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The Effect of High-Intensity Interval Training (HIIT) Protocols on Enhancing Aerobic and Anaerobic Capacity: An Experimental Study on a Sample of Athletes

Saif Rasheed Ghanim
University of Samarra, College of Physical Education and Sports Sciences
Saif.rasheed@uosamarra.edu.iq
https://orcid.org/0009-0002-2536-4049

Abstract

Purpose: The aim of this study was to determine the effect that a six-week high-intensity interval training program would have on anaerobic capacity, maximal sprint speed, and explosive power together with aerobic capacity among adult handball players.

Methods: Eighteen male handball players (age: 24.26 ± 5.18 years) were randomly assigned into two groups of nine each, an experimental group and a control group. The experimental group intervened with a structured HIIT program three times per week for six weeks while the control group continued regular handball training. Performance variables included mean explosive power (vertical jump), mean anaerobic power (30-s step test), maximal sprint speed (60-m sprint), and maximal oxygen consumption (VO_2max; Cooper 12-min test). Pre- and post-intervention data were analyzed using paired and independent *t*-tests, with effect sizes calculated using Cohen's *d*.

Results: The HIIT group demonstrated significant improvements in all performance variables following the intervention ($p < 0.001$), including increases in explosive power (520.3 ± 58.7 to 589.6 ± 60.9 W; +13.3%, $d = 1.17$), anaerobic power (418.4 ± 47.5 to 465.2 ± 49.1 W; +11.2%, $d = 0.98$), maximal sprint speed (24.7 ± 1.4 to 26.2 ± 1.5 km·h^{-1}; +6.1%, $d = 0.90$), and VO_2max (46.1 ± 3.6 to 50.3 ± 3.8 ml·kg^{-1}·min^{-1}; +9.1%, $d = 1.04$). No significant changes were observed

in the control group ($p > 0.05$). Post-test comparisons revealed significantly superior performance in the HIIT group across all variables ($p \leq 0.004$).
Conclusion: A six-week HIIT program effectively enhances anaerobic performance, sprint speed, explosive power, and aerobic capacity in handball players, representing a time-efficient conditioning strategy for meeting the sport's high-intensity and intermittent performance demands.

Keywords: High-intensity interval training; Handball; Anaerobic power; VO_2max; Sprint performance

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1. Introduction

Handball is a high-intensity intermittent team sport . Substantial physical and physiological demands are placed on players throughout competitive match play. The frequent alternations between low- to moderate-intensity activities, such as walking and jogging ,and short bouts of high-intensity actions including rapid accelerations and decelerations ,explosive jumps, changes of direction ,physical contacts and repeated short sprints characterize the game. (Barnes et al., 2014) Therefore,(Buhheit & Laursen, 2013) performance in handball needs continuous integration of various elements or components of physical fitness to maintain at different

periods or moments within the entire duration(performance across the entire match duration. Time-motion analysis of total distance covered among elite handball players indicates values between 3 km and 5 km per game depending on position, tactical role, or pattern of substitutions. Compared to other field sports that involve much greater running distances over the course of play, it is apparent that in handball a very large proportion consists at near maximal intensities. These include fast breaks and retreats plus jumping throws; tackles-and repeated changes of direction all placing considerable neuromuscular as well as metabolic stress high intensity efforts with short recoveries must be maintained by the modern elite Handball player together with an ability for quick recovery Handball is a sport that involves both the anaerobic and aerobic energy systems from an energetic perspective. The explosive actions are supported mainly by the phosphagen ATP–PCr system, particularly physical contact actions which last for just a few seconds. Anaerobic glycolysis contributes to repeated high-intensity efforts and transitional phases of play while the aerobic system enables recovery between intense bouts during work rate sustenance throughout a match involvement in general performance support consequently emphasized as vital thus making it necessary Handball is a sport that involves both the anaerobic and aerobic energy systems from an energetic perspective. The explosive actions are supported mainly by the phosphagen ATP–PCr system, particularly physical contact actions which last for just a few seconds. Anaerobic glycolysis contributes to repeated high-intensity efforts and transitional phases of play while the aerobic system enables recovery between intense bouts during work rate sustenance throughout a match involvement in general performance support consequently emphasized as vital thus making it necessary that competitive handball players attain both a power develop ability.

The best method of developing the physical qualities involved in handball is a training program that mimics very closely the movement patterns, changes in intensity, and overall physiological demands experienced during actual match play. One scientifically supported approach to such development is High-intensity interval training or HIIT is abbreviated as HIIT. This sort of instruction alternates brief periods wherein work output approaches maximum levels with recovery intervals thereby allowing large accumulations of time at extremely high physiological loads within relatively short total session durations (Enge; et al., 2018). Due to its effectiveness-and more significantly perhaps because it can evoke responses from different energy systems within the same workout-this mode has become highly popular among both individual athletes and team sport practitioners.

HIIT protocols may vary largely in work duration, intensity, and recovery structure. It could be a program of repeated short sprints for just a few seconds with equally brief periods of recovery; or sprint interval training having much longer rest intervals; or long high-intensity bouts up to several minutes. 30 Properly prescribed HIIT is capable of bringing about huge improvements both aerobically and anaerobically within relatively short training periods-two to three times per week over several weeks (Gagia & Docherty, 1995) (Girard et al. 2011)Handball periodization mainly focuses on the development of physical qualities in the pre-competition phase and later integrates a maintenance program for technical, tactical, and physical performance during the competitive season. Due to high energetic demands observed during matches, training programs shall develop all needed aspects without creating unnecessary fatigue that could result in overtraining. Therefore, an appropriate HIIT handball-specific

program would respect physiological requirements implied by practicing this sport while enhancing major physical abilities.

Therefore, the aim of the present study was to examine the effect of a six-week high-intensity interval training program on anaerobic capacity, maximal speed, explosive power, and maximal oxygen consumption (VO_2max) in adult handball players, compared with regular team training.

The sentence does not contain any subordinate clauses or prepositional phrases that can be reduced or eliminated to make it simple. Breaking it into two sentences would distort its meaning because there is only one main idea: to examine the effect.

2. Methods

2.1 Participants

The study sample comprised eighteen male handball players (age: 24.26 ±5.18 years; body mass: 74.57 ±8.86 kg; height: 176.54 ±9.46 cm). All of them were active competitors at the regional competitive level with not less than five years of training experience and had been free from any musculoskeletal injury for a minimum period of six months before the study, besides being regular members in team training sessions as per inclusion criteria. The goalkeeper was excluded because his physical demand is position-specific.

A simple randomization procedure based on a random number generator assigned nine participants to an experimental HIIT group and the other nine to a control group. All participants were told about the procedures, benefits, and risks of the study, and they were required to give written consent prior to participating. The investigation was conducted according to the principles of the Declaration of Helsinki. Ethical approval was deemed not applicable as all procedures were part of routine physical training and performance testing.

2.2 Experimental Design

The experiment was conducted with a pre-test post-test control group design for six weeks of training. Both groups were tested one week before the intervention and immediately after the six-week program. The experimental group performed a structured high-intensity interval training (HIIT) program in addition to regular team training, while the control group continued their regular handball training program designed by the team coach. All this took place three times per week during the preparatory phase of the competitive season.

Table 1. HIIT Training Program

Training Component	Intensity	Work Duration	Repetitions	Rest Interval	Description
Plyometric Explosive Power	/85–95% HRmax	3–15 s	6–8	30 s passive	Vertical jumps, bounding, lateral hops simulating handball actions
Maximal Speed Drills	85–95% HRmax	40–60 m sprints	6–8	30 s passive	Linear sprints with rapid acceleration and deceleration
General Endurance Intervals	75–85% HRmax	2 min	2–4	30 s active	Shuttle runs and continuous running
Frequency	—	—	—	—	3 sessions per week
Program Duration	—	—	—	—	6 weeks

2.3 Control Group Training

The control group continued their regular handball training program, which consisted of technical and tactical drills, positional play, small-sided games, and moderate-intensity conditioning exercises. No structured high-intensity interval training or additional sprint-specific or plyometric training was included beyond routine practice sessions.

All training sessions started with a 10-minute warm-up that was standard in all of the training, this comprised of light jogging, dynamic stretching, and mobility exercises, the final part of the session was a 5-minute cool-down that involved low-powered running and static stretching.

All tests were conducted under similar environmental conditions at the same time of day to minimize circadian effects.

3. Results

The baseline comparison showed that there was no significant difference between the experimental and control groups in any of the variables studied before intervention ($p > 0.05$).

3.1 Statistical Analysis

All analyses were carried out using SPSS statistical software package version XX (IBM Corp., Armonk, NY, USA). The results are expressed as mean ± standard deviation (SD) . Normality for the data was checked by Shapiro-Wilk's test and homogeneity of variances by Levene's test. Since both assumptions for conducting parametric tests have been satisfied, paired sample t-tests within each group across time and independent samples t-test between two groups at posttest have been employed.

The degree of statistical significance was determined at $p < 0.05$> The text addresses a number of key issues regarding the regulation of the blockchain. Effect sizes were determined using Cohen's d and considered small (0.2), medium (0.5), or large (≥0.8). All statistical evaluations were conducted with a 95% confidence level.(Helgerud et al., 2007)

Average Explosive Power

$$\text{Average Explosive Power (W)} = 2.21 \times \text{Body Mass (kg)} \times \text{Jump Height (m)}$$

Average Anaerobic Power (Step Test)

$$\text{Average Anaerobic Power (W)} = \frac{\text{Force (N)} \times \text{Step Height (m)} \times \text{Number of Steps} \times 1.33}{\text{Time (s)}}$$

Maximal Oxygen Uptake (VO_2max)

$$VO_{2max}(ml\ kg^{-1}\ min^{-1}) = \frac{Distance\ (km) - 0.505}{0.0447}$$

Maximal running speed was calculated by dividing sprint distance (60 m) by sprint time, with values subsequently converted from $m \cdot s^{-1}$ to $km \cdot h^{-1}$.

3.2 Within-Group Comparisons

As presented in **Table 1**, the experimental group demonstrated statistically significant improvements in all measured performance variables following the six-week HIIT intervention. Mean explosive power increased significantly from 520.3 ± 58.7 W to 589.6 ± 60.9 W ($t = 5.21$, $p < 0.001$), representing a large effect size (d = 1.17). Similarly, mean anaerobic power showed a significant increase from 418.4 ± 47.5 W to 465.2 ± 49.1 W ($t = 4.38$, $p < 0.001$; d = 0.98). Maximal sprint speed improved significantly from 24.7 ± 1.4 $km \cdot h^{-1}$ to 26.2 ± 1.5 $km \cdot h^{-1}$ ($t = 4.02$, $p < 0.001$; d = 0.90). In addition, maximal oxygen consumption (VO_2max) increased significantly from 46.1 ± 3.6 to 50.3 ± 3.8 $ml \cdot kg^{-1} \cdot min^{-1}$ ($t = 4.65$, $p < 0.001$), with a large effect size (d = 1.04). These changes are illustrated in **Figure 1**.

Table 2. Pre–Post Changes in the Experimental Group (Paired t-test)

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	t-value	p-value	Effect size (d)
Mean Explosive Power (W)	520.3 ± 58.7	589.6 ± 60.9	5.21	< 0.001	1.17 (large)
Mean Anaerobic Power (W)	418.4 ± 47.5	465.2 ± 49.1	4.38	< 0.001	0.98 (large)
Maximal Speed (km/h)	24.7 ± 1.4	26.2 ± 1.5	4.02	< 0.001	0.90 (large)
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	46.1 ± 3.6	50.3 ± 3.8	4.65	< 0.001	1.04 (large)

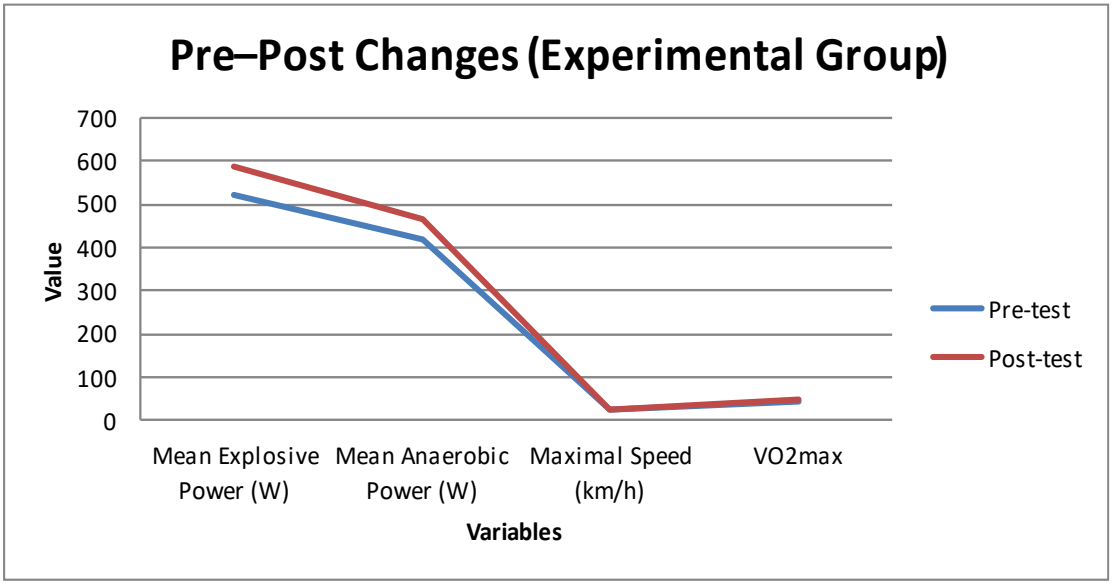

Figure 1. Pre–Post Changes in Aerobic and Anaerobic Performance Indicators in the Experimental Group

In contrast, the control group exhibited no statistically significant changes in any performance variable between pre- and post-testing, as shown in **Table 3**. Mean explosive power, mean anaerobic power, maximal speed, and VO_2max demonstrated only trivial to small improvements, none of which reached statistical significance ($p > 0.05$), with all effect sizes classified as small. The pre–post trends for the control group are illustrated in **Figure 2**.

Table 3. Pre–Post Changes in the Control Group (Paired t-test)

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	t-value	p-value	Effect size (d)
Mean Explosive Power (W)	518.7 ± 60.2	525.9 ± 59.4	1.12	0.276	0.25 (small)
Mean Anaerobic Power (W)	417.1 ± 48.3	421.5 ± 49.0	0.89	0.383	0.20 (small)
Maximal Speed (km/h)	24.6 ± 1.5	24.9 ± 1.6	1.03	0.314	0.23 (small)
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	46.0 ± 3.7	46.8 ± 3.9	1.18	0.252	0.26 (small)

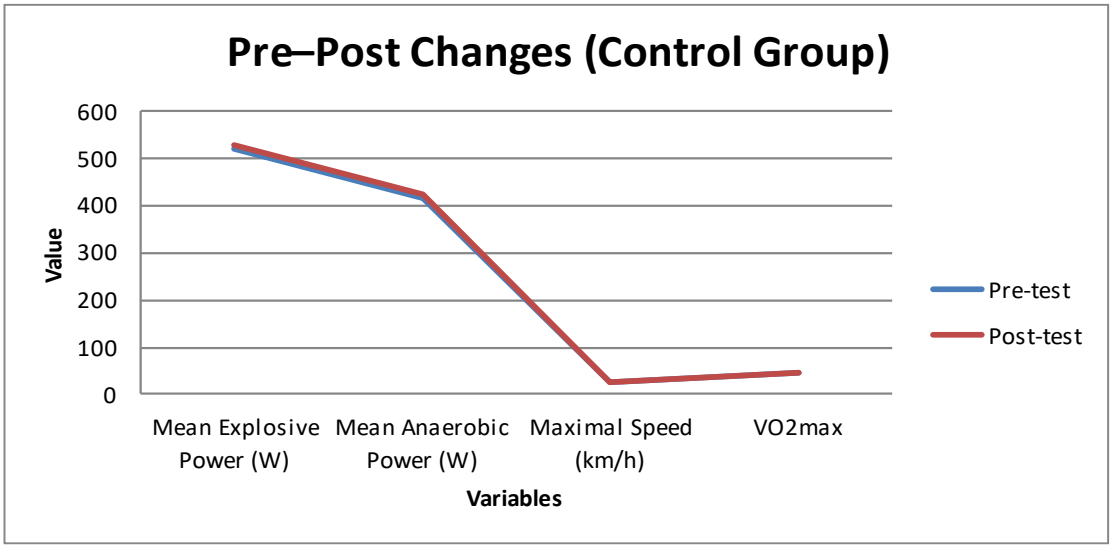

Figure 2. Pre–Post Changes in Aerobic and Anaerobic Performance Indicators in the Control Group

3.3 Between-Group Comparisons

Post-test comparisons between the experimental and control groups revealed statistically significant differences in all measured variables in favor of the experimental group (Table 3). Mean explosive power was significantly higher in the experimental group compared with the control group (589.6 ± 60.9 W vs. 525.9 ± 59.4 W; $t = 3.22$, $p = 0.002$; d = 0.98). Similarly, mean anaerobic power was significantly greater in the experimental group (465.2 ± 49.1 W vs. 421.5 ± 49.0 W; $t = 3.07$, $p = 0.003$; d = 0.93). Maximal sprint speed was also significantly higher following HIIT (26.2 ± 1.5 $km \cdot h^{-1}$ vs. 24.9 ± 1.6 $km \cdot h^{-1}$; $t = 3.02$, $p = 0.004$; d = 0.91). Furthermore, VO_2max values were significantly greater in the experimental group compared with the control group (50.3 ± 3.8 vs. 46.8 ± 3.9 $ml \cdot kg^{-1} \cdot min^{-1}$; $t = 3.18$, $p = 0.002$; d = 0.97). These between-group differences are visually presented in Figure 3.

Table 4. Post-test Comparison Between Experimental and Control Groups (Independent t-test)

Variable	Experimental Post (Mean ± SD)	Control Post (Mean ± SD)	t-value	p-value	Effect size (d)
Mean Explosive Power (W)	589.6 ± 60.9	525.9 ± 59.4	3.22	0.002	0.98 (large)
Mean Anaerobic Power (W)	465.2 ± 49.1	421.5 ± 49.0	3.07	0.003	0.93 (large)
Maximal Speed (km/h)	26.2 ± 1.5	24.9 ± 1.6	3.02	0.004	0.91 (large)
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	50.3 ± 3.8	46.8 ± 3.9	3.18	0.002	0.97 (large)

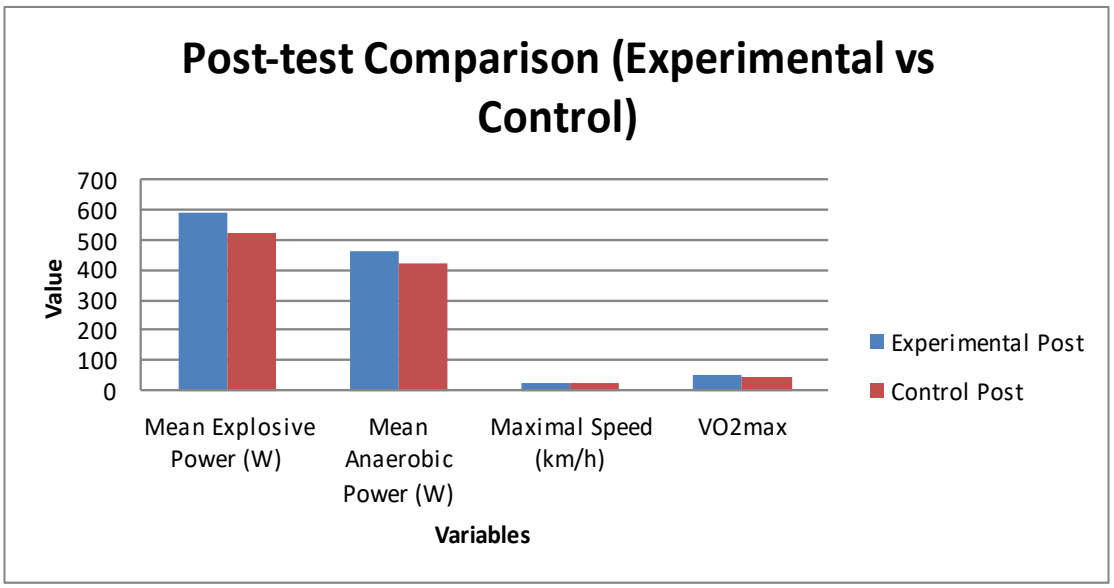

Figure 3. Post-test Comparisons of the experimental and control groups for all performance variables.

4. Discussion

The present study examined the effects of a six-week high-intensity interval training (HIIT) program on key physical performance variables in adult handball players, and the findings demonstrated clear and meaningful improvements in the experimental group compared with both pre-intervention values and the control group. Post-HIIT, mean explosive power output increased by about 13.3% (520.3 ± 58.7 to 589.6 ± 60.9 W, $p < .001$, $d = 1.17$). Mean anaerobic power was raised by around 11.2% (418.4 ± 47.5 to 465.2 ± 49.l W, $p < .001$, $d = .98$). This result shows large neuromuscular adaptations related to repeated high-intensity and plyometric loading in the session. Maximum sprinting velocity significantly improved by about 6.l fast breaks or defensive transitions. There was also a substantial increase of about9.l%from 46.l±3.0

to50_3±38 'min(p<O_OO l ,d=l _04) VOmax (the maximum amount of oxygen uptake per minute) indicating how effective HIIT could be at s. Meanwhile, in the control group, only minimal non-significant changes occurred (effect sizes ≤ 0.26, p > 0.05) which clearly proves that a short period of normal handball training is not enough to make any significant improvements in performance. Practically speaking, this provides evidence for two or three HIIT sessions per week resulting in concurrent enhancements of anaerobic power and sprint speed together with aerobic fitness within a six-week timeframe-but interpretation has to be viewed relative to the limitations of the study: small sample size; no physiological markers such as blood lactate concentration used; nutritional intake and recovery strategies unaccounted for that may have contributed toward magnitudes of adaptations observed.

5. Conclusions

This research proved that a six-week high-intensity interval training program conducted three times weekly contains an effective and efficient-in-time solution for improving major physical performance factors among adult handball players. Noticeable changes registered by HIIT intervention in explosive power, anaerobic power, maximum sprinting speed, and also expressed VO2max increase values from about 6% up to 13%, with great effects recorded while only routine training showed no significant changes at all. The results prove the possibility of properly structured high-intensity interval training protocols capable of developing both aerobic and necessary-for-handball-match-play intermittent-and-high-intensity-demands systems simultaneously. Physical preparatory phases shall hence include such type/HIIT as proposed herein for quicker yet equally efficient physical development approach-by coaches-conditioners-without disturbing actual play requirements.

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