

The Role of Anaerobic Lactic Capacity in Squash Performance

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(Submission Track: Received: 11-Agustus -2026, Final Revision: 18-09-2026, Available Online: 28-09- 2026)

Abstract. Squash is a high intensity intermittent racket sport in which the anaerobic lactic (glycolytic) energy system may contribute to sustaining repeated sprints, rapid direction changes, and prolonged rallies. However, research on the contribution of anaerobic lactic capacity to squash performance remains limited compared to studies on aerobic capacity. This study aimed to examine the correlation between anaerobic lactic capacity and match performance and to determine its contribution to performance among squash athletes. A correlational quantitative design was used, involving 18 national squash athletes (9 males, 9 females) from the Bandung City Squash team, selected through purposive sampling. Anaerobic lactic capacity was assessed using a 150 meter run test, while performance was measured through match ranking obtained from a round-robin internal competition. Data were analyzed using Spearman's rho correlation and simple linear regression. Results showed a strong, significant positive correlation between anaerobic lactic capacity and match ranking ($r = 0.891$, $p = 0.001$), with anaerobic lactic capacity explaining 75.3% of the variance in performance ($R^2 = 0.753$). This relationship remained significant for both male and female athletes. These findings suggest that anaerobic lactic capacity is a potential performance related factor and may be considered in training program design.

Keywords: *anaerobic lactic capacity; squash; match performance; energy system; athlete*



INTRODUCTION

Squash is a high-intensity intermittent racket sport that demands a combination of aerobic and anaerobic capacities through short sprint bouts, rapid changes of direction, and repeated rallies interspersed with brief recovery periods. Like other racket sports, squash is dominated by explosive activities including short sprints, rapid changes of direction (agility), lunges, and repeated strokes throughout rallies. All racket sports share an intermittent characteristic, in which rally duration ranges from 3 to 10 seconds in tennis and badminton, and approximately 18 seconds in squash, with a work-to-rest ratio ranging from 1:2 to 1:5 (Jansen et al., 2021). Squash athletes are required to perform repeated short sprints, rapid changes of direction, explosive lunges, and high-intensity rallies within a dynamic work-rest pattern (Charron et al., 2020; Wilkinson et al., 2009).

These activity characteristics cause the energy demands during a match to be dominated by the anaerobic system, particularly during high-intensity rally phases. Anaerobic metabolism (without oxygen), which includes substrate-level phosphorylation through the breakdown of phosphocreatine (PCr) and muscle glycogen (the phosphagen and glycolytic systems), is ideal for providing immediate, short-term energy delivery during explosive, high-intensity efforts (Gastin & Suppiah, 2026). In squash, which requires rapid movement, the body must deliver energy quickly. During a match, elite squash athletes work at an average intensity of 81–92% of maximum heart rate, with approximately 25% of playing time occurring at an intensity above 90% $\text{VO}_{2\text{max}}$, indicating substantial aerobic demand, while average blood lactate concentrations exceeding 8 mmol/L specifically indicate a high contribution from the anaerobic glycolytic (anaerobic lactic) system during the match (James et al., 2022; Turner et al., 2024). This is why good anaerobic lactic capacity is one of the important factors for squash athletes in maintaining on court performance.

Anaerobic lactic capacity is an important aspect of squash performance because it is directly related to an athlete's ability to sustain repeated high-intensity efforts throughout a match. This is due to the high energy demands of repeatedly performed high-intensity activities, such that the anaerobic glycolytic system plays a role in maintaining ATP production as phosphagen stores begin to decline. Anaerobic glycolysis is an important source of ATP during a single sprint, and an increased contribution from anaerobic metabolism can enhance repeated sprint performance. In addition, the ability

to recover between sprints is supported by aerobic fitness through an increased rate of phosphocreatine resynthesis and muscle buffering capacity (Bishop et al., 2011). Conversely, limitations in anaerobic lactic capacity can reduce movement speed, stroke accuracy, and the effectiveness of game strategy, particularly in the final stages of a match when physiological fatigue increases. Therefore, evaluating anaerobic lactic capacity is important in the process of assessing athletes' physical condition and in designing training programs based on the specific metabolic demands of squash.

Various studies have identified that reaction time, coordination, agility, and aerobic capacity (VO_{2max}) play important roles in squash performance (Palgunadhi et al., 2018; Palgunadhi, Nuryanti, Kurniawan, Hidayat, et al., 2025; Palgunadhi, Nuryanti, Kurniawan, Jajat, et al., 2025). Previous research conducted by the author has also shown that aerobic capacity (VO_{2max}) is one of the physiological factors contributing to squash athletes performance. These findings confirm the importance of the aerobic system in supporting the inter-rally recovery process and in sustaining performance throughout a match. On the other hand, the characteristics of squash play dominated by repeated sprints, rapid changes of direction, and high-intensity rallies indicate that the anaerobic system, particularly anaerobic lactic capacity, also plays an equally important role. Most studies on national-level squash athletes have focused on aerobic capacity and motor skill components, while studies evaluating anaerobic lactic capacity as a determinant of performance remain very limited. This condition means that information regarding the contribution of anaerobic lactic capacity to squash athletes' performance remains incomplete, necessitating further research as a basis for developing training programs appropriate to the metabolic demands of squash. Based on the above, the objectives of this study are: 1) to determine whether there is a correlation between anaerobic lactic capacity and squash performance; and 2) to determine the magnitude of the influence or contribution of anaerobic lactic capacity to squash performance.

METHOD

The research method used was correlational research with a quantitative approach. A correlational study describes the extent to which two or more quantitative variables are related to one another, and this is done using a correlation coefficient (J. Fraenkel et al., 2015). This study was conducted over different time periods, with the

ranking test performed on 17–23 January 2025, while the anaerobic lactic test was conducted on 26 January 2025.

The research sample consisted of national squash athletes who are members of the Bandung City Squash team, West Java. The sample was selected using a purposive sampling technique, based on specific criteria or considerations. The sample size in a correlational study should not be less than 50 (J. R. . Fraenkel et al., 2023). However, due to the limited number of athletes meeting the specified criteria, the sample used was fewer than 50. In this study, the sample consisted of 18 National Squash athletes from Bandung City, comprising 9 male athletes and 9 female athletes.

The instrument used in this study was a 150 meter run test to measure athletes' anaerobic lactic capacity, a field-based running test consistent with the category of running-based anaerobic sprint assessments shown to have acceptable compatibility with the Wingate anaerobic test as a criterion measure of anaerobic power (Nara et al., 2022). Anaerobic lactic capacity was measured using a 150 meter run test, with the protocol based on the procedure described in 101 Performance Evaluation Tests (Mackenzie, 2005). Prior to testing, each athlete completed a standardized warm-up. Athletes then performed a single maximal effort run over a 150 meter distance from a standing start, with time recorded using a stopwatch to the nearest 0.01 second. This test was originally designed to monitor sprint specific endurance and to predict 100-meter sprint performance in track athletes (Mackenzie, 2005). In the present study, this protocol was adapted as a field based instrument to assess anaerobic lactic capacity, on the basis that during a maximal effort lasting approximately 30 seconds, the glycolytic (anaerobic lactic) energy system provides the greatest relative contribution (56%), compared to the ATP-PC (28%) and aerobic (16%) systems (Smith & Hill, 1991). Meanwhile, to assess athletes performance, match ranking data were used, obtained through an internal match simulation using a round-robin system, so that every athlete competed against every other athlete. Rankings were determined based on the number of points obtained during the competition. All matches were conducted using a best of five games format.

After the sample and research instruments were established, the next stage was data collection. Data collection began with the organization of an internal competition using a round-robin system to obtain ranking data for each athlete. Subsequently, on a different, non-consecutive day, all sample athletes performed the 150 meter run test to

measure anaerobic lactic capacity. The collected data were then analyzed using IBM SPSS version 25. The analysis of the relationship between anaerobic lactic capacity and match ranking was conducted using Spearman's rho correlation test, since the match ranking variable is ordinal-scale data, with the resulting coefficient interpreted according to standard guidelines for the strength of correlation coefficients (Schober & Schwarte, 2018). Subsequently, a simple linear regression analysis was performed to determine the contribution or influence of anaerobic lactic capacity on performance (match ranking).

RESULT AND DISCUSSION

Result

According to Table 1, a total of 18 athletes participated in the measurement of anaerobic lactic capacity using the 150-meter run test. The mean time obtained was 23.65 seconds (SD = 3.76), with a range of 18.70 to 30.75 seconds, reflecting a fairly wide range of anaerobic lactic capacity within this group.

For the performance measurement using match ranking, the mean value obtained was 9.50 (SD = 5.34), with a range from 1 to 18. This indicates that athletes match performance was distributed across rankings from 1 to 18.

Table 1. Descriptive Statistics

Variable	N	Min	Max	Sum	Mean	Std. Deviation
Anaerobic Lactic	18	18.70	30.75	425.62	23.6456	3.75912
Match Ranking	18	1	18	171	9.50	5.339
Valid N (listwise)	18					

Table 2. Correlations between Anaerobic Lactic with Match Ranking (Spearman's rho)

Variable		Anaerobic Lactic	Match Ranking
Spearman's rho	Anaerobic Lactic	Correlation Coefficient	1.000
		Sig. (2-tailed)	.891**
		N	.001
	Match Ranking	Correlation Coefficient	18
		Sig. (2-tailed)	.891**
		N	.001
			18

Table 1 shows that 18 athletes completed the 150-meter run test, with a mean time of 23.65 ± 3.76 seconds and a range of 18.70–30.75 seconds. Match ranking ranged

from 1 to 18, with a mean of 9.50 ± 5.34 . All 18 athletes had complete data for both variables.

Table 2 shows that the results of the Spearman correlation test showed a significant relationship between anaerobic lactic capacity and squash athletes' match ranking ($r = 0.891$, $p = 0.001 < 0.05$). The direction of the correlation was positive (in the same direction), meaning that higher anaerobic lactic capacity (i.e., shorter time) tended to be followed by a better ranking (i.e., a lower ranking number). The strength of this relationship was very strong and statistically significant.

Table 3 shows that the results of the simple linear regression analysis showed that anaerobic lactic capacity had a significant effect on match ranking ($F = 48.827$; $p = 0.001 < 0.05$). The coefficient of determination ($R^2 = 0.753$) indicated that 75.3% of the variation in match ranking could be explained by anaerobic lactic capacity, while the remaining 24.7% was influenced by other factors outside the research model. The positive regression coefficient ($B = 1.233$; $\beta = 0.868$; $t = 6.988$; $p = 0.001 < 0.05$) indicated that an improvement in anaerobic lactic capacity was followed by better achievement (with rank 1 in match ranking representing the highest value).

Table 3. Results of the Simple Linear Regression Analysis

Variable	B	β	t	F	R	R^2	Adjusted R^2	Sig.
Anaerobic Lactic	1.233	.868	6.988	48.827	.868	.753	.738	.001

As an additional analysis, the authors conducted a simple linear regression analysis based on sex, as shown in Table 4. The results indicated that among male athletes, anaerobic lactic capacity had a significant effect on match ranking ($B = 0.905$; $\beta = 0.815$; $t = 3.717$; $F = 13.819$; $R^2 = 0.664$; $p = 0.007 < 0.05$). These results indicate that 66.4% of the variation in match ranking among male squash athletes could be explained by anaerobic lactic capacity, while the remaining 33.6% was explained or influenced by other factors.

Among female squash athletes, anaerobic lactic capacity also had a significant effect on match ranking ($B = 0.593$; $\beta = 0.842$; $t = 4.125$; $F = 17.019$; $R^2 = 0.709$; $p = 0.004 < 0.05$). An R^2 value of 0.709 indicates that 70.9% of the variation in match ranking among female squash athletes could be explained by anaerobic lactic capacity, while the remaining 29.1% was explained or influenced by other factors. Although the coefficient

of determination for female athletes was slightly higher than that for male athletes, this difference is merely a descriptive finding and should be interpreted with caution, given the relatively small sample size in each group ($n = 9$).

Table 4. Simple Linear Regression Analysis Results by Sex

Variable	Sex	N	B	β	t	F	R	R ²	Adjusted R ²	Sig.
Anaerobic Lactic	Male	9	.90	.81	3.71	13.81	.81	.66	.616	.00
	Female	9	.5	.5	7	9	.5	.4	.667	.7
			.59	.84	4.12	17.01	.84	.70		.00
			3	2	5	9	2	9		4

Based on Table 4, the simple linear regression analysis showed that anaerobic lactic performance was significantly associated with match ranking in both male and female squash athletes. For male athletes, anaerobic lactic performance explained 66.4% of the variance in match ranking ($R^2 = .664$, $\beta = .815$, $F = 13.819$, $p = .007$). For female athletes, it explained 70.9% of the variance ($R^2 = .709$, $\beta = .842$, $F = 17.019$, $p = .004$). These results indicate a significant relationship between anaerobic lactic performance and match ranking in both sexes.

Discussion

This study aimed to examine the relationship between anaerobic lactic capacity and match performance (match ranking) in squash athletes. The results of the Spearman correlation test showed a strong and significant positive relationship between the two variables. This finding was further supported by the results of a simple linear regression analysis, in which anaerobic lactic capacity was shown to contribute significantly to variation in match ranking performance. In other words, athletes with shorter 150 meter run times indicating better anaerobic lactic capacity tended to achieve better match rankings. This finding supports the assumption that the anaerobic lactic energy system plays an important role in supporting competitive performance in squash.

Physiologically, squash is a racket sport characterized by short-duration, high-intensity intermittent movements interspersed with brief recovery periods, such that the anaerobic energy system, particularly the anaerobic glycolysis (anaerobic lactic) pathway, is presumed to be one of the main determinants of athlete performance. The average running speed of squash players when the ball is in play is 1.59 meters per second (m/s); in addition, elite players are able to reach accelerations of up to 1.47 meters per

second squared (m/s^2) and peak running speeds of 1.98 meters per second (m/s) (Jones et al., 2018). Players' ability to reach such running speeds during play indicates that squash matches are dominated by high-intensity activity. Such activity requires a contribution from the anaerobic energy system, particularly the anaerobic lactic (glycolytic) system, to provide energy rapidly when players perform sprints, changes of direction, and repeated rallies. Good anaerobic lactic capacity enables athletes to repeatedly sustain high intensity during rallies without experiencing a decline in performance due to excessive lactic acid accumulation.

The strength of the relationship found in this study is classified as very strong. This finding indicates that anaerobic lactic capacity plays an important role in supporting athlete performance, particularly in racket sports characterized by high-intensity, repetitive activity. Lactate concentrations are commonly found across racket sports; badminton shows the highest value, with an average reaching 10.11 ± 4.99 mmol/L, while table tennis shows the lowest average value at $1.2 (\pm 0.4)$ mmol/L (Cádiz Gallardo et al., 2023). This indicates that possessing good anaerobic lactic capacity can support performance, particularly in racket sports.

Although anaerobic lactic capacity explains most of the variation in match ranking performance (75.3%), 24.7% of the variation remains attributable to other factors outside this study's model. These factors likely include technical and tactical aspects, competitive experience, psychological factors such as motivation and mental readiness, as well as other physical capacity factors including aerobic capacity, agility, reaction time, and speed. This is in line with meta-analytic evidence indicating that psychological factors such as motivation and self-efficacy are moderately associated with athletic performance across a wide range of sports ($d = 0.329$) (Ayranci & Aydin, 2025). The duration of a single game among senior squash players can range from 194 seconds (3 minutes 14 seconds) to 1,113 seconds (18 minutes 33 seconds), with an average of 700 seconds (11 minutes 40 seconds); meanwhile, the total distance covered during a single game ranges from 254 to 1,449 meters, with an average of 915 meters, depending on the length of play, and the average match duration is 49 minutes, of which approximately 59.6% of total match time is spent with the ball in play (Jones et al., 2018). Given this duration, squash players are required to be optimal not only in terms of anaerobic lactic capacity alone, but also in terms of aerobic capacity, which must likewise be optimal.

This confirms that squash match performance is not the result of a single physical component alone, but rather a complex interaction between physical capacity (aerobic-anaerobic), technical skill, game strategy, and the athlete's psychological condition.

An additional analysis based on sex was warranted given the differing anatomical and physiological characteristics, and it showed that anaerobic lactic capacity remained a significant predictor of match ranking in both male and female athletes. The slightly higher coefficient of determination among female athletes indicates that anaerobic lactic capacity may play a relatively more dominant role in match performance within this group compared to male athletes, whose performance may be more strongly influenced by other factors such as muscle strength or competitive experience. Previous research has reported that anaerobic capacity is significantly greater in men than in women, primarily due to a greater contribution from the glycolytic pathway compared to women. This difference is thought to be related to physiological characteristics in men, such as greater muscle mass and muscle fiber cross-sectional area, as well as higher testosterone levels, which enhance anaerobic metabolic capacity (De Poli et al., 2019). Men have a larger cross-sectional area across all muscle fiber types and a higher proportion of Type II fibers (MHC II, MHC IIA, and MHC IIX), whereas women have a more dominant proportion of Type I fibers (MHC I). These differences in muscle fiber characteristics are thought to contribute to muscular strength and power capabilities that are generally higher in men, while women tend to exhibit better muscular endurance capacity in certain types of resistance exercise (Nuzzo, 2023). Nevertheless, the differences observed in this study should be interpreted with caution, given the relatively small sample size in each group ($n = 9$), which is susceptible to estimation bias and limited statistical power. The minimum sample size for correlational research is 50 (J. Fraenkel & Wallen, 2012).

Squash is a sport dominated by high intensity activity combining explosive movements with repeated recovery periods. This condition means that both the anaerobic and aerobic energy systems play a role in supporting athlete performance. Exercise intensity reflects the magnitude of the anaerobic energy system's contribution during activity. Therefore, individuals with higher anaerobic lactic capacity are able to generate greater work intensity, while good aerobic capacity enables that intensity to be sustained for longer. Thus, the balance between these two capacities is an important factor in supporting optimal performance in squash.

These findings have practical implications for coaches and squash athletes in designing training programs. Given the substantial contribution of anaerobic lactic capacity to match performance, training programs focused on developing the anaerobic lactic energy system such as repeated sprint training, high-intensity interval training, and intensive rally-based training should be prioritized within the periodization of squash athletes' training, as these methods have been shown to improve repeated-sprint performance and anaerobic capacity in racket sports athletes (Liu et al., 2024). Periodic evaluation of anaerobic lactic capacity can also be used as one indicator of an athlete's physical readiness ahead of competition. However, it should also be emphasized that before training anaerobic lactic capacity, athletes first need to possess optimal aerobic capacity, meaning athletes must go through the stage of building or optimizing aerobic capacity (the foundation) before proceeding to the next stage of training anaerobic lactic capacity.

This study has a number of limitations that should be taken into consideration when interpreting the results. First, the relatively small sample size ($n = 18$) potentially limits the generalizability of the findings to a broader population of squash athletes. Second, the use of the 150 meter run test as the sole indicator of anaerobic lactic capacity is not specific to squash, so further comparative testing that is more specific to squash is needed. Third, the cross sectional design of this study does not allow for causal conclusions to be drawn between anaerobic lactic capacity and match performance.

CONCLUSION

Based on the results of the data analysis presented above, it can be concluded that anaerobic lactic capacity has a strong, positive relationship with, and serves as a significant predictor of, match performance (match ranking) in squash athletes, both overall and when analyzed by sex. Athletes with better anaerobic lactic capacity tend to achieve better match rankings, thereby confirming the importance of the anaerobic lactic energy system in supporting performance in squash, an intermittent, high-intensity sport.

For coaches and athletes, these findings suggest that squash physical training programs should incorporate the structured development of anaerobic lactic capacity, such as repeated sprint training and high-intensity interval training, as part of preparation ahead of competition. Periodic evaluation of anaerobic lactic capacity can also be used as one parameter for monitoring athletes physical readiness.

For future researchers, it is recommended that studies be conducted with larger sample sizes and longitudinal designs in order to strengthen the generalizability of the findings and to allow for the drawing of causal conclusions. The use of anaerobic lactic measurement instruments that have been specifically validated for squash, as well as the inclusion of other variables related to psychological aspects, is also recommended in order to obtain a more comprehensive picture of the determinants of match performance in squash athletes.

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