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Association of aerobic and anaerobic capacities with body composition in basketball players aged 13-16 years in Chiang Mai Province

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ABSTRACT

Background: Basketball demands both aerobic and anaerobic energy, with adolescent physiological development influencing performance capacities. While body composition impacts energy efficiency, its relationship to aerobic and anaerobic capacities in youth athletes remains underexplored.

Objectives: To examine associations between body composition and aerobic and anaerobic capacities in adolescent basketball players, and to compare these variables by gender.

Materials and methods: A cross-sectional study was conducted with 60 basketball players (33 males, 27 females) aged 13-16 years. Body composition was measured using bioelectrical impedance analysis. Aerobic capacity was assessed via the 20-meter shuttle run (VO_2max estimation), and anaerobic performance via the Running-based Anaerobic Sprint Test (RAST). Pearson's Correlation Coefficient and Independent sample t-test were used for analysis.

Results: Males had significantly higher muscle mass and VO_2max, and lower body fat than females ($p<0.05$). VO_2max was positively correlated with muscle mass ($r=0.466$, $p<0.001$), and negatively with BMI ($r=-0.330$, $p=0.01$) and body fat ($r=-0.463$, $p<0.001$). No significant correlations were found between anaerobic fatigue index and body composition.

Conclusion: Aerobic capacity in youth basketball players is significantly influenced by body composition, with greater muscle mass and lower fat associated with better VO_2max. However, anaerobic capacity appears independent of these morphological factors. These findings support tailored training and monitoring strategies, especially considering sex-based developmental differences.

Introduction

Basketball is a globally popular sport that demands frequent and intense physical activity.[1,2] Movements such as sprinting, changing direction, jumping, and rapid acceleration-deceleration patterns require a combination of aerobic and anaerobic energy systems.[3] Notably, anaerobic energy is dominant in basketball due to its intermittent high-intensity nature, contributing to approximately 80% of energy utilization, with the remaining 20% reliant on aerobic metabolism.[4] Basketball players frequently undergo training designed to improve performance across both

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aerobic and anaerobic domains. The anaerobic system is critical for short bursts of high-intensity efforts, such as fast breaks, quick direction changes, and jumps. Meanwhile, aerobic capacity supports recovery between these bouts and sustains performance across the full duration of the game.[4] These two energy systems work in concert to enable optimal in-game performance, particularly in young athletes who are still undergoing physiological maturation.

Previous research has reported that aerobic capacity in adolescent male basketball players typically ranges between approximately 48-60 ml/kg/min, whereas female players generally demonstrate values between 38-50 mL/kg/min, depending on age and competitive level.[5] These variations reflect differences in training exposure and biological maturation. Despite the predominance of anaerobic actions during competition, adequate aerobic fitness is essential for maintaining repeated sprint performance and facilitating recovery during intermittent play.[2,4] Similarly, anaerobic performance in youth basketball players, often assessed through repeated sprint protocols, shows considerable variability influenced by neuromuscular development and lean muscle mass.[3,5] During adolescence, progressive increases in muscle mass, particularly in males, contribute to improvements in anaerobic power output. Therefore, understanding normative performance characteristics during this developmental stage is essential for optimizing long-term athletic development.

Physiological development during adolescence leads to significant changes in body composition, including increases in muscle mass and fat mass, particularly influenced by hormonal changes.[6] During this period, sex differences become increasingly pronounced, with males typically developing greater lean muscle mass and females experiencing a relatively higher accumulation of body fat. These developmental changes may have meaningful implications for the use and efficiency of the body's energy systems.[7] Body composition is an important performance indicator in sports science, as it reflects the balance of muscle and fat mass, which in turn influences athletic potential. For instance, increased fat mass can impede movement efficiency and aerobic performance, whereas greater muscle mass enhances strength, power, and endurance capacity. Assessing how these body composition parameters relate to energy system capacities may guide training and nutritional strategies aimed at improving performance outcomes in adolescent athletes.[8]

While existing research explores energy system utilization in basketball, limited studies have examined how these capacities relate specifically to body composition in adolescent athletes. Most prior work has focused on elite or adult populations. There remains a need to understand these associations in youth athletes to inform early-stage talent development and conditioning programs.

This study aims to investigate the relationships between aerobic and anaerobic capacities with body composition variables including BMI, body fat percentage, and muscle mass in adolescent basketball players. Additionally, differences between male and female athletes will be explored.

Materials and methods

Participants

Participants were recruited through local basketball academies and schools. The inclusion criteria required that participants be actively involved in basketball training and competitions for at least one year, be between 13 and 16 years of age, and have no current musculoskeletal or cardiovascular conditions. Individuals with chronic illnesses or recent injuries were excluded from the study.

Study design

A cross-sectional study design was used with a sample of 60 adolescent basketball players (33 males, 27 females) aged 13-16 years from Chiang Mai Province. Participants were required to have at least one year of basketball experience. The study protocol was approved by the Human Ethical Review Board of the primary investigator's institution (AMSEC-67EX-039), and informed consent was secured from participants and their parents.

Outcome measures

Body composition, including body mass index (BMI), body fat percentage, and muscle mass, was assessed using a validated bioelectrical impedance analyzer (INBODY), which provides segmental analysis of lean mass and fat distribution. Aerobic capacity was evaluated by estimating VO_2max through the 20-meter shuttle run test, a widely recognized field test for assessing cardiovascular endurance. In this test, participants ran back and forth along a 20-meter track, maintaining pace with audio signals until they failed to reach the line on two consecutive occasions.[9,10] Anaerobic capacity was assessed using the Running based Anaerobic Sprint Test (RAST), in which participants completed six 35-meter sprints with 10 seconds of rest between each sprint. The time for each sprint was recorded and used to calculate the fatigue index and peak power output.[11]

Study procedure

Testing was conducted across three days. On Day 1, participants completed body composition assessments. Day 2 involved the VO_2max test. On Day 3, after 24 hours of rest, the RAST was conducted. Participants were instructed to maintain normal hydration and avoid intense exercise 24 hours before testing. Each session began with a standardized 10-minute warm-up including light jogging and dynamic stretching. All participants completed a familiarization session at least one week prior to testing. Data collection was supervised by trained researchers, and all measurements were taken twice and averaged to ensure reliability. All performance testing took place in a climate-controlled indoor facility to ensure consistency. Ambient temperature was maintained between 22-25 °C, and tests were scheduled at similar times of day to control for circadian rhythm influences (Figure 1).

VO_2max was estimated using the Leger equation derived from the final speed attained during the 20-meter shuttle run.[10] Speed was determined by the final shuttle level reached before voluntary exhaustion.

$$VO_2max(ml/kg/min)=31.025+3.238\times speed(km/hr)-3.248\times age+0.1536\times speed\times age$$

Anaerobic performance was calculated using data from each participant's six sprint times recorded during the RAST test. Power output for each sprint was determined using a formula that incorporates body mass, sprint distance, and time. These values were then used to derive two key indicators including anaerobic capacity and fatigue index. Anaerobic capacity was represented by the average power across all six sprints, while the fatigue index reflected the decline in performance by comparing the maximum and minimum power outputs.[11]

- *Power (W)=(Body mass×Distance²)÷Time³* — $Power(W)=(Body\ mass\times Distance^2)\div Time^3$
- *Anaerobic Capacity=Average of the six calculated power values*
- *Fatigue Index (%)=[(Maximum power-Minimum power)÷Maximum power]×100*

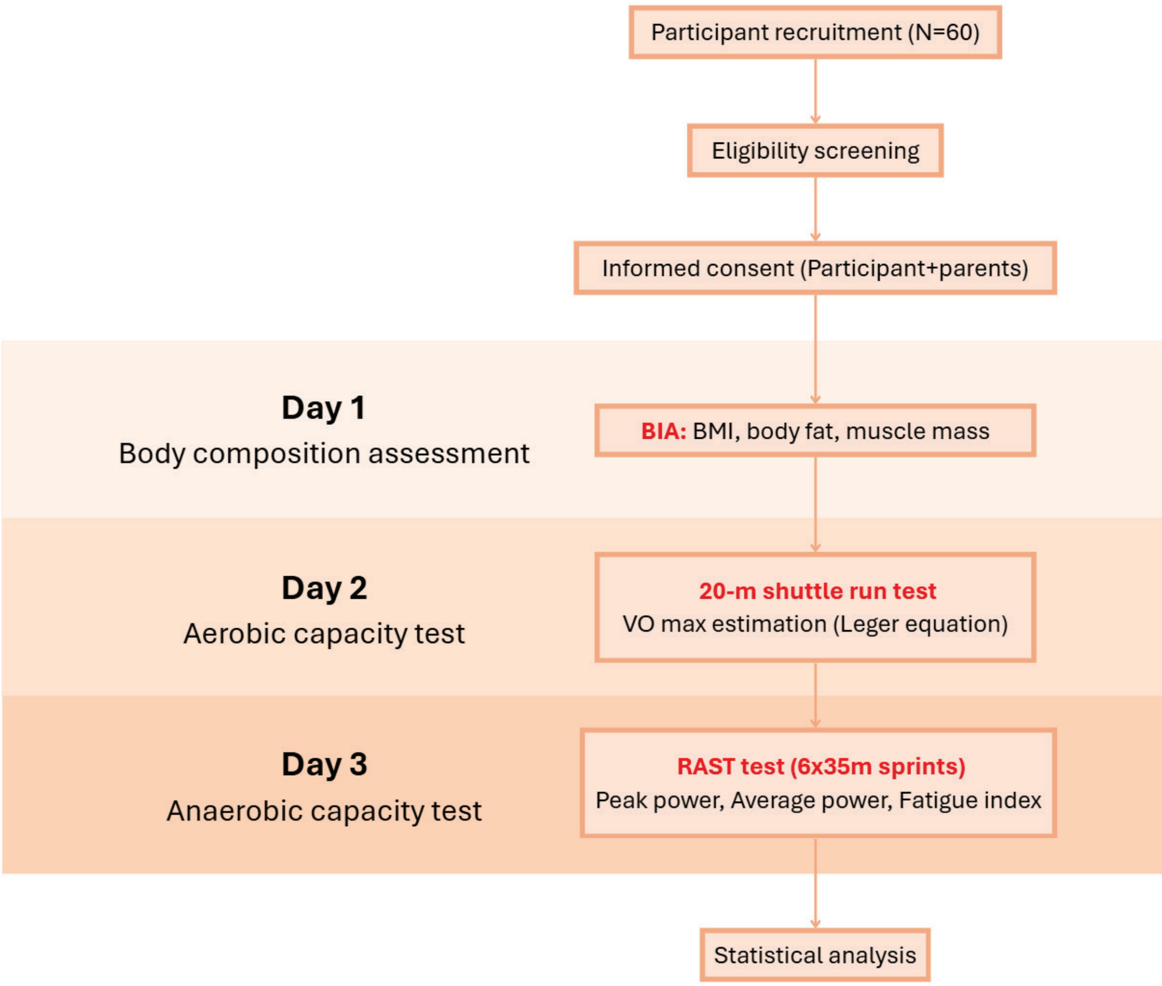

Figure 1. *Flow diagram illustrating participant recruitment, outcome measures, and study procedures.*

Data analysis

All data were analyzed using SPSS software (version 21.0, IBM Corporation, Chicago, IL). Descriptive statistics (mean±standard deviation) summarized demographic and performance data. Pearson's correlation coefficient assessed relationships between aerobic and anaerobic capacities and body composition variables. The strength of correlation was interpreted based on commonly accepted criteria as follows: values of |r|=0.00-0.19 were considered very weak, 0.20-0.39 weak, 0.40-0.59 moderate, 0.60-0.79 strong, and ≥0.80 very strong correlation.[12] Independent sample t-tests compared performance and body composition differences between gender. A significance level of $p<0.05$ was set for all analyses.

Results

The physical characteristics of participants are presented in Table 1. Male athletes demonstrated significantly higher height, weight, muscle mass, and VO_2max, and lower body fat percentage compared to females ($p<0.05$). No significant sex difference was observed in fatigue index.

Pearson's correlation analysis conducted in the overall sample (Table 2) demonstrated a moderate positive correlation between VO_2max and muscle mass (r=0.466, $p<0.001$). VO_2max also showed a moderate negative correlation with body fat percentage (r=-0.463, $p<0.001$) and a weak negative correlation with body mass index (r=-0.330, $p=0.01$). No significant correlations were observed between fatigue index and any body composition variables in the overall sample.

Table 1. Comparison of physical characteristics and energy capacities between genders.

Variables	Male (N=33)	Female (N=27)	*p* value
Height (cm)	171.79±9.28	162.30±7.26	<0.001
Weight (kg)	62.01±17.01	52.02±7.48	0.006
Body mass index (BMI)	20.83±4.02	19.68±2.38	0.196
Body fat (%)	15.35±8.01	23.21±5.96	<0.001
Muscle mass (%)	80.17±7.58	72.14±5.57	<0.001
Fatigue index (%)	38.80±12.69	40.53±12.93	0.603
VO_2max (mL/kg/min)	27.82±10.07	20.79±7.91	0.004

Note: *BMI: body mass index, cm: centimeter, kg: kilogram, min: minute, mL: milliliter.*

Table 2. Correlation between energy capacities and body composition variables.

Body composition variables	Fatigue index		VO_2max	
	r	*p* value	r	*p* value
Body mass index (BMI)	-0.068	0.608	-0.330	0.010
Body fat (%)	-0.012	0.925	-0.463	<0.001
Muscle mass (%)	0.011	0.932	0.466	<0.001

Note: *BMI: body mass index, cm: centimeter, kg: kilogram, min: minute, mL: milliliter.*

Discussion

The findings indicate a moderate correlation between aerobic capacity and body composition in adolescent basketball players. Higher VO_2max was associated with lower body fat percentage and greater muscle mass, suggesting enhanced cardiovascular and metabolic efficiency in athletes with more favorable body composition profiles. These results are consistent with previous studies that highlight the negative impact of excess body fat on aerobic performance and the supportive role of muscle mass in facilitating oxygen consumption during exercise.[2,13] The observed moderate correlations between VO_2max and both muscle mass and body fat percentage suggest that body composition plays a meaningful, although not exclusive, role in aerobic performance among adolescent basketball players. The strength of these associations indicates that while morphological characteristics contribute to aerobic fitness, other factors such as cardiovascular adaptations, training intensity, and genetic predisposition may also influence performance outcomes. The weak correlation observed between VO_2max and BMI further highlights the limitation of BMI as a general indicator, as it does not distinguish between fat and lean mass. No significant correlation was observed between anaerobic capacity and body composition. This outcome may reflect the complex and multifactorial nature of anaerobic performance, which can be influenced by variables such as muscle fiber type, neuromuscular coordination, and sport-specific training adaptations rather than morphological characteristics alone.[6]

Sex-based differences were also evident, with male participants demonstrating higher lean muscle mass, lower body fat percentage, and superior VO_2max compared to females. These differences are likely attributable to hormonal and developmental factors, particularly the effects of puberty on muscle and fat distribution.[14] Such findings support the need for sex-specific training and nutritional interventions during adolescence to optimize physical development and performance. Moreover, the results reinforce the sensitivity of aerobic fitness to variations in body composition during adolescence, a period characterized by rapid growth and hormonal fluctuations.[15] In practical application, conditioning programs aimed at enhancing VO_2max in youth athletes should integrate strategies that simultaneously encourage muscle development and reduce body fat. This can be achieved through a balanced regimen of endurance training, resistance exercise, and targeted nutritional education tailored to the needs of adolescent athletes.

The lack of correlation between fatigue index and body composition suggests that anaerobic performance may be more dependent on neuromuscular and technical training than on morphological characteristics. Fatigue index, while a useful marker, may not capture all relevant dimensions of anaerobic performance in adolescent athletes.[16] Furthermore, the absence of a correlation between fatigue index and body composition indicates that anaerobic performance may hinge more on neuromuscular efficiency and technical skills than purely morphological characteristics. This finding emphasizes the importance of sport-specific drills and movement training to enhance anaerobic output, particularly in adolescents whose physiological systems are still maturing.[16,17]

These results also carry implications for talent identification and individualized training plans in youth basketball. Coaches may benefit from incorporating regular body composition assessments to track physical development and its relationship to energy system performance. Given that females typically show higher body fat percentages and lower muscle mass during adolescence, there may be value in designing sex-specific conditioning protocols that consider both physiological and developmental differences. In addition, the data suggests a possible threshold effect in aerobic performance where body composition must reach a certain balance before VO_2max significantly improves. Future research should aim to quantify these thresholds and investigate how long-term training interventions affect the interaction between morphology and metabolism.

Limitations

This study has some limitations that should be considered when interpreting the results. First, the relatively small sample size may limit the generalizability of the findings to broader populations of adolescent basketball players. A larger cohort would provide more statistical power and a better representation of performance variability. Second, the use of a cross-sectional design limits the ability to establish causal relationships between body composition and energy system capacities, as the data represents a single point in time rather than changes over a period. Longitudinal studies would be more appropriate for examining developmental trends and training effects. Third, the study did not control differences in training intensity, duration, or competitive experience among participants, which could have influenced both body composition and performance outcomes. Lastly, while field-based tests such as the 20-meter shuttle run and RAST are practical for large groups, they may not be as precise as laboratory-based measurements, potentially affecting the accuracy of VO_2max and anaerobic capacity estimations.

Conclusion

In the overall sample of adolescent basketball players, aerobic capacity was significantly associated with body composition, particularly muscle mass and body fat percentage. Male athletes demonstrated superior aerobic performance compared to females, likely due to more favorable body composition. No significant associations were found for anaerobic capacity. These findings support targeted training and body composition monitoring to optimize performance in youth basketball. Future research should include longitudinal data and control for training regimens to enhance interpretability.

Ethical approval

The study was performed in compliance with relevant laws and institutional guidelines and was approved by the Human Ethics Review Board of the Faculty of Associated Medical Sciences, Chiang Mai University (Approval No. AMSEC-67EX-039). Written informed consent was obtained from all participants and their parents or legal guardians prior to participation.

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Conflict of interest

The authors report no conflicts of interest in this work.

Data availability statement

The data presented in this study are available on request from the corresponding authors.

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CRediT authorship contribution statement

Busaba Chuatrakoon: conceptualization, methodology, investigation, data curation, writing original draft, review and editing, supervision; **Sothida Nantakool:** conceptualization, methodology, review and editing; **Panida Prasertpong:** data collection, data curation, writing original draft, review and editing.

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