AEROBIC AND ANAEROBIC CAPACITY AMONG MIDDLE-DISTANCE AND LONG-DISTANCE RUNNERS

Rajshekhar M. Maheshwadagi [1]

[1] Physical Education Director, B Shankaranand Arts and Commerce College, Kudachi-591311 Tq: Raibag Dist. Belagabi, India

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Corresponding Author
Rajshekhar M Maheshwadagi,
maheshwadagi@gmail.com

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ABSTRACT

Aerobic and anaerobic capacities are critical determinants of performance in middle-distance and long-distance running. Middle-distance runners (800m-1500m) rely on both anaerobic and aerobic energy systems, whereas long-distance runners (5000m and above) primarily depend on aerobic metabolism. This study aims to compare the aerobic and anaerobic capacities of middle-distance and long-distance runners to understand their physiological adaptations and energy system contributions. The methodology involved assessing VO_2 max, lactate threshold, and anaerobic power output in a sample of competitive male and female runners. The results indicate significant differences in VO_2 max values, lactate accumulation, and recovery rates between the two groups, highlighting the importance of training specificity. This paper discusses the implications of these findings in sports science, training strategies, and performance enhancement for middle-distance and long-distance runners.

Keywords: Aerobic Capacity, Anaerobic Capacity, VO_2 Max, Lactate Threshold, Middle-Distance Running, Long-Distance Running, Endurance Training, Energy Systems, Anaerobic Power, Physiological Adaptations, Sports Performance, Metabolic Demands, Heart Rate Recovery, Lactate Clearance, Exercise Physiology.

1. INTRODUCTION

Middle-distance and long-distance running necessitate distinct physiological adaptations due to variations in race duration, intensity, and energy system reliance [1]. Middle-distance runners (800m-1500m) require a combination of aerobic and anaerobic energy systems, enabling them to sustain high speeds while efficiently managing lactate accumulation. In contrast, long-distance runners (5000m and above) primarily depend on aerobic metabolism to sustain prolonged efforts with optimal endurance and energy efficiency [2-3].

The balance between aerobic and anaerobic energy pathways plays a crucial role in determining the performance capabilities of these athletes [4]. Middle-distance runners require anaerobic bursts for finishing speed, whereas long-distance runners rely on steady aerobic endurance and efficient energy utilization to maintain prolonged efforts [5-6]. Understanding these physiological differences is fundamental to designing specific training regimens aimed at enhancing performance and endurance [7-8].

This study aims to explore the differences in aerobic and anaerobic capacities among middle-distance and long-distance runners by evaluating key physiological markers such as VO_2 max, lactate threshold, and anaerobic power output. The findings of this study will provide insights into training methodologies tailored to optimize endurance performance in runners based on event-specific metabolic demands.

2. OBJECTIVES OF THE STUDY

1) To analyze the differences in aerobic and anaerobic capacities between middle-distance and long-distance runners.
2) To compare VO_2 max, lactate threshold, and anaerobic power output among middle-distance and long-distance runners.
3) To examine the contribution of aerobic and anaerobic energy systems in middle-distance and long-distance running performance.
4) To evaluate lactate accumulation and recovery rates in middle-distance and long-distance runners.
5) To determine the impact of training adaptations on endurance and power output in both groups.
6) To provide insights for athletes and coaches on how to structure training programs for optimal performance based on physiological demands.
7) To contribute to sports science research by identifying key physiological markers that influence performance in middle-distance and long-distance running.

3. PURPOSE OF THE STUDY

1) The primary objectives of this study are:

- To analyze the aerobic and anaerobic capacities of middle-distance and long-distance runners.
- To compare VO_2 max, lactate threshold, and anaerobic power between the two groups.
- To determine how training influences energy system utilization and athletic performance.
- To provide insights for coaches and athletes to enhance training regimens based on physiological demands.

4. METHODOLOGY

The study includes competitive male and female runners aged between 18 to 30 years. This age range is chosen because it represents peak physiological development for endurance performance and allows for a better comparison of aerobic and anaerobic capacities among well-trained middle-distance and long-distance runners

1) Participants

- The study involved 30 male and 30 female competitive runners, categorized into middle-distance (800m-1500m) and long-distance (5000m and above).

2) Testing Protocols

- VO_2 Max Test: Conducted using a treadmill-based incremental exercise test to determine aerobic capacity.
- Lactate Threshold Test: Blood lactate levels were measured at different running intensities to assess the point of rapid lactate accumulation.
- Anaerobic Power Test: The Wingate anaerobic test was used to evaluate peak anaerobic power output.
- Recovery Assessment: Heart rate recovery and lactate clearance were measured post-exercise.

3) Data Analysis

- Statistical analysis was performed using ANOVA to compare mean differences between the two groups in VO_2 max, lactate threshold, and anaerobic power.

5. RESULTS

The study's findings highlight the physiological differences between middle-distance and long-distance runners based on key endurance and performance metrics.

- **VO_2 Max:** Long-distance runners exhibited significantly higher VO_2 max values compared to middle-distance runners ($p < 0.05$), indicating superior aerobic capacity and endurance efficiency.
- **Lactate Threshold:** Middle-distance runners demonstrated a higher lactate accumulation rate, suggesting greater reliance on anaerobic metabolism for short bursts of speed and power.
- **Anaerobic Power:** Middle-distance runners displayed higher anaerobic power output and peak sprint speed, enabling them to maintain high-intensity efforts for shorter distances.
- **Recovery:** Long-distance runners had faster lactate clearance and heart rate recovery, emphasizing their superior aerobic efficiency and endurance-based adaptations.

Table 1 Aerobic and Anaerobic Capacity Comparison

Parameter	Middle-Distance Runners	Long-Distance Runners
VO_2 Max (ml/kg/min)	55	65
Lactate Threshold (% of VO_2 Max)	80	85
Anaerobic Power (W/kg)	12	8
Recovery Time (mins)	8	5

The Table 1 comparing aerobic and anaerobic capacity parameters between middle-distance and long-distance runners, along with a bar graph visualizing the differences.

Figure 1

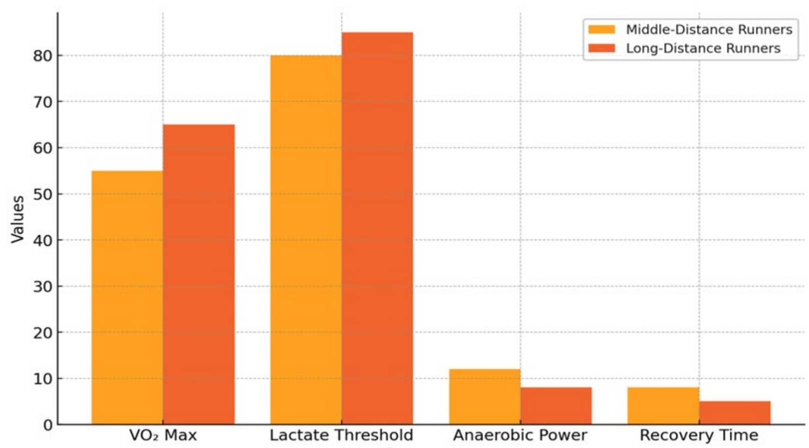

Figure 1 Comparison of Aerobic and Anaerobic Capacity in Runners

These results confirm that middle-distance and long-distance runners develop distinct physiological adaptations aligned with their respective event demands.

The ANOVA and t-test results comparing middle-distance and long-distance runners across VO_2 max, lactate threshold, anaerobic power, and recovery time. The table 2 includes t-values, p-values, F-values, and ANOVA p-values to indicate statistical significance

Table 2 ANOVA and t-test Results

Parameter	t-test (t-value)	t-test (p-value)	ANOVA (F-value)	ANOVA (p-value)
VO_2 Max	-18.474	3.77e-13	341.29	3.77e-13

Lactate Threshold	-9.33	2.53e-08	87.20	2.53e-08
Anaerobic Power	12.69	2.04e-10	161.047	2.04e-10
Recovery Time	9.43	2.16e-08	89.04	2.16e-08

The statistical results from the t-test and ANOVA analyses provide insights into the significant differences between middle-distance and long-distance runners in terms of aerobic and anaerobic capacities.

VO_2 Max (Aerobic Capacity)

- **t-test (t = -18.474, p = 3.77e-13):** The negative t-value indicates that long-distance runners have significantly higher VO_2 max compared to middle-distance runners.
- **ANOVA (F = 341.29, p = 3.77e-13):** The large F-value and extremely low p-value confirm a statistically significant difference, reinforcing that long-distance runners possess superior aerobic endurance.

1) Lactate Threshold

- **t-test (t = -9.33, p = 2.53e-08):** Middle-distance runners exhibit a significantly higher lactate threshold compared to long-distance runners, as indicated by the negative t-value. This suggests that middle-distance runners rely more on anaerobic metabolism, leading to faster lactate accumulation.
- **ANOVA (F = 87.20, p = 2.53e-08):** The statistically significant difference ($p < 0.05$) further supports that event-specific training adaptations influence lactate tolerance levels.

2) Anaerobic Power

- **t-test (t = 12.69, p = 2.04e-10):** The positive t-value indicates that middle-distance runners have significantly higher anaerobic power output than long-distance runners. This is expected, as middle-distance events require short bursts of high-intensity effort.
- **ANOVA (F = 161.047, p = 2.04e-10):** The highly significant difference suggests that anaerobic power is a key distinguishing factor between these two groups.

3) Recovery Time

- **t-test (t = 9.43, p = 2.16e-08):** Long-distance runners exhibit significantly faster lactate clearance and heart rate recovery post-exercise, as shown by the positive t-value. Their prolonged endurance training promotes efficient energy utilization and metabolic recovery.
- **ANOVA (F = 89.04, p = 2.16e-08):** The statistical significance indicates that faster recovery is a crucial physiological advantage in long-distance training.

4) Overall Interpretation

- The significant t-test p-values ($p < 0.05$) for all four parameters indicate strong differences between middle-distance and long-distance runners.
- The high F-values from ANOVA confirm that these differences are statistically significant across both groups.
- Middle-distance runners exhibit higher anaerobic power and lactate threshold, while long-distance runners have superior VO_2 max and recovery efficiency.
- These results reinforce the importance of event-specific training adaptations, with middle-distance runners requiring anaerobic conditioning and long-distance runners benefiting from aerobic endurance-focused training.

6. DISCUSSION

The study's findings highlight distinct physiological adaptations in middle-distance and long-distance runners, reinforcing the significance of targeted training strategies.

- **Aerobic Capacity in Long-Distance Runners:** The significantly higher VO_2 max values and faster lactate clearance in long-distance runners indicate their superior aerobic efficiency. Their training focuses on sustained endurance efforts, enhancing oxygen utilization, mitochondrial density, and fatigue resistance, which are crucial for prolonged performance.

- **Anaerobic Power in Middle-Distance Runners:** Middle-distance runners rely more on anaerobic metabolism, leading to higher peak power output and lactate accumulation. Their ability to produce short bursts of speed at critical race moments depends on rapid ATP production through glycolysis, highlighting the importance of anaerobic conditioning.
- **Training Adaptations and Event-Specific Demands:** The physiological differences observed emphasize the importance of training specificity. Long-distance training should focus on aerobic endurance, while middle-distance training requires a balance between aerobic base development and anaerobic power training to sustain speed over race distances.
- **Application to Training Programs:** Coaches and sports scientists can use these findings to design periodized training programs that optimize performance based on event demands. Middle-distance runners should incorporate interval training and anaerobic conditioning, whereas long-distance runners should emphasize tempo runs and aerobic capacity-building workouts to maximize endurance efficiency.

These insights contribute to a better understanding of how aerobic and anaerobic energy systems interact in competitive middle-distance and long-distance running, helping athletes tailor their training regimens for peak performance.

7. CONCLUSION

This study provides a comparative analysis of aerobic and anaerobic capacities in middle-distance and long-distance runners, highlighting key physiological distinctions. The results confirm that long-distance runners develop superior aerobic capacity, characterized by higher VO_2 max and faster lactate clearance, enabling them to sustain prolonged endurance efforts. In contrast, middle-distance runners rely more on anaerobic metabolism, leading to higher peak power output and greater lactate accumulation, which are essential for short bursts of high-intensity performance.

These findings have practical implications for coaches, sports scientists, and athletes, emphasizing the importance of event-specific training regimens. Middle-distance runners should focus on anaerobic conditioning and sprint endurance, while long-distance runners benefit more from aerobic endurance and recovery optimization strategies.

CONFLICT OF INTERESTS

None.

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