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ORIGINAL

Maximal oxygen uptake and cardiovascular adaptation to handball game specific endurance circuit training in handball players

Captación máxima de oxígeno y adaptación cardiovascular al entrenamiento en circuito de resistencia específico para el balonmano en jugadores de balonmano

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ABSTRACT

Now a day, the sports team coaches, trainers and other support staffs have a hectic job to deal with the preparation of their team players with consistent, precise and greater effort to meet the demands of the competition in shortest duration. Various training modalities were adopted depending upon the necessity that improves sports performance. Handball team coaches apparently felt that fitness and skill go hand in hand, where sports specific training caters to achieve this goal. Thus, the present study focussed on assessing the adaptations of maximal oxygen uptake and cardiovascular variables to handball game specific endurance circuit training. To accomplish the purpose twenty-four (24) trained university male handball players with a playing experience of more than eight years gave consent to participate. The selected twenty-four players were classified into two groups as Handball Game Specific Endurance Circuit Training Group (HGSECTG = 12) and Control Group (CG = 12). To test the effectiveness of handball game specific endurance circuit training (HGSECT) players performed specifically constructed handball circuit 3 days in a week for 12 weeks at 90-95 % of maximal heart rate for two minutes duration and active recovery by walking. HGSECTG showed significant improvement on maximal oxygen uptake (t = 8,516, p < 0,05) and distance covered in Yo-Yo test also increased (t = 8,4, p < 0,05). Similarly, cardiovascular modifications are noted in maximum heart rate (HR_{PEAK}, t = 2,372, p < 0,05) and resting heart rate (HR_{REST}, t = 3,975, p < 0,05) and percentage of heart rate reserve ($\%HR_{RESERVE}$, t = 3,004, p < 0,05). We conclude that handball game specific endurance training programs could be sufficiently suitable to develop maximal oxygen uptake and positive adaptation of cardiovascular variables in twelve weeks of training among handball players. The intensity, duration, frequency and recovery of the intervention displayed improvement in VO_{2PEAK} with reduced condition on cardiovascular stress.

Keywords: Handball; Heart Rate; Endurance; Maximal Heart Rate; VO_2 Max.

RESUMEN

Hoy en día, los entrenadores, preparadores físicos y demás personal de apoyo de los equipos deportivos tienen la ajetreada tarea de ocuparse de la preparación de los jugadores de sus equipos con un esfuerzo constante, preciso y mayor para satisfacer las exigencias de la competición en el menor tiempo posible. Se adoptaron diversas modalidades de entrenamiento en función de la necesidad de mejorar el rendimiento deportivo. Al parecer, los entrenadores de los equipos de balonmano consideraban que la forma física y la habilidad van de la mano, y que el entrenamiento específico del deporte sirve para lograr este objetivo. Así pues, el presente estudio se centró en evaluar las adaptaciones del consumo máximo de oxígeno y las

variables cardiovasculares al entrenamiento en circuito de resistencia específico para el balonmano. Para ello, veinticuatro (24) jugadores universitarios de balonmano con una experiencia de juego de más de ocho años dieron su consentimiento para participar. Los veinticuatro jugadores seleccionados se clasificaron en dos grupos: grupo de entrenamiento de resistencia en circuito específico para balonmano (HGSECTG = 12) y grupo de control (CG = 12). Para probar la eficacia del entrenamiento en circuito de resistencia específica para el juego de balonmano (HGSECT), los jugadores realizaron un circuito de balonmano construido específicamente 3 días a la semana durante 12 semanas al 90-95 % de la frecuencia cardíaca máxima durante dos minutos y con recuperación activa caminando. El HGSECTG mostró una mejora significativa en el consumo máximo de oxígeno ($t = 8,516$, $p < 0,05$) y la distancia recorrida en la prueba Yo-Yo también aumentó ($t = 8,4$, $p < 0,05$). Del mismo modo, se observan modificaciones cardiovasculares en la frecuencia cardiaca máxima (HRPEAK, $t = 2,372$, $p < 0,05$) y la frecuencia cardiaca en reposo (HRREST, $t = 3,975$, $p < 0,05$) y el porcentaje de reserva de frecuencia cardiaca (%HRRESERVE, $t = 3,004$, $p < 0,05$). Concluimos que los programas de entrenamiento de resistencia específicos para el juego de balonmano podrían ser suficientemente adecuados para desarrollar la captación máxima de oxígeno y la adaptación positiva de las variables cardiovasculares en doce semanas de entrenamiento entre los jugadores de balonmano. La intensidad, duración, frecuencia y recuperación de la intervención mostraron una mejora en el VO2PEAK con una condición reducida en el estrés cardiovascular.

Palabras clave: Balonmano; Frecuencia Cardiaca; Resistencia; Frecuencia Cardiaca Máxima; VO2 Max.

INTRODUCTION

Handball swiftly became one of the most beloved team sports since its introduction at the 1972 Munich Olympic Games, characterized by its rapid pace.[1,2] The game's glamour has been elevated through numerous changes in rules and playing styles, drawing vast audiences and players globally. Today, handball holds a prominent position, played professionally and at the amateur level in 167 countries, with nearly 19 million players spanning across all continents. In India, the game handball is played by both male and female at different levels throughout the country.

Contemporary handball requires players to maintain a high level of fitness, engaging in both offensive and defensive maneuvers gracefully throughout the 60 minutes of play on the court. During the game players perform sprints, jumps, throws, feints, holds and turns which require well developed fitness.[3,4,5] During the 60 minutes of handball match aerobic and anaerobic energy systems were taxed in players. In order to perform they require high level endurance capacity for their success.[6,3,7] High level of endurance would delay the onset of fatigue and induce faster recovery. The players perform repeated sprints of high intensity during the match frequently for whom endurance capacity is required.[8,9]

Platen[10] identified VO_{2MAX} as basic requirement for team handball players on the international level. Handball game is of intermittent nature where aerobic metabolism dominates.[11,12,13] Therefore, players aerobic capacity demonstrated significant relationship to the efficiency of oxygen uptake, transport and utilization of oxygen in ATP synthesis during aerobic metabolism.[14,15] The constant supply of energy to the muscle would improve the muscle working rate during the long duration of exercise which facilitates to balance the disturbed functional system of the organism.[16,17] In the present day, handball is played at a fast pace for a full 60 minutes without succumbing to fatigue. Throughout the game, players must execute repeated sprints, highlighting the essential need for both aerobic and anaerobic endurance in handball athletes. To maintain and develop both components requires systematic and scientific approach on training.

When designing an endurance training program, it is crucial to take into account the intensity, duration, and frequency of the training sessions. Since, handball demands high intensity activity interspersed with period of recovery. The training at high intensity with sufficient recovery would suit the condition of the game. Earlier studies displayed an increase in $VO_{2\,MAX}$ of trained athletes after training at 90 to 95 % HR_{MAX} which corresponds to high intensity.[18,19,20,21] However, the efficacy relies on how often and for how long the training is conducted.[22] Traditionally, coaches train their players without ball and monotonously run around the track to improve their VO_{2MAX} but sports specific training would facilitate the player to perform activity which they perform during the game. Therefore, the players' technical and tactical skills are enhanced as they increase their interaction with the ball and encounter common game situations more frequently.[23] Nowadays, coaches encounter significant challenges when preparing their teams for inter-university competitions due to the limited time provided. To overcome this issue, we designed a new training programme of short duration. Therefore, the objective of the study was to evaluate maximal oxygen uptake and cardiovascular adaptation to handball game specific endurance circuit training in handball players.

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METHODS

Subjects and Study Design

The participant selection and grouping for a study involving male handball players from Annamalai University. It notes that 24 players participated voluntarily after providing written consent and undergoing medical examinations to ensure their fitness. Approval from the Institutional Human Ethics Committee at Rajah Muthiah Medical College, Annamalai University was obtained for the research. All participants were confirmed to be medically fit by registered medical practitioners.

The players were randomly divided into two groups: HGSECTG and CG, with each group consisting of 12 participants. Importantly, there were no dropouts or participants who withdrew from the study during its duration. The selected handball players had an average (± standard deviation) age of 24,35 ± 4,05 years, a height of 178,75 ± 8,18 cm, and a weight of 72,59 ± 9,70 kg.

This information sets the groundwork for understanding the demographics and grouping of participants in the study, ensuring transparency and clarity in how the research was conducted.

Collection of Data

Both the experimental and control groups underwent testing on two occasions: initially before the commencement of training as a pre-test and subsequently after twelve weeks of training as a post-test. Parameters such as maximal oxygen uptake, distance covered, resting heart rate, peak heart rate, average heart rate, and percentage of heart rate reserve were assessed both before the initiation of training and after the completion of twelve weeks of training.

Variables and Tests

Maximal Oxygen Uptake

The methodology involving the assessment of maximal oxygen uptake (VO2 max) and distance covered using the Yo-Yo intermittent recovery test level II in handball players. The procedure involves a warm-up period of ten minutes for the players. Then, they're positioned in front of a marked area and directed to run half the distance and return upon hearing a sound signal from a music player. The distance covered by the players is recorded during this test. Additionally, the formula VO2 MAX = distance in meters × 0,0136 + 45,3, as mentioned,[24] is used for the estimation of VO2 max.

Cardiovascular

Cardiovascular variables, including resting heart rate, peak heart rate, average heart rate, and the percentage of heart rate reserve, were assessed. Subjects were instructed to wear a Polar heart rate monitor while undertaking the Yo-Yo intermittent endurance test. Transducers detected the electrical signals transmitted through the heart muscle at the skin, and the resulting electromagnetic signals containing heart rate data were transmitted by the transmitter to the wrist-worn watch for display by the subjects. The number of heart beats per minute at the conclusion of the exercise testing was recorded as shown on the Polar watch.

The percentage of heart rate reserve and VO2 MAX were calculated using the formula:

$$\%HRR = (HRmean - HRrest) / (HRpeak - HRrest) \times 100$$ [25]

Training

The specifics of a handball game-specific endurance circuit training program conducted over a twelve-week period. In this program, the HGSECTG (one of the participant groups) engaged in training sessions three days a week. The training regimen consisted of 2-minute work intervals at intensities reaching 90 to 95 % of their maximum heart rate, followed by 2 minutes of active recovery through walking.

The aim of the 2-minute work duration was to utilize both aerobic and anaerobic energy sources, contributing evenly (50 % each) during maximal exertion. This approach was based on prior research[26] and maintained a 1:1 work-to-rest ratio, following a training protocol adapted.[27]

Additionally, the number of repetitions within each training session progressed over the twelve weeks. It started with 6 repetitions in the first four weeks, increased to 7 in the subsequent four weeks, and finally reached 8 repetitions in the last four weeks of the training program.

This information outlines the structure and progression of the specific endurance circuit training program implemented for the HGSECTG during the twelve-week study period, incorporating intensity, work-to-rest ratios, and progression in repetitions.

Each circuit's average running time was 64 seconds, covering a total distance of approximately 110 meters. The breakdown showed that 63,63 % of the activity was offensive, while 36,36 % was defensive, as illustrated in Figure 1. During the run they travel 60 m without ball and 50 m with ball. They also perform 1 long pass, 2 fast break receiving, 2 push pass, 2 wrist pass, 2 jump shot long (1 left right left feint & 1 right left right feint)

and 1 jump shot high.

The Polar heart rate monitor was employed to gauge peak heart rate by securely strapping it onto the subjects during circuit performance. The training intensity was set within the range of 90 to 95 % of the maximum heart rate. If players operated below or above the specified intensity, the watch would emit a beep sound to prompt adjustments in their intensity.

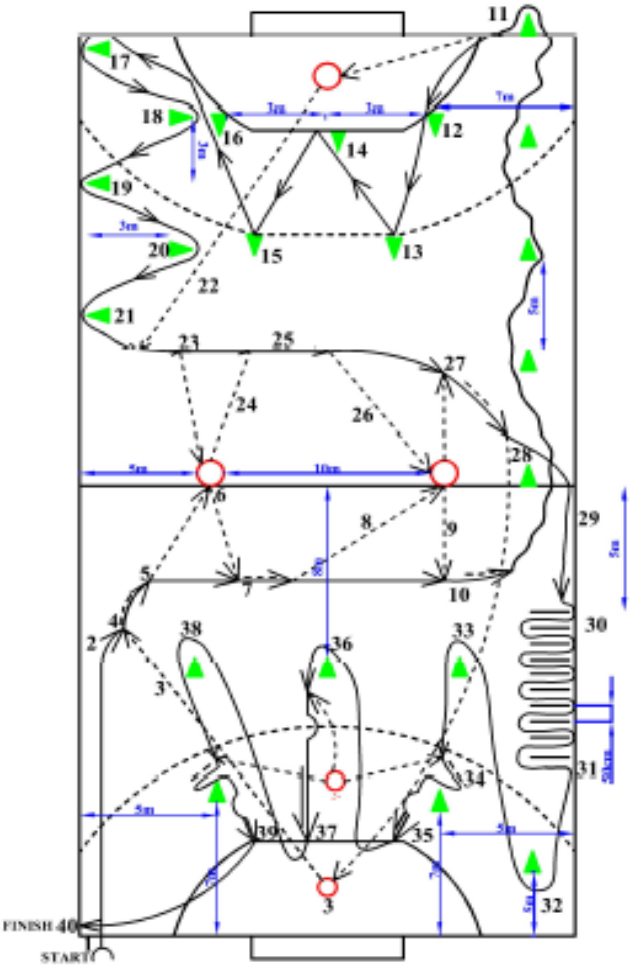

Figure 1. Handball game specific endurance circuit

Description of handball game specific endurance circuit

1 to 2 – sprint forward; 3 – goalkeeper passes the ball to sprinting players near the centre of the court; 4 to 5 – player receives the ball from goalkeeper and move; 5 to 6 – take three step and makes push pass to the player; 6 to 7 – receives the ball back from the players; 7 to 8 – take three step and makes push pass to the player; 8 to 9 - receives the ball back from the players; 10 to 11 – zig zag dribble between the cones and pass the ball to the goalkeeper at last, 11 to 12 – sprint forward, 12 to 16 – forward and diagonal defensive movement, 16 to 17 – sprint towards the cone, 17 to 21 – zig zag run between the cone, 22 – goalkeeper pass the ball to the players when he near the centre of the court, 23 to 24 – moving player receives the ball from goalkeeper and moves parallel to the centre line, 24 to 25 - take three step and makes wrist pass to the player, 25 to 26 – receives the ball back from player, 26 to 27 - take three step and makes wrist pass to the player, 27 to 28 - receives the ball back from player, 28 to 29 - the moving player pass the ball to the goalkeeper, 29 to 30 - sprints forward, 30 to 31 – side shuffle in between the wands, 31 to 33 – sprint forward, 34 – receives the ball from player placed near penalty line and performs right left right feint and make jump shot long, 35 – after jump shot long player runs to next cone, 36 - receives the ball from player placed near penalty line and performs jump shot high, 37 - after jump shot high player runs to next cone, 38 - receives the ball from player placed near penalty line and performs left right left feint and make jump shot long, 39 to 40 – sprints and finish. –

Statistical Technique

The methodology used to evaluate changes between the pre-test and post-test in both the HGSECTG and CG within the study. Paired t-tests were utilized to compare means before and after the intervention within

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each group. The significance of these mean differences, represented by the t value, was further examined using effect size calculations, specifically Cohen's d (ES), providing additional insight into the practical significance of the observed changes.

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) designed for Windows, specifically Version 16. A predetermined level of statistical significance was established at a p-value of less than 0,05. This significance level helps discern whether observed differences between pre-test and post-test measurements are likely due to the intervention or could have occurred by chance.

By employing paired t-tests, effect size assessments, and setting a predefined threshold for statistical significance, this study methodology aims to offer a comprehensive analysis of the changes observed before and after the intervention in both groups, providing a reliable basis for interpreting the study's outcomes.

RESULTS

VO_{2max} and Distance Covered

The outcomes observed after twelve weeks of specific handball game endurance circuit training, focusing on improvements in VO2max and distance covered in the Yo-Yo test. In the HGSECTG, significant enhancements were noted: VO2max increased from 52,36 to 55,81 ml kg-1 min-1, marking a substantial 6,58 % improvement. The effect size (Cohen's d) of 2,16 indicates a substantial impact of this improvement.

Additionally, the distance covered in the Yo-Yo intermittent test exhibited a notable improvement of 44,77 % in the HGSECTG after the twelve-week period, showing a substantial effect with a Cohen's d of 2,11.

Conversely, the control group did not exhibit statistically significant changes in either VO2max or the distance covered in the Yo-Yo test.

These findings suggest that the specific handball game endurance circuit training led to considerable improvements in both VO2max and performance in the Yo-Yo test among participants in the HGSECTG, highlighting the effectiveness of the training regimen. The lack of significant changes in the control group emphasizes the specificity and impact of the training protocol on these measured variables.

Cardiovascular

The cardiovascular parameters also show adaptation to twelve weeks of HSECT (Table 1). The HR_{PEAK} also showed significant reduction after twelve weeks of training which displayed 3,70 % (MD – 7,66 beats min^{-1} & Cohen's *d* = 0,859). Similarly, HR_{REST} also elicited significant reduction of 11,53 % (MD – 6,16 beats min^{-1} & Cohen's *d* = 1,46). This shows that HSECT has large effect and which confirm that HR_{PEAK} and HR_{REST} reduced after twelve weeks of training.

Percent of heart rate reserve also showed significant improvement of 9,30 % (MD – 8,17 Percentage of beats min^{-1} & Cohen's *d* = 1,54). This shows that large effect of changes is noticed due to HSECT for twelve weeks. In contrast control group remained unaltered statistically in HR_{PEAK}, HR_{REST} and $\%HR_{RESERVE}$.

Table 1. Changes obtained to handball game specific endurance circuit training

Variables	Groups	Testing conditions		*t value*	*p value*
		Pre test	Post test		
VO_{2MAX} (ml kg^{-1} min^{-1})	HGSECTG	52,36 ± 1,71	55,81 ± 1,48	8,516	0,000
	CONG	51,95 ± 1,31	52,48 ± 1,23	1,058	0,313
Distance covered (m)	HGSECTG	523,33 ± 126,73	773,33 ± 109,32	8,419	0,000
	CONG	523,45 ± 96,90	528,33 ± 91,23	1,085	0,412
HR_{PEAK} (beats min^{-1})	HGSECTG	189,17 ± 8,90	181,50 ± 8,94	2,372	0,037
	CONG	183,17 ± 5,76	184,67 ± 5,24	0,835	0,421
HR_{REST} (beats min^{-1})	HGSECTG	63,41 ± 4,60	57,25 ± 3,81	3,975	0,002
	CONG	65,58 ± 9,93	66,66 ± 7,40	0,575	0,577
$\%HR_{RESERVE}$ (% of beats min^{-1})	HGSECTG	87,80 ± 3,49	95,97 ± 7,09	3,004	0,012
	CONG	89,20 ± 6,77	90,14 ± 7,69	0,317	0,757

DISCUSSION

Comprehensive overview of the impact of twelve weeks of handball-specific endurance circuit training on male players' physiological aspects, particularly focusing on VO2MAX enhancement and cardiovascular improvements.

The study's results revealed a significant 8,516 % enhancement in VO2MAX following the designated training period. Notably, the Yo-Yo intermittent recovery test also indicated a significant increase in covered distance, showcasing the effectiveness of performing the designed circuit at 90,95 % intensity in developing both VO2MAX and improving cardiovascular functions.[28]

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Referenced studies support these findings, showing that high-intensity training combined with active recovery positively impacts aerobic capacity.[29] Similar improvements were observed in other sports like soccer,[27,30] basketball,[31] and rugby,[32] further validating the effectiveness of specific training protocols across various athletic domains.

Various training methods, such as small-sided handball games[33,34] and high-intensity interval training have proven effective in eliciting improvements in aerobic capacity among handball players.[35] Specifically, high-intensity aerobic interval training at 90-95 % HRMAX resulted in notable enhancements in VO2MAX (7,2 %) and stroke volume (10 %), surpassing the effects of low and moderate training.[36,37]

Moreover, the adaptations induced by handball-specific aerobic training may lead to cardiovascular changes, including increased maximal cardiac output, enhanced stroke volume, and reduced resting and submaximal exercise heart rates.[38] Notably, prolonged endurance training predominantly elevates maximal cardiac output due to enhanced stroke volume, highlighting their interplay and responsiveness to training intensity.[36,37]

Overall, this passage draws on a range of studies to emphasize the efficacy of handball-specific endurance circuit training in enhancing VO2MAX and cardiovascular parameters, showcasing the interrelation between training intensity and physiological adaptations, offering valuable insights into optimizing athletic performance in handball.

HGSECTG showed significant cardiovascular adaptation through significant modification in HR_{REST} (11,53 %) and HR_{PEAK} (3,70 %) after twelve weeks of training. The intensity of exercise can be quantified as a percentage of either maximal heart rate (%HRmax) or heart rate reserve (%HRR). The exercise intensity was found to be high after twelve weeks of training in HGSECTG ($p < 0,05$). Regular aerobic exercise among both sedentary athletes and endurance athletes typically leads to a decrease in HR_{REST} and HR_{PEAK}. There is a significant relationship exist between maximal oxygen uptake and HR_{PEAK} which indicate that as VO_{2MAX} improves with training but HR_{PEAK} tends to decrease about 3 to 7 % in aerobic training.[39,40] Earlier studies showed that moderate aerobic training showed significant modification in autonomic function and also on antioxidant status.[41] However, high-intensity aerobic interval training (4 × 4 min at 90 to 95 % of maximum heart rate) leads to more favourable adaptations in heart function compared to those observed after low-to-moderate exercise intensity.[42]

The physiological effects of endurance training on the autonomic nervous system and cardiovascular function. It suggests that endurance training leads to an imbalance favoring increased parasympathetic (vagal) activity over sympathetic (accelerator) activity. This shift towards greater vagal dominance is attributed to heightened parasympathetic function and a slight decrease in sympathetic discharge. Additionally, it mentions that endurance training results in a reduction in the intrinsic firing rate of sinoatrial (SA) nodal pacemaker tissue. These adaptations collectively contribute to resting and submaximal exercise bradycardia, particularly observed in well-conditioned endurance athletes or previously sedentary individuals who engage in aerobic training.[43]

CONCLUSION

The findings suggest that a twelve-week regimen of handball game-specific endurance circuit training, maintaining a heart rate at 90-95 % of the maximum with active recovery, may be recommended for enhancing maximal oxygen uptake and cardiovascular variables in male handball players. The specially designed handball circuit is sufficient enough to bring improvement in VO_{2MAX} and cardiovascular functions. This can be administered to athletes and also to non athletes with reduced load which bring greater modification in their health and fitness. The present study showed that VO_{2MAX} improved over twelve weeks of training but the influence on anaerobic endurance and fatigue mechanism was not monitored.

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