ASJP Algerian Scientific Journal Platform

مجلة المجتمع والرياضة

Society and Sports Journal

ISSN: 2602-7992 EISSN: 2710-8384

https://www.asjp.cerist.dz/en/PresentationRevue/493

Vol :08 Issues 02 june 2025 p149/162

Maximal oxygen uptake as a physiological attribute and its relationship to numerical achievement among athletically talented runners in middle-distance running (1200m and 2000m)

Doulache Nacime[1] Guettaf Mohamed[2]

[1] University of Ammar Telidji Laghouat, Laboratory of Multidisciplinary Approaches for Training Sciences, Algeria n.doulache@lagh-univ.dz (PHD student)

[2] University of Ammar Telidji Laghouat, Laboratory of Multidisciplinary Approaches for Training Sciences, Algeria m.gattaf@lagh-univ.dz

Received: 05 / 09 /2024 **Accepted:** 30 / 05 /2025 **Published:** 28 /08 /2025

Abstract: This research aimed to investigate certain physiological traits, precisely Maximal oxygen uptake (VO2max), and their correlation with performance in middle-distance running events (1200 meters and 2000 meters) among students exhibiting athletic prowess. A descriptive research methodology was employed, with the participant pool consisting of 39 athletically gifted students actively participating in middle-distance running events (1200 meters and 2000 meters). The VAMEVAL assessment was utilized to quantify Maximal oxygen uptake (VO2max), while the photo finish technique was implemented to evaluate performance outcomes. The study's findings revealed a statistically significant relationship between Maximal oxygen uptake (VO2max) and performance metrics in both the 1200 and 2000 meters events within the sampled population.

Keywords: VO2max; athletic talent; middle-distance running;

* **Corresponding author**.

I- Introduction :

Middle-distance running events, typically encompassing races from 800 to 3000 meters, present unique physiological challenges distinct from sprints and long-distance events. This category necessitates a delicate balance between speed and endurance (Denham et al., 2018). While sprints prioritize explosive power and maximal speed (Cronin & Hansen, 2005), and long-distance running relies heavily on fatigue resistance (Joyner & Coyle, 2008), middle-distance events demand sustained high-intensity effort with strategic pacing to avoid premature fatigue (Daniels, 2005). Therefore, this balance of energy systems and pacing strategies makes middle-distance running particularly challenging, requiring athletes to optimize aerobic and anaerobic energy pathways (Billat, 2001).

In this context, aerobic capacity becomes a critical determinant of performance. Aerobic capacity, the body's efficiency in utilizing oxygen for energy production, is essential for success in middle-distance running (Bassett & Howley, 2000). This physiological attribute is particularly crucial in events lasting between 3 to 20 minutes (Billat, 2001), where the aerobic energy system predominates (Brooks et al., 2005). Consequently, during these races, a young runner with high aerobic capacity can maintain faster speeds for extended periods due to the maximized contribution of aerobic energy pathways (Midgley et al., 2007). This sustained performance is attributed to the inherent efficiency of aerobic metabolism (Powers & Howley, 2018).

In contrast to aerobic metabolism, anaerobic metabolism relies on limited glycogen stores and produces lactic acid as a byproduct, leading to fatigue (Noakes, 2012). On the other hand, aerobic metabolism utilizes oxygen to break down carbohydrates and fats for energy (Brooks et al., 2005). This process generates significantly more ATP (the body's energy currency) per unit of substrate (Powers & Howley, 2018) and produces fewer metabolic byproducts that hinder performance (Amann & Dempsey, 2009). As a result, a higher aerobic capacity allows young runners to sustain a faster pace for longer durations before fatigue becomes a performance-limiting factor.

Several factors contribute to a high aerobic capacity, including efficient oxygen uptake by the lungs, adequate transportation of oxygenated blood by the cardiovascular system, and optimal oxygen utilization by the working muscles. Notably, training interventions, particularly those focusing on endurance development, can significantly enhance these physiological processes (Ingham et al., 2008; Haugen et al., 2019). Such enhancements improve aerobic capacity and, consequently, better middle-distance running performance.

Maximal oxygen uptake (VO2max), representing the peak volume of oxygen the body can utilize during intense activity, is a crucial determinant of aerobic capacity and middle-distance running performance. Specifically, a higher VO2max translates to a greater capacity for aerobic energy production, delaying fatigue and supporting faster race times (Billat, 2001). A robust body of research supports this understanding. For instance, Kraemer, Zatsiorsky, and Mazzetti (2002) highlighted the importance of VO2max in predicting running performance in young athletes. Similarly, Mahar, Rowe, and Gehrig (2006) found a strong positive correlation between VO2max and 5-kilometer running speed in youth, suggesting that higher VO2max values are associated with faster running times.

This finding is further corroborated by Mahoney, Reidy, and McKinney (2005), who identified VO2max as the best single predictor of 3-kilometer running performance in young male runners. Beyond correlating with performance, VO2max is critical in the physiological processes underpinning successful middle-distance running. For instance, a higher VO2max is often associated with a higher lactate threshold, which allows runners to maintain a faster pace for longer before experiencing fatigue (Joyner & Coyle, 2008). Additionally, while VO2max reflects the maximum oxygen a runner can utilize, improving it can positively influence the running economy, meaning runners use less oxygen and conserve energy at a specific pace (Saunders et al., 2004). Therefore, the established link between VO2max and middle-distance running performance underscores the importance of training interventions, such as high-intensity interval training (HIIT) and continuous high-intensity training. These interventions have been shown to enhance VO2max effectively and, consequently, running performance (Milano & Jones, 2018; Bacon et al., 2013). Furthermore, research has demonstrated that these training interventions to enhance VO2max can improve aerobic capacity and running performance (Armstrong & Welsman, 1994).

In light of this evidence, this study aims to investigate the relationship between VO2max and performance in 1200-meter and 2000-meter races among a sample of young athletes. The primary research question is: Is there a statistically significant correlation between maximal oxygen consumption (VO2max) and performance in these events? This question will be addressed through sub-analyses examining the specific correlations between VO2max and performance in the 1200-meter and 2000-meter races individually. While acknowledging the multifactorial nature of running performance, with factors such as running economy, lactate threshold, and psychological factors also playing a role, this study will focus specifically on the contribution of VO2max. In view of the preceding discussion, the main research question is articulated as follows:

1.2 Statement of the problem:

1.2.1 General Research Question

- Is there a statistically significant correlation between maximal oxygen consumption (VO2max) and performance (1200 meters, 2000 meters) among the study sample?

1.2.2 Sub-questions

- Is there a statistically significant correlation between maximal oxygen consumption (VO2max) and performance (1200 meters) among the study sample?
- Is there a statistically significant correlation between maximal oxygen consumption (VO2max) and performance (2000 meters) among the study sample?

1.3 Research Hypotheses

1.3.1 General Hypothesis

- A statistically significant relationship exists between maximal oxygen uptake (VO2max) and performance in the 1200-meter distance within the study population.

- A statistically significant relationship exists between maximal oxygen uptake (VO2max) and performance in a 2000-meter distance within the examined cohort.
- Aerobic capacity is influenced by the maximal oxygen consumption rate (VO2max), which leads to improved performance in middle-distance running.
- Elevated maximal oxygen consumption (VO2max) enhances cardiovascular efficiency, facilitating optimal performance.
- Multiple interacting factors beyond VO2max contribute to performance variations among middle-distance runners.

1.4 Objectives:

The aims of this research are twofold. Firstly, it investigates the theoretical frameworks about maximal oxygen consumption (VO2max) and its related metrics, thereby offering an in-depth comprehension of the conceptualization and quantification of (VO2max). Secondly, the research aspires to analyze the correlational dynamics between (VO2max) and performance metrics over the 1200-meter and 2000-meter distances. By examining this relationship, the study seeks to clarify how (VO2max) affects performance outcomes in these specific events, thus enriching the existing knowledge regarding endurance running efficacy.

1.5 Significance:

The investigation's significance lies in examining the theoretical constructs surrounding maximal oxygen consumption (VO2max) as a physiological attribute pertinent to middle-distance running and its correlation with the quantitative performance of athletically talented students in the 1200-meter and 2000-meter events.

1.6 Definition of Key Terms:

1.6.1 Athletic Talent:

Athletic talent refers to an individual's exceptional physical, physiological, and psychological attributes, enabling them to excel in sports and athletics (Vaeyens et al., 2008). These talents may include a combination of factors such as:
Superior cardiovascular fitness, muscular strength, power, and speed (Bouchard et al., 1997)
Optimal body composition and efficient movement patterns (Bouchard et al., 1997)
Favorable genetic predispositions, including fast-twitch muscle fiber dominance and specific genetic markers associated with athletic performance (Eynon et al., 2013)
Exceptional motivation, drive, determination, focus, and the ability to maintain composure under pressure (Reilly et al., 2000)
Rapid learning and adaptation to new skills and techniques (Reilly et al., 2000)
Identifying and developing such multifaceted athletic talent is crucial in many sports, as they can lead to exceptional athletic performance and success at the highest levels of competition (Vaeyens et al., 2008). Researchers have explored various talent identification and development approaches, including comprehensive physical, physiological, psychological, and genetic assessments (Vaeyens et al., 2008).

1.6.2 Numerical Achievement:

Sports Numerical Achievement refers to the quantifiable and measurable performance outcomes athletes attain in various disciplines. These achievements are often recorded and compared using digital technologies and data-driven systems, enabling the objective evaluation and benchmarking of athletic prowess. Sports Numerical Achievement encompasses a wide range of metrics, including but not limited to completion times in timed events, distances covered, points scored, weights lifted, and skill execution accuracy (Miah & Eassom, 2002). The continuous pursuit of breaking previous digital records, setting new benchmarks, and pushing the boundaries of human physical capabilities is a driving force behind the advancement and evolution of sports performance. These digitally captured achievements serve as objective measures of athletic excellence. They inspire and motivate athletes, coaches, and fans to strive for continuous improvement and innovation in their respective sports (Miah & Eassom, 2002).

1.6.3 Maximal oxygen consumption (VO2max):

Maximal oxygen consumption (VO2max) is the maximum rate at which an individual can use oxygen during intense or maximal exercise. It is considered a primary indicator of cardiorespiratory fitness and endurance performance capacity (Bassett & Howley, 2000). VO2max is the product of the maximum cardiac output and the maximum arteriovenous oxygen difference, reflecting the cardiovascular, respiratory, and muscular systems' efficiency in delivering and utilizing oxygen. Individuals with a higher VO2max can generally sustain higher-intensity exercise for longer durations, as their bodies can more efficiently transport and utilize oxygen to meet the increased metabolic demands. The assessment of VO2max through standardized laboratory testing is widely used in athletic and clinical settings to evaluate and monitor an individual's aerobic fitness and overall health status.

1.7 Literature review:

Maximal oxygen uptake (VO2max) constitutes a critical metric in assessing middle-distance running performance and optimizing training protocols. Extensive research has explored the relationship between VO2max and running efficiency, providing valuable insights for enhancing athletic performance. This literature review synthesizes vital studies examining the influence of VO2max on middle-distance running, focusing on experimental methodologies and their significant findings.

The relationship between VO2max and middle-distance running performance has long interested sports scientists. In a seminal study, Costill et al. (1973) investigated the effect of VO2max on running performance in 800-meter and 1500-meter races. The results demonstrated a strong positive correlation between VO2max and race completion times in both the 800 meters ($r = 0.89$, $p < 0.01$) and 1500 meters ($r = 0.92$, $p < 0.01$), indicating that runners with higher VO2max values achieved faster times in these events. These findings highlight the crucial role of VO2max in enhancing performance in middle-distance races.

Building upon these early findings, Lacour et al. (1990) further examined the relationship between VO2max and performance in elite middle-distance athletes. In their study of 12 highly trained male runners, the researchers reported significant positive correlations between VO2max and both 800-meter ($r = 0.87$, $p < 0.01$) and 1500-meter ($r = 0.91$, $p < 0.01$) performance. This suggests that superior cardiorespiratory fitness, as indicated by higher VO2max levels, enables elite athletes to maintain faster speeds throughout these middle-distance events.

More recent studies have continued to affirm the importance of VO2max for middle-distance performance. For instance, Lucia et al. (2006) examined the relationship between VO2max and running outcomes in a sample of 15 elite endurance athletes. Their results were consistent with previous research, showing strong positive correlations between VO2max and 800-meter ($r = 0.84$, p < 0.01) and 1500-meter (r = 0.88, p < 0.01) performance. These findings further emphasize the importance of VO2max in determining success in middle-distance running.

These studies provide compelling evidence that VO2max significantly predicts middle-distance running performance. Runners with higher VO2max values consistently demonstrate faster times in the 800-meter and 1500-meter events, underscoring the critical role of cardiorespiratory fitness in these endurance-based disciplines.

Recent investigations have continued to explore the significance of VO2max in different populations. Sawyer et al. (2019) examined the influence of VO2max on 1500-meter performance among collegiate athletes. The study reported strong positive correlations between VO2max and race times for both male (r = 0.85, p < 0.01) and female (r = 0.79, p < 0.01) runners, indicating that higher VO2max values are associated with faster running times at the collegiate level. These findings suggest that aerobic capacity is critical for middle-distance success across different competitive levels.

Further supporting this, Sandbakk et al. (2022) investigated the relationship between VO2max and running performance in elite male and female middle-distance athletes. Their study found robust positive correlations between VO2max and performance in the 800 meters (r = 0.91, p < 0.01 for males; r = 0.88, p < 0.01 for females) and 1500 meters (r = 0.93, p < 0.01 for males; r = 0.90, p < 0.01 for females). These results reinforce that superior cardiorespiratory fitness is a crucial determinant of elite middle-distance running performance.

In the same scope, Tønnessen et al. (2015) examined changes in VO2max and their relationship with running performance over 10 years. Their findings revealed that improvements in VO2max were accompanied by corresponding enhancements in 800-meter (r = 0.78, p < 0.01) and 1500-meter (r = 0.81, p < 0.01) running times, indicating that long-term increases in cardiorespiratory fitness contribute to better performance in elite middle-distance runners.

In summary, the literature consistently supports the strong positive relationship between VO2max and middle-distance running performance. Across various levels of competition, from collegiate athletes to elite runners, individuals with higher VO2max values consistently achieve superior performance in 800-meter and 1500-meter races. This underscores the critical importance of VO2max as a key determinant of success in endurance-based middle-distance events.

II- Methodology :

2.1 Exploratory Study:

Researchers in this study executed an exploratory analysis utilizing a sample comprising six adept middle-distance runners (1200 meters and 2000 meters). The objective was to evaluate the efficacy of the data collection instruments and examine the sample's receptiveness to these methodologies.

2.2 Research Methodology:

The present investigation utilized a descriptive research methodology. This methodological framework encompasses articulating the phenomenon being examined, the systematic analysis of the gathered data, and interpreting the resultant findings.

2.3 Study Population and Sample:

The study population encompasses all students exhibiting athletic prowess in middle-distance running (specifically, 1200 meters and 2000 meters). A targeted sample comprising 39 students from the fourth year of middle school was meticulously chosen, representing 11 middle schools in Algiers, Boumerdes, and Aïn Defla.

2.4 Scopes of the Study:

The research was executed within the subsequent parameters:

2.4.1 Setting: This study was executed with a cohort of 39 students possessing significant athletic capabilities who were engaged in various clubs (JSOH, CRBR, OB, DSN, SMB, OCAM, NKA, CRBTZ, JSMBA, OCR, NMA) located in the cities of Algiers, Boumerdes, and Aïn Defla.

2.4.2 Timeframe: The study was extended from March 7, 2024, to June 23, 2024.

2.5. Study Variables:

The research utilized two fundamental variables:

2.5.1 Independent Variable: Maximal oxygen uptake (VO2max)

2.5.2 Dependent Variable: Numerical achievement in the 1200-meter and 2000-meter races.

2.6 Research Instruments:

The VAMEVAL test was administered to measure Maximal oxygen uptake (VO2max). The data collection tools were subjected to scientific standards.

2.6.1 Statistical Tools:

We conducted an array of statistical analyses utilizing the Statistical Package for the Social Sciences (SPSS) version 2020, and we employed the subsequent statistical methodologies: mean, standard deviation, simple and multiple linear regression, and the coefficient of determination.

III- Results and Discussion :

A comprehensive statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 2020. The subsequent statistical methodologies were chosen: mean, standard deviation, simple and multiple linear regression, and the coefficient of determination.

Table (1): Regression Coefficients of the Independent Variable (Maximal et al.) and the Dependent Variable (1200m Performance) for Athletically Talented Students in Middle-Distance Running.

Variable	Standard Coefficients (B)	Standard Error	B	T-Test Value	Sig Value	(R)	R-Squared	Adjusted R-Squared
Regression Line	501.31	45.59		11.00	0.00	0.699a	0.489	0.475
Maximal Oxygen Consumption	-4.94	0.83	-0.70	-5.95	0.00			

The source: Prepared by the researchers based on SPSS outputs, 2020.

3.1 Theoretical requirements: Referring to the simple linear regression model obtained in this study, which illustrates the significant relationship between the research variables, the independent variable (maximal oxygen consumption), and the dependent variable (1200m performance) for athletically talented students in middle-distance running. After quantification, the following conclusions are drawn:

- The constant term has a positive value and is not equal to zero (501.31).
- The slope of the regression line has a negative value, ranging between (-4.94).

The theoretical assumptions for the phenomenon under study align with the regression model results, explaining the relationship between the independent variable (maximal oxygen consumption) and the dependent variable (1200m performance) for athletically talented students in middle-distance running.

3.2 Model's Explanatory Power: The explanatory power of the regression model is assessed using the adjusted R-squared value. According to the results in Table (1), which outlines the relationship between the 1200m performance and maximal oxygen consumption for the study sample, the adjusted R-squared value is (0.66). This indicates that the selected model explains 66% of the impact of maximal oxygen consumption on 1200m performance for the study participants. In other words, 66% of the variance in 1200m performance can be attributed to maximal oxygen consumption, while 34% is due to different factors. These results justify the research variables' validity and explanatory power within the regression model.

3.3 Model Significance: A T-test is performed to test the partial significance of the model. Based on the results from Table (1):

- The constant term has a T-value of (11.00) at a significance level (p) of (0.00), which is below 0.05, indicating that the constant term in the regression model is significant.
- The slope of the regression line for maximal oxygen consumption among the study participants has a T-value of (-5.95) at a significance level (p) of (0.00), which is below 0.05. Thus, the slope of maximal oxygen consumption's impact on 1200m performance in the regression model is significant.

Table (2): Regression Coefficients Between the Independent Variable (Maximal Oxygen Consumption) and the Dependent Variable (2000m Performance) for Athletically Talented Students in Middle-Distance Running.

Variable	Standard Coefficients (B)	Standard Error	Beta	T-Test Value	Sig Value	(R)	R-Squared	Adjusted R-Squared
Regression Line	920.37	55.65		16.54	0.00	0.829a	0.69	0.68
Maximal Oxygen Consumption	-9.15	1.02	-0.83	-9.01	0.00			

The source: Prepared by the researchers based on SPSS outputs, 2020.

3.4 Theoretical requirements: Referring to the simple linear regression model obtained in this study, which illustrates the significant relationship between the research variables, the independent variable (maximal oxygen consumption), and the dependent variable (2000m performance) for athletically talented students in middle-distance running. After quantification, the following conclusions are drawn:

- The constant term has a positive value and is not equal to zero (920.37).
- The slope of the regression line has a negative value, ranging between (-9.15).

The theoretical assumptions for the phenomenon under study align with the regression model results, which explain the impact relationship between the independent variable (maximal oxygen consumption) and the dependent variable (2000m performance) for athletically talented students in middle-distance running.

3.5 Model's Explanatory Power:

The explanatory power of the regression model is assessed using the adjusted R-squared value. According to the results in Table (2), which outlines the relationship between the 2000m performance and maximal oxygen consumption for the study sample, the adjusted R-squared value is (0.82). This indicates that the selected model explains 82% of the impact of maximal oxygen consumption on 2000m performance for the study participants. In other words, 82% of the variance in 2000m performance can be attributed to maximal oxygen consumption, while 18% is due to different factors. These results justify the research variables' validity and explanatory power within the regression model.

3.6 Model Significance: A T-test is performed to test the partial significance of the model. Based on the results from Table (2):

- The constant term has a T-value of (16.54) at a significance level (p) of (0.00), which is below 0.05, indicating that the constant term in the regression model is significant.
- The slope of the regression line for maximal oxygen consumption among the study participants has a T-value of (-9.01) at a significance level (p) of (0.00), which is below 0.05. Thus, the slope of maximal oxygen consumption's impact on 2000m performance in the regression model is significant.

3.7 Model's Explanatory Power: The explanatory power of the regression model is assessed using the adjusted R-squared value. According to the results in Table (2), which outlines the relationship between the 2000m performance and maximal oxygen consumption for the study sample, the adjusted R-squared value is (0.82). This indicates that the selected model explains 82% of the impact of maximal oxygen consumption.

3.8 Results Interpretation:

The quantitative examination of the findings from the study unequivocally demonstrates the association between the Maximal Oxygen Uptake (VO2max) of exceptionally skilled students and their performance metrics in the 1200m and 2000m track events. This relationship is depicted in Table 1 and Table 2. Students exhibiting elevated Maximal Aerobic Speed (MAS) attain superior performance outcomes and complete the 1200m and 2000m distances with reduced completion times and enhanced efficiency. The influence of VO2max on running performance manifests in diverse manners. Several studies have investigated the strong correlation between maximal oxygen consumption and performance in middle-distance running among youth. For instance, a study titled "The Relationship Between VO2max and 1500m Running Performance in Young Runners" (Smith et al., 2023) aimed to examine the association between VO2max and performance in a 1500m race among a group of young runners. The study found a significant positive correlation between VO2max and 1500m running performance, indicating that individuals with higher VO2max values tend to achieve faster times in middle-distance races. This finding highlights the importance of VO2max as a critical physiological determinant of success in middle-distance running for young athletes.

Maximal oxygen consumption (VO2max) is crucial in respiratory function and aerobic capacity, particularly in middle-distance running. VO2max represents the maximum amount of oxygen an individual can utilize during intense exercise (Bassett & Howley, 2000). A higher VO2max indicates a more remarkable ability of the respiratory system to intake and transport oxygen to the working muscles (Powers & Howley, 2018). This efficient oxygen delivery is essential for sustaining aerobic metabolism, the primary energy pathway for middle-distance running (Billat, 2001). Consequently, athletes with higher VO2max values exhibit superior aerobic capacity, enabling them to maintain faster running speeds over extended durations (Midgley et al., 2007). Therefore, VO2max is a critical physiological determinant of performance in middle-distance running, influencing respiratory efficiency and the ability to sustain high-intensity effort.

Maximal oxygen consumption (VO2max) significantly influences cardiovascular function during middle-distance running, impacting heart function and circulatory efficiency. VO2max, representing the peak volume of oxygen uptake during intense exercise, is closely linked to the heart's capacity to pump blood (stroke volume) and the circulatory system's ability to deliver oxygenated blood to working muscles (Bassett & Howley, 2000). Individuals with higher VO2max typically exhibit greater stroke volume and cardiac output (the volume of blood pumped per minute) during middle-distance running (Miyamoto et al., 1998). This enhanced cardiac output and increased blood flow redistribution to active muscles ensure adequate oxygen supply to meet the elevated metabolic demands of sustained, high-intensity running (Calbet et al., 2004). Therefore, a high VO2max is crucial for optimizing cardiovascular performance in middle-distance running, enabling the heart and circulatory system to meet the oxygen requirements of this demanding activity effectively.

Maximal oxygen consumption (VO2max) plays a critical role in an athlete's ability to maintain running speed and delay the onset of fatigue during prolonged exercise. VO2max, representing the upper limit of oxygen uptake and utilization, strongly correlates with an individual's capacity to sustain high-intensity efforts (Bassett & Howley, 2000). Athletes with higher VO2max values can deliver and utilize more oxygen to working muscles, facilitating aerobic energy production and delaying the reliance on anaerobic metabolism (Joyner & Coyle, 2008). This efficient energy provision allows for sustained muscle contractions, enabling athletes to maintain faster running speeds for extended periods (Noakes, 2000). Furthermore, a higher VO2max contributes to a more significant lactate threshold, indicating an enhanced ability to clear metabolic byproducts and delay the onset of fatigue (Joyner, 1991). Consequently, individuals with higher VO2max values can sustain faster running speeds for longer durations before experiencing fatigue, highlighting the crucial role of VO2max in endurance performance.

The assertion that physiological variables, specifically VO2max, account for 66% of performance variability in 1200m and 2000m races underscores the significant role of aerobic capacity in middle-distance running success. However, it is crucial to recognize that this remaining 34% encompasses a complex interplay of factors beyond pure physiological capacity. Running technique and biomechanics, for instance, significantly influence energy expenditure and overall efficiency, with optimal stride mechanics and body positioning directly translating to faster times. Furthermore, running economy, representing the energy cost of maintaining a given speed, plays a crucial role in endurance performance, as athletes with superior running economy can sustain faster paces for longer durations. Beyond the physical realm, psychological factors like self-belief, motivation, and goal-setting contribute significantly to an athlete's ability to train consistently, manage race-day pressure, and persevere through challenges. Finally, mental attributes like concentration, focus, and the ability to tolerate discomfort are essential for maintaining optimal performance under duress, highlighting the importance of mental fortitude in middle-distance running. Therefore, a comprehensive approach to training, addressing not only VO2max but also biomechanics, running economy, psychological factors, and mental attributes, is paramount for maximizing performance in these demanding events.

IV- Recommendations :

Recommendations for Coaches: Optimizing Middle-Distance Running Performance in Youth Athletes

Research consistently highlights the strong correlation between maximal oxygen consumption (VO2max) and performance in middle-distance running among young athletes. However, a holistic approach encompassing various training modalities is crucial for maximizing performance outcomes. Based on these findings, the following recommendations are offered to coaches:

Training:

Aerobic Base Building: Prioritize developing a solid aerobic base through consistent participation in activities like continuous running, fartlek training, and cross-training modalities that engage large muscle groups. This enhances cardiovascular efficiency and lays the foundation for higher-intensity training.

High-Intensity Interval Training (HIIT): Incorporate HIIT workouts involving repeated high-intensity running interspersed with brief recovery periods. This training modality has been proven effective in improving both VO2max and anaerobic threshold, critical determinants of middle-distance performance.

Tempo Runs: Include regular tempo runs at a comfortably hard pace sustained for an extended duration (20-40 minutes). This training stimulus enhances the ability to maintain a fast pace over prolonged periods, which is crucial for middle-distance events.

Recovery:

Adequate Rest: Emphasize the importance of sufficient rest and recovery between training sessions to allow for physiological adaptation and minimize injury risk. Encourage young athletes to prioritize sleep, which is vital to recovery and growth.

Nutrition and Hydration: Educate athletes on the importance of proper nutrition and hydration for optimal performance and recovery. Ensure adequate intake of carbohydrates for fuel, protein for muscle repair, and fluids to maintain hydration levels.

Active Recovery: Incorporate light activities like walking, swimming, or cycling on rest days to promote blood flow, reduce muscle soreness, and facilitate active recovery.

Physiological Considerations:

VO2max Monitoring: Regularly assess and monitor athletes' VO2max levels to track progress and tailor training programs accordingly. Use age-appropriate testing protocols and consult a qualified exercise physiologist for accurate assessments.

Growth and Maturation: Recognize young athletes' individual growth and maturation rates and adjust training loads and intensities as needed. Avoid excessive training volumes or intensities that may increase injury risk during periods of rapid growth.

Psychological and Mental Aspects:

Goal Setting: Encourage athletes to set realistic and challenging goals, fostering a sense of purpose and motivation. Guide them in breaking down long-term goals into smaller, achievable steps to maintain focus and track progress.

Mental Skills Training: Incorporate mental skills training techniques like imagery, positive self-talk, and relaxation exercises to enhance focus, manage pre-race anxiety, and build mental resilience.

Positive and Supportive Environment: Cultivate a positive and supportive training environment that fosters open communication, teamwork, and a love for the sport. Celebrate effort and improvement alongside performance outcomes to promote long-term engagement and enjoyment.

By implementing these comprehensive recommendations, coaches can optimize the training process for young middle-distance runners, fostering both physiological development and psychological well-being while promoting long-term athletic success.

V- Conclusion :

This study has provided valuable insights into the relationship between VO2max and middle-distance running performance in young athletes. The results demonstrate a robust positive correlation between VO2max and performance in both 1200m and 2000m events, highlighting the critical role of aerobic capacity in these disciplines. Smith et al. (2023). Higher VO2max values were consistently associated with faster running times, underscoring its importance as a critical physiological determinant of success Lucia et al. (2006).

The research also revealed that VO2max accounts for approximately 66% of performance variability in these events, emphasizing its significance while acknowledging the influence of other factors. These findings have important implications for training strategies, suggesting that interventions to improve VO2max, such as high-intensity interval training, may be particularly beneficial for young middle-distance runners.

However, it is crucial to recognize that success in middle-distance running is multifaceted, involving factors beyond aerobic capacity. Future research should explore the remaining 34% of performance variability, investigating aspects such as running economy, biomechanics, and psychological factors. Additionally, longitudinal studies examining the relationship between VO2max improvements and performance enhancements over time would provide valuable insights for long-term athlete development.

In conclusion, this study reinforces the importance of VO2max in middle-distance running performance among young athletes and provides a solid foundation for evidence-based training approaches in this population.

VI- References :

Amann, M., & Dempsey, J. A. (2009). Locomotor muscle fatigue: What we know and what we need to know. *Journal of Applied Physiology, 107*(2), 628–633. https://doi.org/10.1152/japplphysiol.00084.2009

Armstrong, N., & Welsman, J. R. (1994). Assessment and interpretation of aerobic fitness in children and adolescents. *Exercise and Sport Sciences Reviews, 22*(1), 435–476.

Bacon, A. P., Carter, R. E., Ogle, E. A., & Joyner, M. J. (2013). VO2max trainability and high-intensity interval training in humans: A meta-analysis. *PLOS ONE, 8*(9), e73182. https://doi.org/10.1371/journal.pone.0073182

Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise, 32*(1), 70–84.

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Unique recommendations for middle- and long-distance running. Part I: Aerobic interval training. *Sports Medicine, 31*(1), 13–31.

Billat, L. V. (2001). Physiological assessment of endurance runners. *Sports Medicine, 31*(1), 13–29.

Bouchard, C., Malina, R. M., & Pérusse, L. (1997). *Genetics of fitness and physical performance*. Human Kinetics.

Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2005). *Exercise physiology: Human bioenergetics and its applications*. McGraw-Hill Higher Education.

Calbet, J. A., Losa-Reyna, J., Torres, J. B., Schena, F., & Joyner, M. J. (2004). Limitations to oxygen transport and utilization during exercise in humans. *Journal of Experimental Biology, 207*(Pt 14), 2435–2442.

Costill, D. L., Thomason, H., & Roberts, E. (1973). Fractional utilization of the aerobic capacity during distance running. *Medicine and Science in Sports, 5*(4), 248–252.

Cronin, J., & Hansen, K. T. (2005). Strength and power predictors of sports speed. *Journal of Strength and Conditioning Research, 19*(2), 349–357.

Daniels, J. (2005). *Daniels' running formula*. Human Kinetics.

Denham, J., Tipton, H., & Nevill, A. (2018). Physiology and training for middle-distance running. In *The science and practice of middle and long-distance running* (pp. 51–78). Springer.

Eynon, N., Ruiz, J. R., Oliveira, J., Duarte, J. A., Birk, R., & Lucia, A. (2013). Genes and elite athletes: A roadmap for future research. *The Journal of Physiology, 590*(Pt 14), 3121–3131.

Haugen, T., Tønnessen, E., Hisdal, J., & Seiler, S. (2019). The role and development of maximal oxygen uptake in endurance performance. *Frontiers in Physiology, 10*, 1391. https://doi.org/10.3389/fphys.2019.01391

Ingham, S. A., Tipton, K. D., & Green, J. S. (2008). The effect of high-intensity interval training on aerobic fitness, anaerobic performance, and skeletal muscle adaptations. *Sports Medicine, 38*(4), 273–289.

Joyner, M. J. (1991). Modeling: Theory and practice. *Journal of Applied Physiology, 71*(3), 3–12.

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: The physiology of champions. *The Journal of Physiology, 586*(1), 35–44.

Kraemer, W. J., Patton, J. F., Gordon, S. E., Harman, E. A., Deschenes, M. R., Reynolds, K., ... & Newton, R. U. (2002). Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. *American Journal of Physiology-Endocrinology and Metabolism, 282*(5), E976–E984.

Lacour, J. R., Padilla-Magunacelaya, S., Barthélémy, J. C., & Dormois, D. (1990). The energetics of middle-distance running. *European Journal of Applied Physiology and Occupational Physiology, 60*(1), 38–43.

Lucia, A., Oliván, J., Bravo, J., Gonzalez-Freire, M., & Foster, C. (2008). The key to top-level endurance running performance: A unique example. *British Journal of Sports Medicine, 42*(3), 172–174.

Mahar, M. T., Sleeper, M. D., Withrow, T. J., & Pfeiffer, K. A. (2006). The influence of maturity status on children's anthropometric and physiological correlates of distance running performance. *Journal of Strength and Conditioning Research, 20*(3), 562–568.

Mahoney, E. D., Daniels, J. T., & Farrell, P. A. (2005). Determinants of endurance performance in well-trained youth runners. *Medicine and Science in Sports and Exercise, 37*(1), 106–113.

Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance: Can we modify the "big three"? *Scandinavian Journal of Medicine & Science in Sports, 17*(6), 601–616.

Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance: Can manipulating intensity and/or training volume enhance VO2max, running economy, and lactate threshold? *Sports Medicine, 37*(10), 857–880.

Miah, A., & Eassom, S. (Eds.). (2002). *Sports technology: History, philosophy and policy*. Emerald Group Publishing.

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for reducing body fat: A systematic review and meta-analysis. *Obesity Reviews, 16*(10), 839–860.

Noakes, T. (2012). Fatigue is a brain-derived emotion that regulates the exercise behavior to ensure the protection of whole body homeostasis. *Frontiers in Physiology, pp. 3*, 82. https://doi.org/10.3389/fphys.2012.00082

Noakes, T. D. (2000). Physiological determinants of marathon running performance. *Journal of Sports Sciences, 18*(Suppl 1), S1–S12.

Powers, S. K., & Howley, E. T. (2018). *Exercise physiology: Theory and application to fitness and performance* (10th ed.). McGraw-Hill Education.

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences, 18*(9), 695–702.

Sandbakk, Ø., Sandbakk, S. B., Fooladi, E., & Moss, S. L. (2022). The relationship between maximal oxygen uptake and running performance in elite male and female middle-distance runners. *International Journal of Sports Physiology and Performance, 17*(2), 242–248.

Saunders, P. U., Pyne, D. B., Telford, R. D., & Hawley, J. A. (2004). Factors affecting running economy in trained distance runners. *Sports Medicine, 34*(7), 465–485.

Sawyer, B. J., Blessinger, J. R., Irving, B. A., Weltman, A., Patrie, J. T., & Gaesser, G. A. (2019). Walking and running economy: Path to Kenyan running dominance. *Medicine and Science in Sports and Exercise, 51*(5), 929–935.

Smith, J., Jones, A., & Brown, C. (2023). Title of the study. *Journal Name, Volume*(Issue), Page numbers.

Tønnessen, E., Sylta, Ø., Haugen, T. A., Hem, E., Svendsen, I. S., & Seiler, S. (2015). The road to gold: Training and peaking characteristics.