

Application of Circuit Training Methods to Improve VO₂max Physical Condition: An Experimental Study on Handball Athletes

Aplicación de Métodos de Entrenamiento en Circuito para Mejorar la Condición Física del VO₂max: Un Estudio Experimental en Atletas de Balonmano

*Roy Ardian, *Yudik Prasetyo, *Sulistiyono, *Fatkurahman Arjuna, *, **Didi Suryadi, *Julian Dewantara, *Irvan Septianto, **Subarjo

*Universitas Negeri Yogyakarta (Indonesia), **Universitas Tanjungpura (Indonesia)

Abstract. The sport of handball is an intense game that is carried out over a long duration of two rounds, each of which runs for 30 minutes. A good VO₂max condition is very important for every player to have in order to support performance during training and matches. This study aims to examine the application of circuit training methods to improving physical conditions, especially VO₂max levels, in handball athletes. The circuit training method is considered an effective approach to improving athletes' endurance and fitness. This research is a type of experiment that uses a one-group pre-test-post design. The subjects in this study were the Sambas district handball team, aged 17–22 years. The purposive sampling technique resulted in 15 athletes being sampled. The handball athletes involved in this study underwent a circuit training method designed into the training program and carried out for 12 meetings with a frequency of three times a week. Measurement of VO₂max level is carried out before and after the training period using the Yoyo Intermittent Recovery Test Level 1 instrument. The results showed a significance value of $0.000 < 0.05$. Based on these results, circuit training has proven to provide a significant increase in VO₂max in handball athletes. The results of this study are expected to contribute to an understanding of the effectiveness of circuit training methods in improving physical conditions, especially VO₂max levels, in handball athletes. The implications of this study can be useful in designing a more focused training program to improve the performance of handball athletes through a training approach that suits their physiological needs.

Keywords: Circuit Training, VO₂max, Handball.

Resumen. El deporte del balonmano es un juego intenso que se desarrolla a lo largo de dos rondas de 30 minutos cada una. Es muy importante que todos los jugadores tengan una buena condición de VO₂max para favorecer el rendimiento durante los entrenamientos y los partidos. Este estudio pretende examinar la aplicación de métodos de entrenamiento en circuito para mejorar las condiciones físicas, especialmente los niveles de VO₂max, en atletas de balonmano. El método de entrenamiento en circuito se considera un enfoque eficaz para mejorar la resistencia y la condición física de los atletas. Esta investigación es un tipo de experimento que utiliza un diseño pre-test-post de un grupo. Los sujetos de este estudio fueron el equipo de balonmano del distrito de Sambas, con edades comprendidas entre los 17 y los 22 años. La técnica de muestreo intencional dio como resultado una muestra de 15 atletas. Los deportistas de balonmano participantes en este estudio se sometieron a un método de entrenamiento en circuito diseñado en el programa de entrenamiento y llevado a cabo durante 12 encuentros con una frecuencia de tres veces por semana. La medición del nivel de VO₂max se llevó a cabo antes y después del periodo de entrenamiento utilizando el instrumento Yoyo Intermittent Recovery Test Level 1. Los resultados mostraron un valor de significación de $0,000 < 0,05$. En base a estos resultados, se ha demostrado que el entrenamiento en circuito proporciona un aumento significativo del VO₂max en atletas de balonmano. Se espera que los resultados de este estudio contribuyan a la comprensión de la eficacia de los métodos de entrenamiento en circuito para mejorar las condiciones físicas, especialmente los niveles de VO₂max, en atletas de balonmano. Las implicaciones de este estudio pueden ser útiles en el diseño de un programa de entrenamiento más centrado para mejorar el rendimiento de los atletas de balonmano a través de un enfoque de entrenamiento que se adapte a sus necesidades fisiológicas.

Palabras clave: Entrenamiento en circuito, VO₂max, Balonmano.

Fecha recepción: 15-12-23. Fecha de aceptación: 28-02-24

Roy Ardian

royardian2023@student.uny.ac.id

Introduction

Regular physical exercise has been established as a valuable means of improving overall fitness, quality of life, and accomplishments (Athaya et al., 2023). Consistent engagement in physical activities also has a positive impact on the body's aerobic endurance, resulting in enhancements (Hardinata et al., 2021). The importance of VO₂max, regarded as the benchmark for measuring aerobic capacity, cannot be overstated, given its pivotal role as a determinant of aerobic performance (Jemni et al., 2019). Aerobic endurance, closely linked to VO₂max, serves as the foundational aspect for participation in sports activities (Bo, 2023; Hardinata, B, et al., 2023). Additionally, aerobic endurance plays a vital role in facilitating rapid recovery and effectively managing fatigue (Vasileios et al., 2018). Handball, being a

sport that demands robust aerobic endurance, further highlights the significance of this attribute. Handball involves team-based gameplay with frequent body contact, characterized by rapid shifts between anaerobic and aerobic movements (Saavedra et al., 2018). Consequently, players must be physically prepared, emphasizing endurance, to execute movements efficiently, outpace opponents, and sustain the game's speed and intensity throughout matches (Karcher & Buchheit, 2014; Michalsik et al., 2018). Moreover, players in handball necessitate a diverse range of physical attributes, including sprinting, throwing, jumping, and strength, to excel in both anaerobic and aerobic aspects of the game (Massuca et al., 2014; Wagner et al., 2014). This underscores the pivotal role of endurance in achieving success in handball. Several studies have addressed the contribution of the aerobic system to handball (Belka et al., 2016;

Kniubaite et al., 2019; Michalsik, Madsen, et al., 2015; S. C. Póvoas et al., 2014). Further research identified that ball players spend more than 50% of the time at >80% of maximal pulse rate (Povoas et al., 2012; S. Póvoas et al., 2014). The distance covered by players during a handball match, ranging from 4000 to 65000 meters, underscores the crucial need for well-developed aerobic and anaerobic endurance capacities (Marques & González-Badillo, 2006), further emphasizing the pivotal role of VO₂max endurance in handball. Moreover, comprehending the physical requirements during official competitions is crucial for attaining optimal performance in handball (García-Sánchez et al., 2023).

Additionally, VO₂max is widely acknowledged as the gold standard and the most significant measure of aerobic capacity (Jemni et al., 2019). Various studies have investigated methods to enhance VO₂max through low, medium, and high-intensity interval training, demonstrating positive results in increasing athletes' aerobic endurance (Wen et al., 2019). Other research has explored training approaches that positively impact VO₂max, including engaging in simple field games (Kusuma & Purnomo, 2019; Puriana, 2019; Zainudin et al., 2019), triangle run training (Hardinata et al., 2021), intermittent soccer (Bo, 2023), polarize training (Malyani & Fashi, 2021), continuous running training (Syahroni et al., 2020), high-intensity resistance circuit training (Marín-Pagán et al., 2020), and high-intensity training (Alvira et al., 2020).

This study was conducted with a recognition of the crucial role of aerobic endurance in handball and the significance of training methods in enhancing it. The primary aim was to evaluate the effectiveness of circuit training methods in improving the aerobic endurance of handball players. This research is vital for imparting knowledge and understanding regarding the critical importance of physical conditioning, which is a cornerstone in sports ((Karcher & Buchheit, 2014). Acknowledging the essential nature of physical conditioning is pivotal for achieving peak performance in handball (García-Sánchez et al., 2023; Mashud et al., 2024; Rubiyatno et al., 2023). Coaches must meticulously address each aspect of physical conditioning, including aerobic endurance, to optimize performance (Côté & Gilbert, 2009).

Aerobic endurance holds great significance for athletes, serving as a foundational element that supports gameplay and contributes to overall athletic success (Suryadi, Yanti, et al., 2023). Moreover, it acts as a crucial indicator of superior performance (Lacome et al., 2018). Additionally, numerous studies have highlighted that during gameplay, players engage in various general movements such as walking, running, jumping, and changing direction, alongside handball-specific actions like passing, catching, throwing, and blocking. Particularly in elite handball, different playing positions (back, pivot, wing, and goalkeeper) entail distinct functions within the team, resulting in varied movement patterns and physical demands for each position (Karcher & Buchheit, 2014;

Michalsik et al., 2018; Wagner et al., 2014). Hence, this research serves as a significant assessment of the effectiveness of the coaching and training processes implemented (Supriatna et al., 2023).

Materials and Methods

Participant

The participants in this study were members of the Sambas district handball team, aged between 17 and 22 years old. The sample comprised amateur handball athletes competing at the provincial sports week level, with heights ranging from 165 to 177 centimeters. Total sampling was employed, ensuring that all athletes were included as research participants, totaling 15 individuals, aligning with the principles of training.

Research Design

This study adopts an experimental research approach employing a one-group pre-test-post design. The intervention involves implementing a circuit training method, wherein participants perform exercises by moving between 14 designated posts. The circuit training regimen is incorporated into the exercise program and conducted over the course of 12 sessions, with a frequency of three times per week. The exercises are administered at 100% intensity, utilizing maximum repetitions.

This research commenced by collecting initial data on the aerobic endurance (VO₂max) of the Sambas team handball players, serving as the baseline information. Subsequently, the players underwent a prescribed regimen of circuit training, which was incorporated into a comprehensive training program alongside other exercises. Finally, at the conclusion of the study, measurements were once again taken to assess the VO₂max physical condition of the Sambas team handball players. The resulting data will be juxtaposed with the initial information obtained prior to the implementation of the training regimen.

The instrument used in this study is the Yo-yo intermittent recovery test level 1 as a valid tool for measuring VO₂max levels (Astagna et al., 2009; Castagna et al., 2008), a relevant field test in handball teams and as a consequence a useful tool for evaluating physical performance in intermittent sports (Bangsbo et al., 2008).

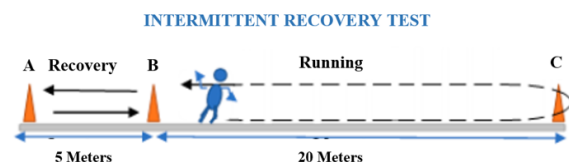


Figure 1. Yo-Yo Intermittent Recovery Test Instrument (Hardinata, B, et al., 2023)

Statistical Analysis

Data analysis was carried out to determine the effect of circuit training on VO₂max physical condition through the normality test and hypothesis testing stages. This research data analysis uses descriptive percentages to determine the

physical condition (endurance) of handball players. The fitness norm category used to determine the explanation of the VO2max value achieved by the player. The analysis was assisted using the SPSS 26 application. The VO2max assessment norm category can be seen in table 1.

Table 1.

Intermittent Yo-Yo VO2max Assessment Norms Male		
Ratings	Level	Value range
Elite	>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

Source: (Hardinata, B, et al., 2023)

Result

The VO2max levels of handball athletes are illustrated based on the presented data in Tables 2 and 3. According to the pretest results, 26.67% of the athletes fall into the Below Average category, 53.33% into the Average category, and 20% into the Good category in terms of VO2max ability. These findings indicate that the average VO2max ability of handball athletes is in the average range. This level is considered relatively low for handball players, who are expected to have a higher VO2max. In the posttest results, 33.33% of the athletes fall into the Average category, 40% into the Good category, and 20% into the Excellent category in terms of VO2max ability. These results also suggest that the average VO2max ability of handball athletes remains in the Good category.

Table 2.

Pretest Results VO2max Levels in Handball Athletes		
Ratings	Frequency	Percentage %
Elite	0	0%
Excellent	0	0%
good	3	20%
Average	8	53.33%
Below average	4	26.67%
Poor	0	0%

Table 3.

Posttest Results VO2max Levels in Handball Athletes		
Ratings	Frequency	Percentage %
Elite	0	0%
Excellent	4	26.67%
good	6	40%
Average	5	33.33%
Below average	0	0%
Poor	0	0%

Based on the results of this normality test, it can be seen that the data obtained with a significance value ($p > 0.05$). These results indicate that this data is normally distributed. After the data is known to be normally distributed, the next stage is the influence test (t test). The results can be seen in table 4.

Based on table 5, the results of the analysis using the pgararuh test, namely the paired sample t test, it can be seen that the results in the study showed a significance value obtained of ($0.000 < 0.05$). Based on these results, there is a significant effect of using the circuit training method on

increasing VO2max of handball athletes. Further results also show that the mean posttest value of 50.20 is greater than the pretest mean value of 45.77 with a difference of 4.43. The results can be seen in table 6 and figure 2.

Table 4.

Shapiro-Wilk Normality Test Results			
Result	Statistic	df	Sig.
Pretest VO2max	0,897	15	0,085
Posttest VO2max	0,847	15	0,116

Table 5.

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

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

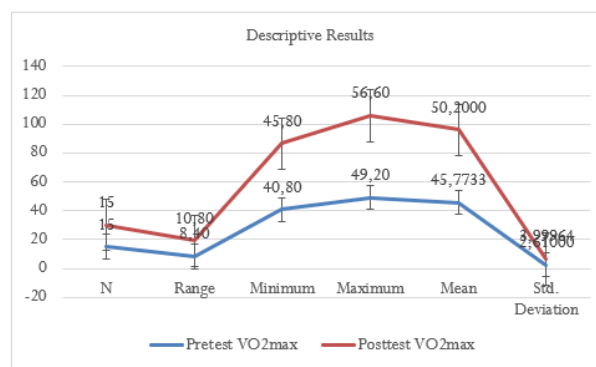


Figure 2. Descriptive Results of VO2max

Discussion

This study aims to prove the effect of circuit training on VO2max of handball athletes. The findings of this study provide information related to the use of circuit training methods to provide an increase in VO2max, this can be seen that the mean posttest value of 50.20 is greater than the pretest mean of 45.77. Based on the results of the t test, it also shows a significant increase in VO2max for handball athletes. The results of this study can provide good results due to the training process and good training program planning. Endurance training must be carried out continuously, regularly, structured and for a long time in order to achieve maximum performance (Hardinata et al., 2021). As said by (Bompa & Buzzichelli, 2015) organized training consisting of long duration or multiple repetitions can have positive results in the development of endurance, and therefore exercise has an important role in life (Hardinata, Ahwan, et al., 2023; Suryadi, Okilanda, et al., 2023).

Relevant research in support of these findings has been conducted by (Hermassi et al., 2020) by conducting circuit strength training for 12 weeks with a frequency of 2 sessions per week. The results show that male handball players can

substantially increase strength, sprinting ability, power, and ability to change direction. Further research using dynamic loads used during circuit training programs is suitable for maximizing strength (Fieseler et al., 2017; Hermassi et al., 2017). In addition, the impact of circuit training also has an influence on the agility of handball players (Hermassi et al., 2020). The results of the study showed a significant increase in the circuit training group compared to the control. A study examined the effect of a strength and conditioning program conducted by the Danish national handball team before the Beijing Olympics. The results showed an increase in strength and agility (Kvorning et al., 2017). Furthermore, the results of relevant research supporting this research were conducted by (Jeukendrup, 2011) supporting aspects in improving physical conditions including routine and programmed training, nutritional intake and vitamins that are maintained. Therefore, with the training program, the goal of achieving high achievement will be achieved, the training process becomes clearer and more directed.

Athletes and coaches should focus on building aerobic capacity, not only helping to maintain endurance capacity and avoid fatigue, but also helping to maintain concentration, technical skills, and coordination until the end of the match (Michalsik, Aagaard, et al., 2015; Popescu-Brădiceni & Plăstoi, 2014; Thorlund et al., 2008; Zapartidis et al., 2009). In another study handball players had to work actively at the moment the ball was released from possession in high-intensity aerobic activity (Mikalonytė et al., 2022). High aerobic capacity is important to maintain a high level of performance during 60 minutes of playing time (Camacho-Cardenosa et al., 2019). The results showed that elite handball players covered an average distance of 3664.4 ± 1121.6 m during a match (from 1346.6 ± 3852.5 to 6943.9 ± 364.4 m) (García-Sánchez et al., 2023). According to the research findings conducted by Wen et al., (2019) to improve aerobic endurance ability, the exercises performed can be low, medium, and high interval training. Besides that, small side games training (Alben et al., 2022), linear acceleration (Taskin & Taskin, 2021), fartlek (Gumantan & Fahrizqi, 2020; Syahroni et al., 2020; Syaroni & Kusuma, 2020), tabata (Herlan & Komarudin, 2020), and aerobic circuit (Ashfahani, 2020) are able to increase VO₂max. Additional studies focusing on activities that contribute to the improvement of maximum oxygen volume encompass various approaches, including triangle run training (Hardinata et al., 2021), intermittent soccer training (Bo, 2023), polarized training (Malyani & Fashi, 2021), continuous running training (Syahroni et al., 2020), high-intensity resistance circuit training (Marín-Pagán et al., 2020), and high-intensity training (Alvira et al., 2020). These exercises have demonstrated positive effects on enhancing aerobic endurance.

Conclusion

Based on the study's outcomes and research findings, it

can be deduced that a 12-week circuit training program, conducted three times a week, is notably effective in enhancing VO₂max among handball athletes. However, it's crucial to note that these findings are specific to young handball athletes, and variations in intensity, duration, repetitions, and training seasons may yield different results. The study's results are anticipated to contribute valuable insights into the efficacy of circuit training methods for enhancing physical fitness, particularly VO₂max levels, in handball athletes. The implications of this research may guide the development of targeted training programs to enhance the performance of handball athletes, aligning with their physiological requirements. Future research is recommended to explore training methods that comprehensively address various aspects of physical fitness.

Acknowledgement

The author would like to thank all parties for the cooperation so that the research can run well and smoothly.

Conflict of interest

There is no conflict of interest.

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Datos de las/os autoras/es y traductor/a:

Roy Ardian	royardian2023@student.uny.ac.id	Autor/a- Traductor/a
Yudik Prasetyo	yudik@uny.ac.id	Autor/a
Sulistiyono	sulistiyono@uny.ac.id	Autor/a
Fatkurahman Arjuna	arjuna@uny.ac.id	Autor/a
Didi Suryadi	didisurya1902@gmail.com	Autor/a
Julian Dewantara	juliandewantara.2023@student.uny.ac.id	Autor/a
Irvan Septianto	irvanseptianto.2023@student.uny.ac.id	Autor/a
Subarjo	subarjo@fkip.untan.ac.id	Autor/a