AEROBIC AND ANAEROBIC ENERGY SUPPLY SYSTEMS IN THE DEVELOPMENT OF SPEED ENDURANCE IN MIDDLE-DISTANCE RUNNERS

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Abstract

This article presents a scientific analysis of the role of aerobic and anaerobic energy supply mechanisms in the process of developing speed endurance among middle-distance runners. The effectiveness of various energy metabolism strategies aimed at achieving maximum work capacity and endurance in athletes is examined in connection with practical applications.

Keywords: middle distance, running, speed endurance, aerobic system, anaerobic system, energy metabolism, sports physiology.

Introduction

In the global sports arena, determining the limits of human physiological capabilities, achieving peak performance, and developing individualized optimal training mechanisms have become priorities in modern sports physiology, biochemistry, and coaching methodologies. Middle-distance running events in athletics (ranging from 800 to 3000 meters) require athletes to sustain high-intensity workloads over an extended period — that is, to develop the quality of speed endurance. The integration and functional harmony of aerobic and anaerobic energy supply systems are decisive in shaping this quality (Verkhoshansky, 2005; Platonov, 2013).

Recent biomedical studies indicate that speed endurance depends not only on biomechanical factors related to muscle activity but also on the complex, multi-stage processes of the cardiovascular system, respiratory system, central nervous system, and energy metabolism. From a physiological perspective, generating large amounts of energy in a short time is primarily achieved through anaerobic (alactic and lactic) mechanisms; however, as the competition duration increases, the aerobic system becomes increasingly active (Brooks, Fahey & Baldwin, 2004; Joyner & Coyle, 2008).

Khamidullayev (2025) notes that during the training phase for middle-distance specialists, the balance between energy systems is considered the primary determinant of competitive performance. The planned combination of fartlek, interval running, zonal workloads, and anaerobic–alactic and lactic training is viewed as an effective approach to developing maximum work capacity.

According to research (Seiler, 2010; Bangsbo et al., 2010), since middle-distance events last longer than two minutes, energy provision relies on approximately 40–60% anaerobic and 40–60% aerobic components. This requires a balanced training approach aimed at developing both systems simultaneously. The anaerobic capacity enables the athlete to reach maximum speed, whereas the aerobic system allows for sustaining that speed over a longer duration (Wilmore & Costill, 2005).

Modern elite athletes' training systems employ technologies designed to train and mobilize various pathways of energy metabolism — such as hypoxic training, lactate threshold improvement techniques, VO_2 monitoring, oxygen uptake indices, and high-intensity zonal interval training. These methods maximize the athlete's bioenergetic potential (Billat, 2001; Noakes, 2000).

This article analyzes the physiological, biochemical, and pedagogical bases of aerobic and anaerobic energy systems in developing speed endurance in middle-distance runners through an integrated approach. The study's relevance lies in its contribution to optimizing individual athlete preparation and enabling coaches to scientifically design training structures.

Speed endurance is the athlete's ability to sustain high-intensity physical loads for a certain period effectively and consistently. This quality mainly depends on the integrated functional state of the cardiovascular, respiratory, and muscular systems, as well as the activity of bioenergetic systems (Platonov, 2013; Verkhoshansky, 2005). In middle-distance running (800–3000 meters), both movement speed and duration are high, requiring continuous and sequential cooperation between energy-producing systems.

During running, energy supply occurs in three stages:

- **Initial phase** – the anaerobic alactic system (ATP–PCr pathway) dominates;
- **Intermediate phase** – the anaerobic lactic system (glycolysis) becomes predominant;
- **Final phase** – the aerobic oxidative system (mitochondrial respiration) plays the leading role (Brooks et al., 2004).

Anaerobic Energy System

The anaerobic system functions without oxygen and ensures rapid, powerful movements. It includes:

1. **Anaerobic alactic system (ATP–PCr pathway):** Operates during the first 10–15 seconds of activity, supplying energy to muscles through creatine phosphate reserves. This system dominates in short sprints and explosive actions.
2. **Anaerobic lactic system:** Functions for activities lasting 30 seconds to about 2–3 minutes, producing energy through glycolysis. Muscle glycogen breakdown leads to lactate accumulation, which signals fatigue (Wilmore & Costill, 2005; Gastin, 2001).

In the middle segment of a race, the lactic system becomes highly active, requiring the athlete to enhance anaerobic endurance. Interval training, high-intensity sprints, and lactate tolerance drills are used for this purpose.

Aerobic Energy System

The aerobic system produces ATP in the presence of oxygen, enabling sustained muscle activity over long periods. The body oxidizes glycogen, fats, and amino acids via mitochondria to generate ATP.

VO_2max — the maximal oxygen uptake — is a key indicator of aerobic capacity. A higher VO_2max allows athletes to utilize oxygen more effectively, maintaining high performance in prolonged efforts (Joyner & Coyle, 2008). Another important parameter is the **lactate threshold (LT)**, marking the transition between aerobic and anaerobic metabolism, directly influencing endurance (Billat, 2001).

To develop the aerobic system, fartlek sessions, long low-intensity runs, and zonal training at 60–80% HRmax are commonly applied. These methods increase cardiac output, enhance mitochondrial density, and improve overall endurance.

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Middle-distance running exemplifies the interplay between energy systems. Throughout the race, the dominant energy pathway transitions from ATP–PCr at the start, to glycolysis in the middle, and aerobic oxidation towards the end (Seiler, 2010; Noakes, 2000).

Research shows that no matter how strong anaerobic capacity is, without a solid aerobic base, fatigue will set in quickly in the final stages of a race, reducing performance (Bangsbo, 2010). Therefore, modern sports methodology recommends proportional and phased development of both systems, sequentially activating them to deepen adaptation.

Key methodological principles for planning training include:

- Managing training based on individual physiological monitoring (VO_2max, HRmax, LT, RPE).
- Periodizing zonal workloads: aerobic base in the initial stage, mixed loads in the middle, anaerobic emphasis before competition.
- Adjusting interval training variables (distance, heart rate, time, recovery).
- Combining hybrid workloads: fartlek + intervals + tempo runs to enhance results.

Conclusion

From the perspective of sports physiology and training theory, developing speed endurance in middle-distance runners is a complex, multi-stage process that activates the body's energy systems in harmony. The foundation of this process lies in thoroughly studying the biochemical and physiological bases of aerobic and anaerobic systems and adapting them to the athlete's somatic and psychophysiological characteristics.

Research shows that middle-distance performance depends on maximal oxygen uptake (VO_2max), anaerobic work capacity, oxygen debt, glycolytic potential, and the rate at which these are mobilized. In high-intensity running of 2–5 minutes, energy supply is about 40–60% anaerobic and the remainder aerobic, varying with the athlete's age, training level, gender, and individual endurance potential.

The anaerobic energy system (alactic and lactic pathways) ensures rapid responses to short-term high-intensity loads. The alactic pathway utilizes ATP–PCr reserves for immediate energy release, while the lactic pathway enables sustained power output but accelerates fatigue through lactate accumulation. The aerobic system, based on oxygen-dependent oxidation of glycogen and fats, supports prolonged endurance and is closely linked to cardiovascular efficiency.

As analyzed in this study, an integrated, phased training approach — combining fartlek, intervals, and both aerobic and anaerobic conditioning — yields the best results. Such individualized, physiology-based training not only optimizes the balance between strength and endurance but also contributes to stable competitive performance, resilience, and injury prevention.

Used literature:

1.Bangsbo, J., Iaia, F. M., & Krustrup, P. (2010). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. Sports Medicine, 38(1), 37–51. https://doi.org/10.2165/00007256-200838010-00004

2.Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Sports Medicine, 31(1), 13–31. https://doi.org/10.2165/00007256-200131010-00002

3.Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2004). Exercise Physiology: Human Bioenergetics and Its Applications (4th ed.). McGraw-Hill.

4.Gastin, P. B. (2001). Energy system interaction and relative contribution during maximal exercise. Sports Medicine, 31(10), 725–741. https://doi.org/10.2165/00007256-200131100-00003

5.Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: The physiology of champions. The Journal of Physiology, 586(1), 35–44. https://doi.org/10.1113/jphysiol.2007.143834

6.Noakes, T. D. (2000). Lore of Running (4th ed.). Human Kinetics.

7.Platonov, V. N. (2013). Sistema podgotovki sportsmenov v olimpijskom sporte [System of athlete training in Olympic sports]. Kiev: Olimpijskaya literatura.

8.Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes? International Journal of Sports Physiology and Performance, 5(3), 276–291. https://doi.org/10.1123/ijspp.5.3.276

9.Wilmore, J. H., & Costill, D. L. (2005). Physiology of Sport and Exercise (3rd ed.). Human Kinetics.