Asian Journal of Basic Science & Research
Volume 7, Issue 3, Pages 155-165, July-September 2025

# Physiological Relationship and Differences in $VO_2$ Max, Lactate Threshold, and Peak Blood Lactate between Power and Endurance Athletes

Manish Acharjee[1*], Dr. Rahul Dev Choudhury[2] & Dr. Gunjana Atreya[3]

*[1]Student, Department of Physical Education, Swarnim Gujarat Sports University, Desar, Gujarat, India. [2]Assistant Professor, Regional College of Physical Education, Panisagar, North Tripura, India. [3]Post Graduate Scholar, Parul Institute of Ayurved and Research, Parul University, Vadodara, Gujarat, India. Corresponding Author (Manish Acharjee) Email: acharjeemanish07@gmail.com[*]*

*DOI: Under Assignment*



*Article Received: 09 July 2025* *Article Accepted: 18 September 2025* *Article Published: 21 September 2025*

ABSTRACT

**Background:** Physiological markers such as maximal oxygen uptake ($VO_2$ Max), lactate threshold (LT), and peak blood lactate (PBL) are critical for understanding the aerobic and anaerobic adaptations that influence athletic performance. However, their combined assessment across different sporting disciplines is limited.

**Objectives:** This study aimed to compare $VO_2$ Max, LT, and PBL between power and endurance athletes and to explore their interrelationships among these variables within each group.

**Methods:** A cross-sectional comparative design was employed involving 60 athletes aged 18-21 years (30 power athletes and 30 endurance athletes) with a minimum of three years of competitive experience. $VO_2$ Max was measured via graded exercise testing, Lactate Threshold through serial capillary blood sampling, and Peak Blood Lactate with three minutes post-exercise. Independent t-tests and Pearson's correlation coefficient were used for data analysis ($p < 0.05$).

**Results:** Endurance athletes exhibited significantly higher $VO_2$ Max and LT values, reflecting superior aerobic capacity and delayed lactate accumulation, whereas power athletes showed significantly greater PBL, indicating enhanced anaerobic glycolysis and metabolic acidosis tolerance. Strong positive correlations were found between $VO_2$ Max and LT in both groups, where LT and PBL were not significantly correlated.

**Conclusion:** Distinct metabolic profiles characterize power and endurance athletes, underscoring the importance of sport-specific training interventions and comprehensive physiological assessments to optimize performance and conditioning strategies.

**Keywords:** $VO_2$ Max; Lactate Threshold; Peak Blood Lactate; Power and Endurance Athletes; Aerobic Adaptations; Anaerobic Adaptations; Physiological Profiling; Sport-Specific Training; Performance Optimization; Anaerobic Glycolysis.

## 1. Introduction

Success in diverse sports disciplines is largely determined by an athlete's aerobic and anaerobic capacities, which affect their capacity to maintain performance, recover quickly, and tolerate high-intensity training. By improving oxygen supply and utilization efficiency, aerobic capacity—which is represented by maximal oxygen uptake, or $VO_2$ max—supports sustained submaximal activity (Midgley & McNaughton 2021). The ability of an athlete to produce energy through glycolysis and prevent metabolic acidosis during extreme exertion is reflected in their anaerobic capacity, which is measured by parameters like lactate threshold (LT) and peak blood lactate (PBL) (Faude et al. 2022). By monitoring these markers for physiological profiling, customized training optimization is made possible, guiding interventions that focus on particular energy systems and tracking adaptation over (Jones et al. 2022). Coaches and sports scientists can customize conditioning programs to match the metabolic demands of various sports by combining $VO_2$ max, LT, and PBL assessments. This allows them to optimize load management to minimize injury risk and maximize performance outcomes [4]. The maximum rate at which the body can take up oxygen during intense, progressive activity is known as $VO_2$ max, or maximal oxygen uptake. It is measured in millilitres per kilogram per minute ($mL \cdot kg^{-1} \cdot min^{-1}$). As the primary measure of aerobic capacity, it indicates how effectively the respiratory, circulatory, and muscular systems work together to transport and utilise oxygen. Because it establishes the maximum sustainable intensity before fatigue sets in, a greater $VO_2$ max is closely linked

Asian Journal of Basic Science & Research
Volume 7, Issue 3, Pages 155-165, July-September 2025

to superior endurance performance [5]. Additionally, through improved oxidative metabolism, increased $VO_2$ max promotes quicker recovery between repeated high-intensity sessions in intermittent sports [6]. Physiologically, skeletal muscle mitochondrial density, which controls oxidative enzyme activity and ATP resynthesis efficiency, maximal cardiac output, and arterial oxygen-carrying capacity—which is mostly dependent on haemoglobin concentration—all affect $VO_2$ max [7]. All of these elements work together to highlight $VO_2$ max as a key performance profiler for a given sport.

The activity intensity at which the rate of lactate generation in working muscles surpasses the body's ability to remove and metabolise it, resulting in a gradual buildup in the blood, is known as the Lactate Threshold, as previously noted. This threshold is a critical determinant of sustainable performance, as it marks the upper limit of steady-state aerobic metabolism beyond which fatigue-related metabolites accumulate rapidly, impairing muscular function (Jones et al. 2022). In terms of physiology, Lactate Threshold is affected by elements like muscle fibre composition, where a larger percentage of type I fibres favours delayed lactate accumulation because of their superior oxidative qualities, and oxidative enzyme activity, which increases mitochondrial capacity for aerobic ATP resynthesis [4]. Chronic adaptations from prolonged aerobic training that enhance lactate clearance efficiency and metabolic stability are the reason why endurance athletes tend to have a higher LT, which frequently occurs at 75–90% of $VO_2$ max, as opposed to 50–70% in less-trained or power-oriented athletes (Midgley & McNaughton 2021). Peak blood lactate (PBL) is defined as the highest concentration of lactate detected in the bloodstream following exhaustive exercise, typically measured within minutes post-cessation of activity [10]. It shows how much anaerobic glycolytic activity is present during high-intensity activities, when the breakdown of muscle glycogen speeds up ATP resynthesis and causes an increase in lactate buildup [11]. Allen et al. (2008) studies athletes' ability to tolerate exercise-induced metabolic acidosis, which is crucial for maintaining maximal efforts for brief periods, is indicated by elevated PBL values, which also show a significant dependence on the glycolytic pathway. Additionally, PBL acts as an indirect indicator of the body's ability to buffer, specifically the effectiveness of the blood and intramuscular bicarbonate systems in preventing the buildup of hydrogen ions [13]. Higher PBL values are frequently linked to improved performance potential in sports requiring explosive power or repeated sprints because of superior anaerobic energy system adaptation.

There has been much research on the physiological distinctions between power and endurance athletes, especially concerning $VO_2$ max, lactate threshold (LT), and peak blood lactate (PBL); however, these factors are frequently studied separately rather than together. Since greater aerobic capacity is necessary for sustained high-intensity workouts, endurance athletes usually have noticeably higher $VO_2$ max values [6]. Adaptations, including higher cardiac output, capillarization, and mitochondrial density, are responsible for this improved aerobic fitness [14]. On the other hand, power athletes typically have higher PBL levels but lower $VO_2$ max, which suggests that they have a larger anaerobic glycolytic capacity and can withstand metabolic acidosis during brief, high-intensity bursts of activity [15]. These categories are further distinguished by lactate threshold, as per [16] endurance athletes typically have LT at a higher percentage of their $VO_2$ max, which allows them to perform at higher intensities before performance is hampered by lactate accumulation. Few studies have examined these physiological markers' concurrent correlations within the same cohort of athletes, despite the fact that several have described them

Asian Journal of Basic Science & Research
Volume 7, Issue 3, Pages 155-165, July-September 2025

individually. To create sport-specific training plans and maximize performance results, it is essential to understand the profile of $VO_2$ max, LT, and PBL among athlete types as discussed earlier. Thus, comprehensive investigations that assess these parameters remain limited but necessary for advancing applied sports physiology.

### 1.1. Statement of the Problem

The physiological profiles of power and endurance athletes exhibit distinct characteristics due to the differing metabolic demands of their respective sports. Despite being recognized indicators of aerobic and anaerobic capacity, $VO_2$ max, lactate threshold, and peak blood lactate are primarily examined in isolation and among homogeneous athlete groups in the majority of current research. A thorough grasp of how these factors interact with one another and vary among athletic specializations is limited by this fragmented approach. The individual and combined variation in $VO_2$ max, lactate threshold, and peak blood lactate in power versus endurance athletes must therefore be thoroughly investigated. Filling this knowledge gap will improve understanding of physiological adaptations unique to a given activity, guiding customized training regimens and maximizing athletic performance in a variety of sports.

### 1.2. Objectives of the Study

1. To compare the difference in $VO_2$ Max between power athletes and endurance athletes.

2. To compare the difference in lactate threshold expressed as a percentage of $VO_2$ Max between power and endurance athletes.

3. To compare the difference in peak blood lactate concentration following maximal power exercise in power and endurance athletes.

4. To assess the relationship between $VO_2$ Max and Lactate Threshold within each athlete group.

5. To assess the relationship between Lactate Threshold and Peak Blood Lactate within each athlete group.

6. To identify sport-specific physiological profiles that can inform tailored training interventions for different athletic disciplines.

### 1.3. Significance of the Problem

For advancing sport-specific performance optimization, it is essential to understand the physiological link and variations in $VO_2$ max, lactate threshold, and peak blood lactate between power and endurance athletes. These important indicators reveal unique contributions from the energy system and metabolic changes that are crucial for optimal performance in various sports. Power athletes rely more on anaerobic glycolysis and acid-base buffering than endurance athletes do on aerobic capacity and effective lactate clearance. However, the integrative interplay of these variables remains underexplored, limiting comprehensive athlete profiling. By filling this gap, customized training plans that improve each person's performance and recovery are made possible. Additionally, knowledge gained from these comparative studies can help develop methods for identifying talent and preventing injuries, which will ultimately support evidence-based coaching and sports science practices for various sporting populations.

## 2. Methodology

### 2.1. Research Design

A cross-sectional comparative study design will be used to examine and compare the physiological variables $VO_2$ Max, Lactate Threshold (LT), and Peak Blood Lactate (PBL) between power and endurance athletes. Additionally, Correlational analyses will be conducted to explore the relationship among these parameters within each group.

### 2.2. Participants

A purposive sample of 60 athletes between the ages of 18 to 21 will be recruited for the study; Among 60 participants, 30 will be endurance athletes (long-distance runners, swimmers, and cyclists), and 30 will be power athletes (sprinters and weightlifters). The sample included both male and female participants, though the gender distribution was not equal (Power athletes: 17 males and 13 females; Endurance athletes: 14 males and 16 females). All participants had a minimum of three years of competitive experience at the state or national level and were free from metabolic or cardiovascular conditions. Before data collection, ethical approval was obtained from the Institutional Ethics Committee of the Regional College of Physical Education (RCPE). Written informed consent was secured from all participants.

### 2.3. Instruments

**$VO_2$ Max Testing:** Depending on the athlete's specialization, a graded exercise test (GXT) on a motorized treadmill or cycle ergometer will be used to determine $VO_2$ max. As per the protocol, suggested by the American College of Sports Medicine (2021), the program will begin with minimal exertion and increase every one to three minutes until volitional exhaustion. A calibrated metabolic cart will be used to continually analyse respiratory gas exchange to estimate the maximum amount of oxygen that can be taken in.

**Lactate Threshold Determination:** Lactate Threshold (LT) will be assessed concurrently during the incremental exercise test by collecting capillary blood samples from the fingertip or earlobe at the end of each stage. Blood lactate concentration will be analysed using a portable lactate analyser. LT is operationally defined as the exercise intensity or workload at which there is a sustained rise in blood lactate above baseline values, typically identified via the Dmax or fixed blood lactate concentration procedures.

**Peak Blood Lactate:** Peak blood lactate will be measured immediately post-exercise (within 3minutes of exhaustion) using the same lactate analyser to assess the maximal glycolytic response to the graded exercise test.

### 2.4. Statistical Analysis

Statistical analyses were conducted using SPSS version 27.0, with descriptive statistics (mean ± standard deviation) computed for all variables. The Shapiro–Wilk test was applied separately for power and endurance groups to assess normality ($p > 0.05$ indicating normal distribution). For normally distributed data, independent samples t-tests were used to compare $VO_2$ max, lactate threshold (LT), and peak blood lactate (PBL) between groups. Relationships among $VO_2$ max, LT, and PBL within each athlete group were examined using Pearson's correlation coefficient for normally distributed variables.

## 3. Findings

The descriptive statistics indicate clear physiological distinctions between power and endurance athletes across all measured variables. Endurance athletes exhibited a markedly higher $VO_2$ max (63.80 ± 1.19 $mL \cdot kg^{-1} \cdot min^{-1}$) compared to power athletes (48.95 ± 1.32 $mL \cdot kg^{-1} \cdot min^{-1}$), reflecting superior aerobic capacity consistent with adaptations from prolonged, high-volume endurance training. Similarly, lactate threshold values were higher in endurance athletes (82.45 ± 1.50 $mmol \cdot L^{-1}$) than in power athletes (68.20 ± 1.84 $mmol \cdot L^{-1}$), indicating an enhanced ability to sustain higher exercise intensities before significant lactate accumulation. In contrast, peak blood lactate was substantially greater in power athletes (15.42 ± 0.55 $mmol \cdot L^{-1}$) than in endurance athletes (9.04 ± 0.24 $mmol \cdot L^{-1}$), suggesting a greater reliance on anaerobic glycolysis and a higher tolerance for metabolic acidosis during short-duration, high-intensity efforts. These findings align with established training-induced physiological adaptations, whereby endurance athletes optimize oxygen transport and utilization, while power athletes develop maximal anaerobic output and buffering capacity.

**Table 1.** Descriptive statistics (Mean ± SD) for physiological variables in power and endurance athletes

| Variables | Power Athletes (n = 30) | Endurance Athletes (n = 30) |
|---|---|---|
| $VO_2$ Max ($mL.kg^{-1}.min^{-1}$) | 48.95 ± 1.32 | 63.80 ± 1.19 |
| Lactate Threshold ($mmol.L^{-1}$) | 68.20 ± 1.84 | 82.45 ± 1.50 |
| Peak Blood Lactate ($mmol/L^{-1}$) | 15.42 ± 0.55 | 9.04 ± 0.24 |

We will use inferential statistics to determine whether the mean difference between endurance and power athletes is statistically significant at the 5% significance level. However, before choosing a test, we will use the Shapiro-Wilk test to verify that the data are normal at the 0.05 significance level. The type of test will be selected based on the Shapiro-Wilk test results.

**Table 2.** Comparison of physiological variables amid power and endurance athletes using Shapiro-Wilk test results

| Variables | Shapiro-Wilk p-value (Power) | Shapiro-Wilk p-value (Endurance) | Normality Assumption Met? | Statistical Test Used | p-value | Significance |
|---|---|---|---|---|---|---|
| $VO_2$ Max ($ml.kg^{-1}.min^{-1}$) | .767 | .077 | Yes | Independent Sample t-test | .001 | Significant |
| Lactate Threshold ($mmol.L^{-1}$) | .304 | .293 | Yes | Same as Above | .001 | Significant |
| Peak Blood Lactate ($mmol/L^{-1}$) | .557 | .904 | Yes | Same as Above | .001 | Significant |

**Independent Test df for all variables = 58.*

The Shapiro–Wilk test results indicate that all physiological variables for both power and endurance athletes met the assumption of normality ($p > 0.05$), thereby justifying the use of parametric testing. Independent samples t-tests revealed statistically significant differences between the two groups for $VO_2$ max, lactate threshold, and peak blood lactate (all $p = 0.001$). Endurance athletes demonstrated significantly higher $VO_2$ max and lactate threshold values, reflecting superior aerobic capacity and delayed onset of blood lactate accumulation, while power athletes exhibited significantly higher peak blood lactate levels, indicative of greater anaerobic glycolytic capacity and tolerance to metabolic acidosis during high-intensity exertion. These results confirm distinct metabolic and cardiovascular adaptations associated with the demands of each sporting discipline, reinforcing the necessity of sport-specific conditioning approaches.

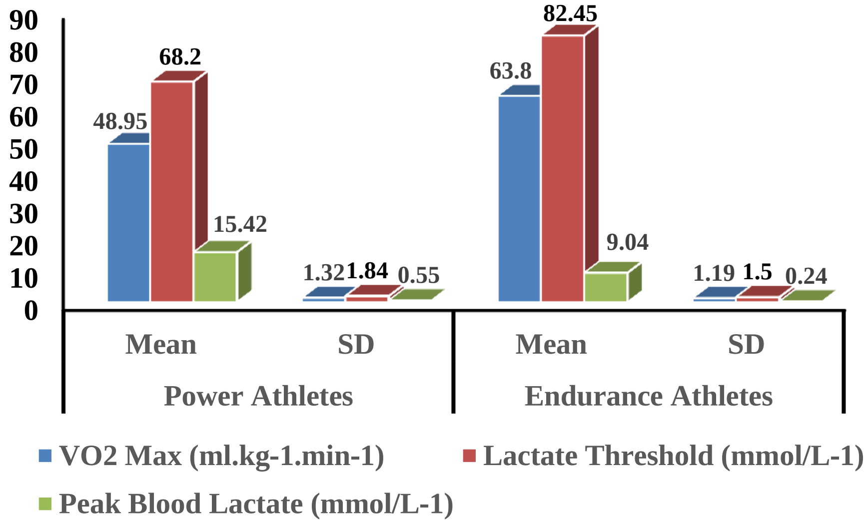


**Figure 1.** Graphical Representation of Mean and Standard Deviation of $VO_2$ Max, Lactate Threshold, and PBL of Power and Endurance Athletes

As per Table 2, the data of power and endurance athletes across all the variables are normally distributed. Therefore, the Pearson Correlation test will be used to assess the direction of the relationship between $VO_2$ Max, Lactate Threshold, and PBL among two groups.

**Table 3.** Correlation Analysis of $VO_2$ Max and LT among Power and Endurance Athletes

| Correlation between Variables | Power Athletes | Endurance Athletes |
|---|---|---|
| $VO_2$ Max – Lactate Threshold | .959** | .968** |
| Significance (2-tailed) | .000 | .000 |
| N (Sample Size) | 30 | 30 |

***. Correlation is significant at 0.05.*

The correlation analysis revealed a strong positive association between $VO_2$ max and lactate threshold in both power and endurance athletes. Among power athletes, $VO_2$ max demonstrated a statistically significant correlation with lactate threshold ($r$ = 0.959, $p$ < 0.01), indicating that higher aerobic capacity is closely linked to improved lactate clearance ability. Similarly, endurance athletes exhibited an even slightly stronger correlation ($r$ = 0.968, $p$ < 0.01), suggesting that their training adaptations may further enhance the interdependence of these physiological parameters. The high magnitude of correlation in both groups underscores the critical role of aerobic fitness in determining lactate threshold performance, regardless of athletic specialization. However, the marginally stronger correlation in endurance athletes may reflect the specific endurance training stimulus, which is known to optimize both maximal oxygen uptake and lactate kinetics.

Asian Journal of Basic Science & Research
Volume 7, Issue 3, Pages 155-165, July-September 2025

**Table 4.** Correlation Analysis of PBL and LT among Power and Endurance Athletes

| Correlation Between Variables | Power Athletes | Endurance Athletes |
|---|---|---|
| Lactate Threshold – Peak Blood Lactate | .381 | .291 |
| Significance (2-tailed) | .980 | .214 |
| N (Sample Size) | 30 | 30 |

***. Correlation is significant at 0.05.*

The correlation analysis between lactate threshold (LT) and peak blood lactate (PBL) among power and endurance athletes revealed no statistically significant association in either group. For power athletes, the Pearson correlation coefficient between LT and PBL was $r$ = 0.381 ($p$ = 0.980), indicating a weak positive relationship that did not reach significance. Similarly, in endurance athletes, the correlation was $r$ = 0.291 ($p$ = 0.214), also suggesting a weak, non-significant positive association. These findings imply that variations in lactate threshold are not strongly or consistently related to peak blood lactate levels in either athlete category. The lack of significance may be attributed to physiological differences in energy system utilization, lactate production, and clearance mechanisms across training specializations. Additionally, the absence of a meaningful correlation supports the notion that LT and PBL may represent distinct metabolic markers, influenced by different performance determinants, and should be considered independently when evaluating athletic conditioning.

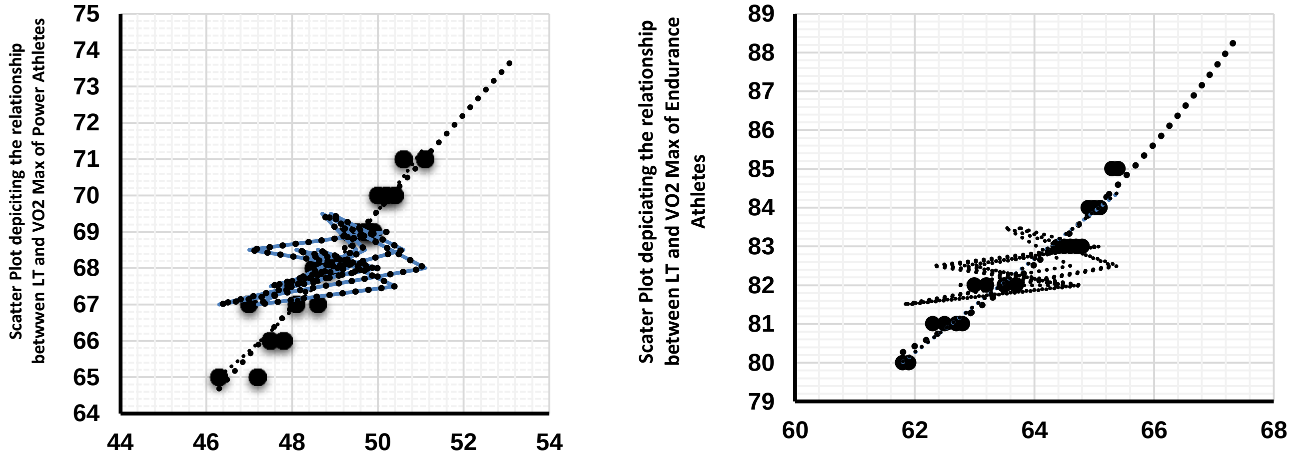


**Figure 2.** Graphical Relationship between $VO_2$ Max and Lactate Threshold among Power and Endurance Athletes

## 4. Discussion

The present study aimed to investigate the physiological differences and the relationship between Peak Blood Lactate (PBL), Lactate Threshold (LT), and $VO_2$ Max in power and endurance athletes. The result showed clear changes that were in line with the metabolic requirements of their respective sports. Long-term aerobic training causes both central and peripheral adaptations, including increased maximal cardiac output, increased mitochondrial density, and increased capillary networks, which together improve oxygen transport and utilization efficiency. This is supported by the much higher $VO_2$ max seen in endurance athletes [6,14]. According to Midgley & McNaughton (2021) these adaptations are linked to better performance in endurance sports and enable prolonged submaximal training.

Similarly, superior lactate clearance and a delayed transition to anaerobic glycolysis—adaptations typical of high-volume, moderate-intensity training—are reflected in endurance athletes' higher LT, both in absolute terms and as a percentage of $VO_2$ Max (Billat et al. 2023; Jones et al. 2022). The results of Faude et al. (2022) who emphasized LT as a more sensitive predictor of endurance performance than $VO_2$ max alone, are in line with this finding. The physiological interdependence of these variables is further supported by the strong positive correlations between $VO_2$ Max and LT in both athlete groups ($r = 0.959$ for power, $r = 0.968$ for endurance), as shown in Table 3, which confirms that aerobic capacity has a significant impact on the intensity at which lactate starts to accumulate [5]. The somewhat greater correlation in endurance athletes might result from their particular training plans, which improve metabolic stability and oxygen uptake kinetics over extended exertions (Midgley & McNaughton 2021).

In contrast, power athletes' significantly higher PBL is a result of their increased dependence on anaerobic glycolysis and improved buffering capacity, which allows them to tolerate high amounts of hydrogen ion accumulation during brief maximal activity [10,20]. In sprint-based or explosive events, where repeated high-intensity efforts necessitate quick ATP resynthesis from non-oxidative pathways, this adaptation is beneficial [15]. Since LT and PBL did not significantly correlate in either group, these metrics may reflect different physiological characteristics: As per Gladden (2020) PBL is more representative of maximal anaerobic power and acid-base buffering capacity, while LT mostly represents submaximal aerobic efficiency.

All of these results collectively support the idea that $VO_2$ max, LT, and PBL are complementary but different performance indicators, even though they may be connected in some situations [4]. The implications for coaches and practitioners are twofold: first, training regimens should be customized to meet the metabolic demands of the sport, with power athletes emphasizing anaerobic capacity and lactate tolerance, and endurance athletes focusing on increasing both $VO_2$ max and LT; second, athlete monitoring systems should use a multi-marker approach to capture the full physiological profile instead of depending on a single measure. To ascertain how specific training variable manipulations impact the interaction between aerobic and anaerobic performance markers in various athlete groups, future research could build on these findings by incorporating longitudinal intervention studies.

## 5. Conclusion

This study showed that power and endurance athletes had different physiological profiles, emphasizing how sport-specific training demands affect peak blood lactate (PBL), lactate threshold (LT), and $VO_2$ max. The $VO_2$ max and LT values of endurance athletes were noticeably higher, indicating improved oxygen transport, increased aerobic efficiency, and delayed lactate accumulation—adaptations linked to prolonged high-intensity performance. On the other hand, power athletes showed significantly higher PBL, which suggests a stronger tolerance to metabolic acidosis and a higher anaerobic glycolytic capacity—both of which are beneficial in high-intensity, brief activities.

While there was no significant link between LT and PBL, which shows that these variables reflect different aspects of performance, there was a large positive correlation between $VO_2$ max and LT in both athlete groups, demonstrating their tight physiological relationship. These results highlight the significance of adjusting training methods to the metabolic demands of individual sports: power athletes should prioritize anaerobic power and buffering ability, while endurance athletes should prioritize aerobic capacity and lactate clearance. A more thorough assessment of athletic ability can be obtained by using a multi-marker assessment framework, which makes it possible to identify talent intelligently, prescribe training precisely, and monitor performance effectively.

## 6. Suggestions for Future Research

To build upon the findings of this study, future research may consider:

1. Conduct longitudinal experimental studies to examine how targeted training programs influence $VO_2$ Max, Lactate Threshold, and Peak Blood Lactate over time in different athlete groups.

2. Include larger and more diverse samples, incorporating athletes from varied age groups, competitive levels, and sporting disciplines to enhance generalizability.

3. Explore gender-specific physiological responses, analyzing whether male and female athletes exhibit distinct adaptations in anaerobic and anaerobic markers.

4. Integrating biochemical and hormonal profiling, such as blood pH, bicarbonate levels, and lactate dehydrogenase activity, to deepen understanding of metabolic stress responses.

5. Assess the impact of nutritional strategies, including buffering agents and carbohydrate loading, on lactate kinetics and performance outcomes.

**Declarations**

**Source of Funding**

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Competing Interests Statement**

The authors declare that they have no competing interests related to this work.

**Consent for publication**

The authors declare that they consented to the publication of this study.

**Authors' contributions**

All the authors took part in literature review, analysis, and manuscript writing equally.

**Availability of data and materials**

Supplementary information is available from the authors upon reasonable request.

**Ethical Approval**

Ethical approval was obtained from the Institutional Ethics Committee of the Regional College of Physical Education (RCPE).

**Institutional Review Board Statement**

Not applicable for this study.

**Informed Consent**

All participants in this study voluntarily gave their informed consent prior to their involvement in the research.

**Acknowledgement**

Manish Acharjee sincerely expresses his gratitude to Dr. Rahul Dev Choudhury for his expert guidance in shaping the research concept and developing the methodology, which provided a strong foundation for this study. Manish Acharjee extends his heartfelt thanks to Dr. Gunjana Atreya for her invaluable support during the data collection process, ensuring the accuracy and reliability of the findings. Manish Acharjee also acknowledges his own contribution to writing the research paper and performing the data analysis.

**References**

[1] Midgley, A.W., & McNaughton, L.R. (2021). Time at $VO_2$ max: How much is needed for optimal training adaptations? Sport Medicine, 51(4): 41–52.

[2] Faude, O., Kindermann, W., & Meyer, T. (2022). Lactate threshold concepts: How valid are they? Sport Medicine, 52(4): 15–29.

[3] Jones, A.M., Burnley, M., Black, M.I., Poole, D.C., & Vanhatalo, A. (2022). The maximal oxygen uptake: Physiology, measurement, and application. European Journal of Sports Science, 22(1): 1–23.

[4] Kenney, W.L., Wilmore, J.H., & Costill, D.L. (2021). Physiology of sport and exercise (7th Edition). Human Kinetics.

[5] Coyle, E.F. (1999). Physiological determinants of endurance exercise performance. Journal of Science and Medicine in Sport, 2(3): 181–189.

[6] Bassett, D.R., & Howley, E.T. (2020). Limiting factors for maximum oxygen uptake and determinants of endurance performance. Medicine & Science in Sport & Exercise, 32(1): 70–84.

[7] Bassett, D.R., & Howley, E.T. (2021). High-intensity interval training, solutions to the programming puzzle. Sports Medicine, 43(5): 313–338.

[8] Jones, A.M., Burnley, M., Black, M.I., Poole, D.C., & Vanhatalo, A. (2022). The maximal metabolic steady state: Redefining the 'gold standard'. Physiological Reports, 10(2): 153–167.

[9] Midgley, A.W., & McNaughton, L.R. (2021). Lactate threshold strategies for endurance performance. Current Sports Medicine Reports, 20(9): 503–509.

[10] Beneke, R., Leithauser, R.M., & Ochentel, O. (2022). Blood lactate diagnostics in exercise testing and training. International Journal of Sports Physiology and Performance, 17(8): 1162–1170.

[11] Cairns, S.P. (2020). Lactic acid and exercise performance: Culprit or friend? Sports Medicine, 50(1): 15–23.

[12] Allen, D.G., Lamb, G.D., & Westerblad, H. (2008). Skeletal Muscle Fatigue: Cellular Mechanisms. Physiological Reviews, 88(1): 287–332.

[13] Gladden, L.B. (2020). Lactate metabolism: A new paradigm for the third millennium. Journal of Physiology, 599(3): 863–888.

[14] Laursen, P.B., & Rhodes, E.C. (2021). Factors affecting performance in an endurance event. Sports Medicine, 51(4), 789–804.

[15] Ross, A., & Leveritt, M. (2022). Energy system contributions to sprint performance in power athletes. Journal of Strength & Conditioning Research, 36(1): 45–54.

[16] Billat, V., Padilla, S., & Lepretre, P.M. (2023). Lactate threshold: Physiology and applications in endurance training. International Journal of Sports Physiology and Performance, 18(2): 150–160.

[17] Jones, A.M., Wilkerson, D.P., & Fulford, J. (2022). Physiological determinants of endurance performance: integrating $VO_2$ max, lactate threshold, and economy. Sports Medicine, 52(7): 1301–1314.

[18] Midgley, A.W., & McNaughty, L.R. (2021). Time at or near $VO_2$ max during continuous and intermittent running. Journal of Sports Science, 39(2), 123–132.

[19] Faude, O., Kindermann, W., & Meyer, T. (2009). Lactate threshold concepts: how valid are they? Sports Medicine, 52(9): 1910–1916.

[20] Carins, S.P. (2020). Lactic acid and exercise performance: culprit or friend? Sports Medicine, 50(1): 15–23.