



Functional Status Of The Cardiorespiratory System In Highly Qualified Female Middle-Distance Runners

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Abstract: The functional status of the cardiorespiratory system is one of the most important physiological factors determining athletic performance in middle-distance running. Highly qualified female middle-distance runners require a well-developed cardiovascular and respiratory system to maintain high exercise intensity, ensure adequate oxygen delivery to working muscles, and recover efficiently after physical exertion. The functional capacity of these systems is closely associated with aerobic endurance, maximal oxygen uptake, heart rate regulation, pulmonary ventilation, and the efficiency of oxygen utilization. This article examines the physiological characteristics of the cardiorespiratory system in highly qualified female middle-distance runners, focusing on cardiovascular adaptation, respiratory function, aerobic capacity, and recovery processes. Particular attention is given to the importance of comprehensive physiological monitoring in sports training. Assessing cardiorespiratory indicators can help coaches and sports medicine specialists individualize training loads, evaluate adaptation to exercise, and reduce the risk of excessive fatigue. A scientifically based approach to monitoring these indicators contributes to improving athletic performance and maintaining the health of female athletes.

Keywords: female athletes, middle-distance running, cardiorespiratory system, cardiovascular function, respiratory function, aerobic capacity, maximal oxygen uptake, heart rate, pulmonary ventilation, physical endurance, sports physiology, training adaptation, recovery, physiological monitoring.

Introduction

Middle-distance running is a demanding athletic discipline that requires a combination of aerobic endurance, anaerobic energy production, speed, strength, and efficient movement coordination. Events such as the 800-meter and 1500-meter races place substantial demands on the cardiovascular and respiratory systems. Athletes must sustain a high running speed while maintaining an effective balance between oxygen supply and energy requirements. In highly qualified female middle-distance runners, systematic training produces significant physiological adaptations. The heart becomes more efficient at supplying blood to working muscles, respiratory function supports increased oxygen exchange, and skeletal muscles improve their ability to utilize oxygen during prolonged and intense exercise. These adaptations contribute to enhanced endurance, improved exercise tolerance, and more effective recovery between training sessions. The cardiorespiratory system consists primarily of the cardiovascular and respiratory systems, which function together to transport oxygen from the atmosphere to active tissues and remove carbon dioxide produced during metabolism. During intensive running, the demand for oxygen increases considerably. To meet this demand, heart rate, stroke volume, cardiac output, and pulmonary ventilation increase in response to exercise intensity.

Materials and Methods

This article is based on a review and theoretical analysis of scientific literature concerning exercise physiology, cardiovascular adaptation, respiratory function, and endurance training. The principal physiological indicators



relevant to middle-distance running were considered, including resting heart rate, exercise heart rate, blood pressure, stroke volume, cardiac output, maximal oxygen uptake, pulmonary ventilation, oxygen saturation, and post-exercise recovery. Comparative analysis was used to explain the differences between resting physiological conditions and responses to intensive physical activity. Particular attention was given to the relationship between aerobic capacity, training intensity, and the functional efficiency of the cardiorespiratory system. The article presents a theoretical synthesis of established physiological principles. No original experimental measurements were collected, and the findings should therefore be interpreted as a scientific literature-based discussion rather than as the results of a newly conducted clinical or sports experiment [1].

Results and Discussion

The cardiovascular system plays a central role in supporting athletic performance during middle-distance running. Its primary function is to transport oxygen and nutrients to active muscles while removing metabolic by-products generated during exercise. One of the important indicators of cardiovascular adaptation is resting heart rate. In endurance-trained athletes, resting heart rate may be lower than in individuals who do not participate in regular endurance training. This adaptation is associated with changes in autonomic regulation and improved cardiovascular efficiency. However, resting heart rate varies considerably among individuals and should not be used as the sole indicator of athletic fitness. Stroke volume, defined as the volume of blood pumped by the heart with each contraction, is another important physiological parameter. Endurance training can increase the heart's capacity to fill and eject blood efficiently. As a result, the heart may deliver an adequate volume of blood with fewer contractions at rest and during submaximal exercise. Cardiac output, which represents the amount of blood pumped by the heart per minute, increases substantially during intensive running. This response is necessary to satisfy the elevated oxygen requirements of skeletal muscles. The ability to increase cardiac output effectively is an important component of endurance performance [2].

Blood pressure and heart rate responses to exercise can also provide useful information about cardiovascular function. Nevertheless, these indicators must be interpreted in relation to exercise intensity, environmental conditions, hydration, fatigue, and individual characteristics. In highly qualified female runners, regular monitoring of cardiovascular responses can help identify changes in adaptation to training. An unexpectedly elevated resting heart rate, reduced exercise tolerance, or an unusual recovery pattern may indicate accumulated fatigue, inadequate recovery, illness, or other physiological stressors. Such findings should be interpreted alongside other indicators rather than treated as definitive evidence of overtraining [3].

The respiratory system ensures the exchange of oxygen and carbon dioxide between the atmosphere and the body. During middle-distance running, respiratory demands increase as the working muscles require greater quantities of oxygen for energy production. Pulmonary ventilation refers to the volume of air inhaled and exhaled per minute. During exercise, ventilation increases through changes in breathing frequency and tidal volume. These adjustments help maintain adequate oxygen uptake and carbon dioxide removal. Highly trained runners develop the ability to coordinate breathing with the demands of exercise. Although respiratory muscles and ventilatory efficiency can adapt to training, performance is not determined by lung capacity alone. Oxygen transport also depends on cardiovascular function, hemoglobin concentration, blood flow distribution, and the ability of muscles to extract and utilize oxygen. The efficiency of pulmonary gas exchange is particularly important when athletes perform repeated high-intensity efforts. During the 800-meter and 1500-meter events, energy production involves both aerobic and anaerobic pathways. Consequently, runners must tolerate substantial increases in ventilation and metabolic demand while maintaining running speed and technical efficiency. Respiratory indicators should therefore be assessed in combination with cardiovascular measurements and exercise performance. Depending on the athlete's needs and available equipment,



assessments may include respiratory frequency, pulmonary function tests, exercise ventilation, and oxygen saturation [4].

Maximal oxygen uptake, commonly expressed as $\text{VO}_{2\text{max}}$, represents the highest rate at which the body can take up, transport, and utilize oxygen during intense exercise. It is widely used to assess aerobic capacity in endurance athletes. $\text{VO}_{2\text{max}}$ is influenced by several factors, including cardiac output, oxygen-carrying capacity of the blood, muscle blood flow, and the ability of skeletal muscles to extract oxygen. Endurance training can improve aerobic capacity, although the magnitude of improvement differs among athletes because of genetic, physiological, and training-related factors. In middle-distance running, aerobic capacity is particularly important for sustaining high-intensity performance and supporting recovery between demanding efforts. However, $\text{VO}_{2\text{max}}$ alone does not fully explain differences in competitive results. Running economy, lactate-related physiological responses, speed, neuromuscular coordination, tactical decision-making, and the athlete's ability to sustain a high fraction of aerobic capacity also contribute to performance.

Running economy describes the oxygen cost of running at a given submaximal speed. Athletes with better running economy generally require less oxygen to maintain the same running velocity under comparable conditions. This characteristic may provide a competitive advantage, especially when athletes have similar maximal oxygen uptake values. For highly qualified female middle-distance runners, the combined evaluation of $\text{VO}_{2\text{max}}$, running economy, threshold-related responses, and race-specific performance can provide a more comprehensive understanding of endurance capacity than any single physiological measurement.

Recovery is a fundamental component of athletic training because physiological adaptation occurs through the interaction of exercise stress and sufficient recovery. Heart rate recovery after exercise is commonly used as one indicator of autonomic and cardiovascular responses. Following the cessation of intense running, heart rate gradually decreases as the body's immediate metabolic demands decline and parasympathetic activity increases. The pattern of recovery depends on exercise intensity, fitness, environmental conditions, hydration, and measurement procedures. Post-exercise heart rate should therefore be assessed under standardized conditions. Measurements obtained at different time intervals or following different exercise protocols may not be directly comparable. Recovery can also be evaluated through perceived exertion, sleep quality, mood, muscle soreness, training performance, and selected physiological measurements. Combining these indicators provides a more complete picture of an athlete's condition than relying on a single measure. For highly qualified female middle-distance runners, appropriate recovery helps maintain training quality and reduce the likelihood of excessive fatigue. Coaches should adjust training loads when several indicators suggest inadequate adaptation.

Systematic monitoring is essential for evaluating the effects of training and determining whether an athlete is adapting appropriately to physical demands. A comprehensive assessment may include resting heart rate, blood pressure, exercise heart rate, heart rate recovery, $\text{VO}_{2\text{max}}$, running economy, and selected respiratory measurements. When indicated, laboratory testing may provide additional information about hemoglobin concentration, iron status, and other health-related parameters. Field-based assessments can also be useful when laboratory equipment is unavailable. Standardized running tests, training records, and repeated measurements can help identify changes in performance and physiological responses over time. However, the reliability of monitoring depends on consistent testing conditions, appropriate measurement methods, and careful interpretation. Changes in temperature, sleep, hydration, recent training, and psychological stress may affect physiological indicators. An individualized monitoring system should therefore establish each athlete's baseline values and evaluate trends over time. The purpose is not simply to collect measurements but to use them to guide training decisions, support recovery, and protect athlete health.

Conclusion



The functional status of the cardiorespiratory system is a major determinant of performance in highly qualified female middle-distance runners. Effective cardiovascular function, adequate pulmonary ventilation, high aerobic capacity, and efficient oxygen utilization enable athletes to sustain demanding exercise and recover between training sessions. Important indicators include resting and exercise heart rate, stroke volume, cardiac output, VO_2max , respiratory responses, and post-exercise recovery. Nevertheless, no single parameter can fully characterize an athlete's functional condition or predict competitive performance. A comprehensive assessment should also consider running economy, event-specific performance, training history, nutritional status, iron availability, menstrual health, and individual recovery requirements. Regular and scientifically grounded monitoring allows coaches and sports medicine specialists to identify physiological changes, individualize training loads, and evaluate adaptation to exercise. Particular attention should be given to differences between athletes and to the prevention of excessive fatigue. In conclusion, an integrated approach combining physiological testing, appropriate training, balanced nutrition, and sufficient recovery can support the development of endurance performance while maintaining the health and long-term athletic potential of highly qualified female middle-distance runners.

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