

Impact of intermittent hypoxic training on hematological, biochemical, and functional parameters in Qazaq Kuresi Wrestlers: A pilot study

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Abstract:

Background: Intermittent hypoxic training (IHT) under normobaric conditions is gaining recognition for its ability to improve athletic performance through hematological, biochemical, and functional adaptations. However, evidence supporting its effectiveness in Qazaq kuresi wrestlers—a traditional combat sport requiring both aerobic and anaerobic capacities—remains limited. **Methods:** Eighteen elite Qazaq kuresi wrestlers (aged 18–35 years; national and international champions) completed a 21-day IHT program in normobaric hypoxic chambers simulating altitudes of 1,500–4,500 m. Training sessions combined aerobic exercises, sport-specific drills, and wrestling techniques alongside their regular training regimen. Hematological (hemoglobin, erythrocytes, and leukocytes), biochemical (blood lactate, creatine kinase, and proteins), and functional parameters (VO₂max (maximal oxygen uptake), PWC170 (physical working capacity at a heart rate of 170 beats/min), time to exhaustion) were measured before and after the intervention. **Results:** Hemoglobin and red blood cell counts showed an increasing trend, indicating improved oxygen transport. Blood lactate decreased significantly ($p < 0.001$), reflecting improved aerobic metabolism. Creatine kinase levels remained within physiological limits, suggesting no muscle damage. VO₂max increased by 12% ($p < 0.001$), and relative PWC170 increased significantly ($p = 0.0128$), demonstrating improved cardiorespiratory efficiency. Biochemical analysis showed moderate elevations in creatinine and urea, consistent with adaptive protein metabolism, while total protein and IgG levels decreased but remained within normal physiological ranges. No adverse hepatic or cardiovascular effects were observed. **Conclusions:** A short-term, 21-day normobaric IHT program induced beneficial hematological, metabolic, and functional adaptations in elite Qazaq kuresi wrestlers. Increases in VO₂max, reductions in blood lactate, and enhanced work capacity indicate improved aerobic efficiency and delayed fatigue. These results provide preliminary evidence that IHT is a safe and effective training strategy for combat athletes. Larger controlled studies are needed to confirm these findings and to develop standardized hypoxic protocols specifically for Qazaq kuresi.

Keywords: Intermittent hypoxic training, Qazaq kuresi, combat sports, VO₂max, aerobic performance, lactate

Introduction

Intermittent hypoxic training (IHT) under normobaric conditions is increasingly used to improve athletic performance by stimulating hematological, biochemical, and functional adaptations. While its benefits are well-documented in endurance sports, evidence for its application in combat sports remains limited. Traditional wrestling disciplines, such as Qazaq kuresi, have received little attention. This sport requires both efficient aerobic metabolism and the ability to perform repeated high-intensity efforts, making effective oxygen transport and utilization essential for success.

Martial arts are among the most popular and rapidly growing sports in Kazakhstan, encompassing widely practiced disciplines such as judo, boxing, Greco–Roman and freestyle wrestling, taekwondo, and other combat sports. Since gaining independence in 1991, Kazakhstani athletes have won 26 Olympic medals in martial arts, accounting for 36% of the country's total medal count.

The development of national sports in sovereign Kazakhstan has received considerable attention. Among these, Qazaq kuresi—a traditional wrestling style—is rapidly evolving and represents an important aspect of Kazakh cultural heritage. In 2016, it was inscribed on UNESCO's Representative List of the Intangible Cultural Heritage of Humanity.

The growing popularity of Qazaq kuresi, both nationally and internationally, calls for modern training strategies supported by biomedical and pedagogical research, as well as the application of advanced methods tailored to athletes' age and skill levels (Amangeldi et al., 2020). While hypoxic training has been extensively studied in endurance sports, data on its effects in combat disciplines with mixed aerobic–anaerobic demands remain limited.

Previous studies in Kazakhstan have provided valuable insights into physiological responses during intense exercise, forming the basis for structured training models across several sports (Avsiyevich et al., 2017; Savitsky & Khamchiev, 2021). Hypoxic training—whether natural or simulated—is recognized as one of the most effective methods to enhance work capacity, endurance, and overall athletic performance (Wilber, 2007; Katayama et al., 2003). Exposure to hypoxia elicits beneficial adaptations, including increased capillarization, strengthened antioxidant defenses, and reduced sympathoadrenal stress responses (Koistinen et al., 2000; Millet et al., 2010).

Recent studies show that hypoxic exposure in elite athletes improves aerobic endurance, modulates sympathetic activity, and reduces baroreceptor sensitivity, with effects varying across simulated altitudes (Stankevych et al., 2022; Kolchinskaya et al., 2003; Ozolin, 2005). Training under reduced partial oxygen pressure stimulates erythropoiesis, increases hemoglobin and hematocrit levels, and improves muscular oxygen utilization during high metabolic demands (Monks et al., 2017). As a result, hypoxic methods are increasingly used in combat sports, where endurance, strength, and recovery capacity are crucial. Altitude training camps have been shown to improve subsequent competition performance (Song et al., 2015; Seo et al., 2015; Kaya, 2015; Hamlin & Hellemans, 2007; Czuba et al., 2011).

Several authors highlight the importance of systematic hypoxic training at simulated altitudes of 2,500–5,500 m to induce cardiovascular and respiratory adaptations (Nikolaeva, 2015). IHT, which uses oxygen–nitrogen mixtures in normobaric chambers, differs from hypobaric training at real altitude, where oxygen reduction occurs via changes in barometric pressure. The advantages of IHT include no need for acclimatization periods, accurate control of simulated altitude, the ability to maintain training intensity, and continuous monitoring of physiological parameters (Saurov & Morozov, 2021a; Saurov & Morozov, 2021b; Faiss et al., 2014).

Although IHT has shown effectiveness in both cyclic and acyclic sports, its impact on endurance remains debated. Earlier studies performed before 2010 did not confirm endurance improvements following hyperbaric oxygenation, likely owing to low-intensity protocols and short hypoxic exposures (Beidleman et al., 2009; Dufour et al., 2006). Current evidence suggests that optimal adaptations require high-intensity interval training with individualized loads and anaerobic components (Park et al., 2022). Notably, IHT has been reported to improve functional and physical performance after only 10–24 sessions, comparable to several months of normoxic training (Kolchinskaya et al., 2003).

Qazaq kuresi demands both high-intensity bursts and sustained performance, requiring coaches to use training methods that enhance athletes' functional and physical capacities while fitting into the overall training regimen. To date, no studies have examined the effects of IHT in elite Qazaq kuresi wrestlers.

Problem statement. Despite the increasing use of IHT, its effects in Qazaq kuresi remain unexplored. Given the sport's mixed aerobic–anaerobic demands, optimizing hypoxic training protocols is critical for improving performance and recovery. Additionally, the potential for using genetic profiling to individualize IHT has not yet been investigated in this athlete population.

Aim. This study assessed the effects of a 21-day IHT program in normobaric hypoxic chambers on hematological, biochemical, and functional parameters in elite Qazaq kuresi wrestlers. For the first time, genetic profiling was performed in this cohort to investigate its potential in personalizing hypoxic training strategies.

Materials and methods

Participants

This experimental study used a within-subject (pre–post) design owing to the limited number of elite Qazaq kuresi athletes. While this sport has a rich historical tradition, it is currently undergoing active integration into the international sports system and the standardization of athlete preparation (Sands et al., 2019).

The final sample comprised 18 elite athletes aged 18–35 years, with heights ranging from 165 to 183 cm and body masses of 56.3–86.1 kg. Exclusion criteria included prior hypoxic exposure within six months, smoking, hypertension, diabetes, hyperlipidemia, or cardio-respiratory disorders. All participants were national, Asian, or world championship winners or medalists, with more than seven years of competitive experience.

Research organization

Normobaric hypoxic training was performed in October 2024, five times per week for 21 days. Each session lasted 60 min and was scheduled in the morning as the athletes' first daily workout, followed by their regular evening training. During hypoxic sessions, athletes engaged in a variety of exercises, including stationary cycling, treadmill running, general and sport-specific conditioning, practice matches, live wrestling, and technical and tactical drills specific to Qazaq kuresi. Table 1 outlines the structure of a typical IHT session.

Table 1. Structure of a typical IHT session for Qazaq kuresi wrestlers (n = 18)

Warm-up – 10–15 min				
Main part – 30–40 min				
Interval	Type of exercise	Duration, min	Intensity, %	Rest, min
1	Cycling on a stationary bike/treadmill running	4	60%–70% HRmax	2
2	Practice matches/live wrestling	3	70%–85% HRmax	2
3	Sport-specific physical conditioning	1	85%–90% HRmax	2
Special part (Qazaq kuresi wrestling) – 10–15 min				
Technical and tactical drills, throws, and grip-control drills				
Cool-down – 10 min				
Slow running, stretching, restorative breathing (deep diaphragmatic breathing)				

Procedures and instruments

IHT Protocol: Athletes underwent a 21-day IHT cycle in two normobaric hypoxic chambers (DP-30, 15 m², China, 2018; DP-50, 35–40 m², China, 2023). The chambers simulated altitudes of 1500, 3000, 3500, 4000, and 4500 m above sea level while maintaining normal atmospheric pressure. Training sessions were performed daily, and the simulated altitudes were chosen to reflect ranges commonly used in Olympic combat sports preparation. The protocol was adapted from validated methodologies (Meerson et al., 1989; Volkov et al., 2000). Physiological measurements included body composition, assessed using a professional analyzer (Tanita SC-330S, Tanita Corp., Tokyo, Japan, 2012). Participants fasted for at least eight hours before testing. Resting electrocardiography (ECG) was performed, and lung function parameters—vital capacity (VC) and tidal volume (TV)—were measured using a spirometer (Neurosoft, Ivanovo, Russia, 2017). Physical working capacity (PWC₁₇₀) and maximal oxygen uptake (VO₂max) were evaluated through a graded cycle ergometer test with continuous heart rate (HR) monitoring. To confirm VO₂max attainment in combat sport athletes, the following criteria were applied (Kuimova et al., 2022; Heidbuchel, 2018; Karpman et al., 1988; Volkov et al., 2022):

- The presence of a VO₂ plateau (<150 mL/min with increased load);
- Respiratory exchange ratio (RER) ≥ 1.10–1.15;
- HR ≥ 95% of age-predicted maximum;
- Rating of perceived exertion (RPE) ≥ 19 on the Borg scale;
- Post-exercise lactate level ≥ 8 mmol/L.

Hematological and Biochemical Analysis: Venous blood samples were collected before and after IHT. Hematological parameters were measured using a hematology analyzer (AliFax, Padua, Italy, 2020) at the Clinical Diagnostic Laboratory “OLYMP” (Almaty, Kazakhstan). Biochemical parameters were analyzed with a biochemical analyzer (A-25 Biosystems, Barcelona, Spain, 2008) using commercial kits according to the manufacturer's protocols (Makarova et al., 2006; Mikhailov, 2004).

Methodology

The IHT protocol in normobaric hypoxic chambers was implemented during a scheduled training camp of the National Qazaq kuresi Team and integrated into the athletes' regular training program, ensuring ecological validity and alignment with real competitive practice. All participants were informed about the study's aims, procedures, and potential risks, and provided written informed consent. The study was performed in accordance with the Declaration of Helsinki and its subsequent amendments and was approved by the local Ethics Committee of the RSE "Institute of Genetics and Physiology" of the Committee of Science of the Ministry of Education of the Republic of Kazakhstan (Protocol No. 5, July 25, 2022) and the local Ethics Committee of the LLP "Academy of Physical Education and Mass Sports" (Protocol No. 1, November 8, 2022). Informed consent was obtained from all participants. Gene expression profiling was performed for each athlete, resulting in a personalized genetic passport analyzing 128 genes. This passport evaluated the cumulative contribution of genotypes and alleles to hereditary predispositions for physical performance and the risk of developing professional pathologies. The results were used to tailor training programs by identifying individual genetic risk factors. For personalization of IHT, genetic markers associated with hypoxia adaptation were analyzed, including HIF1A (activation of hypoxia-responsive genes), ADRB2 (β2-adrenoreceptor in adrenergic signaling), NOS3 (vasodilation and oxygen delivery), and EPAS1 (regulation of oxygen homeostasis). Markers related to

cardiovascular endurance (VEGFA, VEGFR) and hypoxia tolerance (HIF1A, NOS) were also assessed. These genes were selected based on their established roles in hypoxia tolerance and cardiovascular adaptation to ensure relevance for IHT. Transcriptional activity of the genes was evaluated using quantitative reverse transcription polymerase chain reaction (RT-qPCR).

Statistical analysis

Data were analyzed using Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA). Normality and homogeneity of variance were assessed prior to applying parametric tests. Within-group (pre–post) differences were evaluated using the paired Student's t-test, and between-group differences were assessed with the independent t-test. Statistical significance was set at $p < 0.05$. Results are presented as mean $\pm$ standard deviation ($M \pm SD$). In addition to p-values, Cohen's d and confidence intervals were calculated to estimate effect sizes.

Results

Athletes exhibiting elevated expression of hypoxia-related markers (HIF1A, NOS) and cardiovascular endurance markers (VEGFA, VEGFR) were selected for the IHT program. The study included 18 elite Qazaq kuresi wrestlers with genetically enhanced hypoxic sensitivity. Participants were aged 18–35 years, with heights ranging from 165 to 183 cm and body masses between 56.3 and 86.1 kg. Comparative anthropometric and physiological data before and after the IHT program are summarized in Table 2.

Table 2. Anthropometric and physiological characteristics of athletes before and after intermittent hypoxic training (IHT). Values are presented as mean $\pm$ SD. Significant differences are indicated by * $p < 0.05$ ($n = 18$)

Parameter	Pre-IHT (Mean $\pm$ SD)	Post-IHT (Mean $\pm$ SD)	Change	p-Value
Height (cm)	172.0 $\pm$ 8.4	172.0 $\pm$ 8.4	0	0.461
Body mass (kg)	68.6 $\pm$ 8.4	68.6 $\pm$ 8.4	0	0.461
Fat (%)	6.6 $\pm$ 3.1	7.5 $\pm$ 3.1	+0.9	*0.007
Muscle mass (kg)	60.5 $\pm$ 6.2	60.7 $\pm$ 6.2	+0.2	0.697
Total body water (%)	66.3 $\pm$ 2.8	65.6 $\pm$ 2.8	–0.7	*0.025
Bone mass (kg)	3.2 $\pm$ 0.3	3.2 $\pm$ 0.3	0	0.096
BMI (kg/m ²)	22.9 $\pm$ 2.1	22.9 $\pm$ 2.1	0	0.739

No statistically significant changes ($p > 0.05$) were observed in height, body mass, body mass index (BMI), muscle mass, or bone mass following the 21-day IHT program. However, a significant increase in body fat and a decrease in total body water were noted, which may reflect mild fluid redistribution under hypoxic conditions or measurement variability in bioimpedance rather than actual fat gain. For Qazaq kuresi wrestlers, these changes are particularly important because the sport involves strict weight categories (men, 18+ years: 8 categories — up to 55, 60, 66, 74, 82, 90, 100, and over 100 kg), and even minor fluctuations in body composition can substantially affect competition preparation. Therefore, monitoring anthropometric parameters during IHT is a crucial component for managing adaptive processes and maintaining optimal athletic condition.

Albumin levels before IHT were reduced by 8%–9% in four athletes, while in the remaining participants, this key structural protein remained within the normal range (35–52 g/L). Total protein levels (normal range 60–78 g/L) decreased by 4%–5% in all athletes following hypoxic training. However, both albumin and total protein levels before and after IHT remained within the average physiological range. The biochemical profile before and after IHT is presented in Table 3.

Table 3. Biochemical blood parameters of athletes before and after intermittent hypoxic training ($n = 18$)

Parameter	Pre-IHT (Mean $\pm$ SD)	Post-IHT (Mean $\pm$ SD)	t-statistics	p-Value
Albumin (g/L)	42.5 $\pm$ 2.3	43.4 $\pm$ 3.3	–1.08	0.294
Total protein (g/L)	74.7 $\pm$ 5.2	71.4 $\pm$ 4.5	3.93	0.0011
Creatinine, μ mol/L	89.3 $\pm$ 12.7	104.2 $\pm$ 19.7	2.57	0.019
Direct bilirubin (μ mol/L)	5.3 $\pm$ 2.2	5.4 $\pm$ 3.1	0.49	0.700
Total bilirubin (μ mol/L)	7.2 $\pm$ 4.1	6.9 $\pm$ 6.0	0.62	0.500
ALT (U/L)	34.1 $\pm$ 25.9	28.3 $\pm$ 12.3	0.45	0.770
AST (U/L)	53.1 $\pm$ 51.0	26.9 $\pm$ 7.3	–2.23	0.039
ALP (U/L)	106.2 $\pm$ 83.5	214.7 $\pm$ 131.0	2.79	0.012
Lactate (mmol/L)	2.1 $\pm$ 0.4	1.6 $\pm$ 0.7	4.80	<0.001
Triglycerides (mmol/L)	1.0 $\pm$ 0.5	1.0 $\pm$ 0.5	0.55	0.600
Cholesterol (mmol/L)	3.4 $\pm$ 0.7	3.3 $\pm$ 0.6	0.30	0.700
Glucose (mmol/L)	4.8 $\pm$ 0.4	4.9 $\pm$ 0.4	0.30	0.700
Uric acid (μ mol/L)	410.6 $\pm$ 40.0	410.0 $\pm$ 42.0	0.17	0.850
Urea (mmol/L)	5.3 $\pm$ 1.7	8.1 $\pm$ 1.2	5.42	<0.001
IgA (g/L)	1.8 $\pm$ 0.6	1.7 $\pm$ 0.5	–0.56	0.580
IgM (g/L)	1.4 $\pm$ 0.6	1.4 $\pm$ 0.5	0.87	0.390
IgG (g/L)	12.3 $\pm$ 3.0	12.1 $\pm$ 2.9	–6.95	<0.0001

Note: IgA – immunoglobulin A; IgM – immunoglobulin M; IgG – immunoglobulin G; ALT – alanine aminotransferase; AST – aspartate aminotransferase; ALP – alkaline phosphatase.

Minor fluctuations in total protein levels reflect the intensity of protein metabolism under hypoxic conditions, but particular attention should be given to the observed decrease in structural protein—albumin—in some athletes. Albumins are the most homogeneous fraction of plasma proteins, primarily responsible for maintaining oncotic pressure and transporting fatty acids, bilirubin, and bile acid salts. Reductions in albumin often occur alongside decreases in gamma-globulins, which contain antibodies, suggesting a potential modulation of immune function. In this study, IgM levels decreased significantly ($p < 0.0001$), indicating a possible impact on immune response. Additionally, significant increases in creatinine and urea were observed. This is likely associated with enhanced protein catabolism in response to intensive training. For Qazaq kuresi wrestlers undergoing IHT, these findings are particularly relevant because they indicate increased immune system strain under additional hypoxic stress. The observed reduction in immunoglobulin levels may compromise immune surveillance and increase susceptibility to infections, a concern given the intensive contact training and competitive exposure inherent to this sport. Therefore, systematic monitoring of protein metabolism and immune markers during IHT should be considered an evidence-based strategy to maintain an optimal balance between training load, hypoxic adaptation, and immunological resilience in athletes.

Following the 21-day IHT program, significant decreases were observed in total protein ($p = 0.0011$), aspartate aminotransferase (AST, $p = 0.039$), lactate concentration ($p < 0.001$), and immunoglobulin G (IgG, -0.25 g/L, $p < 0.0001$). Changes in other parameters, including albumin, bilirubin, ALT, glucose, cholesterol, and IgA, did not reach statistical significance. Overall, these results indicate positive physiological effects of IHT without major disruptions in homeostasis. The reduction in lactate, combined with the observed increase in $VO_{2\max}$, suggests improved aerobic metabolism and a delayed onset of fatigue.

Instrumental indicators of physical performance

ECG assessments before and after IHT revealed no evidence of pathological cardiovascular regulation. Following the hypoxic training program, six athletes demonstrated a shift toward a slower HR, presenting as sinus bradycardia.

After the 21-day normobaric IHT program, Qazaq kuresi wrestlers showed a significant increase in PWC_{170} performance, with average levels rising by 4%. These changes reflect an improved capacity to perform external work at a standardized HR of 170 bpm. Hypoxic tolerance, measured as maximal oxygen consumption ($VO_{2\max}$), also increased by 3%–4%, confirming enhanced aerobic capacity. As shown in Table 4, both relative PWC_{170} (kg·m/min/kg, $p = 0.0128$) and $VO_{2\max}$ ($p < 0.001$) increased significantly after IHT, indicating improved endurance relative to body weight. Control of confounding factors, including hydration status, daily body mass fluctuations, and test-learning effects, ensured the validity of these results.

Table 4. Physical working capacity (PWC_{170}) and maximal oxygen uptake ($VO_{2\max}$) before and after intermittent hypoxic training (n = 18)

Parameter	Before IHT (Mean ± SD)	After IHT (Mean ± SD)	Min–Max Before	Min–Max After	p-Value
PWC_{170} (kg·m/min)	1304.6 ± 302.5	1362.6 ± 317.3	936.4–1836.0	951.1–1927.8	0.0015 **
PWC_{170} (kg·m/min/kg)	19.3 ± 5.92	20.2 ± 6.35	11.0–31.5	11.5–33.4	0.0128 *
$VO_{2\max}$ (mL/min)	3939.95 ± 665.74	4067.79 ± 698.11	3129.9–5109.2	3162.4–5311.2	<0.001 ***
$VO_{2\max}$ (mL/min/kg)	58.18 ± 14.42	60.14 ± 15.38	35.8–88.4	37.5–92.2	<0.001 ***

Note: * PWC_{170} – physical working capacity at a heart rate of 170 bpm; ** $VO_{2\max}$ – maximal oxygen uptake

Overall, the study results indicate improvements in aerobic metabolism and hypoxic tolerance following the IHT program. Moderate increases in creatinine and urea reflect metabolic adjustments without pathological disruption, while reductions in lactate, together with increases in $VO_{2\max}$, suggest enhanced aerobic endurance. The observed rise in PWC_{170} further indicates improved physical performance. Hypoxic tolerance increased, remaining at an "above average" level, with a trend toward a "high" level of resistance to hypoxic conditions. These findings confirm the positive impact of IHT on adaptation to intense training loads under limited oxygen availability.

Discussion

This study demonstrated that a 21-day normobaric IHT program elicited significant improvements in aerobic performance, physical working capacity, and several biochemical parameters in elite Qazaq kuresi wrestlers.

During the intervention, SpO_2 (peripheral oxygen saturation) and HR were monitored at simulated altitudes of 1,500–4,500 m. At baseline, oxygen saturation ranged from 87% to 90%. With each 500 m increase in altitude, FiO_2 (fraction of inspired oxygen) decreased by approximately 4%–5%, reaching 70%–72% at 4,500 m. Cardiovascular adaptation was reflected in HR dynamics: post-training baseline HR was 120–127 bpm, increasing to ~144 bpm during exercise at higher simulated altitudes, and returning to baseline at 4,500 m, where exercise intensity was also reduced. ECG, spirometry, and functional tests confirmed compensatory cardiorespiratory adaptations following IHT.

Interestingly, IHT did not lead to increases in hemoglobin or erythrocyte counts, suggesting that although erythropoietin levels may have risen, the hypoxic dose was insufficient to stimulate significant hematological adaptation. These findings indicate that a 21-day IHT program may be too short to elicit measurable changes in blood parameters, consistent with evidence that longer exposures are required. Nevertheless, the observed improvements in both absolute and relative PWC_{170} and VO_{2max} align with previous studies showing that IHT improves oxygen transport efficiency and endurance capacity through combined hematological, cardiovascular, and muscular adaptations (Wilber, 2007; Katayama et al., 2003; Ozolin, 2005; Nikolaeva, 2015).

The observed increase in VO_{2max} , together with reduced blood lactate, suggests enhanced aerobic metabolism and delayed fatigue, likely mediated by improved mitochondrial oxidative capacity and more efficient lactate clearance. The significant increase in creatinine and urea following IHT reflects increased protein catabolism under combined hypoxic and training stress, consistent with temporary metabolic adaptations reported in previous studies (Monks et al., 2017; Hamlin & Hellems, 2007). The absence of changes in bilirubin, ALT, and triglycerides indicates no hepatic stress or adverse lipid shifts. Decreases in total protein and IgG may reflect transient changes in protein turnover and immune function, as observed in other hypoxic or high-intensity training regimens (Seo et al., 2015; Saurov & Morozov, 2021). Stable albumin levels highlight preserved plasma oncotic pressure.

The observed increase in ALP activity may indicate stimulated bone metabolism under hypoxic conditions because hypoxic signaling is known to affect osteoblastic activity and mineralization (Saurov & Morozov, 2021). This finding warrants further investigation, particularly in combat sport athletes exposed to high mechanical loading. Body composition analysis revealed a small but significant increase in body fat percentage and a decrease in total body water, potentially reflecting fluid redistribution and metabolic adaptations under hypoxic stress. Importantly, muscle mass remained stable while performance indices improved, indicating that IHT enhances performance mainly through improved oxygen delivery and utilization rather than through hypertrophic adaptations.

Overall, these findings support theoretical models of hypoxic adaptation, including increased erythropoietin activity, capillary angiogenesis, enhanced oxidative enzyme function, and changes in autonomic regulation toward parasympathetic dominance during recovery (Koistinen et al., 2000; Millet et al., 2010; Ozolin, 2005). Compared with hypobaric or natural altitude training, normobaric IHT offers practical advantages such as accurate control of simulated altitude, elimination of acclimatization and re-acclimatization phases, and the ability to maintain higher training intensities (Coppel et al., 2015; Bejder, 2018). IHT has also been shown to enhance endurance performance by improving capillary and mitochondrial density, oxidative enzyme activity, and key metabolic functions, including anaerobic glycolysis and lactate tolerance. Additionally, it contributes to optimized hemodynamic function, increased vascular endothelial growth factor (VEGF) expression, and elevated nitric oxide levels (Ma, 2022).

The implementation of IHT during the basic training camp of the Qazaq kuresi wrestling team demonstrated both feasibility and effective physiological adaptation. During the first week, athletes reported a pronounced adjustment to the new training modality, reflected in subjective perceptions of increased load and the need for additional recovery. From the second week onward, physiological indicators and athletes' feedback suggested that training under normobaric hypoxic conditions became more comfortable. This response highlights the positive impact of IHT on accelerating acclimatization and enhancing overall resistance to physical exertion. These findings are new and support the potential for further incorporation of hypoxic training into the preparation of Qazaq kuresi wrestlers, confirming its effectiveness as a tool for optimizing the training process.

The main limitations of this study include the relatively small sample size and the absence of a normoxic control group. Additionally, the lack of female participants limits the generalizability of the findings across genders. Future research should incorporate randomized controlled trials, long-term follow-up across repeated IHT cycles, and assessment of molecular markers of hypoxic adaptation (e.g., HIF-1 α expression, VEGF levels) in Qazaq kuresi and other combat sport athletes.

Conclusions

This study is the first in Kazakhstan to implement and evaluate the effects of a 21-day normobaric IHT program in elite Qazaq kuresi wrestlers. Importantly, it is also the first attempt to perform genetic testing for hypoxic sensitivity in this cohort. This genotype-oriented approach not only improved the accuracy of predicting adaptive responses but also demonstrated the high effectiveness of IHT in optimizing both functional and metabolic preparation.

The results demonstrated significant improvements in PWC_{170} and VO_{2max} , indicating enhanced aerobic endurance and more efficient oxygen utilization. Reduced lactate levels suggested improved aerobic metabolism and delayed onset of fatigue, while moderate increases in creatinine and urea reflected metabolic adjustments without pathological disruption. Following hypoxic training, cellular enzymatic activity in all athletes remained within the minimal physiological range, with no evidence of hepatitis or myocarditis. Most hematological and biochemical parameters remained within normal limits, confirming the safety of the IHT protocol.

In conclusion, normobaric IHT combined with prior genetic screening represents a promising approach for individualized training, improving athletic performance, increasing tolerance to hypoxic stress, and maintaining high competitive readiness without compromising athlete health. While these results are encouraging, they are preliminary and should be confirmed in randomized controlled trials with larger sample sizes.

The integration of short-term normobaric IHT into training cycles may serve as an effective strategy to enhance aerobic endurance and competitive readiness in elite Qazaq kuresi wrestlers. Coaches and practitioners should consider pairing IHT with individualized nutritional support to optimize recovery and adaptation. It should be emphasized that the successful integration of IHT into athletes' training routines largely depends on the accessibility of hypoxic chambers, which ideally should be located at the sports facility or in a conveniently accessible location to minimize time spent on training sessions.

Limitations. This pilot study involved a small sample of athletes, which may limit the generalizability of the findings. The absence of a control group and the short duration of the intervention also constrain the strength of the conclusions. Future research should include larger randomized controlled trials and incorporate long-term monitoring of adaptations to IHT.

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