

A comparison of aerobic and anaerobic capacities in different positional roles of basketball players aged 13-16 years

Plaifun Naweeppattana¹, Sothida Nantakool², Busaba Chuatrakoon^{2*}

¹Multidisciplinary and Interdisciplinary School, Chiang Mai University, Chiang Mai, Thailand.

²Integrated Neuro-Musculoskeletal, Chronic Disease, and Aging Research Engagement Center (ICARE Center), Department of Physical Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, Thailand.

ARTICLE INFO

ORCID of all authors

Plaifun Naweeppattana: <https://orcid.org/0009-0002-8768-3002>

Sothida Nantakool: <https://orcid.org/0000-0003-4990-0838>

Busaba Chuatrakoon: <https://orcid.org/0000-0001-7880-797X>

Correspondence

Busaba Chuatrakoon

Integrated Neuro-Musculoskeletal, Chronic Disease, and Aging Research Engagement Center (ICARE Center), Department of Physical Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, Thailand, 50200

Email: busaba.c@cmu.ac.th

Article history

Received 2 April 2026

Accepted as revised 21 July 2026

Available online 1 September 2026

Keywords

aerobic capacity, anaerobic performance, playing positions, adolescent athletes, basketball training

ABSTRACT

Background: Basketball is a high-intensity intermittent sport that requires both aerobic and anaerobic energy systems. Physical demands vary across playing positions; however, evidence in adolescent players remains limited.

Objectives: To compare aerobic and anaerobic capacities across different playing positions in basketball players aged 13-16 years.

Materials and methods: This cross-sectional study included 60 adolescent basketball players in Chiang Mai Province. Participants were categorized into five positional roles: point guard, shooting guard, small forward, power forward, and center. Aerobic capacity was assessed using estimated maximal oxygen consumption (VO_2max) from the 20-meter shuttle run test, while anaerobic capacity was evaluated using fatigue index (FI). The body composition variables were recorded, including body mass index, body fat percentage, and muscle mass percentage. Differences among groups were analyzed using one-way ANOVA with Bonferroni post hoc analysis.

Results: No significant differences in anaerobic capacity (FI) were found among the five positions ($p>0.05$). In contrast, aerobic capacity (VO_2max) differed significantly between positions ($p<0.05$), with point guards demonstrating significantly higher VO_2max compared to centers. Other positional comparisons were not statistically significant.

Conclusion: Aerobic capacity differed only between point guards and centers, with point guards demonstrating higher estimated VO_2max than centers, whereas anaerobic capacity appeared comparable across playing positions. These findings suggest that playing position may be associated with differences in aerobic performance and should be considered when designing training programs for adolescent basketball players.

Introduction

Basketball is a widely popular team sport played at various competitive levels, from youth to professional. According to the International Basketball Federation, a standard game consists of four quarters, each lasting 10 minutes, requiring players to maintain performance throughout the match.¹ The ability to compete effectively depends on multiple components, including physical fitness, technical skills, and psychological readiness.

Physical fitness is an essential determinant of performance in basketball and can be categorized into health-related components, such as cardiovascular endurance, muscle strength, muscle endurance, flexibility, and body composition, and skill-related components, including speed, power, agility, balance, reaction time, and coordination.² These components collectively contribute to an athlete's ability to perform sport-specific movements efficiently.

Basketball involves continuous movement patterns, including jogging, running, sprinting, and jumping, with players covering distances ranging from approximately 4,400 to 7,500 meters during a game.³ The intensity of movement can be classified into different levels, from low-intensity activities such as walking and standing to high-intensity actions such as sprinting, jumping, and static exertion.⁴ These variations in activity intensity reflect the intermittent nature of the sport and highlight the importance of both aerobic and anaerobic energy systems.

In addition, the physical and physiological demands of basketball vary by position. Each position has distinct roles and responsibilities, including ball handling, scoring, defense, rebounding, and physical contact. Guards typically require high agility and ball control, while forwards and centers are more involved in physical contact and inside play.⁵ These differences suggest

that energy system demands and physical fitness characteristics may vary according to positional roles.

Previous studies have investigated physical fitness and energy system characteristics in basketball players; however, findings remain inconsistent. One previous study reported differences in physical fitness among positions in adolescent players,⁶ while another found no significant differences in aerobic capacity among professional players.⁷ These inconsistencies may be due to differences in age, training level, and study design. Moreover, most previous research has focused on aerobic capacity, with limited investigation of anaerobic capacity, particularly in early adolescent athletes.

Therefore, there remains a need to examine both aerobic and anaerobic energy systems across playing positions in early adolescent basketball players. Understanding these differences may provide valuable information for training design and player selection. Accordingly, this study aimed to compare aerobic and anaerobic capacities in different positional roles of basketball players aged 13-16 years.

Materials and methods

Participants

A total of 60 adolescent basketball players aged 13-16 years were recruited from Chiang Mai Province. Participants were categorized into five playing positions based on their primary role in the team: point guard (PG), shooting guard (SG), small forward (SF), power forward (PF), and center (C). Each participant was assigned to a playing position according to the team coach's classification of their primary playing position based on their usual role during training and official competitions.

All participants were actively engaged in regular

basketball training and competition and had at least one year of competitive basketball experience. Participants were eligible if they were aged between 13-16 years, currently participating in organized basketball training, and free from musculoskeletal injury or medical conditions that could affect physical performance. Participants with a history of recent injury or any condition that contraindicated exercise testing were excluded.

Study design

This cross-sectional study compared aerobic and anaerobic capacities across different playing positions in adolescent basketball players aged 13-16 years in 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

Anthropometric and body composition variables, including body weight, height, body mass index (BMI), body fat percentage, and muscle mass percentage, were assessed to describe participants' physical characteristics. Body weight, body fat percentage, and muscle mass percentage were measured using a bioelectrical impedance analysis device (InBody, Biospace Co., Ltd., Seoul, Korea), while height was measured using a standard stadiometer. BMI was calculated as weight in kilograms divided by height in

meters squared (kg/m^2).⁸ Aerobic capacity was evaluated using the 20-meter shuttle run test (20-m multistage fitness test), and maximal oxygen consumption (VO_2max) was estimated using the prediction equations developed by Léger *et al.*⁹ The 20-meter shuttle run test has demonstrated good test-retest reliability and moderate-to-high criterion-related validity for estimating maximal oxygen uptake in children and adolescents. Nevertheless, the derived value represents estimated rather than directly measured VO_2max and should therefore be interpreted with appropriate caution. VO_2max was expressed in milliliters per kilogram per minute (ml/kg/min).⁹ Anaerobic capacity was assessed using the Running-based Anaerobic Sprint Test (RAST), from which the fatigue index (FI) was calculated to reflect the decline in power output during repeated maximal sprints. Previous studies have demonstrated that the RAST is a reliable and valid field-based test for assessing running-based anaerobic performance, including in children and adolescents. A higher FI indicates a greater decline in performance across repeated sprints.¹⁰

Study procedure

Participants attended the testing sessions at a designated venue, where all assessments were conducted under standardized conditions (Figure 1). Data collection was performed over three separate days to minimize fatigue effects. On the first day, anthropometric and body composition measurements, including body weight, height, body fat percentage, and muscle mass percentage, were measured.

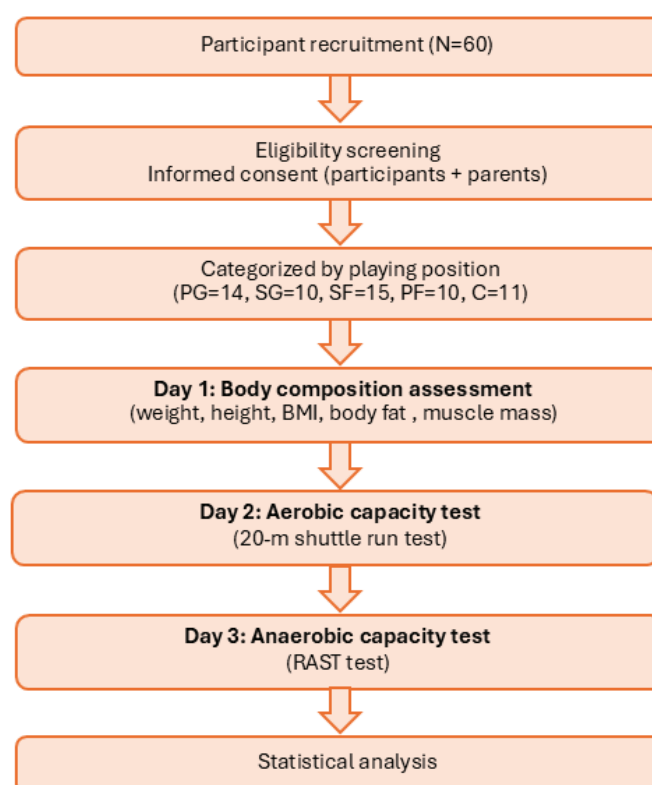


Figure 1. Flow diagram of participant recruitment, outcome measures, and study procedures.

On the second day, participants completed a standardized warm-up consisting of light aerobic activity and dynamic stretching, followed by the assessment of aerobic capacity using the 20-meter shuttle run test. During the test, participants ran back and forth between two lines in time with audio signals until exhaustion. Maximal oxygen consumption (VO_2max) was estimated using the following equation: $\text{VO}_2\text{max (ml/kg/min)} = 31.025 + (3.238 \times \text{speed}) - (3.248 \times \text{age}) + (0.1536 \times \text{speed} \times \text{age})$, where speed represents the final running speed achieved during the test.⁹

Participants were instructed to avoid vigorous physical activity for at least 24 hours before both the aerobic and anaerobic assessments. The anaerobic assessment was conducted on a separate day following at least 24 hours of rest to ensure adequate recovery. Participants performed the Running-based Anaerobic Sprint Test (RAST), which consisted of six maximal sprints over 35 meters with short recovery intervals between each sprint. Power output for each sprint was calculated using the following equation: $\text{Power (W)} = \text{Body mass} \times \text{Distance}^2 / \text{Time}^3$.¹⁰ The fatigue index (FI) was then calculated using the following equation: $\text{FI} = (\text{Maximum power} - \text{Minimum power}) / \text{Total time}$.¹⁰ All participants were instructed to perform at their maximal effort throughout the testing sessions.

Data analysis

All statistical analyses were performed using SPSS software (version 21.0, IBM Corporation, Chicago, IL, USA). Descriptive statistics were presented as mean

$\pm$ standard deviation (SD). Prior to inferential analysis, the normality of data distribution was assessed using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test. Variables satisfying the assumptions of normality and homogeneity of variance were analyzed using one-way analysis of variance (ANOVA), whereas variables that violated these assumptions were analyzed using the Kruskal-Wallis test. Differences in anthropometric variables, aerobic capacity (VO_2max), and anaerobic capacity (fatigue index) among the five playing positions were analyzed using one-way analysis of variance (ANOVA). When significant differences were identified, post hoc comparisons were performed using the Bonferroni correction to determine pairwise differences between groups. The level of statistical significance was set at $p < 0.05$.

Results

A total of 60 adolescent basketball players aged 13-16 years were included in the study and categorized into five playing positions: point guard (PG, N=14), shooting guard (SG, N=10), small forward (SF, N=15), power forward (PF, N=10), and center (C, N=11). Table 1 presents the anthropometric characteristics and body composition of participants across playing positions. No significant differences were observed among the five playing positions in any anthropometric or body composition variables (all $p > 0.05$), including body weight, which was analyzed using the Kruskal-Wallis test.

Table 1. Anthropometric characteristics of basketball players according to playing position.

Variables	PG (N=14)	SG (N=10)	SF (N=15)	PF (N=10)	C (N=11)
Male, N (%)	10 (71.4)	6 (60.0)	7 (46.7)	4 (40.0)	6 (54.4)
Age (years)	13.93 $\pm$ 1.44	14.70 $\pm$ 1.34	13.67 $\pm$ 1.23	14.50 $\pm$ 1.08	13.82 $\pm$ 1.33
Body weight (kg)	53.16 $\pm$ 8.89	56.10 $\pm$ 7.98	52.53 $\pm$ 8.52	61.88 $\pm$ 8.42	67.12 $\pm$ 26.59
Height (cm)	164.93 $\pm$ 8.51	164.50 $\pm$ 10.29	164.80 $\pm$ 9.57	170.60 $\pm$ 9.23	174.45 $\pm$ 7.76
Body mass index (kg/m^2)	19.54 $\pm$ 1.87	20.73 $\pm$ 2.11	19.23 $\pm$ 1.75	21.26 $\pm$ 2.46	21.52 $\pm$ 6.70
Body fat (%)	14.65 $\pm$ 5.55	20.52 $\pm$ 9.73	17.95 $\pm$ 6.29	22.34 $\pm$ 9.35	20.93 $\pm$ 9.21
Muscle mass (%)	80.67 $\pm$ 5.42	75.16 $\pm$ 9.34	77.41 $\pm$ 6.15	73.15 $\pm$ 9.07	74.51 $\pm$ 8.58

Note: PG: point guard position, SG: shooting guard position, SF: small forward position, PF: power forward position, C: center position. Body weight was analyzed using the Kruskal-Wallis test. All other continuous variables were analyzed using one-way ANOVA.

Aerobic capacity, expressed as VO_2max , differed significantly among playing positions ($p < 0.05$), as shown in Table 2. The highest mean VO_2max was observed in point guards, whereas the lowest values were found in centers. Post hoc analysis using the Bonferroni correction revealed that point guards had significantly higher VO_2max than centers ($p < 0.05$), while no other pairwise differences were observed.

Anaerobic capacity, assessed using the RAST test, showed no significant differences among playing positions for peak power, mean power, or fatigue index (all $p > 0.05$). Furthermore, Bonferroni post hoc analysis revealed no significant pairwise differences between any playing positions for these variables, as presented in Table 2.

Table 2. Comparison of aerobic and anaerobic performance among basketball players according to playing position.

Variables	PG (N=14)	SG (N=10)	SF (N=15)	PF (N=10)	C (N=11)	p value
Peak power	515.67±352.73	370.64±162.52	345.83±125.04	456.35±195.18	342.46±124.06	0.180
Mean power	360.77±187.22	294.59±123.87	274.57±104.73	337.74±141.62	276.59±102.79	0.402
Fatigue index	7.72±8.21	4.09±3.39	3.59±2.08	5.82±3.94	3.03±1.87	0.086
VO_2max (ml/kg/min)	30.21±8.08*	24.08±8.51	26.47±11.07	21.12±8.39	18.85±8.82	0.030**

Note: VO_2max : Maximal oxygen consumption, PG: point guard position, SG: shooting guard position, SF: small forward position, PF: power forward position, C: center position. *significant difference from the center position (Bonferroni post hoc test, $p < 0.05$), **significant difference based on one-way ANOVA, $p < 0.05$.

Discussion

The present study aimed to compare aerobic and anaerobic capacities among basketball players across different playing positions in early adolescence. The main findings indicated that aerobic capacity, expressed as VO_2max , differed significantly among positions, with point guards showing higher values than centers, whereas anaerobic capacity, assessed by fatigue index, did not differ significantly across positions.

The observed differences in VO_2max among positions may be explained by variations in physiological demands and movement patterns inherent to each playing role. Basketball is characterized by intermittent high-intensity activities interspersed with periods of moderate and low intensity, requiring both aerobic and anaerobic energy systems.¹¹⁻¹³ However, the relative contribution of these systems varies by position. Guards, particularly point guards, are typically involved in continuous movement, including ball handling, fast breaks, and frequent changes of direction. These activities result in greater cumulative distance and higher frequency of moderate-to-high intensity efforts during gameplay, which provide a stronger stimulus for aerobic adaptation.^{12,14}

From a physiological perspective, the higher estimated VO_2max observed in point guards may be explained by physiological adaptations associated with repeated aerobic exercise. According to the Fick equation, VO_2max is determined by the product of cardiac output and the arteriovenous oxygen difference.¹⁵ Previous studies have suggested that regular aerobic training may promote adaptations such as increased stroke volume, enhanced capillary density, greater mitochondrial content, and improved oxidative enzyme activity, which could enhance oxygen delivery and utilization.¹⁵⁻¹⁷ However, these physiological variables were not directly measured in the present study; therefore, their contribution to the observed positional differences remains speculative.

One possible explanation is that point guards typically accumulate greater movement demands during basketball-specific drills and gameplay,¹⁸ despite all players participating in the same team-based training program without position-specific conditioning. Accordingly, the higher estimated VO_2max observed in point guards may reflect greater movement demands during training and competition rather than differences in the prescribed training program. Nevertheless, individual differences in training load, adherence, and previous playing experience were not assessed and therefore cannot be excluded as potential contributing factors.

In contrast, players in the center position demonstrated lower VO_2max values, which may partly reflect both physiological and functional factors. Centers typically perform activities that emphasize strength, positioning, rebounding, and short bursts of explosive movements within a limited area. These actions rely more heavily on phosphagen and anaerobic glycolytic systems than on sustained aerobic metabolism.^{4,11} Additionally, the generally higher body mass and BMI observed among centers may contribute to lower relative VO_2max values when expressed in ml/kg/min.¹⁹ Previous studies have also reported that VO_2max is positively associated with muscle mass and negatively associated with body fat and BMI, suggesting that body composition may influence aerobic performance.²⁰

Although a significant difference in VO_2max was observed across positions, post hoc analysis indicated that this difference was primarily between point guards and centers, with no significant differences among other positional comparisons. These findings suggest that positional differences in aerobic capacity may exist but were not consistently observed across all playing positions, possibly because of inter-individual variability during adolescence, including differences in biological maturation and training experience.^{21,22}

Regarding anaerobic capacity, the present study found no significant differences in fatigue index among

playing positions. This finding may reflect the similar exposure of all players to high-intensity, short-duration activities inherent in basketball, regardless of position.^{11,23} Although positional roles differ, most players are required to perform repeated sprints, jumps, and rapid accelerations during training and competition, which may lead to comparable adaptations in anaerobic performance.²³⁻²⁵ Similarly, no significant differences were observed in peak power or mean power among the playing positions, suggesting that anaerobic power was also relatively comparable across positional roles in this cohort. Another possible explanation for the lack of significant differences in fatigue index is the high variability observed within groups, particularly among point guards. This variability may reduce the statistical power to detect differences between positions. Furthermore, participants' developmental stage (aged 13-16 years) may contribute to variability in neuromuscular and metabolic adaptations, as adolescents differ in growth, maturation, and training history.²¹ The findings of this study are partially consistent with previous research. Studies involving adolescent basketball players have reported that guards generally demonstrate superior aerobic capacity and overall physical fitness compared with forwards and centers, largely because of their greater movement demands and higher involvement in continuous play.^{6,12}

These findings are consistent with the present study, in which point guards exhibited significantly higher estimated $\text{VO}_{2\text{max}}$ than centers. However, unlike some previous studies that reported differences across several playing positions, the present study identified a significant difference only between point guards and centers. This discrepancy may be related to the relatively small sample size within each positional group, the wide inter-individual variability during adolescence, and differences in biological maturation and training experience. In contrast, studies involving professional basketball players have reported no significant positional differences in aerobic capacity.^{7,13} This difference may be associated with the more extensive and systematic training typically undertaken by professional players. However, this interpretation remains speculative and should be confirmed by longitudinal studies. In adolescent athletes, the greater variability in aerobic fitness observed in the present study may be related to differences in biological maturation, positional specialization, and training experience; however, these factors were not directly assessed.

Limitations

This study has several limitations that should be considered when interpreting the findings. Firstly, the sample size in each playing position was relatively small, particularly in the shooting guard and power forward groups, which may have limited the statistical power

to detect differences across all pairwise comparisons. Consequently, the absence of statistically significant differences, particularly for fatigue index, should be interpreted with caution. Secondly, variability within groups, especially in the fatigue index, was relatively high, which may have limited the ability to detect differences in anaerobic capacity among positions. Thirdly, although participants were within a relatively narrow age range (13-16 years), biological maturation was not directly assessed using standardized methods such as Tanner staging. Variations in biological maturation, growth, sex distribution across playing positions, and training experience may therefore have influenced physiological performance. In addition, aerobic capacity was estimated using the 20-meter shuttle run test rather than directly measured by cardiopulmonary exercise testing. Although the test has demonstrated good validity and reliability, using a prediction equation may introduce estimation error and should be considered when interpreting the reported $\text{VO}_{2\text{max}}$ values. Finally, the cross-sectional design limits the ability to determine causal relationships between playing position and physiological capacities.

Longitudinal studies are needed to better understand how training and positional roles influence the development of aerobic and anaerobic fitness over time. In addition, the study did not record the duration of basketball training. Variations in training experience among players may have influenced aerobic and anaerobic capacities and could partly explain the observed differences between playing positions.

Future studies should collect detailed information regarding training duration, training frequency, training load, and biological maturation to better account for these potential confounding factors. In addition, recruiting a larger, more balanced sample across playing positions and sex, or using stratified sampling during recruitment, may reduce intra-group variability and improve the robustness of future findings.

Practical implications

The findings provide useful information for coaches and sports scientists involved in youth basketball training. The higher aerobic capacity observed in point guards compared with centers suggests that position-specific training programs may help optimize performance. Coaches may consider incorporating more aerobic conditioning for players in positions requiring continuous movement, such as guards, while emphasizing strength and short-duration high-intensity training for centers.

In addition, the lack of significant differences in anaerobic capacity among positions indicates that all players may benefit from training programs that include repeated sprint and high-intensity interval exercises. These findings may also assist in talent identification and player selection by highlighting the importance of aligning physiological characteristics with positional demands.

Conclusion

In conclusion, a significant difference in aerobic capacity was observed only between point guards and centers, with point guards demonstrating higher estimated VO_2max than centers. In contrast, anaerobic capacity, as assessed by fatigue index, did not differ significantly among positions. These findings suggest that positional roles may influence aerobic fitness more than anaerobic performance in young basketball players. Understanding these differences may support the development of position-specific training strategies and improve performance in adolescent basketball athletes.

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.

Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to improve the language, readability, and clarity of the text. The authors subsequently reviewed and revised the content and took full responsibility for the final version of the manuscript.

Funding

This research received no external funding.

Conflict of interest

The authors declare no conflicts of interest.

CRediT authorship contribution statement

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

Acknowledgements

The authors thank all participants who took part in this study. Thanks also to the Multidisciplinary and Interdisciplinary School, Chiang Mai University, and the Faculty of Associated Medical Sciences, Chiang Mai University for supporting this research project.

References

- [1] FIBA. Official Basketball Rules 2022 [Internet]. 2022 [cited 2026 Jan 1]. Available from: <https://www.fiba.basketball>.
- [2] American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 11th ed. Philadelphia: Wolters Kluwer; 2021.
- [3] Morrison M, Martin DT, Talpey S, Scanlan AT, Delaney J, Halson SL, et al. A Systematic Review on Fitness Testing in Adult Male Basketball Players: Tests Adopted, Characteristics Reported and Recommendations for Practice. *Sports Med.* 2022 Jul; 52(7): 1491-1532. doi: 10.1007/s40279-021-01626-3.
- [4] Delextrat A, Badiella A, Saavedra V, Matthew D, Schelling X, Torres-Ronda L. Match activity demands of elite basketball players. *Front Psychol.* 2015; 6: 1486. doi: 10.3389/fpsyg.2015.01486.
- [5] Péndola-Reinecke MI, Jiménez-Sáiz S, Mochales Cuesta I, Bustamante-Sánchez Á. Exploring new dimensions in the classification of basketball player positions. *Appl Sci.* 2025; 15(11): 6159. doi: 10.3390/app15116159.
- [6] Ivanović J, Kukić F, Greco G, Koropanovski N, Jakovljević S, Dopsaj M. Specific Physical Ability Prediction in Youth Basketball Players According to Playing Position. *Int J Environ Res Public Health.* 2022 Jan 16; 19(2): 977. doi: 10.3390/ijerph19020977.
- [7] Stojmenović D, Trunić N, Stojmenović T. A comparative study of aerobic capacity among elite basketball players according to five different positions in the team. *J Phys Educ Sport.* 2022; 22(10): 2522–9. doi: 10.7752/jpes.2022.10320.
- [8] Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, et al. Bioelectrical impedance analysis--part I: review of principles and methods. *Clin Nutr.* 2004 Oct; 23(5): 1226-43. doi: 10.1016/j.clnu.2004.06.004.
- [9] Léger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci.* 1988 Summer; 6(2): 93-101. doi: 10.1080/02640418808729800.
- [10] Zagatto AM, Beck WR, Gobatto CA. Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *J Strength Cond Res.* 2009 Sep; 23(6): 1820-7. doi: 10.1519/JSC.0b013e3181b3df32.
- [11] McInnes SE, Carlson JS, Jones CJ, McKenna MJ. The physiological load imposed on basketball players during competition. *J Sports Sci.* 1995 Oct; 13(5): 387-97. doi: 10.1080/02640419508732254.
- [12] Ben Abdelkrim N, El Fazaa S, El Ati J. Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med.* 2007 Feb; 41(2): 69-75; discussion 75. doi: 10.1136/bjism.2006.032318.
- [13] Castagna C, Impellizzeri FM, Rampinini E, D'Ottavio S, Manzi V. The Yo-Yo intermittent recovery test in basketball players. *J Sci Med Sport.* 2008 Apr; 11(2): 202-8. doi: 10.1016/j.jsams.2007.02.013.
- [14] Bredt SGT, Torres JO, Diniz LBF, Praça GM, Andrade AGP, Morales JCP, et al. Physical and physiological demands of basketball small-sided games: the influence of defensive and time pressures. *Biol Sport.* 2020 Jun; 37(2): 131-138. doi: 10.5114/biolSport.2020.93038.

- [15] Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sports Exerc.* 2000 Jan; 32(1): 70-84. doi: 10.1097/00005768-200001000-00012.
- [16] MacInnis MJ, Gibala MJ. Physiological adaptations to interval training and the role of exercise intensity. *J Physiol.* 2017 May 1; 595(9): 2915-2930. doi: 10.1113/JP273196.
- [17] Poole DC, Jones AM. Oxygen uptake kinetics. *Compr Physiol.* 2012 Apr; 2(2): 933-96. doi: 10.1002/cphy.c100072.
- [18] Gottlieb R, Shalom A, Calleja-Gonzalez J. Physiology of Basketball - Field Tests. Review Article. *J Hum Kinet.* 2021 Jan 30; 77: 159-167. doi: 10.2478/hukin-2021-0018.
- [19] Rowland TW. *Children's Exercise Physiology*. 2nd ed. Champaign (IL): Human Kinetics; 2005.
- [20] Prasertpong P, Nantakool S, Chuatrakoon B. Association of aerobic and anaerobic capacities with body composition in basketball players aged 13-16 years in Chiang Mai Province. *J Assoc Med Sci.* 2026; 59(2): 280-285. doi: 10.66285/JAMS.2026.059.
- [21] Moran JJ, Sandercock GR, Ramírez-Campillo R, Meylan CM, Collison JA, Parry DA. Age-Related Variation in Male Youth Athletes' Countermovement Jump After Plyometric Training: A Meta-Analysis of Controlled Trials. *J Strength Cond Res.* 2017 Feb; 31(2): 552-565. doi: 10.1519/JSC.00000000000001444.
- [22] Armstrong N, Barker AR. Endurance training and elite young athletes. *Med Sport Sci.* 2011; 56: 59-83. doi: 10.1159/000320633.
- [23] Spencer M, Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities: specific to field-based team sports. *Sports Med.* 2005; 35(12): 1025-44. doi: 10.2165/00007256-200535120-00003.
- [24] Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Med.* 2013 May; 43(5): 313-38. doi: 10.1007/s40279-013-0029-x.
- [25] Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability - part I: factors contributing to fatigue. *Sports Med.* 2011 Aug 1; 41(8): 673-94. doi: 10.2165/11590550-000000000-00000.