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Effects of circuit and interval training on Vo_2max in adolescent basketball athletes: The moderating role of body mass index

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Abstract

Background: Aerobic capacity (VO_2max) is a critical determinant of basketball performance due to the sport's intermittent high-intensity demands. Although circuit training and interval training are widely used to improve aerobic fitness, limited evidence exists regarding the role of Body Mass Index (BMI) in moderating training outcomes among adolescent basketball athletes.
Aims: This study aimed to examine the effects of training method (circuit vs. interval) and BMI category on VO_2max in adolescent basketball athletes, as well as the interaction between these variables.
Methods: A 2×2 factorial experimental design was employed involving 40 basketball athletes aged 15–18 years. Participants were allocated to four groups based on training method (interval or circuit) and BMI category (low or high). VO_2max was assessed using the Beep Test, while BMI was calculated from height and weight measurements. Data were analyzed using two-way ANOVA at a significance level of 0.05.
Result: No significant difference was found between interval and circuit training in VO_2max outcomes ($p = 0.362$), indicating that both methods produced comparable aerobic adaptations. A significant difference was observed between BMI categories ($p = 0.036$), with athletes in the low-BMI group demonstrating higher VO_2max values than those in the high-BMI group. No significant interaction between training method and BMI category was found ($p = 0.685$).
Conclusion: Both interval and circuit training effectively improved VO_2max in adolescent basketball athletes. Nevertheless, BMI significantly affected the magnitude of improvement, suggesting that maintaining an optimal BMI may support better aerobic adaptation in youth basketball training programs.

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INTRODUCTION

Physical fitness refers to a combination of measurable health- and skill-related components, including cardiorespiratory endurance, muscular strength, flexibility, balance, agility, and muscle tone (Cao et al., 2024; Navarrete-Villanueva et al., 2021; Tabacchi et al., 2019). Among these components, cardiorespiratory endurance is particularly important in supporting the efficiency of the circulatory and respiratory systems during continuous physical activity (Atradinal et al., 2025; Ikenna et al., 2020). Improving physical fitness requires regular physical exercise to enhance overall body performance (Taufik et al., 2021). In addition to improving physical capacity, physical exercise also contributes to cognitive function, psychological well-being, mobility, and independent

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functioning (Akbar et al., 2025; Bratic et al., 2022; Daimiel et al., 2020; Eckstrom et al., 2020; Görner & Reineke, 2020; Herbert et al., 2020). In competitive sports, adequate physical fitness is essential for supporting athletic performance and recovery, as well as maintaining high-intensity activity during training and competition.

Basketball is a sport characterized by intermittent high-intensity activities such as sprinting, jumping, rapid directional changes, and continuous transitions between offensive and defensive play. These physical demands require athletes to possess not only anaerobic power but also strong aerobic capacity to sustain performance throughout the game. One of the main indicators of aerobic capacity is maximal oxygen uptake (VO_2max), which reflects the body's ability to absorb, transport, and utilize oxygen during intense physical activity (Al-Khelaifi et al., 2020; Deliceoğlu et al., 2024; Junita et al., 2024; Lundby et al., 2017). Higher VO_2max levels are associated with improved endurance, faster recovery, and better overall basketball performance. Therefore, improving VO_2max is considered an important component of physical conditioning programs for basketball athletes, particularly adolescents who are still undergoing physical and physiological development.

To improve aerobic capacity and support basketball performance, various training methods have been widely implemented, particularly circuit training and high-intensity interval training (HIIT) (Feng et al., 2023). Among these methods, circuit and interval training have demonstrated significant effectiveness in enhancing VO_2max, with circuit training showing superior improvement in professional futsal athletes (Yunus & Raharjo, 2022). Circuit training combines aerobic and resistance exercises performed sequentially across several stations to simultaneously improve muscular strength and cardiorespiratory fitness (Ballesta-García et al., 2020; Ikenna et al., 2020), and has been shown to enhance physical fitness and exercise performance across different athletic populations (Bossmann et al., 2022; Gutiérrez-Arroyo et al., 2023). These adaptations are particularly relevant to basketball athletes, who must repeatedly sprint, jump, and change direction rapidly throughout a match. Meanwhile, HIIT and sprint interval training (SIT) involve repeated bouts of moderate- to near-maximal intensity exercise interspersed with recovery periods. They can be adapted to improve both athletic performance and health-related outcomes (MacInnis & Gibala, 2017).

Previous studies have demonstrated that HIIT improves aerobic capacity and peak oxygen consumption (VO_2max), important indicators of cardiorespiratory fitness (Atakan et al., 2021; Wu et al., 2021). In addition, HIIT has been shown to enhance overall physical fitness and exercise performance while promoting favorable changes in body composition (Coates et al., 2023; Wu et al., 2021). Improved aerobic fitness may help basketball players maintain performance during repeated high-intensity actions and recover more efficiently between game phases. Among overweight adolescents, HIIT interventions have also been associated with reductions in body weight, waist-to-hip ratio, and body fat percentage (Domaradzki et al., 2020). However, most previous studies have examined circuit training and HIIT separately or in sports other than basketball, making it difficult to determine which training method is more effective for improving VO_2max in adolescent basketball athletes. Consequently, comparative evidence between these two training approaches within the context of youth basketball remains scarce.

While training interventions such as circuit training and HIIT play an important role in improving VO_2max, nutritional status, and body composition, these factors also contribute substantially to physical fitness and physiological adaptation in adolescents. Body Mass Index (BMI) is one of the most commonly used measures for evaluating nutritional status and physical readiness in adolescent athletes. In basketball, maintaining an appropriate BMI is particularly important because excessive or insufficient body mass may negatively affect movement efficiency, endurance, and overall game performance. Adolescents with non-ideal body weight tend to demonstrate lower physical fitness levels, whereas adequate carbohydrate and protein intake is associated with improved physical performance (Bratic et al., 2022; Oukheda et al., 2023). Balanced nutritional intake supports recovery, immune function, and overall health, all of which are essential for optimizing athletic development (Bogataj et al., 2021; Shao et al., 2021). Conversely, inadequate nutrition and unfavorable body composition may increase fatigue and negatively affect exercise adaptation and cardiovascular fitness (Ahmeti et al., 2020; Azzolino et al., 2020; Ferozi et al., 2024; Oliveira-Junior et al., 2021). On the other hand, non-compliance with nutritional guidelines in athletes, as well as the consumption of new foods or supplements, can lead to gastrointestinal (GI) disorders (Martínez-Sanz et al., 2020).

Beyond serving as an indicator of nutritional status, BMI may also influence the effectiveness of aerobic training interventions aimed at improving VO_2max. An ideal BMI reflects balanced body composition that supports efficient energy production, recovery, movement efficiency, and physiological adaptation during intensive exercise (Sánchez-Díaz et al., 2021; Welis et al., 2023; Yendrizal et al., 2025). In contrast, excessively low or high BMI levels may reduce aerobic capacity, increase fatigue, and elevate the risk of injury during physical activity. In basketball athletes, BMI may influence not only aerobic capacity but also agility, jumping performance, repeated sprint ability, and movement efficiency during high-intensity play. Although previous studies have demonstrated the effectiveness of circuit and interval training in improving aerobic capacity (Gutiérrez-Arroyo et al., 2023; Sampaio et al., 2020), most investigations have examined these training methods independently or in athletic populations other than basketball players (Idrizovic et al., 2021; Nowaczyk et al., 2023). Consequently, it remains unclear whether BMI influences the effectiveness of different aerobic training methods commonly used to improve VO_2max in adolescent basketball athletes. Furthermore, body composition variables, such as BMI, are often treated as descriptive characteristics rather than as factors that may influence training responsiveness. Addressing this gap is important because adolescence is a critical period of growth and physiological adaptation, during which variations in body composition may influence responses to exercise training. To the best of our knowledge, no previous study has simultaneously compared circuit and interval training while examining BMI as a moderator of VO_2max adaptation in adolescent basketball athletes, using a factorial experimental design. Therefore, this study employed a factorial experimental approach to compare the effects of circuit and interval training on VO_2max and to examine the moderating role of BMI among adolescent basketball athletes.

METHOD

Research Design

This study employed a 2×2 factorial design to examine the effects of interval and circuit training methods on VO_2max improvement in adolescent basketball athletes, with Body Mass Index (BMI) considered as a moderating variable. This experimental framework enabled the identification of both main effects and potential interactions between training type and BMI on aerobic capacity. A total of 40 participants aged 15–18 years were classified by BMI category and subsequently assigned proportionally to interval or circuit training groups. VO_2max was measured before (pretest) and after (posttest) the six-week intervention to determine changes in aerobic capacity. Certified trainers supervised all sessions, and standardized procedures were consistently applied across groups. To minimize external influences, participants were instructed to maintain consistent dietary habits and avoid additional high-intensity physical activities throughout the study period.

Table 1. Participant Allocation in the 2 × 2 Factorial Design

BMI	VO_2max Training				TOTAL
	Interval Training (A1)	N	Circuit Training (A2)	N	
Low (B1)	A1B1	10	A2B1	10	20
High (B2)	A1B2	10	A2B2	10	20
Total	A1	20	A2	20	40

Notes: BMI = Body Mass Index,

Description:

A1 : Interval training group
A2 : Circuit training group
B1 : Low BMI group
B2 : High BMI group
A1B1 : Interval training group with low BMI
A2B1 : The circuit training group with low BMI
A1B2 : Interval training group with high BMI

A2B2 : Circuit training group with high BMI

Research Participants

A total of 76 adolescent basketball athletes from a single training program participated in this study. Based on the percentile distribution of Body Mass Index (BMI), 20 participants with the highest BMI values and 20 with the lowest were selected as the research sample. Consequently, the final sample analyzed consisted of 40 athletes, with a mean age of 17.8 years (Ilham et al., 2025; Padli et al., 2024; Sari et al., 2025). All participants were required to meet predefined inclusion criteria, including having a resting heart rate within the normal range, adequate oxygen saturation levels, and systolic and diastolic blood pressure within physiological limits (SpO_2: 96–100%). Once the BMI data for all athletes were collected, a follow-up analysis was conducted using ordinal pairing techniques to form matched pairs and determine the initial allocation of participants into experimental groups.

Participant allocation was conducted using an A–B–B–A pairing approach to ensure balanced group distribution. Randomization procedures were facilitated using IBM SPSS Statistics Version 25 to minimize potential selection bias. Aerobic capacity was assessed using the Multi-Stage Fitness Test (Beep Test), which served as the primary instrument for estimating VO_2max. Pretest and posttest measurements were conducted before and after the six-week intervention period (Selviani et al., 2024).

Before data collection, all participants received a detailed explanation regarding the study procedures and intervention stages, and provided written informed consent. For participants under 18 years of age, written permission was obtained from parents or legal guardians, accompanied by verbal and written assent from the adolescents. All procedures were conducted in accordance with applicable ethical standards and research regulations.

Training Protocol

The intervention program lasted six weeks, with training sessions held three times per week. Each session began with a 10-minute warm-up involving static and dynamic stretching, followed by a 45-minute endurance-focused workout. The interval training group performed short bursts of high-intensity activity interspersed with active or passive recovery phases to enhance aerobic capacity and energy recovery. The circuit training group completed continuous exercises across multiple stations with structured work-rest intervals, aiming to maintain heart rate within the aerobic zone and improve cardiovascular and muscular endurance. Sessions concluded with a five-minute cooldown consisting of active recovery and stretching. Training intensity was progressively increased each week, adhering to the principles of overload and individualization. The first two weeks emphasized movement familiarization and technical refinement. Weeks three and four introduced multi-directional drills and speed variations, while weeks five and six focused on maximal effort, rapid transitions, and peak performance. A tapering phase was implemented in week four to support recovery before the intervention's final stage.

Measurement and Data Collection

Body weight was measured in kilograms using a digital scale (OMRON HN-289, Japan), while height was assessed with a portable stadiometer (Seca®, North America). Body Mass Index (BMI) was calculated using the standard formula: body weight (kg) divided by height squared (m^2). Aerobic capacity was evaluated using the Multi-Stage Fitness Test (Beep Test), a standardized field test commonly used to indirectly estimate VO_2max. The test was conducted on a basketball court marked in accordance with official testing guidelines. Participants performed continuous shuttle runs in response to audio signals at progressively increasing speeds until volitional exhaustion or failure to maintain pace with the beep intervals. VO_2max estimates were determined based on the final level and number of shuttles completed. Certified trainers supervised all testing procedures to ensure protocol consistency and minimize measurement variability.

Statistical Analysis

Descriptive statistical analysis was employed to characterize participant profiles and evaluate the impact of the training program. The Shapiro–Wilk test was applied to assess the normality of the data distribution, while Levene's test was used to verify the homogeneity of variances across groups.

VO_2max was analyzed using a two-way analysis of variance (Two-Way ANOVA). Effect sizes were calculated using partial eta squared (η^2p), and results were interpreted with a 95% confidence interval. All statistical procedures were performed using IBM SPSS Statistics Version 25, with a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

Result

The research data were analyzed using descriptive statistical techniques, with VO_2max (Y) as the outcome variable and the primary treatment factor (X1) being Training Method (A), comprising Interval Training (A1) and Circuit Training (A2). Additionally, Body Mass Index (BMI) was incorporated as a secondary factor (X2), classified into Low BMI (B1) and High BMI (B2) categories.

Data Description

Descriptive statistics of VO_2max across training methods and BMI categories are presented in Table 3.

Table 3. Calculation of Basic Statistics

Statistic	A1	A2	B1	B2	A1B1	A1B2	A2B1	A2B2
N	20	20	20	20	10	10	10	10
Mean	43.74	44.67	45.3	43.1	44.63	42.84	45.98	43.36
SD	3.09	3.55	2.54	3.68	2.42	3.53	2.6	3.99
Varians	9.53	12.58	6.46	13.55	5.88	12.45	6.74	15.99
Minimum	38.5	38.5	42.1	38.5	42.1	38.5	43	38.5
Maximum	50.2	50.4	50.4	49.6	50.2	49.3	50.4	49.6

Source: *Output* SPSS 25

As shown in Table 3, the mean VO_2max for the Interval Training group was 43.74, while the Circuit Training group recorded a higher mean of 44.67. This indicates that Circuit Training yielded slightly greater improvements in aerobic capacity than Interval Training. Among participants with low Body Mass Index (BMI) (B1), the mean VO_2max was 45.3. In contrast, those with high BMI (B2) had a lower mean of 43.1, suggesting that lower BMI is associated with superior aerobic performance.

Further comparison of the combined variable groups—A1B1, A1B2, A2B1, and A2B2—revealed that the highest mean VO_2max was observed in the A2B1 group (Circuit Training with low BMI), at 45.98. This finding suggests that, among participants with low BMI, the most favorable VO_2max outcomes were achieved through Circuit Training.

Prerequisite Test Analysis

Prior to hypothesis testing using a two-way ANOVA, assumption tests were conducted to verify that the data met the required assumptions. The assumption testing included normality and homogeneity of variance tests. Data normality was assessed using the Shapiro–Wilk test, while homogeneity of variance across groups was evaluated using Levene's test. These preliminary analyses are important to confirm that the dataset satisfies the assumptions underlying parametric statistical procedures and that the ANOVA results can be interpreted appropriately. The results of the normality and homogeneity tests are presented in Table 4.

Table 4. Testing For Normality and Homogeneity

Normality Test			Homogeneity Test		
Shapiro-Wilk			Levene's		
Statistic	Df	p	df1	df2	P
0.168	40	0.135	3	36	0.112

Note: Data is normally distributed and homogeneous (P>0.05).

Group A1B1 recorded a mean VO_2max of 44.63, while Group A2B1 achieved a higher mean of 45.98. Concurrently, Group A1B2 reported a mean of 42.84, and Group A2B2 recorded 43.36. As presented in Table 3, Group A2B1 demonstrated the most notable improvement in VO_2max compared to all other treatment groups. A visual representation of these data is provided in Table 3.

Results from the normality and homogeneity tests, shown in Table 4, indicate that all data points were normally distributed and homogenous ($p > 0.05$).

Hypothesis Test

Hypothesis testing was conducted using a two-way Analysis of Variance (ANOVA). The results of the statistical calculations, performed using IBM SPSS Statistics Version 25, are presented in Table 5.

Table 5. Two-way Factorial ANOVA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	$\eta^2 p$
Metode	8.74	1	8.74	.85	.362	0.330
BMI	48.62	1	48.62	4.73	.036	0.261
Metode BMI	1.72	1	1.72	.168	.685	0.112

Source: *Output* SPSS 25

The analysis revealed no statistically significant difference in VO_2max between the Interval Training and Circuit Training groups ($F = 0.85$, $p = 0.362$). However, a significant main effect of BMI category on VO_2max was observed ($F = 4.73$, $p = 0.036$), indicating that participants with lower BMI had higher aerobic capacity than those with higher BMI. Furthermore, no significant interaction effect between training method and BMI category on VO_2max was found ($F = 0.168$, $p = 0.685$), suggesting that the effectiveness of the training methods was not influenced by BMI classification. The effect size analysis showed that the training method had a large effect on VO_2max ($\eta^2 p = 0.330$), whereas BMI demonstrated a large effect size ($\eta^2 p = 0.261$). The interaction between training method and BMI produced a moderate effect ($\eta^2 p = 0.112$). These findings suggest that both training method and BMI contributed meaningfully to variations in aerobic capacity, although the ANOVA results indicated that only BMI reached statistical significance. Therefore, BMI appears to be a more consistent determinant of VO_2max among adolescent basketball athletes. At the same time, the influence of training method and its interaction with BMI may require further investigation using larger samples and longer intervention periods.

Discussion

This study investigated the effects of interval and circuit training on VO_2max improvement among adolescent basketball athletes, while accounting for Body Mass Index (BMI) as a moderating factor. The findings revealed that both training methods effectively improved aerobic capacity, with no statistically significant difference observed between interval training and circuit training. In contrast, BMI significantly influenced VO_2max outcomes, whereas no significant interaction between training method and BMI category was observed.

The lack of significant differences between interval and circuit training suggests that both methods are equally effective at enhancing aerobic capacity when implemented progressively and systematically. Although the structure of the training programs differs, both approaches provide repeated cardiovascular stimulation, promoting physiological adaptations associated with aerobic fitness. These adaptations may include increased mitochondrial density, enhanced oxidative enzyme activity, improved stroke volume, and more efficient oxygen extraction by working muscles. Consequently, both training methods can improve oxygen utilization efficiency and exercise endurance. This finding is consistent with previous studies reporting that interval-based and circuit-based training programs produce comparable improvements in VO_2max and overall physical fitness (Arslan et al., 2022; Cao et al., 2025; Song et al., 2023). Therefore, the effectiveness of aerobic conditioning appears to depend more on the adequacy of training load, progression, and exercise intensity than on the specific training format employed.

Although the difference between training methods was not statistically significant, the effect size analysis demonstrated a large practical effect of training method on VO_2max ($\eta^2 p = 0.330$). This finding suggests that the choice of training method may still meaningfully affect aerobic performance outcomes, despite the lack of statistical significance. Previous methodological literature emphasizes that statistical significance alone does not reflect the magnitude or practical importance of an intervention, whereas effect size provides information regarding the strength and meaningfulness of the observed effect (Lakens, 2013; Lininger et al., 2017). In sports science, effect size has been recommended as an important complement to null-hypothesis significance testing because it helps practitioners evaluate the practical impact of training interventions beyond p-values (Yagin et al., 2024). The discrepancy between statistical significance and effect size observed in the present study may indicate that both interval and circuit training induced meaningful physiological adaptations. Still, the magnitude of the difference was insufficient to be detected at the current sample size. Consequently, coaches should not disregard the practical value of selecting training methods that best align with athletes' needs, training objectives, and competition schedules.

From a program planning perspective, these findings provide coaches with a more flexible way to design training programs. Interval training can be used during the preparation phase to increase aerobic capacity more quickly. Meanwhile, circuit training can be applied during the competition phase because it simultaneously stimulates the neuromuscular and cardiovascular systems (Messaggi-Sartor et al., 2019). Thus, the selection of training methods can be adjusted according to the objectives of periodization, the competition schedule, and the athlete's readiness without assuming that one method is inherently superior to another.

The significant effect of BMI indicates that body composition plays an important role in aerobic performance among adolescent athletes. Participants with lower BMI had higher VO_2max values than those with higher BMI. This finding supports previous literature suggesting that lower body mass may improve oxygen transport efficiency and reduce physiological burden during exercise (Liao et al., 2024; Suhardjono et al., 2019). Since VO_2max is commonly expressed relative to body weight ($mL \cdot kg^{-1} \cdot min^{-1}$), excess body mass may increase metabolic demands without proportionally increasing oxygen delivery capacity. Consequently, athletes with lower BMI may achieve superior aerobic performance due to greater movement efficiency and reduced physiological burden during exercise.

The effect size analysis further demonstrated that BMI exerted a large effect on VO_2max outcomes ($\eta^2p = 0.261$). This result reinforces the importance of body composition as a determinant of aerobic performance. The relatively large effect size indicates that BMI accounted for a substantial proportion of the variability in aerobic capacity among participants. In addition, adequate nutrition supports important physiological processes, such as hemoglobin synthesis, energy metabolism, and muscle recovery (Baranauskas et al., 2020). These factors indirectly influence body composition and create more favorable physiological conditions for aerobic adaptation. Therefore, maintaining an optimal BMI should be considered an essential component of athlete development programs, particularly during adolescence, when growth and maturation are ongoing.

The interaction analysis revealed that BMI did not significantly modify the effects of interval training and circuit training on VO_2max improvement. This finding suggests that the influence of BMI on aerobic capacity operates independently of the training method applied. In practical terms, athletes across different BMI categories responded similarly to both interval and circuit training, although their overall aerobic capacity varied. Thus, neither training method appears to provide a distinct advantage for athletes within specific BMI categories. Interestingly, the interaction between training method and BMI showed a moderate effect size ($\eta^2p = 0.112$), although it did not reach statistical significance. Previous evidence suggests that substantial interindividual variability exists in cardiorespiratory fitness adaptations to exercise training, with physiological and anthropometric characteristics contributing to differences in training responsiveness (Bouchard & Rankinen, 2001; Ross et al., 2019). This finding suggests that the combined influence of training method and BMI may still be relevant in determining aerobic adaptation. Although the current study did not detect a statistically significant interaction, the moderate effect size suggests the possibility of underlying physiological relationships warranting further investigation. Future studies involving larger samples, longer intervention durations, and more comprehensive body composition assessments may provide greater insight into how anthropometric characteristics influence responsiveness to different aerobic training strategies.

In practice, these results affirm that aerobic capacity development programs for adolescent athletes should adopt a multidimensional approach. Structured training programs should be integrated with anthropometric monitoring and systematic nutrition management to ensure that athletes' physiological conditions remain within optimal ranges. This becomes increasingly important in sports such as basketball, which demand high endurance, rapid recovery, and good fatigue tolerance during matches (Birat et al., 2018; Han et al., 2023; Helgerud et al., 2023; Schiphof-Godart et al., 2018).

Methodologically, this study also emphasizes the importance of considering body composition variables as control factors or covariates in exercise intervention studies to ensure that interpretations of training method effectiveness are not biased. These findings also support a more holistic approach to the development of young athletes, in which improvements in aerobic performance are influenced not only by training stimuli but also by individual physiological factors. Overall, the findings indicate that both interval training and circuit training represent effective approaches for improving aerobic capacity in adolescent basketball athletes. However, BMI appears to be a key determinant of aerobic performance and adaptation. Therefore, optimizing aerobic fitness in youth basketball should involve not only appropriate training prescription but also effective management of body composition and overall physiological readiness.

Research Contribution

This study makes an important contribution to the development of sports science by deepening the understanding of the interaction between training methods and body composition in influencing the development of aerobic capacity in adolescent basketball athletes. Unlike most previous research, which examined training methods or anthropometric factors separately, this study integrates both variables within a single analytical framework through a factorial experimental design. The study's findings indicate that both interval and circuit training are effective at enhancing VO_2max, but there is no statistically significant difference between the two approaches. Conversely, Body Mass Index (BMI) has been shown to exert a more substantial influence on the extent of improvement in aerobic capacity. These results suggest that individual physiological characteristics may play an equally significant, if not more influential, role compared to variations in training methods in determining the body's adaptive response to aerobic training. Consequently, this study challenges the prevailing assumption that increases in aerobic capacity among young athletes are primarily determined by the training method employed. Instead, the results underscore the importance of considering body composition as a critical determinant in models of adolescent athletic performance. Practically, this research provides a scientific foundation for coaches and sports practitioners to integrate structured training programs with anthropometric monitoring and nutrition management strategies to optimize the development of aerobic capacity in young athletes.

Limitation

The researchers acknowledge several limitations inherent in this study. Firstly, the relatively small sample size (n = 40) may constrain the generalizability of the findings to a broader population of adolescent basketball athletes. Future research with larger samples is recommended to enhance the validity of the results. Secondly, VO_2max was estimated using the Beep Test rather than direct laboratory measurement, which may not fully capture precise physiological adaptations. Thirdly, Body Mass Index (BMI) was employed as the primary indicator of body composition. However, BMI does not differentiate between fat mass and lean body mass, which may influence aerobic performance outcomes. Finally, other factors that may affect VO_2max improvement, such as daily physical activity, nutritional intake, sleep patterns, and hydration status, were not controlled in this study and may have influenced the results.

Suggestions

The results of this research indicate that the enhancement of aerobic capacity in young basketball players is affected not just by the training methods used but also by individual physiological traits, especially Body Mass Index (BMI). Consequently, programs designed to boost VO_2max should incorporate both organized physical training and the management of athletes' body composition. Coaches and practitioners are advised to combine aerobic training techniques with suitable nutritional oversight and anthropometric evaluations to facilitate optimal physiological adaptation. Future research should encompass larger sample sizes and extended intervention durations to achieve a more comprehensive understanding of aerobic development in youth athletes. Furthermore, subsequent studies might incorporate more precise measures of body composition, such as body fat percentage or lean body mass, alongside other influencing factors, including daily physical activity levels, nutritional intake, sleep quality, and hydration status. Examining these variables may yield deeper insights into the multifactorial determinants of VO_2max improvement in adolescent basketball players.

CONCLUSION

This study examined the effects of interval training and circuit training, as well as Body Mass Index (BMI) categories, on VO_2max improvement among adolescent basketball athletes. The findings demonstrated that both interval and circuit training were effective in improving aerobic capacity, with no statistically significant difference between the two methods. In contrast, BMI exerted a significant influence on VO_2max outcomes, with athletes in the lower BMI category achieving greater aerobic improvements than those in the higher BMI category. Furthermore, no significant interaction between training method and BMI was identified, indicating that the influence of BMI on aerobic adaptation operates independently of the training approach. These findings suggest that improvements in aerobic capacity are influenced not only by training stimuli but also by individual physiological characteristics. While coaches may flexibly select either interval or circuit training based on training objectives, periodization plans, and athlete readiness, maintaining an optimal body composition appears equally important for maximizing aerobic development. The present study contributes to the growing body of sports science literature by demonstrating, through a factorial experimental design, that body composition represents an important determinant of VO_2max adaptation in adolescent basketball athletes. Therefore, aerobic conditioning programs for youth athletes should integrate structured training interventions with regular anthropometric monitoring and appropriate nutritional management to optimize performance development.

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AUTHOR CONTRIBUTION STATEMENT

M.F.R. conceived and designed the study, conducted the training intervention and data collection, performed the statistical analysis, and drafted the manuscript. A. supervised the research process and provided academic guidance throughout the study. A.M.N. contributed to the refinement of the research design, data interpretation, and critical review of the manuscript. S.K.B. and T.D. contributed to the theoretical review, manuscript refinement, and critical input on the discussion section. F.I.C., R, and F.A. assisted in data collection, data organization, and manuscript preparation. All authors read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors acknowledge the use of AI-assisted tools for language editing and improvement of writing clarity. The authors take full responsibility for the content and integrity of the manuscript.

CONFLICTS OF INTERES

The authors declare that there are no financial, institutional, or personal conflicts of interest that could have influenced the results or interpretation of this study.

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