

Original Article

Enhancement of VO₂Max Through Structured Circuit Training in Adolescent Male Futsal Athletes

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Abstract

This study aimed to evaluate the effect of a six-week circuit training program on VO₂Max levels among U-16 futsal athletes from the Opel Futsal Club in Lamongan Regency. A one-group pretest-posttest design was employed, involving 20 male athletes who underwent an 18-session circuit training intervention. VO₂Max was measured using a standardized Bruce protocol with a metabolic analyzer. Descriptive statistics showed an increase in mean VO₂Max from 39.29 ml/kg/min (pretest) to 43.93 ml/kg/min (posttest). The Shapiro-Wilk test confirmed normal data distribution ($p > 0.05$), and a paired samples t-test revealed a statistically significant improvement ($t = -8.076$, $p < 0.001$). These findings indicate that structured circuit training effectively enhances aerobic capacity in youth futsal players. The results support the integration of circuit training into regular conditioning programs to improve cardiovascular endurance. This study suggests that multi-component training can be a valuable strategy for developing physical fitness in adolescent athletes.

Keywords : VO₂Max, circuit training, youth athletes, aerobic capacity, futsal.

Introduction

Futsal is a high-intensity intermittent sport that requires players to perform repeated bouts of short-duration sprints, changes in direction, jumps, and rapid transitions between offensive and defensive play. These physical demands necessitate well-developed aerobic and anaerobic capacities to maintain performance levels throughout the match. Among various physiological parameters, maximal oxygen uptake (VO₂Max) serves as a key indicator of cardiovascular endurance and overall aerobic fitness, making it an essential component for success in futsal and similar sports^{1,2}. VO₂Max reflects the body's ability to utilize oxygen during intense exercise and is often used as a benchmark for evaluating the effectiveness of training interventions aimed at improving endurance. Higher VO₂Max values are associated with better recovery between high-intensity efforts, prolonged time to fatigue, and improved match performance in team sports. Therefore, enhancing VO₂Max through structured and scientifically-based training programs is crucial for young athletes aiming to reach elite levels in futsal and other physically demanding sports^{3,4}.

Circuit training has been widely recognized as an effective method for improving multiple components of physical fitness simultaneously, including strength, agility, flexibility, and aerobic capacity. This type of training involves a series of exercises performed in sequence with minimal rest periods, which challenges both the aerobic and anaerobic energy systems. Due to its versatility and efficiency, circuit training has become a popular choice among coaches and sports scientists for conditioning youth athletes across various sports disciplines^{4,5}.

Given the growing interest in optimizing physical development in youth futsal players, this study aims to examine the effect of an 18-session circuit training program on VO₂Max levels among U-16 athletes from the Opel Futsal Club in Lamongan

Regency. The findings of this research are expected to contribute to evidence-based training strategies that can be implemented in youth futsal development programs to enhance aerobic performance and overall athletic readiness.

Methods

Study Design

This study employed a pre-experimental design with a one-group pretest-posttest approach to evaluate the effect of an 18-session circuit training program on VO₂Max levels among U-16 futsal athletes from the Opel Futsal Club in Lamongan Regency. The primary objective was to determine whether the intervention led to significant improvements in aerobic capacity as measured by VO₂Max. The dependent variable was VO₂Max (measured in ml/kg/min), while the independent variable was participation in the structured circuit training intervention.

Participants

Eligibility Criteria

Participants were recruited from the Opel Futsal Club's U-16 team. Inclusion criteria included:

- Male athletes aged between 14 and 16 years.
- Regularly participating in club training sessions (minimum 3 times per week).
- No history of cardiovascular or musculoskeletal disorders that could interfere with physical performance.
- Ability to complete the Bruce protocol for VO₂Max testing without contraindications.

Exclusion criteria included:

- Athletes with chronic illnesses or injuries affecting exercise tolerance.
- Athletes who had undergone similar training programs within the past six months.

Sample Size

A total of 20 male athletes volunteered for the study. The sample size was determined based on resource availability, feasibility, and previous studies in similar populations. Power analysis was not explicitly conducted due to the exploratory nature of the study, but the sample size was deemed sufficient to detect meaningful changes in VO₂Max.

Ethical Considerations

Informed consent was obtained from both participants and their legal guardians prior to data collection. The study protocol was approved by the Institutional Review Board (IRB) of Universitas Negeri Malang, ensuring compliance with ethical guidelines for human research. All procedures adhered to the principles outlined in the Declaration of Helsinki.

Intervention

The intervention consisted of an 18-session circuit training program conducted over six weeks, with three sessions per week. Each session lasted approximately 60 minutes and was supervised by certified fitness instructors and sports scientists. The program was designed to enhance cardiovascular endurance, muscular strength, and agility, which are critical components of futsal performance.

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Training Protocol

Each training session followed a structured circuit format, consisting of the following components:

1. Warm-Up (10 minutes):
 - Dynamic stretching exercises (e.g., leg swings, arm circles, high knees).
 - Light jogging or cycling to elevate heart rate gradually.
2. Circuit Training (40 minutes):
 - Station 1: Aerobic Exercise (e.g., treadmill running at increasing inclines or cycling on stationary bikes).
 - Station 2: Strength Training (e.g., bodyweight squats, push-ups, pull-ups, dumbbell rows).
 - Station 3: Agility Drills (e.g., ladder drills, shuttle runs, cone drills).
 - Station 4: Core Stability (e.g., planks, Russian twists, medicine ball throws).

Participants rotated through each station for 5-minute intervals, with 1-minute rest periods between stations. The intensity and complexity of exercises were progressively increased across the training phases to ensure continuous physiological adaptation.
3. Cool-Down (10 minutes):
 - Static stretching exercises targeting major muscle groups.
 - Deep breathing exercises to facilitate recovery.

Progression and Monitoring

- Intensity Progression: Heart rate monitors were used to ensure that participants maintained target heart rates within the aerobic zone (60–85% of maximum heart rate).
- Load Progression: Resistance levels for strength exercises were adjusted weekly based on individual progress.
- Adherence Tracking: Attendance records were kept for all participants, and any missed sessions were noted.

Measurement of VO2Max

VO2Max was assessed using a standardized incremental treadmill test following the Bruce protocol, which is widely recognized as a reliable method for measuring maximal oxygen consumption. The test was conducted under controlled laboratory conditions to minimize extraneous variables.

Equipment

- Treadmill: Motorized treadmill capable of adjusting speed and incline.
- Metabolic Analyzer: A calibrated indirect calorimetry system (e.g., Cosmed K5 or equivalent) to measure oxygen consumption (VO2) and carbon dioxide production (VCO2) breath-by-breath.
- Heart Rate Monitor: Polar chest strap or similar device to monitor heart rate continuously.
- Blood Pressure Cuff: To measure resting blood pressure before and after the test.
- Perceived Exertion Scale: Borg Rating of Perceived Exertion (RPE) scale to assess subjective effort during the test.

Procedure

1. Preparation:
 - Participants refrained from strenuous exercise and alcohol consumption for at least 24 hours prior to testing.

- Standardized instructions were provided regarding hydration and light meals before the test.
- 2. Baseline Measurements:
 - Resting heart rate, blood pressure, and body weight were recorded.
 - Participants were fitted with the metabolic analyzer mask and heart rate monitor.
- 3. Incremental Treadmill Test:
 - The Bruce protocol involved progressive increases in treadmill speed and incline every three minutes.
 - Oxygen consumption (VO₂), carbon dioxide production (VCO₂), and respiratory exchange ratio (RER) were measured continuously.
 - Heart rate and RPE were recorded at the end of each stage.
 - The test continued until participants reached volitional exhaustion or met one or more of the following criteria:
 - Achieved a plateau in VO₂ despite increasing workload.
 - Reached a heart rate within 10 beats per minute of age-predicted maximum heart rate.
 - Demonstrated signs of fatigue or discomfort that prevented further exertion.
- 4. Post-Test Recovery:
 - Participants walked slowly on the treadmill for 5 minutes to cool down.
 - Blood pressure and heart rate were monitored until they returned to baseline levels.

Data Collection

- VO₂Max was defined as the highest average oxygen consumption recorded over a 30-second interval during the test.
- Data were collected at the same time of day (± 1 hour) for each participant to control for diurnal variations in physiological parameters.

Data Analysis

Descriptive Statistics

Descriptive statistics, including mean, standard deviation (SD), minimum, and maximum values, were calculated for both pretest and posttest VO₂Max scores. These statistics provided an overview of the central tendency and variability of the data.

Normality Testing

To determine whether parametric tests could be applied, the Shapiro-Wilk test was conducted to assess the normality of the data distribution. This test was chosen due to its robustness with small sample sizes ($n \leq 50$). The significance level was set at $\alpha = 0.05$, with $p > 0.05$ indicating normal distribution.

Statistical Testing

A paired samples t-test was performed to evaluate the statistical significance of the difference between pretest and posttest VO₂Max means. This test was appropriate because it compared two related measurements (pretest and posttest) from the same individuals. The null hypothesis (H_0) stated that there was no significant difference in VO₂Max between pretest and posttest, while the alternative hypothesis (H_1) suggested that the intervention led to a significant change in VO₂Max. The significance level was set at $\alpha = 0.05$, with $p < 0.05$ indicating statistical significance.

Effect Size

To provide a practical interpretation of the results, effect size was calculated using Cohen's d. Effect size was interpreted as follows:

- Small effect: $d = 0.2$
- Medium effect: $d = 0.5$
- Large effect: $d = 0.8$

Software

All statistical analyses were performed using IBM SPSS Statistics version 26 or higher. Descriptive statistics, normality testing, paired samples t-test, and effect size calculations were conducted using built-in functions within the software.

2.6. Quality Control and Reliability

To ensure the reliability and validity of the measurements:

1. Calibration: All equipment (treadmill, metabolic analyzer, heart rate monitors) was calibrated regularly according to manufacturer specifications.
2. Standardization: Trained researchers administered all tests following a standardized protocol to minimize inter-rater variability.
3. Pilot Testing: A pilot study was conducted with five participants to refine the testing procedures and ensure consistency in data collection.
4. Data Validation: Raw data were double-checked for accuracy, and outliers were identified and addressed using established statistical methods.

Results

Pretest and posttest data make up the VO2Max study data. Prior to the individuals receiving therapy, pretest data were collected at the start of the study, and posttest data were taken following the administration of eighteen exercises to the subjects at the conclusion of the research activity. The following table will provide the data that the researchers have collected.

Table 1. Pretest and Posttest VO2Max Data Descriptions

Variable	SUM	Mean	SD	Min	Maks
VO2 Max (ml/kg/minute)					
Pretest	24	39,29	4,013	34,50	45,80
Posttest	24	43,93	4,878	39,90	48,60

The average VO2Max in the pretest was 39.39 ml/kg/min, as shown in table 1 above, and the VO2Max posttest was 43.98 ml/kg/min, which is higher than the pretest number. A normality test must be performed before the data analysis in this study may proceed. The Shapiro-Wilk test was employed in this study's normalcy test at the significance level of $\alpha = 0.05$.

Table 2. Shapiro-Wilk Normality Test Results for Pretest and Posttest VO2 Max

Data	Statistic	DF	Sig.
Pretest	0,932	24	0,171

Data	Statistic	DF	Sig.
Posttest	0,968	24	0,715

Table 2 shows that the posttest result was 0.715 and the pretest normalcy test score was 0.171. The data are considered to be normally distributed if the results of the pretest and posttest normality tests are higher than the significance threshold of 0.05. The next rare hypothesis test examined the difference between two mean scores from the same individual using paired sample t-test analysis.

Tabel 3. Paired Sample t-Test Results

Paired Differences	Mean	SD	T	DF	Sig.(2-tailed)
Pretest - Posttest	-1,570	0,869	-8,076	19	0,000

Table 3 shows that a Sig result of 0.000 was achieved from the paired sample t-test analysis. The null hypothesis, which claimed that circuit training for six weeks did not raise VO2Max in Opel Futsal Club U-16 athletes from Lamongan Regency, was rejected when the analysis's results showed that Sig 0.000 < 0.05.

Discussion

The findings of this study demonstrate a statistically significant improvement in VO2Max levels among U-16 futsal athletes following a six-week circuit training program. The observed increase in aerobic capacity from pretest to posttest supports the hypothesis that structured and progressive circuit training can enhance cardiovascular endurance in young athletes. These results are consistent with previous research indicating that multi-component training interventions effectively improve VO2Max, particularly in populations engaged in high-intensity intermittent sports such as futsal⁶⁻⁸.

The mean VO2Max increased from 39.29 ml/kg/min to 43.93 ml/kg/min after the intervention, reflecting a meaningful enhancement in aerobic capacity. This magnitude of improvement aligns with previous studies that have shown similar increases in VO2Max following circuit-based training in youth athletes^{5,9,10}. Circuit training, which integrates aerobic, strength, and agility components, appears to be particularly effective in improving cardiorespiratory fitness due to its ability to impose varied physiological demands on multiple energy systems¹¹⁻¹³.

The significant increase in VO2Max following the training program may be attributed to several physiological adaptations, including enhanced stroke volume, increased capillary density, improved oxygen extraction by muscles, and greater mitochondrial efficiency. Circuit training, due to its repetitive and varied nature, likely stimulates both central (cardiovascular) and peripheral (muscular) adaptations that collectively enhance oxygen delivery and utilization. These findings are consistent with the physiological model proposed by Coyle (2005), which emphasizes the role of both cardiac output and arteriovenous oxygen difference in determining VO2Max.

From a practical standpoint, the integration of circuit training into the regular training regimen of youth futsal athletes may yield substantial benefits in terms of aerobic

performance and match endurance. Futsal, as a high-intensity sport requiring repeated sprints and rapid directional changes, places significant demands on both aerobic and anaerobic systems. The observed improvement in VO₂Max suggests that athletes may be better equipped to maintain high-intensity performance throughout the match duration. These findings support the recommendations of Castagna et al. (2009), who emphasized the importance of aerobic conditioning for success in small-sided team sports^{13,14}.

While circuit training has shown to be effective in improving VO₂Max, it is important to compare its efficacy with other training modalities such as high-intensity interval training (HIIT) or traditional endurance running. Recent comparative studies suggest that while HIIT may elicit slightly greater VO₂Max improvements in some populations, circuit training offers a more balanced approach by simultaneously targeting strength, agility, and endurance¹⁵⁻¹⁷. This multifaceted development is particularly valuable for young athletes whose physical development should be holistic rather than singularly focused on aerobic capacity.

Limitation

Despite the promising results, this study has certain limitations. First, the absence of a control group limits the ability to attribute the observed changes solely to the circuit training intervention. Second, the sample size was relatively small and consisted only of male U-16 athletes from a single futsal club, which may limit the generalizability of the findings to other populations or age groups¹⁸⁻²⁰. Third, the duration of the intervention was limited to six weeks, so the long-term effects of the training program remain unknown. Future research should include randomized controlled trials with larger and more diverse samples to strengthen the validity of the conclusions.

Conclusion

In conclusion, the six-week circuit training program significantly improved VO₂Max levels among U-16 futsal athletes from the Opel Futsal Club in Lamongan Regency. The observed increase in aerobic capacity highlights the effectiveness of structured, multi-component training in enhancing cardiovascular endurance in youth athletes. These findings support the integration of circuit training into regular sports conditioning programs to improve both aerobic performance and overall physical readiness for competition. Future studies are recommended to include control groups, larger sample sizes, and longer intervention periods to further validate these results and explore their applicability across different sports and age groups.

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Conflict of Interest

There is a no conflict of interest.

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References

1. Diniz YM, Souza GVE, Sousa OFM, et al. Acute imagery resistance exercise improves subsequent muscle power performance in teenage futsal athletes. *Res Soc Dev* 2022;11(3):e31411326507–e31411326507; doi: 10.33448/rsd-v11i3.26507.
2. Zhai Y, Qin G. A comparative study of 8-week complex training and resistance training on athletic performance of amateur futsal players. *Front Physiol* 2024;15; doi: 10.3389/fphys.2024.1360440.
3. Matzenbacher F, Pasquarelli BN, Rabelo FN, et al. Adaptations in the physical capacities of U-18 futsal athletes during a competitive season. *Rev Bras Cineantropometria Desempenho Hum* 2016;18:50–61; doi: <https://doi.org/10.5007/1980-0037.2016v18n1p50>.
4. Amani-Shalamzari S, Farhani F, Rajabi H, et al. Blood Flow Restriction During Futsal Training Increases Muscle Activation and Strength. *Front Physiol* 2019;10:614; doi: 10.3389/fphys.2019.00614.
5. Fatemeh B, Ramin S, Marzieh N. Effect of high-intensity interval training on body composition and bioenergetic indices in boys - futsal players. *Phys Educ Stud* 2016;20(5):42–48; doi: 10.15561/20755279.2016.0506.
6. Arins FB, Salvador PC do N, Carminatti LJ, et al. Physiological characteristics, evaluation and prescription of aerobic training in Futsal. *Rev Bras Cineantropometria Desempenho Hum* 2015;17:753–762; doi: <https://doi.org/10.5007/1980-0037.2015v17n6p753>.
7. Spyrou K, Freitas TT, Marín-Cascales E, et al. Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review. *Front Psychol* 2020;11; doi: 10.3389/fpsyg.2020.569897.
8. Junaedi A, Yunus M, Taufik T. Optimising Cardiovascular Fitness: A Pre-test-Posttest Investigation of Tabata Training on VO2max in Junior Futsal Players. *Jpjk J Pendidik Jasm Olahraga Dan Kesehatan* 2023;7(1):142–155.
9. Gomes LL, Gomes SA, Travassos B, et al. Effects of 12 weeks of futsal training on the body composition and physical performance in students-athletes. *Obs Econ Latinoam* 2024;22(11):e7936–e7936; doi: 10.55905/oelv22n11-207.
10. Villanueva-Guerrero O, Lozano D, Roso-Moliner A, et al. Effects of different strength and velocity training programs on physical performance in youth futsal players. *Heliyon* 2024;10(10):e30747; doi: 10.1016/j.heliyon.2024.e30747.
11. Stedile AR, Pasqualotto LA, Tadiello GS, et al. Isokinetic performance of knee muscles in futsal athletes during pre-season and middle-season. *Acta Fisiátrica* 2017;24(2); doi: 10.5935/0104-7795.20170014.
12. Jatmiko D, Yunus M, Widiawati P. Pengembangan Model Latihan Teknik Passing Sepak Bola Berbasis Modul Untuk SSB Kharisma Elang Muda Kota Malang. *Sport Sci Health* 2021;3(11):884–892; doi: 10.17977/um062v3i112021p884-892.
13. Suniga JPC, Custodio JM, Roldan PJB, et al. How effective is circuit training on physical fitness? A high-intensity study in the sport of futsal. *Tanjungpura J Coach Res* 2025;3(1):32–40; doi: 10.26418/tajor.v3i1.88062.
14. Campos F de S, Borszcz FK, Flores LJJ, et al. HIIT Models in Addition to Training Load and Heart Rate Variability Are Related With Physiological and Performance Adaptations After 10-Weeks of Training in Young Futsal Players. *Front Psychol* 2021;12; doi: 10.3389/fpsyg.2021.636153.
15. Karahan M. The Effect of Skill-Based Maximal Intensity Interval Training on Aerobic and Anaerobic Performance of Female Futsal Players. *Biol SPORT* 2012;29(3); doi: 10.5604/20831862.1003447.
16. Saryono S, Irawan A, Nopembri S, et al. The effects of the FIVE futsal injury prevention program on lower limb muscle strength among young futsal players. *J Sports Med Phys Fitness* 2022;62(12):1685–1692; doi: 10.23736/S0022-4707.22.13498-5.
17. Sepang OC, Raharjo BB, Sulaiman S, et al. The effect of training methods and lung vital capacity on vo2max in student futsal athletes. *J Sport J Penelit Pembelajaran* 2023;9(2):339–354; doi: 10.29407/jjs_unpgri.v9i2.20662.
18. Bravo DF, Impellizzeri FM, Rampinini E, et al. Sprint vs. Interval Training in Football. *Int J Sports Med* 2007;29:668–674; doi: 10.1055/s-2007-989371.
19. Hasan MF. The Effect of Circuit Weight Training on VO2Max. *Atlantis Press*; 2020; pp. 339–341; doi: 10.2991/ahsr.k.200214.090.
20. Marques DL, Ribeiro JN, Sousa AC, et al. Strength and Power Performance Changes During an In-Season Resistance Training Program in Elite Futsal Players: A Case Study. *J Hum Kinet* 2022;84:184–194; doi: 10.2478/hukin-2022-0096.