

ความสัมพันธ์ระหว่างสมรรถนะการระเบิดพลัง ความสามารถในการไม่ใช้ออกซิเจน
ความสามารถในการใช้ออกซิเจน และร้อยละไขมันในร่างกาย
ในนักกีฬามวยไทยเยาวชน

ASSOCIATIONS BETWEEN EXPLOSIVE PERFORMANCE, ANAEROBIC POWER,
AEROBIC CAPACITY AND BODY FAT PERCENTAGE
IN YOUTH MUAY THAI ATHLETES

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บทคัดย่อ

มวยไทยเป็นกีฬาต่อสู้ที่มีลักษณะการออกแรงเป็นช่วง ๆ และมีความหนักสูง ซึ่งต้องอาศัยการเคลื่อนไหวแบบระเบิดพลังอย่างซ้ำ ๆ โดยได้รับการสนับสนุนจากระบบพลังงานทั้งแบบไม่ใช้ออกซิเจนและแบบใช้ออกซิเจน แม้ว่าการศึกษาที่ผ่านมาได้อธิบายลักษณะทางสรีรวิทยาของนักกีฬาบางประการแล้ว แต่หลักฐานเชิงประจักษ์ที่ศึกษาความสัมพันธ์เชิงบูรณาการระหว่างสมรรถนะของระบบประสาทและกล้ามเนื้อ ความสามารถในการไม่ใช้ออกซิเจน ความสามารถในการใช้ออกซิเจน และองค์ประกอบของร่างกายในนักกีฬามวยไทยเยาวชนยังมีอยู่อย่างจำกัด ดังนั้น การวิจัยครั้งนี้จึงมีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างสมรรถนะการระเบิดพลังของกล้ามเนื้อขาส่วนล่าง ความสามารถในการไม่ใช้ออกซิเจน ความสามารถในการใช้ออกซิเจน และร้อยละไขมันในร่างกาย ในนักกีฬามวยไทยระดับเยาวชนที่เข้าร่วมการแข่งขันในระดับประเทศ กลุ่มตัวอย่างเป็นนักกีฬามวยไทยเยาวชน จำนวน 23 คน โดยใช้รูปแบบการวิจัยเชิงภาคตัดขวาง สมรรถนะการระเบิดพลัง ประเมินด้วยการทดสอบการกระโดดสูงแนวตั้ง ความสามารถในการไม่ใช้ออกซิเจน ประเมินด้วยการทดสอบ Wingate ระยะเวลา 30 วินาที ซึ่งรายงานค่ากำลังสูงสุดและกำลังเฉลี่ย ขณะที่ความสามารถในการใช้ออกซิเจน ประเมินจากค่าการใช้ ออกซิเจนสูงสุด (VO₂max) ที่ประมาณค่าจากการทดสอบวิ่งแบบหลายช่วงในระยะ 20 เมตร และร้อยละไขมันในร่างกาย ประเมินจากการวัดความหนาของไขมันใต้ผิวหนัง 4 ตำแหน่ง วิเคราะห์ข้อมูลด้วยค่าสัมประสิทธิ์สหสัมพันธ์ของเพียร์สันพร้อมช่วงความเชื่อมั่นร้อยละ 95 ผลการศึกษา พบว่าสมรรถนะการกระโดดสูงในแนวตั้งมีความสัมพันธ์เชิงบวกอย่างมีนัยสำคัญกับ กำลังสูงสุดจากการทดสอบ Wingate ($r = 0.662$, $p = 0.001$, 95%CI [0.344, 0.844]) ในขณะที่กำลังเฉลี่ยจากการทดสอบ Wingate มีความสัมพันธ์เชิงบวกกับค่า VO₂max ($r = 0.552$, $p = 0.006$, 95%CI [0.181, 0.785]) นอกจากนี้ ร้อยละไขมันในร่างกายมีความสัมพันธ์เชิงลบกับทั้งกำลังสูงสุดจากการทดสอบ Wingate ($r = -0.670$, $p < 0.001$, 95%CI [-0.848, -0.356]) และค่า VO₂max ($r = -0.609$, $p = 0.002$, 95%CI [-0.816, -0.263]) ผลการศึกษานี้ชี้ให้เห็นว่า สมรรถนะการระเบิดพลัง ความสามารถในการไม่ใช้ออกซิเจน ความสามารถในการใช้ออกซิเจน และองค์ประกอบของร่างกาย มีแนวโน้มที่จะมีความสัมพันธ์กันในนักกีฬามวยไทยเยาวชน ทั้งนี้ ผลการศึกษาดังกล่าวเป็นการวิเคราะห์เชิงสหสัมพันธ์และไม่สามารถสรุปความเป็นเหตุและผลได้ ดังนั้น การพัฒนาสมรรถนะการระเบิดพลังและการควบคุมองค์ประกอบของร่างกายให้อยู่ในระดับที่เหมาะสม อาจมีความเกี่ยวข้องกับความสามารถในการออกแรงที่มีความหนักสูงภายใต้รูปแบบการแข่งขันที่เป็น ยก ๆ ของกีฬามวยไทย

คำสำคัญ: มวยไทย, ความสามารถในการไม่ใช้ออกซิเจน, ความสามารถในการใช้ออกซิเจน, สมรรถนะการระเบิดพลัง, ร้อยละไขมันในร่างกาย

Abstract

Muay Thai is an intermittent, high-intensity combat sport that requires repeated explosive actions supported by both anaerobic and aerobic energy systems. Although previous studies have described several physiological characteristics of combat sport athletes, limited evidence has examined the integrated relationships among neuromuscular performance, anaerobic capacity, aerobic fitness, and body composition in youth Muay Thai athletes. Therefore, this study aimed to investigate the interrelationships among explosive lower-limb performance, anaerobic capacity, aerobic capacity, and body fat percentage in nationally competitive adolescent Muay Thai athletes. Twenty-three youth athletes participated in this cross-sectional study. Explosive performance was assessed using a vertical jump test. Anaerobic capacity was evaluated using a 30-s Wingate test from which peak power and mean power were obtained. Aerobic capacity (VO_{2max}) was estimated using the 20-m multistage shuttle run test, and body fat percentage was determined using a four-site skinfold protocol. Pearson correlation coefficients with 95% confidence intervals were calculated to examine relationships among variables. The results showed that vertical jump performance was positively associated with Wingate peak power ($r = 0.662$, $p = 0.001$, 95%CI [0.344, 0.844]). Wingate mean power was positively correlated with VO_{2max} ($r = 0.552$, $p = 0.006$, 95%CI [0.181, 0.785]). Body fat percentage was inversely associated with both Wingate peak power ($r = -0.670$, $p < 0.001$, 95%CI [-0.848, -0.356]) and VO_{2max} ($r = -0.609$, $p = 0.002$, 95%CI [-0.816, -0.263]). These findings suggest that explosive performance, anaerobic capacity, aerobic capacity, and body composition are interrelated in adolescent Muay Thai athletes. Importantly, these results are based on correlational analysis and do not imply causation. Accordingly, optimizing explosive performance and maintaining appropriate body composition may be associated with improved high-intensity performance within the demands of round-based Muay Thai competition.

Keywords: Muay Thai, Anaerobic capacity, Aerobic capacity, Explosive performance, Body fat percentage

Introduction

Muay Thai is a traditional Thai combat sport characterized by repeated high-intensity striking exchanges using punches, kicks, knees, and elbows within a structured five-round competitive format. During competition, athletes are required to repeatedly generate explosive force while sustaining progressive cardiovascular strain and metabolic disturbance across rounds. Physiological investigations have demonstrated heart rate responses approaching maximal values and substantial blood lactate accumulation, indicating concurrent engagement of anaerobic and aerobic metabolic pathways (Crisafulli et al., 2009). Time-motion analyses further confirm the intermittent nature of Muay Thai, characterized by brief high-intensity exchanges interspersed with lower-intensity observation and preparation phases (Silva et al., 2011; Slimani et al., 2017).

Despite these intermittent demands, combat sport performance is often interpreted through a simplified aerobic-anaerobic dichotomy. Contemporary exercise physiology, however, emphasizes dynamic energy system interaction rather than isolated metabolic dominance during maximal and repeated high-intensity efforts (Gastin, 2001). Aerobic metabolism plays a critical role in phosphocreatine resynthesis and fatigue resistance during repeated bouts of high-intensity activity (Spencer et al., 2005). Evidence from

intermittent sports indicates that aerobic capacity is associated with repeated sprint performance and fatigue resistance rather than instantaneous peak output (Jones et al., 2013; Sanders et al., 2017). Such findings suggest that oxidative support may meaningfully influence sustained high-intensity output in round-based combat sports. This perspective is further supported by recent meta-analytic evidence highlighting the complex interaction between internal physiological responses and external performance demands in intermittent sports (McLaren et al., 2018).

Anaerobic peak power is commonly assessed using the Wingate anaerobic test, whereas explosive lower-limb performance is frequently evaluated via vertical jump testing. Cross-modality correlations between jump performance and Wingate-derived power outputs have been reported in youth athletes (Rakholiya & Gadesha, 2020), reflecting shared neuromuscular determinants such as rapid motor unit recruitment and contractile velocity (Cormie et al., 2011). In addition, body composition—particularly body fat percentage—has been shown to influence both relative power production and aerobic capacity through its effect on power-to-mass ratio and oxygen uptake normalization (Nikolaidis et al., 2016). Intervention research in Muay Thai further demonstrates that structured training can concurrently modify body composition and physiological performance indicators (Saraiva et al., 2021), highlighting the interdependence of morphological and metabolic adaptations in this sport.

Taken together, these findings suggest that explosive neuromuscular performance, anaerobic power, aerobic capacity, and body composition may be functionally interconnected through shared physiological mechanisms, including neuromuscular activation, energy system interaction, and body mass-related constraints on performance. Specifically, explosive performance and anaerobic power may reflect common neuromuscular determinants, including rapid motor unit recruitment and rate of force development. In contrast, aerobic capacity may contribute to fatigue resistance and the maintenance of high-intensity output across repeated efforts. Additionally, body fat percentage may influence both anaerobic and aerobic performance through its effects on power-to-mass ratio and oxygen uptake efficiency.

Although these determinants have been examined individually, limited evidence has investigated whether explosive neuromuscular capacity, oxidative support, and morphological characteristics operate as an integrated system within the round-based physiological demands of Muay Thai. Most Muay Thai research has focused on descriptive physiological responses (Crisafulli et al., 2009) or general profiling characteristics (Slimani et al., 2017), rather than examining interrelationships among performance determinants. This gap is particularly evident in adolescent populations, where concurrent neuromuscular maturation, lean mass development, and metabolic adaptations may strengthen physiological interdependence. Understanding these relationships may provide practical value for coaches and practitioners by informing integrated training strategies that reflect the multidimensional demands of youth Muay Thai performance. Accordingly, it may be expected that explosive performance would be positively associated with anaerobic power, aerobic capacity would be related to sustained high-intensity output, and body fat percentage would be inversely associated with both anaerobic and aerobic performance indicators.

Therefore, the purpose of this study was to examine the relationships among 1) explosive lower-limb performance and anaerobic peak power, 2) aerobic capacity and sustained anaerobic performance, and 3) body fat percentage and both anaerobic and aerobic performance indicators in adolescent Muay Thai athletes. By investigating these variables collectively, this study aims to contribute to a more integrated understanding of performance physiology in youth Muay Thai.

Methodology

A cross-sectional correlational design was employed to examine the associations among lower-limb explosive performance, anaerobic power and capacity, aerobic capacity, and body fat percentage in adolescent Muay Thai athletes during a standardized pre-competition fitness evaluation.

Participants

Twenty-three adolescent Muay Thai athletes (male and female) were recruited from multiple provinces in northeastern Thailand. All participants were officially registered competitors within the Thai National Youth Games system and were required to complete mandatory pre-competition physical fitness assessments.

A criterion-based purposive sampling approach was used to include athletes who met national youth eligibility standards and were medically cleared for maximal physical testing.

Inclusion criteria were as follows: 1) participation in the Thai National Youth Games system, 2) both male and female athletes, 3) a minimum of two years of continuous Muay Thai training experience, and (4) medical clearance for maximal physical testing. Exclusion criteria included: 1) any musculoskeletal injury within the past three months, 2) known cardiovascular or metabolic conditions, and 3) inability to complete the full testing protocol. All participants completed the full testing battery.

An a priori sample size estimation was conducted using G*Power software (version 3.1.9.4) (Faul et al., 2009) for Pearson correlation analysis. Assuming a large effect size ($r = 0.60$) based on conventional benchmarks (Cohen, 1988), an alpha level of .05, and statistical power of .80, the required minimum sample size was 19 participants. Therefore, the final sample size ($N = 23$) was considered sufficient to detect statistically meaningful associations.

Ethical Approval

This study was approved by the Human Research Ethics Committee of Ubon Ratchathani Rajabhat University (Approval No. HE611011) and conducted in accordance with the Declaration of Helsinki. As all participants were under 18 years of age, written parental consent and athlete assent were obtained prior to testing. All assessments were supervised by team coaches to ensure athlete safety and welfare. Participation was voluntary, and all data were anonymized prior to statistical analysis.

Standardized Testing Protocol

All measurements followed the Sport Authority of Thailand (SAT) manual for youth athletes (Sport Authority of Thailand, 2019). This standardized protocol specifies test objectives, equipment requirements, administration procedures, scoring criteria, and recording formats, and is routinely implemented within Thailand's national youth athlete development and competition eligibility system.

All assessments were conducted by trained sport science personnel in accordance with SAT procedures. Testing was performed indoors during a single pre-competition session to minimize environmental variability. Participants refrained from strenuous exercise for at least 24 hours prior to testing and completed a standardized dynamic warm-up.

To minimize fatigue-related interference, the testing sequence followed the SAT-recommended structure:

1. Anthropometry and body composition
2. Explosive performance
3. Anaerobic performance
4. Aerobic capacity

Measures

Anthropometry

Body mass (kg) and standing height (cm) were measured using calibrated equipment according to SAT (2019) procedures.

Body Composition

Subcutaneous adiposity was assessed using a four-site skinfold protocol (biceps, triceps, subscapular, and suprailiac) measured on the right side of the body with a calibrated Lange skinfold caliper. Two measurements were obtained at each site and averaged. The sum of the four skinfold thicknesses was used to estimate body fat percentage (%BF) using age-specific prediction equations specified in the SAT manual (Sport Authority of Thailand, 2019). This method is widely used in field-based assessments; however, it provides an indirect estimation of body fat percentage.

Lower-Limb Explosive Performance

Explosive performance was assessed using a Yardstick vertical jump test. Participants performed three maximal countermovement jumps with arm swing. Jump height (cm) was calculated as the difference between standing reach height and maximal jump reach, and the highest value was retained for analysis.

Anaerobic Performance

Anaerobic performance was evaluated using a 30-s Wingate anaerobic test performed on a mechanically braked cycle ergometer. Resistance was set at $0.067 \text{ kp} \cdot \text{kg}^{-1}$ relative to body mass. Peak power (W) and mean power (W) were recorded. Relative values ($\text{W} \cdot \text{kg}^{-1}$) were also calculated. Absolute values (W) were used for correlation analyses to reflect total power output, while relative values were calculated to provide additional performance context.

Aerobic Capacity

Aerobic capacity was assessed using the 20-m multistage shuttle run test. The test was terminated when the athlete failed to reach the designated line for three consecutive audio signals. The final stage achieved was recorded, and maximal oxygen uptake ($\text{VO}_{2\text{max}}$) was estimated using standardized prediction equations associated with the test protocol. This approach provides a practical field-based estimation of aerobic capacity in youth populations.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test and inspection of skewness and kurtosis values (± 2 criterion). Descriptive statistics are presented as mean $\pm$ standard deviation (SD). Pearson product–moment correlation coefficients were calculated to examine associations among vertical jump height, Wingate peak power, Wingate mean power, $\text{VO}_{2\text{max}}$, and body fat percentage. Ninety-five percent confidence intervals (95% CI) were calculated for all correlation coefficients using Fisher’s z transformation. Statistical significance was set at $p < .05$ (two-tailed). Effect sizes were interpreted as small ($r = .10-.29$), moderate ($r = .30-.49$), and large ($r \geq .50$).

Results

1. Participant Characteristics

Descriptive characteristics of the adolescent Muay Thai athletes are presented in Table 1. The sample ($N = 23$) had a mean age of 15.65 ± 1.15 years, body mass of 55.01 ± 8.07 kg, and height of 164.22 ± 7.65 cm. Mean body fat percentage was $20.36 \pm 6.31\%$. Mean vertical jump height was 42.04 ± 7.73 cm. Estimated maximal oxygen uptake (VO_{2max}) was 38.56 ± 5.32 $ml \cdot kg^{-1} \cdot min^{-1}$. Anaerobic performance assessed via the 30-s Wingate test yielded a mean peak power output of 497.17 ± 129.25 W and a mean power output of 401.48 ± 103.83 W. Descriptive statistics are summarized in Table 1.

Table 1. Descriptive Characteristics of Youth Muay Thai Athletes ($n = 23$)

Variable	Mean $\pm$ SD
Age (years)	15.65 ± 1.15
Body mass (kg)	55.01 ± 8.07
Height (cm)	164.22 ± 7.65
Body fat (%)	20.36 ± 6.31
Vertical jump (cm)	42.04 ± 7.73
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	38.56 ± 5.32
Wingate peak power (W)	497.17 ± 129.25
Wingate mean power (W)	401.48 ± 103.83

Note. Values are presented as mean $\pm$ standard deviation (SD). VO_{2max} = maximal oxygen uptake.

2. Correlational Analyses

Pearson product-moment correlation coefficients are presented in Table 2. Vertical jump height demonstrated a significant positive correlation with Wingate peak power ($r = 0.662$, $p = 0.001$, 95% CI [0.344, 0.844]). Body fat percentage was significantly negatively correlated with Wingate peak power ($r = -0.670$, $p < 0.001$, 95% CI [-0.848, -0.356]). Wingate mean power was significantly positively associated with VO_{2max} ($r = 0.552$, $p = 0.006$, 95% CI [0.181, 0.785]). Body fat percentage was also significantly negatively associated with VO_{2max} ($r = -0.609$, $p = 0.002$, 95% CI [-0.816, -0.263]). All reported correlation coefficients were statistically significant ($\alpha = .05$), and none of the 95% confidence intervals included zero.

Table 2. Pearson Correlations Among Explosive Performance, Anaerobic Performance, Aerobic Capacity, and Body Fat Percentage

Variables	r	95% CI	p
Vertical jump vs. Wingate peak power	0.662	[0.344, 0.844]	0.001
Body fat % vs. Wingate peak power	-0.670	[-0.848, -0.356]	<0.001
Wingate mean power vs. VO_{2max}	0.552	[0.181, 0.785]	0.006
Body fat % vs. VO_{2max}	-0.609	[-0.816, -0.263]	0.002

Note. r = Pearson correlation coefficient; CI = confidence interval. Only the reported variable pairs are presented. All tests were two-tailed.

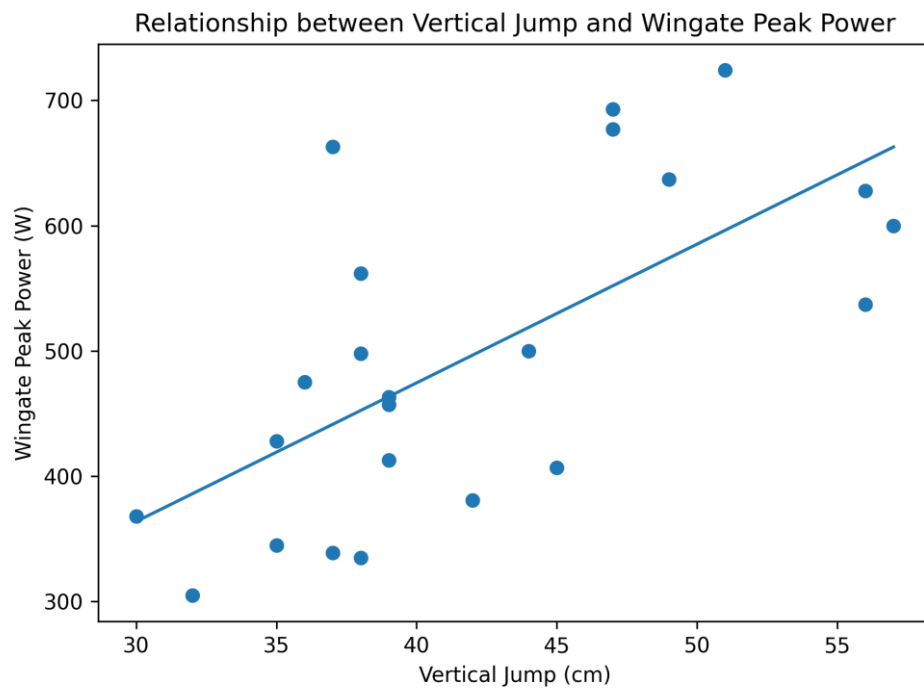


Figure 1. Relationship between vertical jump performance and Wingate peak power in adolescent Muay Thai athletes. The scatter plot illustrates a positive association between vertical jump height and Wingate peak power. The solid line represents the linear regression trend.

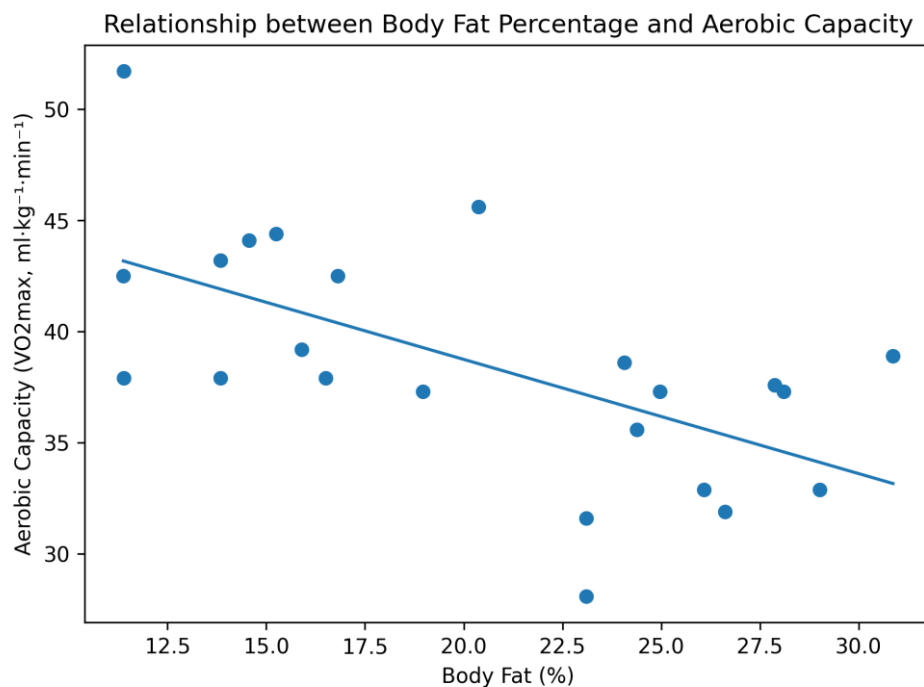


Figure 2. Relationship between body fat percentage and aerobic capacity (VO₂max) in adolescent Muay Thai athletes. The scatter plot shows a negative association between body fat percentage and estimated VO₂max. The solid line represents the linear regression trend.

Discussion

The present study examined whether explosive neuromuscular performance, sustained anaerobic capacity, aerobic fitness, and body composition are interrelated in adolescent Muay Thai athletes. The moderate-to-large correlations observed across variables suggest that these physiological characteristics are interrelated rather than functioning as isolated energy systems. To our knowledge, no previous study has examined these variables concurrently in adolescent Muay Thai athletes. These findings therefore directly address a gap in the literature regarding physiological interrelationships in youth Muay Thai.

First, the association between vertical jump performance and Wingate peak power ($r = 0.662$) suggests shared neuromuscular determinants. Peak anaerobic output is largely dependent on rapid motor unit recruitment, rate of force development, and contractile velocity (Cormie et al., 2011). Similar cross-modality relationships between jump performance and Wingate-derived power outputs have been reported in youth athletes (Rakholiya & Gadesha, 2020). This magnitude suggests that peak power reflects generalized neuromuscular explosiveness rather than task-specific mechanics alone. In a striking-based combat sport such as Muay Thai, where explosive lower-limb actions underpin kicking and rapid offensive transitions, this neuromuscular overlap may have direct competitive relevance. This relationship is further illustrated in Figure 1, where the scatter plot demonstrates a clear positive association between vertical jump performance and Wingate peak power, with the regression trend indicating that greater lower-limb explosiveness may be associated with higher anaerobic power output.

Second, the positive relationship between Wingate mean power and $VO_2\max$ ($r = 0.552$) may suggest the contribution of oxidative metabolism to sustained high-intensity output. Although the Wingate test is traditionally categorized as anaerobic, aerobic metabolism contributes meaningfully during and between repeated maximal efforts (Gastin, 2001; Spencer et al., 2005). Evidence from intermittent team sports demonstrates that higher aerobic capacity is associated with improved fatigue resistance and repeated sprint performance (Jones et al., 2013; Sanders et al., 2017). In round-based combat sports such as Muay Thai, where athletes must repeatedly execute high-intensity striking exchanges across multiple rounds, oxidative support may be associated with maintaining technical precision and tactical responsiveness rather than influencing peak output alone. This interpretation is further supported by recent evidence demonstrating that high-intensity interval training can improve both aerobic capacity and repeated high-intensity performance (Franchini et al., 2019).

Third, body fat percentage was inversely associated with both anaerobic peak power ($r = -0.670$) and $VO_2\max$ ($r = -0.609$). Increased adiposity reduces relative power production and oxygen uptake when expressed relative to body mass (Nikolaidis et al., 2016). Given that Muay Thai is a weight-category sport, body composition may be associated with both explosive and aerobic performance expression. Intervention research in Muay Thai has demonstrated concurrent improvements in body composition and physiological capacity following structured training (Saraiva et al., 2021), reinforcing the importance of optimizing body composition during developmental stages. This inverse relationship is also visually represented in Figure 2, where the scatter plot shows that higher body fat percentage tends to be associated with lower aerobic capacity, as reflected by the negative regression trend.

Collectively, these findings extend previous descriptive profiling work in Muay Thai (Crisafulli et al., 2009; Slimani et al., 2017) by demonstrating interrelationships among neuromuscular, metabolic, and morphological determinants in adolescent athletes. Considering that adolescence is characterized by ongoing maturation in lean mass, neuromuscular efficiency, and oxidative capacity, the present results suggest that integrated performance physiology may already be evident during developmental stages.

Conclusion and Recommendations

The present findings suggest that explosive performance, anaerobic capacity, aerobic fitness, and body composition are interrelated physiological components in adolescent Muay Thai athletes. The observed relationships may reflect shared underlying mechanisms, including neuromuscular function, energy system interaction, and body composition influences on performance. These results provide additional insight into the integrated nature of physical performance in youth combat sports.

This study has several limitations. First, the cross-sectional design does not allow causal inference between variables. Second, the relatively small sample size ($N = 23$) and the use of purposive sampling may limit the generalizability of the findings. Third, VO_2max was estimated using a field-based protocol, which may be subject to measurement error. Finally, body fat percentage was assessed using skinfold measurements, which may introduce additional variability.

Future research is recommended to employ larger sample sizes, longitudinal or experimental designs, and more precise measurement techniques to further examine these relationships. Additionally, studies in different age groups, competitive levels, and sport contexts may provide a more comprehensive understanding of performance-related physiological interactions.

From a practical perspective, these findings may provide useful insights for coaches and practitioners in designing training programs that concurrently target neuromuscular, metabolic, and body composition factors, rather than focusing on a single performance domain.

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