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Original Article

The Effects of an Eight-Week Whole-Body High-Intensity Interval Training on Aerobic and Anaerobic Indices in Male Youth Football Players

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Abstract

Introduction: Functional training, which emphasizes short, intense, and varied whole-body drills, is becoming increasingly popular among younger athletes. This approach may provide a more engaging and challenging experience for youth, catering to their desire for dynamic and stimulating physical activities.
Objective: The Purpose of current research was to investigate the impact of an eight-week whole-body HIIT program on both aerobic and anaerobic performance indicators in youth football players.
Methods: This study employed a semi-experimental design. The participants consisted of male football players aged between 15 and 18 years, with a total of 40 individuals evenly split into experimental and control groups. To evaluate aerobic and anaerobic performance, the graded exercise test (GTX) and the Wingate test were administered, respectively. The intervention involved an eight-week program of whole-body HIIT. ANCOVA was utilized for data analysis.
Results: The HIIT group demonstrated a significant increase in VO2max and AT from pretest to posttest ($P<0.001$). Additionally, there was a significant reduction in peak heart rate ($P<0.001$) for the HIIT group.
Conclusion: Whole-body HIIT is an effective approach for improving performance-related fitness in young football players, making it a valuable training option for athletes undergoing advanced rehabilitation.

Keywords: Interval Training, Football, Aerobic, Anaerobic, Adolescent

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1. Introduction

Football excellence is fundamentally rooted in a combination of physical fitness, technical skill, collaborative teamwork, and strategic insight (1). Sustaining fitness over extended periods is crucial, as it significantly impacts players' on-field performance. Football demands high aerobic capacity; for instance, a midfielder may cover approximately 11.5 km during a match, necessitating substantial energy expenditure (3). Given the dynamic nature of football, anaerobic power is essential for executing short, intense sprints. Consequently, players must optimize both aerobic and anaerobic energy systems to meet the muscular energy demands of the game (4). During matches, the distance covered in high-intensity running varies, with wide midfielders averaging around 1,044 meters and center forwards approximately 854 meters (5). Soccer is characterized as a high-intensity, intermittent team sport, with players engaging in various activities every 4 to 6 seconds. During a typical match, professional athletes execute around 1,350 distinct actions, including approximately 220 high-speed sprints (6). While the majority of these activities are low-intensity and aerobic in nature, the smaller fraction of high-intensity, anaerobic efforts plays a crucial role in determining match outcomes and distinguishing elite players from their peers (7,8). Consequently, anaerobic capacity is a significant factor influencing soccer performance, prompting training programs to incorporate strategies that enhance this aspect of fitness. Youth soccer is marked by frequent fluctuations in intensity during various activities (9). This dynamic nature necessitates the utilization of both aerobic and anaerobic energy systems. While aerobic capacity is recognized as a crucial element for success in young athletes, other factors, including technical skills and tactical understanding, are equally significant in their development (10). Consequently, it is essential for coaches working with young players to implement training methods that address a broad spectrum of requirements, encompassing technical, tactical, and fitness aspects (11).

The effectiveness of exercise training is influenced by several factors, including intensity, volume, duration, and frequency, as well as the athlete's individual capabilities (12). Consequently, significant efforts have been directed toward quantifying the relationship between training load and the athlete's tolerance level (13). Coaches strive to fine-tune these elements to optimize beneficial adaptations in performance. Athletes frequently require a structured training program to attain peak fitness levels within a limited timeframe, particularly following periods of reduced or absent training (14). High-intensity interval training (HIIT) has gained significant traction as a leading training methodology, attracting the attention of athletes, coaches, and researchers in the field of sports science. This method typically involves brief, repetitive training sessions executed at maximum effort or near VO^{2}max intensity (15,16). The duration of each interval can range from a few seconds to several minutes, interspersed with rest periods or low-intensity activities lasting longer than the work intervals. Research indicates that HIIT not only reduces the overall time and volume of training but also yields comparable results to traditional endurance training (15,17). HIIT has consistently demonstrated its ability to enhance cardiorespiratory fitness in a relatively brief period. This training approach consists of brief intervals of high-intensity exercise, during which participants push their heart rates to exceed 90% of their maximum capacity, interspersed with periods of rest or low-intensity recovery (16). The duration of these high-intensity intervals typically ranges from 10 seconds to 5 minutes, while recovery times can vary from 15 seconds to 3 minutes. An effective training-to-recovery ratio is generally considered to be either 1:1 or 2:1. Although research on ultrashort intervals lasting less than one minute is limited, recent studies have shown promising results in their application (17,18)

Recent studies have thoroughly investigated the impact of HIIT on various dimensions of cardiorespiratory fitness. Researchers have concentrated on essential metrics, including peak oxygen uptake, maximal running performance, lactate threshold performance, anaerobic power output, enhancements in stroke volume, and heart rate recovery (19,20). Research shows that HIIT can markedly improve cardiorespiratory fitness and peak oxygen uptake in various groups, including endurance athletes and moderately trained youth (21,22). Numerous studies have indicated that the enhancements in cardiorespiratory fitness resulting from HIIT can be on par with, or even surpass, those achieved through moderate-intensity continuous training across various populations (20,23,24).

Younger athletes often find traditional exercise methods, such as running, cycling, or swimming, to be less appealing. In contrast, the rising popularity of short, intense, and varied whole-body drills, which are integral to functional training, presents a more engaging and challenging alternative. These dynamic drills can be seamlessly incorporated into the training regimens of youth athletes, enhancing their overall experience and performance (25). Whole-body HIIT programs offer advantages that go beyond merely improving aerobic capacity, as they also enhance various physical attributes, including strength endurance. Studies suggest that these comprehensive HIIT routines can produce cardiorespiratory benefits that are comparable to, or even exceed, those achieved through traditional running-based HIIT and moderate-intensity continuous training among healthy individuals, encompassing men, women, and youth (20,26). Yet, the impact of HIIT on the aerobic and anaerobic performance of football players remains ambiguous. Therefore, this study sought to explore the effects of an eight-week whole-body HIIT program on the aerobic and anaerobic capacities of youth football players.

2. Methods

2.1. Participants

Current research employed a semi-experimental design with practical applications, featuring a pre-test and post-test methodology alongside a control group. The focus was on male football players aged 15 to 18 years. Using G*Power software, it was established that a minimum of 32 participants is necessary to effectively evaluate the interaction between groups and measurement time points. This determination was made with parameters indicating a $f>0.8$, $P=0.05$ and $\beta=0.9$. Participants were selected based on specific criteria: they had to be free of musculoskeletal injuries for four months prior, attend over 95% of training sessions, and not be on any medication. Current research involved a sample of 40 teenage soccer players from a football academy, all participating in the national U18 developmental championships. These players were randomly divided into two groups: a control group consisting of 20 participants and an intervention group with the same number. Prior to the study, informed consent was secured from both the players and their parents, following a thorough explanation of the potential benefits and risks associated with the research. The study was conducted in accordance with ethical guidelines as outlined in the Declaration of Helsinki.

2.2. Measurements

2.2.1. Aerobic Test

The graded exercise test (GXT) was employed to assess aerobic performance. This test measured variations in VO2max, anaerobic threshold (AT), and heart rate, which collectively reflect cardiorespiratory fitness. Conducted on a treadmill using a gas analyzer and adhering to the Bruce protocol, the assessment ensured participant safety through continuous monitoring of heart activity via an electrocardiogram device. Participants were briefed on the test's objectives and procedures, and the assessment proceeded until they opted to discontinue. A perceived exertion rating of 17 or higher indicated the point at which heart rate and VO2max levels plateaued despite increasing exercise intensity. Data from participants who terminated the test prematurely, specifically those who did not reach 90% of their predicted maximum heart rate (calculated as 220 minus age), were excluded from the statistical analysis.

2.2.1. Anaerobic Test

The Wingate test is designed to assess anaerobic power and fatigue using a bicycle ergometer, where the load is determined by the individual's body weight, specifically set at 0.075 kg per kg of body weight. Measurements were taken using a friction-braked cycle ergometer, with the bicycle seat and handlebars adjusted to fit each participant's leg and arm length. Initially, athletes warmed up for four minutes at a load of 50 watts and a cadence of 80 revolutions per minute (RPM). The test commenced with a five-second countdown, after which the assistant tester increased the load to the target intensity, prompting the athlete to pedal at maximum effort for 30 seconds. RPM was recorded every five seconds, allowing the tester to calculate peak power and fatigue index based on the maximum and minimum RPM values. The test consisted of three sets, with a two-minute rest interval between each set (28).

2.3. Procedure

The study received official approval from the appropriate educational authorities, after which a briefing session was held to inform participants/parents regarding the research objectives, methodologies, and the intended intervention. Following this, written consent was obtained from the parents. Height, weight and body mass index (BMI), were collected using precise instruments. A high-precision digital scale, made in Germany and accurate to 0.1 kg, was employed for weight measurement, with participants instructed to stand barefoot and in minimal clothing while maintaining an upright posture. Height was measured with a height gauge accurate to 0.1 cm, ensuring proper alignment against a wall. The height was recorded in centimeters as participants looked straight ahead. BMI was calculated by dividing weight in kilograms by the square of height in meters. Before the training program began, initial assessments were performed to determine the appropriate training intensity under experimental conditions. These evaluations involved calculating the maximum heart rate using the formula (age - 220), along with measuring the resting heart rate and heart rate reserve. The heart rate reserve is defined as the resting heart rate plus 0.05 times the difference between the resting heart rate and the maximum heart rate. The test protocols were implemented one week prior to and one week following an 8-week training intervention. To reduce the risk of fatigue, a rest day was scheduled between each consecutive test. Before the data collection commenced, participants were briefed on the testing procedures to ensure they could perform the tasks accurately. The HIIT training for the experimental group involved a regimen of 15 intervals, each lasting 30 seconds of whole-body running, followed by 30 seconds of rest. This resulted in a total workout duration of 15 minutes. Participants were advised to exert themselves at a high intensity, aiming for 90% of their maximum heart rate (26). The specific guidance given to the students was to run each interval at an intensity close to their maximum effort. Participants were advised to refrain from engaging in any other organized sports activities throughout the training period, while those in the control group did not receive any additional interventions.

2.4. Statistical Analysis

In this research, the variables were defined through the calculation of the mean and standard deviation (SD). The Kolmogorov-Smirnov test was employed to evaluate the normality of the data distribution, revealing P values exceeding 0.05 across all results. To analyze the differences in pretest scores among various research groups, an independent t-test was performed. Furthermore, analysis of covariance (ANCOVA) was utilized to examine the changes between groups from pretest to posttest. A significance threshold of 0.05 was upheld for all statistical evaluations, which were conducted using SPSS version 27.

3. Results

Table 1 displays the mean and SD of the demographic characteristics of the study participants. The mean ages for the experimental and control groups were 16.70 ± 0.25 and 16.73 ± 0.29, respectively, with no statistically significant differences found ($P>0.05$). Additionally, initial assessments indicated that the BMI of participants in both groups was similar, again showing no significant differences ($P>0.05$).

Table 1. Comparison of the Demographic Data Across Groups

Variable	Experimental Group	Control Group	Comparison
Age (years)	16.70 ± 0.25	16.73 ± 0.29	P=0.969
Height (m)	1.72 ± 0.05	1.70 ± 0.08	P=0.937
Weight (kg)	65.89 ± 5.47	66.05 ± 5.94	P=0.879
BMI	22.3 ± 1.24	22.9 ± 1.40	P=0.385

Table 2 and Table 3 present the means and SD for various aerobic indices, such as VO$_2$max, AT, and peak heart rate, as well as peak power (as an index for anaerobic performance), measured during both the pretest and posttest phases. The analysis showed no significant differences in these indices between groups at baseline ($P>0.05$). However, the ANCOVA results demonstrated a significant increase in VO$_2$max from pretest to posttest ($F=15.638$, $P<0.001$), with the HIIT group showing marked improvement compared to the control group ($P<0.05$). Similarly, significant enhancements were observed in AT ($F=13.238$, $P<0.001$) and peak power ($F=17.445$, $P<0.001$), both favoring the HIIT group over the control ($P<0.05$). Additionally, there was a significant reduction in peak heart rate ($F=12.527$, $P<0.001$) for the HIIT group compared to the control ($P<0.05$). These results suggest that HIIT significantly enhances both aerobic and anaerobic performance in youth football players relative to a control condition.

Table 2. Baseline Scores across Groups

Variable		Experimental Group	Control Group
VO$_2$max	Pretest	50.32 ± 4.86	50.55 ± 4.28
	Posttest	57.67 ± 5.46	50.46 ± 4.09
AT	Pretest	57.98 ± 5.77	57.79 ± 5.16
	Posttest	68.47 ± 6.93	57.82 ± 2.41
Peak Heart Rate	Pretest	183.56 ± 9.64	183.97 ± 8.76
	Posttest	174.58 ± 8.86	183.89 ± 9.06
Peak Power	Pretest	11.23 ± 1.36	11.17 ± 1.52
	Posttest	13.08 ± 1.56	11.20 ± 1.63

Table 3. The Results of ANCOVA

Variable	Sum of Squares	df	Mean Square	F	P-Value	Partial Eta Squared
VO_2max	296.854	1	5.857	15.638	<0.001	0.25
AT	242.697	1	4.285	13.238	<0.001	0.18
Peak Heart Rate	236.745	1	4.108	12.527	<0.001	0.15
Peak Power	428.559	1	7.854	17.445	<0.001	0.33

4. Discussion

This study sought to explore the impact of an eight-week whole-body HIIT program on aerobic and anaerobic performance metrics in youth football players. The findings revealed a significant increase in VO_2max, AT, and peak power from pretest to posttest for the HIIT group. Furthermore, the HIIT participants experienced a marked decrease in peak heart rate relative. These outcomes indicate that HIIT effectively improves both aerobic and anaerobic capabilities in youth football players.

To interpret these findings, it can be sated that the exact physiological mechanisms that account for the advantages of HIIT remain unclear. Some researchers propose that the heightened muscular stimulus triggers intracellular signaling pathways, which may enhance the activity of 5-AMP-activated protein kinase (AMPK) in muscle cells. This, in turn, could lead to increased expression of peroxisome proliferator-activated receptor-γ coactivator-1α (PGC-1α) at both the mRNA and protein levels, as well as an upregulation of mitochondrial oxygenation enzymes, ultimately resulting in improved aerobic capacity (25,29). Additionally, it is suggested that higher training intensities may elicit more significant cellular and molecular responses, potentially aiding in the partial recovery from endothelial dysfunction. Interval training is notable for its capacity to boost power output in peripheral muscles while also enhancing cardiorespiratory fitness (15,30). The rest periods integrated into this training method effectively reduce blood lactate levels by restoring phosphocreatine and myoglobin reserves and promoting lactate clearance. This mechanism enables interval training to apply significant stress on peripheral muscles and oxygen transport systems without depending on anaerobic metabolism or causing lactic acid accumulation. HIIT is widely recognized for its positive impact on cardiometabolic health, particularly through its effects on skeletal muscle, which include enhanced muscle work capacity, oxidative capacity, and glucose transport (17,31). A key outcome of HIIT is the improvement in cardiorespiratory fitness, typically assessed by VO_2max, the gold standard for measuring fitness levels and a robust indicator of the efficiency of the cardiac, pulmonary, vascular, and peripheral systems. Research has demonstrated that HIIT enhances both the oxygen supply and demand mechanisms; however, it is primarily the cardiovascular adaptations resulting from HIIT that contribute significantly to the increase in VO_2max (20,32,33).

The results indicate that enhancements in aerobic performance following HIIT may stem from an improved capacity to buffer hydrogen ions. Additionally, the observed increase in VO_2max could be attributed to better oxygen transport and delivery to skeletal muscles, facilitated by greater stroke volume and heightened capillary and mitochondrial density, which collectively enhance oxygen uptake during physical activity (34). Research has demonstrated that during brief periods of maximal intensity exercise, various metabolic processes—including high-energy phosphate metabolism, glycolysis, and oxidative metabolism—play significant roles in ATP regeneration (35,36). The heightened activity of critical regulatory enzymes within these energy systems contributes to improved aerobic performance, suggesting that both high-intensity and frequent exercise bouts influence performance and enzymatic adaptation. Furthermore, implementing several short-duration intervals of maximal effort with minimal rest appears to elevate the relative contribution of aerobic metabolism, likely due to enhanced dynamics of oxygen consumption (20,35).

The increase in anaerobic power following the training protocol can be attributed to several mechanisms, including elevated muscle phosphocreatine levels, enhanced activity of anaerobic enzymes such as phosphofructokinase, aldolase, and lactate dehydrogenase, as well as alterations in muscle fiber composition (37,38). Additionally, neuromuscular adaptations play a crucial role, characterized by improved motor unit recruitment, frequency, and synchrony, which collectively enhance muscle strength, efficiency, and coordination. Intense interval training has been shown to significantly boost the activity of key enzymes like phosphofructokinase and creatine kinase, indicating an increase in anaerobic capacity within the trained muscles (37). Furthermore, the notable rise in hexokinase and phosphofructokinase activity post-training suggests that the observed improvements in anaerobic power are likely linked to the upregulation of these anaerobic enzymes (38).

One limitation of the current study is its exclusive focus on male participants, which may restrict the applicability of the findings to female populations. To enhance the generalizability of future research, it is advisable to include participants of both genders. Conversely, a significant strength of this study lies in its use of whole-body HIIT exercises, which adds to the overall robustness of the research design.

4.1. Conclusion

An eight-week whole-body HIIT program resulted in notable improvements across several fitness parameters, such as VO2max, AT, heart rate, and anaerobic power. These results suggest that whole-body HIIT is an effective strategy for enhancing performance-related fitness in young football players, positioning it as a beneficial training method for athletes in the later phases of rehabilitation. To optimize fitness gains and reduce the likelihood of injury, it is crucial to gradually increase the intensity, duration, or volume of HIIT sessions over time.

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Footnotes

Authors' Contribution: This study was carried out solely by the corresponding author.

Conflicts of Interest

Non to declare.

Data Availability: The data that support the findings of this study are openly available upon request from the corresponding author.

Ethical Approval: The author confirms that all steps and requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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