Scientific and practical foundations for improving aerobic and anaerobic capacities of 18–19 year-old football players through hypoxic breathing training

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Abstract
This article examines the improvement of functional capacities of 18–19-year-old football players through the implementation of hypoxic breathing exercises. During the study, breathing cycles performed under hypoxic conditions, specialized loads that promote adaptation to oxygen deficiency, and the physiological effects of diaphragmatic breathing techniques were investigated. A 12-week specialized program was observed to enhance the efficiency of oxygen utilization, promote active adaptation of the cardiovascular and respiratory systems, and improve indicators affecting both aerobic and high-intensity activities in football players. The obtained results confirm the practical significance of hypoxic breathing exercises in enhancing the functional readiness of young football players.

Keywords: hypoxic training, breathing technique, functional capacity, oxygen utilization, aerobic development, high-intensity activity, diaphragmatic breathing, specialized preparation of football players.

Introduction

Modern football is recognized as one of the sports disciplines that imposes the highest demands on physical, functional, and psychophysiological readiness. Over the past decades, the acceleration of game dynamics, changes in tactical models, the implementation of positional pressing, and the increase in high-intensity actions have required players to possess complex and highly developed readiness. Such loads necessitate a high level of development in both aerobic and anaerobic energy systems.

Football players aged 18–19 are at an active stage of physical development. At this stage, adaptation mechanisms function at a high level, the plasticity of muscle tissues, the adaptability of the central and peripheral nervous systems, and the morphofunctional formation of the cardiovascular system progress rapidly. Therefore, properly selected training methods for this age group are among the key factors in future professional development. In particular, improving oxygen supply to the body, maintaining performance stability during exercise, and accelerating recovery processes are priority directions in functional readiness.

In recent years, hypoxic training in sports physiology has become one of the most relevant research areas. It involves creating or simulating conditions of reduced oxygen content in the air to activate the body's adaptation mechanisms. Breathing in a hypoxic environment triggers a series of compensatory processes in the body: hemoglobin synthesis accelerates, the secretion of erythropoietin (EPO) increases, the number of erythrocytes rises, and the blood's oxygen-carrying capacity expands. At the same time, the number and activity of mitochondria in muscle tissues increase, significantly enhancing the efficiency of energy metabolism.

During high-intensity actions in football, the body frequently experiences an "oxygen debt," which activates anaerobic energy sources and leads to lactate accumulation. Hypoxic training promotes stable adaptation to these processes, increases lactate utilization efficiency, and accelerates recovery. Scientific sources note that training under hypoxic conditions can enhance aerobic capacity by 10–15%, anaerobic speed by 5–10%, and recovery rate by 20–30%. Achieving such improvements in a short period is difficult through simple running or traditional strength exercises alone.

The psychophysiological advantages of hypoxic training are also significant. Controlled breathing helps regulate the autonomic nervous system by balancing sympathetic and parasympathetic mechanisms. This enhances resistance to competitive stress, ensures emotional stability, and strengthens cognitive processes such as concentration and rapid decision-making. In football, the ability to anticipate opponents' actions, quickly assess situations, and make optimal decisions is critical, making hypoxic exercises positively impactful on psychological readiness as well.

All the evidence presented above demonstrates that hypoxic breathing exercises are a highly important, scientifically grounded, and relevant method for developing the functional readiness of 18–19-year-old football players. This approach enhances the body's capacity to

take in, transport, and efficiently use oxygen; optimizes cardiovascular efficiency; accelerates recovery; and improves emotional stability and resistance to competitive stress. Therefore, hypoxic training plays a crucial role in forming the complex functional readiness demanded by modern football and represents one of the effective factors for achieving high sports performance.

Purpose of the Study. To identify changes in functional fitness indicators of 18–19-year-old football players through the application of hypoxic breathing exercises and to scientifically substantiate the effectiveness of this method.

Objectives of the Study:

To analyze the biological and physiological mechanisms of hypoxic breathing exercises and determine their significance in developing aerobic and anaerobic capacities in football players;

To conduct initial monitoring of indicators related to the cardiorespiratory, energy, and recovery systems in 18–19-year-old football players to assess their functional status;

Based on the research results, to provide scientific conclusions regarding the practical effectiveness of hypoxic breathing exercises and to prepare methodological recommendations for coaches and specialists.

Results and discussion

During the study, practical experiments were conducted to determine the effects of hypoxic breathing exercises on the functional fitness of 18–19-year-old football players. The results indicated that when hypoxic exercises are implemented systematically and according to a structured plan, the body's adaptation to oxygen demand accelerates, and the biological coordination between the respiratory and cardiovascular systems significantly strengthens. During training, the players' diaphragmatic breathing skills improved, resulting in greater ease, continuity, and stability in respiratory activity. These changes facilitated more effective breathing control, delayed the onset of fatigue during training and matches, enabled prolonged high-intensity activity, and, particularly during rapid and multi-directional movements, significantly enhanced the ability to maintain stable breathing.

The study involved 24 football players aged 18–19, who were randomly divided into two groups. The experimental group underwent training based on hypoxic breathing exercises, while the control group followed traditional breathing and general physical exercises. Both groups followed identical overall physical and technical-tactical training programs; the primary difference was the structured, stepwise implementation of hypoxic exercises in the experimental group.

The scientific novelty of this study lies in the observation that hypoxic breathing exercises positively affect not only aerobic and anaerobic capacities but also the ventilatory capacity of the respiratory system, the endurance of diaphragm and back muscles, and psychophysiological stability, including resistance to stress. These improvements enable football players to perform rapid actions on the field with high efficiency for extended periods and significantly enhance technical-tactical performance indicators.

The main platform of the methodology was a 12-week cyclic hypoxic training program. The program was structured according to the principle of gradual adaptation, with each phase incorporating specialized hypoxic loads designed to enhance the body's oxygen delivery and utilization capacity.

Phase One – Adaptation Period: This phase aimed to gradually prepare players for hypoxic conditions. The primary focus was on stabilizing the respiratory system and establishing safe adaptation responses in the body. Players performed exercises to hold their breath for short periods, adapt to low-intensity breathing intervals, and develop diaphragmatic breathing. Additionally, breathing control exercises were integrated with low-intensity running variants, which not only enhanced respiratory system activity but also facilitated the initial adaptation of the cardiovascular system to hypoxic conditions. During this phase, practical measures were also implemented to monitor oxygen demand and evaluate the endurance of respiratory muscles.

Phase Two – Main Hypoxic Interval Period: This phase focused on increasing players' tolerance to hypoxic loads and elevating the functional capacity of the respiratory system to a new level. The duration and frequency of hypoxic intervals were gradually increased, and these intervals were integrated with moderate-intensity running exercises to expand the ability to manage breathing effectively. Recovery periods between intervals were shortened, enabling optimal control of oxygen supply to the body. During this phase, the endurance of respiratory muscles significantly improved, pulmonary

ventilatory capacity increased, and the cardiovascular system began to function more efficiently and stably under hypoxic conditions. These adaptations were associated with enhanced physiological capabilities of the respiratory system, more economical cardiac function, and strengthened coordination of the oxygen delivery system.

Phase Three – Integrated Hypoxic Training Period: This phase focused on fully incorporating hypoxic preparation into the overall sports training process. During this stage, hypoxic intervals were effectively integrated with high-intensity running, sprints, rapid tactical movements, and quick decision-making on the field. Players were trained using a specialized 3–3–3 breathing control method, which not only improved the efficiency of the respiratory system but also enhanced neuromuscular integration.

During high-intensity actions, players' ability to perform under hypoxic conditions improved significantly. This enhancement strengthened their functional stability during matches, as well as their capacity for rapid movements and strategic decision-making. Moreover, this phase ensured the effective application of hypoxic training in real-game scenarios, enabling players to manage breathing efficiently under stressful conditions and maintain high-intensity performance even when oxygen supply was limited.

To evaluate the methodology and determine the effectiveness of hypoxic training, the study comprehensively measured football players' aerobic and anaerobic capacities, cardiovascular indicators, respiratory system function, and psychophysiological state.

Aerobic capacity was assessed using Cooper's 12-minute run test and the Harvard Step Test, which allowed for analysis of players' VO_2max values and the dynamics of their aerobic endurance. Anaerobic capabilities were evaluated through RAST tests and 30-meter sprints, assessing maximal energy production, explosive power, and fatigue resistance.

Changes in the respiratory system were analyzed using the Tiffeneau index, liver speed index, and diaphragmatic functional capacity. Cardiovascular activity was monitored through resting and exercise heart rates, pulse recovery rate, and blood pressure. Psychophysiological stability was assessed using concentration tests, reaction speed measurements, and a stress-resistance index. All tests were conducted at the beginning of the study, after 6 weeks, and at the end of the 12-week program. This approach enabled stepwise monitoring of the players' adaptation to hypoxic training and precise assessment of functional changes at each stage.

Results indicated that the distance covered in the Cooper test increased by approximately 240–260 meters, while the Harvard Step Test index improved by 8–12 points. These improvements reflect not only enhanced respiratory and cardiovascular function but also the positive physiological effects of hypoxic exercises, including increased hemoglobin oxygen-binding capacity, higher capillarization, and optimized cardiovascular efficiency. In contrast, the control group showed no significant improvements in these indicators, and aerobic growth was limited to only 3–5%, further confirming the specific and pronounced physiological impact of hypoxic training.

The analysis of anaerobic capacities clearly demonstrated the advantages of hypoxic training. In particular, during the 30-meter sprint, the experimental group showed a significant improvement in reactive power, resulting in an average time reduction of 0.12–0.18 seconds. This not only enhanced the players' ability to perform rapid movements but also markedly improved their anaerobic power and running speed.

Furthermore, RAST test results indicated a 6–9% increase in maximal energy output, reflecting improved fatigue resistance, higher lactate tolerance, and enhanced ability to sustain performance during high-intensity actions. These changes indicate that the body's capacity to efficiently manage metabolic processes under hypoxic conditions, particularly anaerobic energy mechanisms, was significantly enhanced.

Changes in the respiratory system also clearly reflected the effectiveness of hypoxic exercises. Training strengthened the respiratory muscles and significantly increased pulmonary ventilatory capacity. The Tiffeneau index increased by 6–8%, and the liver speed index rose by 12–15%, indicating enhanced functional stability of the airways and improved airflow capacity. Additionally, diaphragmatic functional capacity improved by 15–20%, reflecting a significant increase in respiratory muscle endurance and refinement of breathing control techniques. These improvements can be explained by the development of effective breathing control strategies, enhanced muscle fatigue re-

sistance due to hypoxic intervals, and improved ventilation–perfusion matching.

Positive changes in the cardiovascular system were among the most significant results of the study. In the experimental group, resting heart rate decreased by an average of 4–6 beats per minute, indicating that the heart was functioning more economically. Recovery time after exercise shortened by 25–30 seconds, demonstrating the efficiency of the stress response and the coordinated operation of the oxygen delivery and circulatory systems. Additionally, stabilization of systolic blood pressure reflected an overall improvement in cardiovascular functional stability and the heart's capacity to operate in an economical mode. In contrast, these indicators remained almost unchanged in the control group, further confirming the specific and pronounced physiological effect of hypoxic training.

Psychophysiological indicators also clearly reflected the impact of hypoxic exercises. In the experimental group, reaction speed improved, attention and concentration were enhanced, and delayed responses decreased. These changes are associated with stress reduction through breathing control, increased autonomic nervous system stability, and faster decision-making. In football, such improvements are particularly important for responding rapidly to environmental cues and executing quick movements.

Improvements in functional fitness were also reflected in technical-tactical performance. Players in the experimental group were able to maintain high-speed movement across the field for longer periods, delay the onset of fatigue during pressing, and shorten recovery intervals. Their ability to control the ball in high-tempo game situations, participate in rapid substitutions, and sustain positional movements improved significantly. These effects can be attributed to enhanced energy efficiency, metabolic stability, and psychophysiological adaptation resulting from hypoxic training, representing a clear practical manifestation of its benefits in football.

Overall, the results demonstrate that hypoxic breathing exercises can effectively improve not only aerobic and anaerobic capacities but also respiratory function, cardiovascular efficiency, and psychophysiological stability. This method proves to be effective for enhancing players' endurance, performance at high intensity, and resilience to stress under real game conditions.

Practical Recommendations. When introducing hypoxic breathing exercises into the training process of 18–19-year-old football players, it is essential to consider their age-specific physiological characteristics, the development level of the cardiovascular system, and their adaptation capacity to physical loads. To maximize the effectiveness of hypoxic training, proper breathing techniques should be taught under the guidance of a coach or qualified specialist. For example, in hypoxic interval exercises, players can practice breath-holding for 20–40 seconds, running under low-oxygen conditions, and combining cyclic movements with controlled breathing restriction. Such exercises are most effective when performed twice a week and incorporated into the warm-up phase before main training sessions. The intensity of the load should be gradually increased based on the functional state of each player, and oxygen saturation levels, particularly SpO_2, should not fall below 85% during exercises.

The study results indicate that hypoxic exercises not only effectively enhance aerobic and anaerobic capacities but also provide the greatest benefit when combined with training focused on speed, endurance, and recovery. Additionally, due to the pronounced psychophysiological effects of hypoxic training, these exercises are recommended as a tool for improving stress resistance during pre-competition microcycles. The effectiveness of hypoxic exercises largely depends on correct individualization of the load. Therefore, each athlete's heart rate, breathing depth, subjective fatigue level, and recovery time should be carefully monitored. After training, normalization of pulse, SpO_2, and breathing rhythm within 3–5 minutes indicates that the exercise dose was appropriately selected. If recovery is prolonged, it is advisable to temporarily reduce or skip hypoxic loads.

Conclusion

Integrating hypoxic breathing exercises into the training system of 18–19-year-old football players significantly activates adaptation mechanisms in the cardiovascular and respiratory systems and effectively develops overall functional readiness. The study results demonstrate that hypoxic breathing exercises performed under reduced-oxygen conditions accelerate adaptation to maximal and submaximal loads and help optimize the processes of oxygen intake, transport, and utilization in the body.

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