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Circuit training on VO2max physical condition: How does it affect handball athletes?

Research Article

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Abstract.

Background Handball is an intermittent, high-intensity sport that demands sustained aerobic capacity to maintain optimal performance during training and competition. Adequate VO2max levels are therefore essential for athletes to cope with repeated bouts of explosive movement and prolonged physical exertion.

Objectives This study aimed to examine the effectiveness of a circuit training method in improving physical condition, specifically VO2max levels, among handball athletes.

Methods An experimental one-group pretest–posttest design was employed. The participants consisted of 15 athletes from the Sambas district handball team, aged 20–25 years, selected through purposive sampling. The athletes completed a structured circuit training program implemented across 12 sessions with a frequency of three sessions per week. VO2max was assessed before and after the intervention using the Yo-Yo Intermittent Recovery Test Level 1. Data were analyzed using SPSS 26.

Results The findings revealed a significant improvement in VO2max following the circuit training program, with a significance value of 0.000 (< 0.05). These results indicate that circuit training is effective in enhancing aerobic capacity among handball athletes

Conclusion Circuit training provides a substantial positive impact on VO2max development in handball players, supporting its use as a conditioning strategy to improve overall physical performance. This study contributes empirical evidence on the effectiveness of circuit-based conditioning for intermittent sports. The results offer practical insights for coaches and sport practitioners in designing targeted training programs aligned with the physiological demands of handball athletes.

Keywords: circuit training, vo2max, handball, athlete performance.

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INTRODUCTION

Sport plays a crucial role in improving quality of life, enhancing physical fitness, and supporting athletic achievement (Athaya et al., 2023). Regular participation in physical activity has been shown to positively influence aerobic endurance, leading to improved physiological function and overall performance (Hardinata et al., 2021). This is particularly important because maximal oxygen uptake (VO_2max) is widely recognized as the gold standard and the most significant indicator of aerobic capacity (Jemni et al., 2019). Aerobic endurance serves as a fundamental component in sports activities and is closely related to VO_2max (Bo, 2023; Hardinata, B. et al., 2023). Moreover, aerobic endurance contributes to faster recovery, allowing athletes to better manage fatigue during training and competition (Vasileios et al., 2018). Handball is one of the sports in which high aerobic endurance is especially essential.

Handball is characterized as a physically demanding team sport involving frequent body contact, rapid anaerobic actions, and continuous transitions into aerobic movements (Saavedra et al., 2018). Consequently, players are required to possess well-developed physical conditioning, particularly endurance, to maintain speed, intensity, and tactical execution throughout the match (Karcher & Buchheit, 2014; Michalsik et al., 2018). In addition, handball players must demonstrate various physical attributes, including sprinting ability, throwing power, jumping capacity, muscular strength, and aerobic

fitness (Massuca et al., 2014; Wagner et al., 2014). These characteristics underscore the central role of endurance in achieving optimal performance in handball.

Previous research has highlighted the contribution of the aerobic system to performance in handball (Belka et al., 2016; Kniubaite et al., 2019; Michalsik, Madsen, et al., 2015; S. C. Póvoas et al., 2014). Further studies have shown that handball players spend more than 50% of match time at intensities exceeding 80% of their maximum heart rate (Povoas et al., 2012; S. Póvoas et al., 2014). During a match, players typically cover distances ranging from 4,000 to 6,500 meters, emphasizing the need for well-developed aerobic and anaerobic capacities (Marques & González-Badillo, 2006). These findings reinforce the argument that VO_2max plays a vital role in handball performance.

VO_2max continues to be considered the gold standard for evaluating aerobic fitness (Jemni et al., 2019). Numerous studies have explored interventions aimed at improving VO_2max, including low-, moderate-, and high-intensity interval training (Wen et al., 2019), all of which have demonstrated positive effects on aerobic endurance. Additional research has reported increases in VO_2max following various training methods such as small-sided games (Kusuma & Purnomo, 2019; Puriana, 2019; Zainudin et al., 2019), triangle run training (Hardinata et al., 2021), intermittent soccer training (Bo, 2023), polarized training (Malyani & Fashi, 2021), continuous running (Syahroni et al., 2020), high-intensity resistance circuit training (Marín-Pagán et al., 2020), and high-intensity training (Alvira et al., 2020).

Grounded in the evidence regarding the importance of aerobic endurance in handball, the present study investigates circuit training as a method for enhancing aerobic performance. The purpose of this research is to determine the effectiveness of circuit training in improving aerobic endurance among handball players. This study is significant as it contributes to a broader understanding of physical conditioning, which is one of the most critical components of handball performance (Karcher & Buchheit, 2014). A clear understanding of physical conditioning requirements is essential for achieving optimal performance in handball (García-Sánchez et al., 2023). Coaches are therefore expected to monitor each component of physical fitness—including aerobic endurance—to ensure maximal performance outcomes (Côté & Gilbert, 2009).

Aerobic endurance plays a vital role not only in supporting athletes' performance and competitive success (Suryadi, Yanti, et al., 2023) but also as a key indicator of superior physiological capacity (Lacome et al., 2018). Thus, this study holds practical importance as an evaluation tool for assessing the effectiveness of training and athlete development processes (Supriatna et al., 2023).

METHOD

Participants

The participants in this study were athletes from the Sambas district handball team, aged 20–25 years. A total sampling technique was employed, allowing all available athletes to be included in the study. In total, 15 athletes participated, consistent with principles of training implementation and research feasibility.

Research Design

This study adopted an experimental approach using a one-group pretest–posttest design. The intervention consisted of a circuit training program in which athletes performed a series of exercises arranged in stations and completed sequentially. The circuit training protocol was integrated into the team's training program and implemented over 12 sessions, with a frequency of three sessions per week. To measure aerobic capacity, the Yo-Yo Intermittent Recovery Test Level 1 was used, a widely validated instrument for assessing VO_2max (Astagna et al., 2009; Castagna et al., 2008). This test is considered a relevant field measure in handball and serves as a practical tool for evaluating physical performance in intermittent sports (Bangsbo et al., 2008).

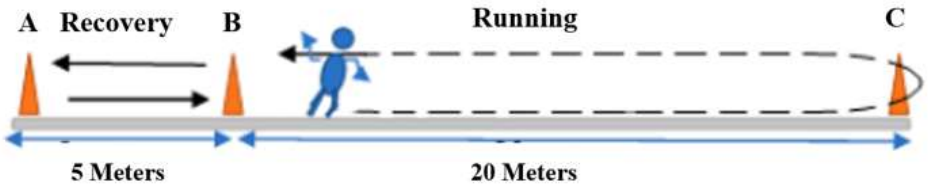

Figure 1. Yo-Yo Intermittent Recovery Test Instrument (Hardinata, et al., 2023)

Statistical Analysis

Data analysis was conducted to determine the effect of the circuit training program on VO_2max. The analytical procedures included normality testing followed by hypothesis testing to examine pre- and post-intervention differences. Descriptive percentage analysis was used to describe the athletes' physical condition, particularly aerobic endurance. VO_2max scores were interpreted using established fitness norm categories, as presented in Table 1. All statistical procedures were performed using SPSS version 26.

Table 1. Men's Intermittent Yoyo VO2max Assessment Norms

Ratings	Level	Value range
Ellite	>20.1	>56.6
Excellent	18.7-20.1	53.2-56.6
good	17.3-18.6	49.2-52.9
Average	15.7-17.2	45.1-48.8
Below average	14.2-15.6	40.8-44.8
Poor	<14.2	<40.8

RESULTS AND DISCUSSION

Results

The study began with the collection of baseline data on the aerobic endurance (VO_2max) of handball players from the Sambas district team. Following this initial assessment, the athletes completed a structured circuit training program integrated into their regular training regimen. At the end of the intervention, VO_2max was reassessed to determine changes relative to the pretest results. These data were subsequently compared to evaluate the effect of the circuit training intervention.

The distribution of VO_2max levels based on pretest and posttest measurements is presented in Tables 2 and 3. The pretest findings show that 26.67% of athletes were classified as Below Average, 53.33% as Average, and 20% as Good. These results indicate that the overall VO_2max level of the athletes was generally within the average category, a level considered suboptimal for handball players who typically require higher aerobic capacity.

In contrast, the posttest results demonstrate clear improvements, with 33.33% of athletes in the Average category, 40% in the Good category, and 26.67% in the Excellent category. These shifts suggest that the athletes' VO_2max levels increased following the circuit training program, with the group average advancing into the Good category.

Table 2. Pretest Results of VO2max Levels in Handball Athletes

Ratings	frequency	Percentage %
Ellite	0	0%
Excellent	0	0%
good	3	20%
Average	8	53.33%
Below average	4	26.67%
Poor	0	0%

Table 3. Posttest Results of VO2max Levels in Handball Athletes

Ratings	frequency	Percentage %
Ellite	0	0%
Excellent	4	26.67%
good	6	40%
Average	5	33.33%
Below average	0	0%
Poor	0	0%

Normality testing using the Shapiro–Wilk test indicated that both pretest and posttest data were normally distributed ($p > 0.05$), as shown in Table 4. Since the normality assumption was met, further analysis employed a paired samples t-test to evaluate the effect of the intervention.

Table 4. Normality Test Results

Result	Statistic	df	Sig.
Pretest VO2max	0,897	15	0,085
Posttest VO2max	0,847	15	0,116

The paired samples t-test results (Table 5) revealed a significance value of 0.000 (< 0.05), indicating a statistically significant improvement in VO_2max following the circuit training program. The descriptive statistics further support this finding, with the mean VO_2max increasing from 45.77 in the pretest to 50.20 in the posttest, representing a mean difference of 4.43 units (Table 6).

Table 5. Paired Samples T-test

Result		Mean	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Pretest VO2max - Posttest VO2max	-4,42667	2,33130	-7,354	14	0,000

Table 6. Descriptive Results of VO2max in Handball Athletes

Result	N	Range	Minimum	Maximum	Mean	Std. Deviation
Pretest VO2max	15	8,40	40,80	49,20	45,77	2,61000
Posttest VO2max	15	10,80	45,80	56,60	50,20	3,99964

Discussion

This study aimed to examine the effect of circuit training on the VO_2max levels of handball athletes. The findings demonstrate that the application of a structured circuit training program led to noticeable improvements in aerobic endurance. This is reflected in the increase in mean VO_2max from 45.77 in the pretest to 50.20 in the posttest results. In addition to the descriptive improvement, the paired samples t-test revealed a statistically significant difference, confirming that circuit training produced a meaningful enhancement in the athletes' aerobic capacity. These positive outcomes are likely attributed to the consistency of the training process and the well-planned training program implemented throughout the intervention period. As emphasized by Hardinata et al. (2021), endurance training must be performed continuously, systematically, regularly, and over an extended duration to achieve maximal performance adaptations.

Bompa and Buzzichelli (2015) further highlight that well-organized training comprising prolonged duration or repeated bouts can yield substantial benefits for endurance development. Similarly, the broader role of sport in supporting physical development reinforces the importance of structured training interventions (Hardinata, Ahwan, et al., 2023; Suryadi, Okilanda, et al., 2023). These theoretical perspectives align with the results of the present study, supporting the conclusion that circuit training is an effective method for enhancing VO_2max in handball athletes.

Several previous studies also corroborate the findings of this research. Hermassi et al. (2020) reported significant improvements in strength, sprinting ability, power, and change-of-direction performance after 12 weeks of circuit-based strength training conducted twice per week among male handball players. Complementary evidence from Fieseler et al. (2017) and Hermassi et al. (2017) suggests that dynamic loads used in circuit training contribute effectively to strength enhancement, while other work by Hermassi et al. (2020) indicates that circuit training positively affects agility. Likewise, Kvorning et al. (2017) found that a strength and conditioning program implemented by the Danish national handball team before the Beijing Olympics resulted in increased strength and agility. These studies collectively highlight the broad physiological benefits of circuit-based training.

Furthermore, Jeukendrup (2011) emphasizes that improvements in physical conditioning are influenced not only by regular, well-planned training but also by nutritional and recovery strategies. In this context, training programs that are structured, progressive, and aligned with performance objectives can help athletes achieve higher performance standards. This perspective reinforces the importance of planned interventions such as circuit training in optimizing athletes' conditioning.

The findings of the present study also align with research emphasizing the importance of aerobic capacity in handball performance. Athletes and coaches must prioritize the development of aerobic fitness, not only to sustain endurance and prevent fatigue but also to maintain concentration, technical execution, and coordination throughout a match (Michalsik, Aagaard, et al., 2015; Popescu-Brădiceni & Plăstoi, 2014; Thorlund et al., 2008; Zapartidis et al., 2009). Handball players are often required to continue high-intensity aerobic activity even during transitions when ball possession is lost (Mikalonytė et al., 2022). High aerobic capacity is essential for sustaining high-level performance over the full 60 minutes of play (Camacho-Cardenosa et al., 2019). Moreover, García-Sánchez et al. (2023) reported that

elite handball players cover an average distance of 3664.4 ± 1121.6 m during a match, further highlighting the aerobic demands of the sport.

Additional evidence supporting the present findings comes from Wen et al. (2019), who demonstrated that low-, moderate-, and high-intensity interval training can significantly improve aerobic endurance. Various other training methods—including small-sided games (Alben et al., 2022), linear acceleration drills (Taskin & Taskin, 2021), fartlek training (Gumantan & Fahrizqi, 2020; Syahroni et al., 2020; Syaroni & Kusuma, 2020), Tabata training (A, P., Munar & Pasaribu, 2020; Herlan & Komarudin, 2020), and aerobic circuit training (Ashfahani, 2020)—have also been shown to enhance VO_2max. Other studies further report that triangle run training (Hardinata et al., 2021), intermittent soccer training (Bo, 2023), polarized training (Malyani & Fashi, 2021), continuous running (Syahroni et al., 2020), high-intensity resistance circuit training (Marín-Pagán et al., 2020), and high-intensity training (Alvira et al., 2020) all produce meaningful improvements in maximal oxygen uptake

CONCLUSION

Based on the findings of this study, it can be concluded that a 12-week circuit-training program implemented three times per week is effective in improving the VO_2max of youth handball athletes. The observed improvement indicates that structured, progressive, and systematically planned circuit-training sessions can enhance aerobic endurance capacity. However, these results are specific to young handball athletes, and performance outcomes may vary depending on training intensity, duration, repetition schemes, athlete maturity, and seasonal training phases. This study contributes to the growing body of evidence supporting circuit training as an efficient method for enhancing aerobic capacity in team-sport athletes. It also offers practical insights for coaches and strength-conditioning practitioners regarding the design of endurance-focused training programs that are time-efficient yet physiologically effective. Furthermore, the findings reinforce the relevance of integrating structured conditioning modalities into regular training cycles to optimize athlete performance. Future research is encouraged to examine circuit-training protocols with varying intensities, loads, and work-to-rest ratios to determine the most effective combinations for different athletic populations. Researchers may also investigate training interventions targeting multiple physical components—such as strength, agility, and speed—to develop a more holistic conditioning model for handball athletes. In addition, incorporating larger sample sizes and long-term performance monitoring could provide deeper insights into the sustained effects of circuit training across competitive seasons.

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AUTHOR CONTRIBUTION STATEMENT

RA contributed to the conception, design, data collection, analysis, and drafting of the manuscript. JD and QBS supervised the research process, provided methodological guidance, validated the data analysis, and reviewed the final manuscript. Both authors approved the final version of the article.

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