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Analysis of Changes in Athletes' Physical Qualities Under the Influence of The Unfavorable Ecological Environment of Karakalpakstan

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Abstract: This study explores how Karakalpakstan's deteriorating ecological environment affects the physical development of athletes. It provides a comparative analysis between athletes from ecologically challenged regions and those from cleaner areas, focusing on endurance, strength, flexibility, agility, and speed. Using empirical data, standard athletic tests, and statistical analysis, the study confirms that athletes exposed to chronic pollution, soil salinity, and airborne toxins show significant declines in key physical performance indicators. These results have implications for sports science, public health policy, and ecological rehabilitation strategies.

Keywords: Karakalpakstan, environmental degradation, athletic performance, endurance, respiratory health, Aral Sea crisis.

Introduction: Environmental degradation has long-term and multifaceted effects on human physiology. Karakalpakstan, located near the desiccated Aral Sea basin, suffers from severe ecological stress due to widespread soil salinity, desertification, and toxic dust storms. These issues not only compromise general public health but also exert pronounced effects on populations with heightened physiological demands—particularly athletes.

The Aral Sea's retreat has exposed vast salt flats now referred to as the "Aralkum Desert", which continuously release fine dust laced with pesticides, salts, and heavy metals into the atmosphere [4]. This airborne mixture impairs respiratory and cardiovascular systems, essential for athletic performance. Studies have shown that even short-term exposure to PM2.5 particles causes reduced oxygen uptake and increased fatigue [7].

Athletes require optimal oxygen transport, metabolic function, and muscular strength to perform at competitive levels. The chronic exposure to airborne contaminants, coupled with nutritional limitations caused by poor soil and water quality, potentially impairs every domain of athleticism [1]. This research addresses a critical gap in sports science—how ecological decline affects the athletic potential of populations living in severely compromised environments.

METHODOLOGY

To systematically evaluate how the unfavorable ecological conditions of Karakalpakstan affect the physical qualities of athletes, a comparative experimental design was employed. The study involved a total of 80 male athletes aged between 18 and 25, all of whom were actively engaged in competitive sports such as athletics, wrestling, and football. These athletes were divided into two equally sized groups: one consisting of 40 individuals residing and training in environmentally stressed regions of Karakalpakstan, and the other composed of 40 peers from ecologically stable areas such as Samarkand and Tashkent. All participants were matched by age, sports specialization, and minimum training experience of three years, ensuring homogeneity in athletic background and developmental stage.

The primary aim was to assess physical performance across five core attributes: endurance, speed, strength, flexibility, and agility. Standardized field-based tests were selected to measure each attribute reliably and consistently. Specifically, endurance was evaluated

using the Cooper 12-minute run test, which is widely recognized for measuring cardiovascular capacity and aerobic endurance. Speed was assessed through a 30-meter sprint, providing insights into explosive acceleration and lower-body neuromuscular coordination. To evaluate muscular strength, the standing long jump and handgrip dynamometry tests were employed, reflecting both lower and upper body power. Flexibility was tested using the sit-and-reach test, which gauges hamstring and lower back elasticity, while agility was measured using the Illinois Agility Test, which evaluates rapid changes in direction and dynamic balance.

Testing was conducted under consistent conditions for both groups to minimize external variation. All athletes were tested in the morning hours after a standard warm-up session, and results were recorded over two trials, with the average value taken for analysis. Concurrently, environmental measurements were gathered at each testing location. Air quality indicators, including concentrations of PM10 and PM2.5 particles, were recorded using handheld environmental monitors, while water and soil quality data were obtained from local ecological reports and validated through laboratory testing. These environmental readings provided critical context for interpreting the physiological outcomes.

The collected data were analyzed using SPSS version 26.0, where descriptive statistics such as means and standard deviations were calculated to summarize performance levels. Inferential analysis, specifically independent t-tests, was then applied to determine whether the differences in performance between the control and experimental groups were statistically significant. A p-value of less than 0.05 was considered the threshold for statistical significance, ensuring that the observed performance gaps were not the result of random variation but rather reflective of environmental influence.

RESULTS

The athletes from Karakalpakstan consistently underperformed in all five physical attributes compared to the control group. Standard deviation data indicates greater variability in performance among the Karakalpak athletes, suggesting uneven adaptation to ecological stress.

Table 1. Results of physical qualities

Physical Quality	Control Group Mean (%)	Std Dev	Karakalpak Athletes Mean (%)	Std Dev	% Decline
Endurance	100	2.0	87	4.0	-13%
Speed	100	1.5	90	3.0	-10%
Strength	100	3.0	82	5.0	-18%
Flexibility	100	2.5	85	4.0	-15%
Agility	100	2.0	88	3.5	-12%

The table comparing physical attributes between control group athletes and those from Karakalpakstan reveals significant declines across all five domains. This decline, ranging from 10% to 18%, confirms that environmental factors have tangible physiological consequences. The sharpest drop, in strength (−18%), likely stems from chronic exposure to pollutants that impair muscle metabolism and recovery. According to Turebekov et al. (2021), long-term environmental stress can result in hormonal imbalances, including reduced testosterone and growth hormone levels—both critical for muscle mass development and maintenance.

Similarly, endurance (−13%) and agility (−12%) are adversely affected due to sustained exposure to high levels of airborne particulate matter (PM10 and PM2.5). These pollutants irritate the respiratory tract, reduce alveolar gas exchange efficiency, and lead to persistent low-grade inflammation, all of which compromise aerobic capacity. This is consistent with WHO's 2021 findings that even short-term exposure to PM2.5 can decrease oxygen delivery and increase perceived exertion in athletes.

The standard deviation values in the Karakalpak group are notably higher across all categories, implying greater inconsistency in physical performance. This suggests that while some athletes have developed compensatory adaptations, others are disproportionately affected, possibly due to individual variability in health status, immune response, or access to nutritional support.

Table 2. Air Quality and Environmental Measures in Karakalpakstan

Environmental Factor	Observed Value	WHO Safe Limit	Impact on Physiology
PM10 (dust)	158 µg/m³	50 µg/m³	Reduced lung function
PM2.5	73 µg/m³	25 µg/m³	Inflammation, fatigue
Soil Salinity	2.8–4.1 dS/m	< 2 dS/m	Nutrient deficiency
Water Salinity	3.5–4.8 g/l	< 2 g/l	Electrolyte imbalance
Pesticide residues (soil)	Above threshold	Below detectable	Hormonal disruption

The table offers essential context to the observed performance declines by quantifying the severity of environmental conditions in Karakalpakstan. The PM10 concentration (158 µg/m³) is more than three times the WHO's recommended limit, posing a severe threat to respiratory health. Athletes engaging in high-ventilation activities like running or wrestling inhale significantly more airborne particles, which can trigger bronchospasms and limit oxygen utilization.

The soil salinity and water contamination exacerbate the situation. High salinity reduces the availability of essential micronutrients such as potassium, magnesium, and calcium, which are vital for muscular contraction, nerve function, and hydration. Water with high salt content not only disrupts electrolyte balance but also contributes to chronic dehydration—a factor that directly impacts strength and flexibility.

Moreover, the presence of pesticide residues in the

soil, as reported in the UNDP 2022 report, may result in long-term endocrine disruption. These substances can impair thyroid function, metabolic rate, and neuromuscular coordination—further contributing to observed reductions in flexibility (−15%) and speed (−10%).

When viewed collectively, the physiological, biochemical, and biomechanical consequences of environmental exposure in Karakalpakstan form a multi-layered challenge to athletic performance. Not only are athletes struggling against natural physical limitations, but their training adaptations are also being undermined by a toxic external environment. This scenario underscores the urgent need for intervention—both to preserve the physical potential of the current athletic generation and to safeguard the developmental future of younger cohorts growing up in the same conditions.

DISCUSSION

The findings of this study clearly illustrate the profound influence of Karakalpakstan's deteriorating ecological environment on the physical qualities of athletes, revealing not only statistically significant performance deficits but also important physiological patterns that deepen our understanding of environmental stress on the human body. The reduced outcomes in strength, endurance, and agility among athletes living in ecologically stressed regions are not isolated abnormalities; rather, they are symptomatic of chronic exposure to pollutants that compromise respiratory efficiency, cardiovascular output, and muscular integrity. The most pronounced decline, observed in strength performance, aligns with existing research linking high particulate matter levels and environmental toxins to systemic inflammation, hormonal disruption, and diminished muscle recovery capacity. In particular, inhalation of PM2.5 and PM10 particles—prevalent in Karakalpakstan's dry and dusty air—triggers oxidative stress at the cellular level, leading to fatigue, reduced oxygen transport, and long-term tissue damage, all of which impair strength and endurance over time.

Moreover, the elevated standard deviations in performance data among Karakalpak athletes suggest not only an overall decline in physical capabilities but also a high degree of unpredictability in individual responses to environmental stress. This variability may reflect a range of factors, including differences in genetic resilience, lifestyle, nutrition, and proximity to sources of pollution, but it underscores a common reality: consistent athletic development is nearly impossible under conditions of ecological instability. Flexibility and agility, while somewhat less impacted than endurance and strength, also showed measurable declines, likely influenced by chronic dehydration and micronutrient imbalances resulting from high soil and water salinity in the region. Electrolyte deficiencies, common in areas with poor water quality, compromise neuromuscular coordination and tissue elasticity, thereby limiting both performance and recovery.

These physiological impairments carry broader implications that extend beyond the realm of sport. Athletes are often viewed as indicators of a population's general health status, and their vulnerability to environmental conditions suggests that the general population in Karakalpakstan may be suffering from similar—if less visible—health consequences. Furthermore, the diminished athletic potential of youth in the region represents not only a public health concern but also a loss of social and cultural capital, as sports serve not only as a means of physical development but also as tools for community cohesion, youth empowerment, and national identity. Without intervention, the current trajectory risks creating a widening gap between Karakalpak athletes and those in more ecologically stable regions, limiting opportunities for competition, scholarship, and professional advancement.

Addressing this issue requires a multifaceted approach. Environmental rehabilitation—such as reforestation efforts around the dried Aral Sea bed, dust suppression technologies, and clean water initiatives—must be complemented by targeted health and nutrition programs for athletes. Training camps should be relocated periodically to cleaner zones to allow for physical recovery, and regular health screenings must be implemented to monitor the physiological toll of ecological exposure. In addition, educational campaigns focused on environmental awareness and self-protection strategies for athletes—such as hydration management, respiratory protection, and immune support—can offer immediate mitigation while long-term policy solutions are developed.

Ultimately, this discussion reinforces the idea that athletic development cannot be isolated from environmental context. The body, as a biological system, responds dynamically to its surroundings, and in the case of Karakalpakstan, the surrounding environment has become a barrier to optimal performance. Recognizing the environment as a determinant of athletic health is not only a scientific imperative but also a social responsibility—one that calls for collaboration among sports organizations, health agencies, environmental ministries, and local communities. Only through such integrated action can we hope to preserve the physical potential of young athletes and protect the long-term health of future

generations living in ecologically vulnerable areas.

CONCLUSION

This study provides clear evidence that the harsh ecological conditions of Karakalpakstan—characterized by high levels of air pollution, soil salinity, and toxic dust exposure—have a direct and measurable negative impact on the physical qualities of athletes. The comparative analysis between athletes from environmentally stable regions and those from Karakalpakstan revealed consistent declines in endurance, speed, strength, flexibility, and agility, with the most severe reductions observed in strength and endurance, which are highly dependent on oxygen uptake and metabolic efficiency. These findings are further supported by environmental data indicating dangerously high concentrations of particulate matter and harmful substances in local soil and water. Moreover, the greater variability in performance among Karakalpak athletes suggests an unequal physiological burden, likely influenced by differing levels of exposure and access to protective resources. Together, the data underscore that environmental degradation does not merely threaten ecological systems but extends its effects deeply into human physiology, limiting the athletic potential of an entire region. Addressing this challenge requires coordinated action, including environmental remediation, targeted medical and nutritional support for athletes, and strategic relocation of training activities to less polluted areas. Ultimately, the future of sports development in Karakalpakstan—and the health and performance of its athletes—depends on recognizing the environment not as a backdrop but as a defining factor in human performance and well-being.

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