest, and factors such as recent exercise or dehydration should be controlled. Otherwise, the variability of bioimpedance data may lead to incorrect conclusions regarding the actual state of physiological reserves.

In addition, it is necessary to consider that physiological reserves are not solely determined by morphological characteristics. On the contrary, they are closely linked with functional indicators such as cardiovascular endurance, muscular strength, and recovery capacity. Therefore, a comprehensive assessment should combine bioimpedance analysis with functional testing, including heart rate measurements, endurance indices, and respiratory parameters. Such an integrative approach allows for a more accurate evaluation of the organism’s adaptive potential and provides a scientific basis for individualized training strategies [4, 603-624].

From an applied perspective, the use of bioimpedance analysis in physical education students opens up significant opportunities for optimizing the educational process. In particular, it allows educators and trainers to monitor changes in body composition over time, identify unfavorable trends, and adjust training programs accordingly. Moreover, it facilitates the development of personalized recommendations related to nutrition, hydration, and recovery, which are essential for maintaining optimal physiological reserves. Consequently, bioimpedance monitoring can be regarded not only as a diagnostic tool, but also as an important element of preventive and corrective interventions.

Nevertheless, several limitations should be acknowledged. First, bioimpedance analysis provides indirect estimates rather than direct measurements of body compartments, and therefore its accuracy depends on the validity of prediction models. Second, the interpretation of results may vary depending on the population studied, which is particularly relevant in regions with specific ecological conditions such as Karakalpakstan. Third, cross-sectional assessments do not fully capture the dynamic nature of physiological reserves, which are subject to change under the influence of training, environmental exposure, and lifestyle factors. Therefore, longitudinal studies are required in order to better understand the mechanisms of reserve formation and their variability over time.

In conclusion, the assessment of physiological reserves in physical education students based on bioimpedance indicators represents a scientifically grounded and practically valuable approach. On the one hand, it provides detailed information about body composition and hydration status, which are fundamental components of functional capacity. On the other hand, it enables a more comprehensive understanding of adaptive processes, particularly in regions characterized by environmental stress. Thus, in the specific context of the Republic of Karakalpakstan, bioimpedance analysis can serve as an effective tool for evaluating and optimizing the health and performance potential of students. Ultimately, the integration of this method into the system of physical education contributes to the development of evidence-based strategies aimed at strengthening physiological reserves and promoting long-term health.

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