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RESEARCH ARTICLE **OPEN ACCESS**

The Effect of Specific High-intensity Exercises on Cardiovascular Balance, Vascularity, and Performance in Female Youth Basketball Players

Fatma Hassan Abd Elbasset Mourgan[1,2,*], Manaf AlMatar[1], Ali Al-Shamli[1], Mahfoodha Al-Kitani[3], Ali Al-Yaaribi[3] and Osman Albarri[4]

[1]*Faculty of Education and Art, Sohar University, Sohar 311, Sultanate of Oman*
[2]*Physical Education College, Helwan University, Helwan, Egypt*
[3]*College of Education, Sultan Qaboos University, Muscat 112, Sultanate of Oman*
[4]*Department of Biotechnology, Institute of Natural and Applied Sciences (Fen Bilimleri Enstitüsü) Çukurova University, Adana, Turkey*

Abstract:

Background: Sports training causes physiological changes in almost every body system; the more successfully these changes accomplish the functional adaptation required to execute the physical load effectively while conserving energy, the greater performance improvement may be anticipated. For training programs to be effective and boost performance in any sport, they must consider the nature and kind of the sport as well as a study of the performance conditions.

Methods: This research investigated how a 5-week, specially designed high-intensity interval training (HIIT) programme affected the aerobic ability of adolescent female basketball players. It also investigated how physical characteristics, skill qualities, heart impulse, oxygen distribution rates, and energy expenditure indices relate to one another. Lastly, research was conducted on the significance of urea-ketone energy consumption.

Results: A basketball-specific high-intensity training program lasting twelve sessions most likely reduced the time for the 20-meter speed test (Pre: 3.22 ± 1.72, Post: 3.02 ± 1.75 Sec) and improved the standing long jump test (Pre: 1.55 ± 0.49, Post: 1.65 ± 0.35 cm) and vertical jump test (Pre: 27.83 ± 6.40, Post: 31.42 ± 7.23 cm).

Conclusion: Oxygen uptake (VO2), VO2/Kg, carbon dioxide generation (VCO2), respiratory exchange ratio (RER), vascular endothelial growth factor (VEGF), and fibroblast growth factor (FGF) were all positively impacted by the training sessions. After 12 sessions, young female basketball players' aerobic performance is improved with HIIT tailored specifically for basketball.

Keywords: Aerobic fitness, Basketball, Consumed oxygen, Team sport, Fibroblast growth factor (FGF), Respiratory exchange ratio (RER), Vascular endothelial growth factor (VEGF).

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*Address correspondence to this author at the Faculty of Education and Art, Sohar University, Sohar 311, Sultanate of Oman and Physical Education College, Helwan University, Helwan, Egypt; Tel: +96893875088;
E-mail: fatma171260@gmail.com

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1. INTRODUCTION

In basketball, there are medium-to-frequent, short bursts of intense activity. Specific movement patterns, energy sources, and physiological requirements are necessary for basketball [1, 2]. The time-movement analysis shows that throughout a women's match, the players engage in a great deal of diverse intensity offensive and defensive manoeuvres [3, 4]. The women's basketball game had an average distance traveled of 5215 ± 314 metres, mostly by walking (456 ± 20 metres), running (1517 ± 93 metres), running (1850 ± 13 metres), and running (925 ± 184 metres) [3, 4]. Additionally, during the women's basketball game, 35-11 jumps, 49-17 quick enemies, and 58-19 high-intensity manoeuvres were recorded [3]. The intermittent character of the game is confirmed by many opponents' return actions (4.3 2.7 enemy lines return at 4.4 1.7 shifts each) [4], averaging 24.1 movements per minute, with a change in activity happening every 2.46 seconds [5]. In addition, women's basketball games have a work-to-rest ratio of 1:4.3 1:1.2 [5]. Group sport data analysis relies on several approaches and assessment models; thus, it is important to address the overestimation and reduction of different movement components [6, 7]. Numerous studies [8, 9] have shown connections between physical prowess and game success. Specifically the distance travelled in high-density dodges. The frequency of high-intensity movements made by male basketball players throughout a game has been connected to their aerial performance [10]. Antenna performance improvement raises the overall resistance against high-density activity [11]. These results imply that air performance training is necessary for high-intensity intermittent exercise, which is necessary for basketball, in addition to other important components of fitness. There is a time restriction on endurance training since game performance is influenced by several other factors, including tactical and technical skills. It has been shown that small-sided games (SSG) are a collaborative, time-saving exercise that enhances athletes' anaerobic and aerobic performance [12, 13]. The emphasis of small-sided games (SSG) is on the technical challenges, intensity, and mobility of competitive gaming. SSG, however, has a higher risk of injury than individual training methods since it is dependent on connectivity. Furthermore, a significant level of technical and tactical competence is needed to achieve the ideal training density inside SSG [14]. Moreover, research has shown that different SSG play types experience different physiological strains [15]. Combined with SSG, high-intensity interval training (HIIT) is a quick way to boost anaerobic and antenna performance [1, 12]. High-density HIIT activities are often focused on running or cycling, while SSG is more akin to a game [16, 17]. Delextrat and Martinez discovered that young male basketball players' maximal aerobic performance increased in a comparable way after incorporating 12 HIIT and SSG training sessions throughout the season, in addition to the many studies that have demonstrated improved aerobic performance of sports team athletes following HIIT [18-21]. This conclusion is supported by several research comparing HIIT and SSG treatments in various team sports [13, 14, 22]. There is still a need for a more specialised alternative approach to sports that incorporates essential basketball components like paying and avoiding, even if HIIT is an essential part of team sports instruction. Hoff, to name a few. It has been shown that, as opposed to just jogging, HIIT using an evasive soccer track may provide equivalent physiological stress [23]. According to Sánchez *et al*., female basketball players who used a customised high-intensity training programme with numerous trends (COD) changes saw significant improvements in their aerobic capacity. This study focuses on a unique mathematical approach to routine basketball workouts that include ball-specific actions in addition to these results. The activities also included a lot of direction changes, as Sanchez-Sanchez *et al*. [24] pointed out. This research sought to ascertain the effects of a 5-week high-intensity interval training (HIIT) programme tailored for adolescent female basketball players on their capacity for aerobic function. Additionally, the relationship between physical qualities, skill attributes, energy expenditure indices, and oxygen distribution rates was examined. Next, the importance of urea-ketone energy consumption was looked at.

2. MATERIAL AND METHODS

2.1. Experimental Approach to the Problem

A two-group randomised trial design was used in this study. Two training groups of female basketball players from three developing teams were formed. While the third team served as the control group (CG) and carried out routine drills, the other two teams participated in training group (TG) activities. The Yo-yo IR 1 intermittent recovery test, running (with and without the ball), vertical leaping (CMJ), CMJ with arm swinging, squat jumping (SJ), long jump standing (SLJ), hand pounding, and other exercises were used to gauge the players' fitness before and after five weeks of season preparation.

2.2. Subjects

The research included twenty-four young female basketball players from the National League (body mass: 60.9± 6.0 kg, 18.1± 4.8%), height: 170 ± 5.2 cm, and age: 15.1 ± 1.1 years. The participants maintained their combined team training routine, acted as controls, and incorporated their five-week HIIT basketball training program into their team.

2.3. Procedures

Over the course of five weeks, there were two two-hour group training sessions every week to conduct the study. The players practiced as a squad and participated in one game each week. Additionally, no extra effort or adaption has been made. The workout for both groups started with a basketball warm-up. After that, TG trained in high-intensity basketball and then performed a rigorous transition drill or CG format. Technical, tactical, and basketball exercises matched both sets at the end of each session. The total amount of time spent exercising by both groups is equal. Two HIIT exercise types (A and B) are added to the regular training sessions on non-consecutive days for a total training duration of 25 minutes (15–16 minutes of load, 9–10 minutes of recovery). Four minutes of intense exercise were followed by three minutes of recuperation in Session A. Two sets of 15 high-density intervals, each lasting 30 seconds, comprised Session B.

Repetitions were spaced 15 seconds apart, and groups were separated by 3 minutes [25]. Session B was held every third training session for a total of three times. All of the HIIT sessions' high-intensity basketball activities focused on developing abilities, including avoidance, scrolling, and payback. The workouts, which include High-Intensity Interval Training (HIIT) at 90–95% of one's maximum heart rate (HrMax), are meant to keep participants moving without wasting time [25].

2.4. Testing Procedures

Every participant was tested the day before and four days after their last training session. At the same time of day, the pre- and post-tests were given to account for daily variations in performance. Prior to every test, a customary 15-minute warm-up was performed. Test results are recorded after participants have become comfortable with the task. With the exception of Yo-yo IR 1, each test was run twice, with the best outcome being chosen for analysis. The Quick Enemy/Agility and Chest Scrolling tests were taken from a prior fitness test administered by the German Basketball Association. Reliability ratings were assigned to each test.

2.5. Sprint Test

Quickness and agility were tested by COD 20. The test consisted of the runner sprinting 5 meters to a line, turning 180 degrees, running 10 metres, turning 180 degrees, and running an additional 5 meters [26, 27]. Through the double infrared barrier, time was measured using a radio transmitter. By evaluating the opponent with and without the ball, the retest's reliability was assessed, yielding ICC values of 0.70 and 0.88 [26].

2.6. Vertical Jump Evaluation

Two swing arm CMJs, two normal CMJs, and two SJs were performed by each participant. It is required to be able to leap vertically in order to perform the techniques mentioned above [28]. Using visual sensors, Optojump was utilised to quantify the air time between two parallel bars.

2.7. Standing Long Jump

The athlete stands behind a line painted on the ground, feet slightly apart. Swinging the arms and bending the knees produce forward force during the two-foot takeoff and landing. The object of the exercise is to jump as far as one can and land on both feet without going overboard. In millimeters, the leap was precisely 0.01 m. Retest reliability (ICC) was 0.90 [26].

2.8. Cardiopulmonary Exercise Testing

Indirect calorimetry was used to measure aerobic performance during a treadmill maximum metabolic activity test. The goal of the maximum metabolic exercise test is for the athlete to reach her maximum aerobic power throughout an 8–12-minute continuous progressive ramp session.

2.9. Measurement of VEGF and FGF

Each participant had venous blood samples drawn both before and after training, and the serum levels of VEGF and FGF were assessed using ELISA kits (Bio-Techne, USA) in accordance with the manufacturer's instructions.

2.10. Measurement UREA and TBRAS

The UREA-GLDH kit (LiquiMAX, India) was used to perform the urea test in accordance with the manufacturer's instructions. The Lipid Peroxidation (MDA) Assay Kit (RayBiotech, USA) was used to assess TBRAS in accordance with the suggested guidelines.

2.11. Statistical Analysis

All findings are shown as mean SD. Paired-dependent sample- t-test were used to compare pre-importance and subsequent values across groups ($P< 0.05$).

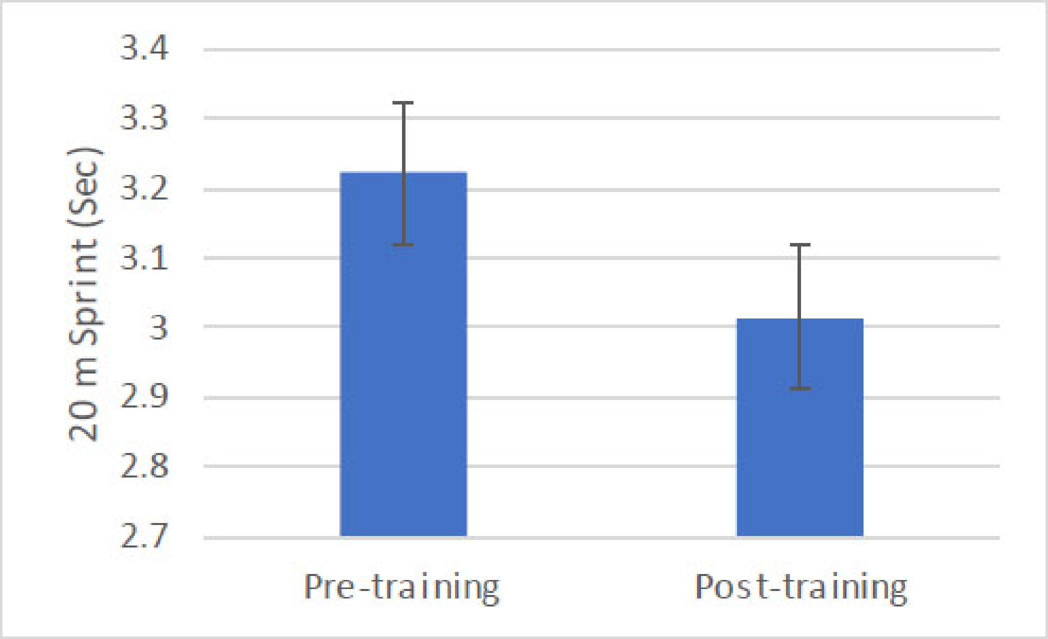
3. RESULTS

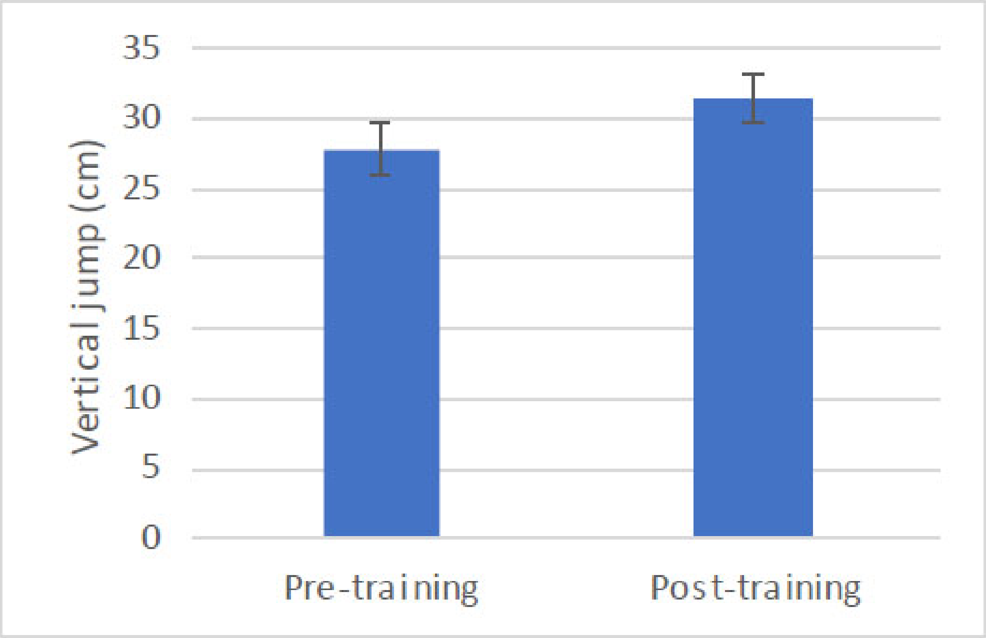
A minimum of 95% of the participants finished the training sessions; the other 5% were hurt and could not finish the course. Table **1** is a list of all the results of the physical variable testing. After twelve sessions of high-intensity basketball-specific training, the time for the 20-meter speed test (Pre: 3.22 ± 1.72, Post: 3.02 ± 1.75 Sec) was probably reduced, and the vertical jump test (Pre: 27.83 ± 6.40, Post: 31.42 ± 7.23cm) and standing long jump test (Pre: 1.55 ± 0.49, Post: 1.65 ± 0.35 cm) were probably improved (Fig. **1**). The groups never showed any differences from one another ($P< 0.05$).

All of the findings from the testing of physiological variables are shown in Table **2**. The effects of the training sessions were favourable for VO2, VO2/Kg, Vco2, RER, VEGF, and FGF. For VO2 (l/min) and VO2/Kg (ml/min/kg), the mean values were 0.42 ± 0.06 for pre-training rest, 0.38 ± 0.08 for post-training rest, and 6.80 ± 1.05 for pre-training rest and 6.10 ± 0.94 for post-training rest, respectively. Furthermore, after training, VCO2 (l/min) (0.37 ± 0.08 pre-training rest, 0.30 ± 0.08 post-training) and RER (VCO2/VO2) (0.85 ± 0.08 pre-training rest, 0.80 ± 0.07 post-training rest) decreased. However, from pre- to post-testing, the levels of VEGF (pg/ml) and FGF (pg/ml) rose. ($P< 0.05$). From pre- to post-testing (rest), the values of O2 pulse (ml/b), Urea (mg%), KETONES (mg/L), and TBARS (m/L) were (3.92 ± 1.08, 4.17 ± 1.34), (24.17 ± 4.95, 22.17 ± 4.47), (26 ± 5.01, 23. 00 ± 4.51), and (1.79 ± 0.12, 1.94 ± 0.21), separately. From pre- to post-testing (Max), the median values of VO2 (l/min), VO2/Kg (ml/min/kg), RER (VCO2/VO2), O2 pulse (ml/b), VEGF pg/ml, FGF pg/ml, KETONES mg/L, TBARS m/L, and Urea (mg%) were as follows: (2.26 ± 0.30, 2.46 ± 0.32), (38.36 ± 6.13, 41.34 ± 9.79), (1.07 ± 0.35, 0.99 ± 0.05), (12.58 ± 2.11, 13.67 ± 2.46), (7.14 ± 1.08, 7.7 ± 1.06), (59.17 ± 8.85, 48.17 ± 4.73), and (50 ± 7.76, 47.42 ± 6.80), respectively (Fig. **2**).

Table 1. Pre- and post-values of tests before and after the training intervention.

Variables	Mean ± S.D	
	Before Program	Post Program
20 m Sprint (Sec)	3.22 ± 1.72	3.02 ± 1.75
Vertical jump (cm)	27.83 ± 6.40	31.42 ± 7.23
Standing long jump (cm)	1.55 ± 0.49	1.65 ± 0.35
Treadmail Time (min)	8.42 ± 1.30	10.49 ± 3.49





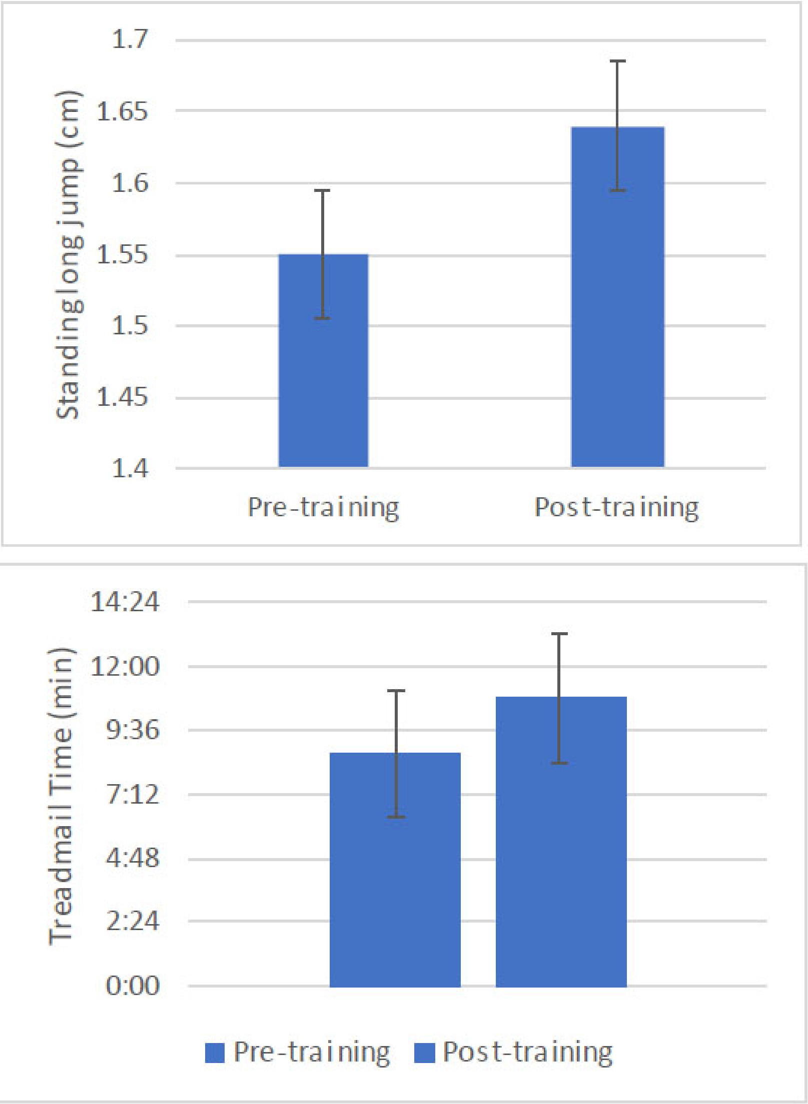
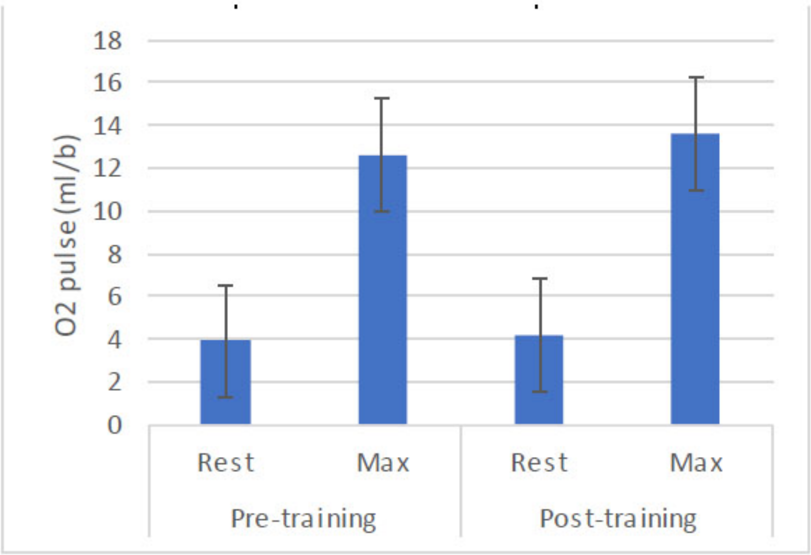
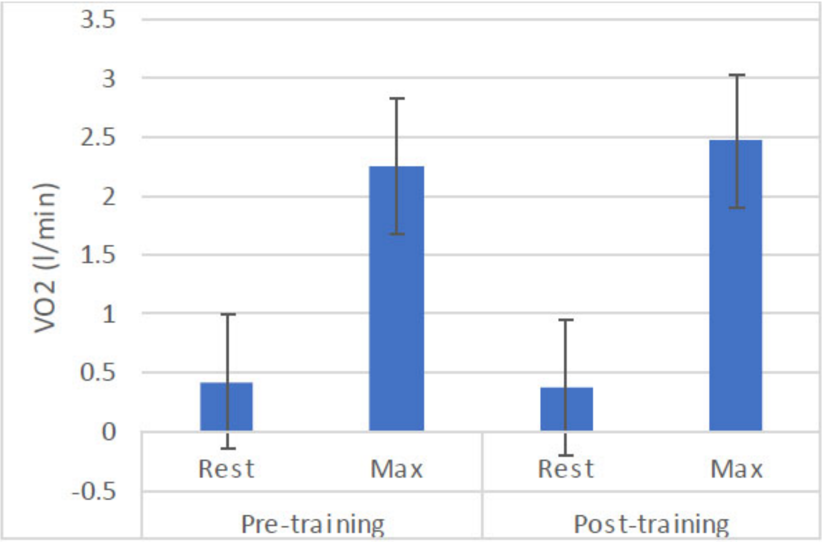


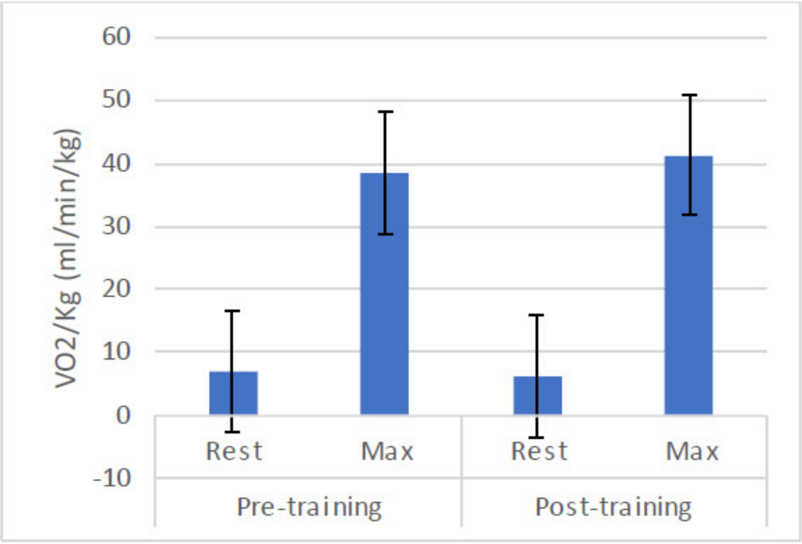
Fig. (1). Pre- and post-values before and after training intervention for subjected tests.

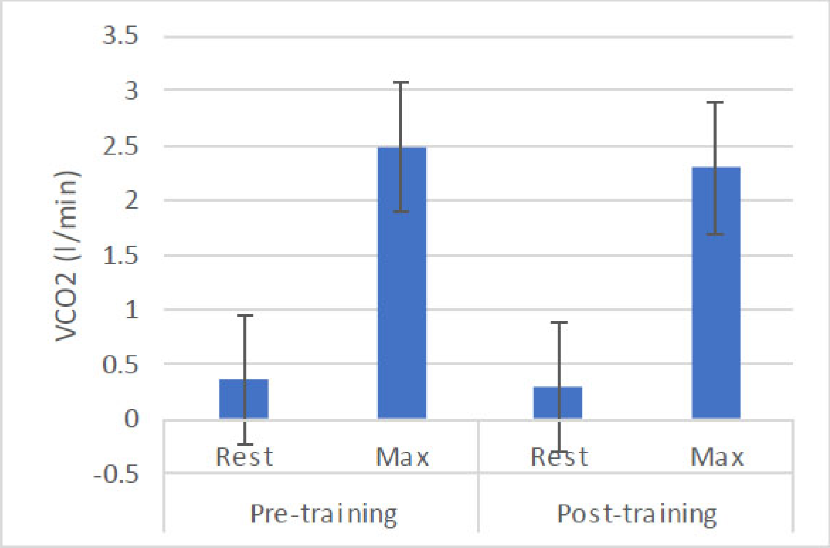
Table 2. Pre- and post-intervention values for aerobic endurance, vascular endothelial growth factors, and ketones.

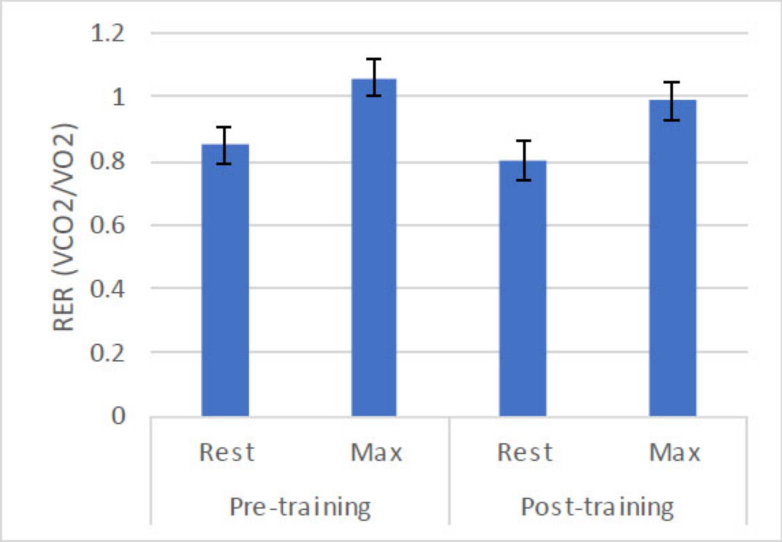
Variables	Before Program		Post Program	
	Rest	Max	Rest	Max
O2 pulse (ml/b)	3.92 ± 1.08	12.58 ± 2.11	4.17 ± 1.34	13.67 ± 2.46
VO2 (l/min)	0.42 ± 0.06	2.26 ± 0.30	0.38 ± 0.08	2.46 ± 0.32
VO2/Kg (ml/min/kg)	6.80 ± 1.05	38.36 ± 6.13	6.10 ± 0.94	41.34 ± 9.79
VCO2 (l/min)	0.37 ± 0.08	2.48 ± 0.37	0.30 ± 0.08	2.31 ± 0.35
RER (VCO2/VO2)	0.85 ± 0.08	1.07 ± 0.35	0.80 ± 0.07	0.99 ± 0.05
VEGF (pg/ml)	29.95 ± 4. 06	31.03 ± 5.24	31.15 ± 4.88	36.34 ±5.67
FGF (pg/ml)	5.34 ± 1.02	7.14 ± 1.08	5.78 ± 1.04	7.74 ± 1.06
UREA (mmol)	24.17 ± 4.95	50 ± 7.76	22.17 ± 4.47	47.42 ± 6.80
KETONES (mmol/L)	26 ± 5.01	59.17 ± 8.85	23. 00 ± 4.51	48.17 ± 4.73
TBARS (nm)	1.79 ± 0.12	4.15 ± 0.33	1.94 ± 0.21	4.10 ± 0.21

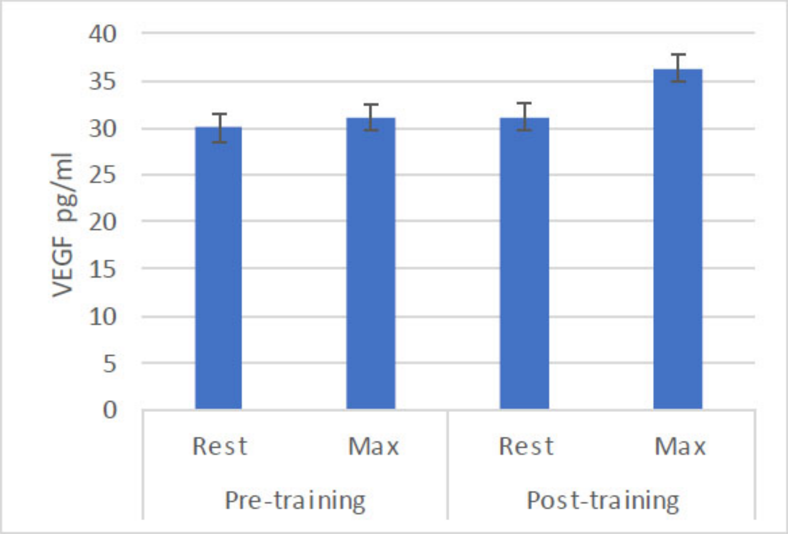

O2 pulse (ml/b)
18
16
14
12
10
8
6
4
2
0
Rest
Max
Rest
Max
Pre-training
Post-training


VO2 (l/min)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Rest
Max
Rest
Max
Pre-training
Post-training


VO2/Kg (ml/min/kg)
60
50
40
30
20
10
0
-10
Rest
Max
Rest
Max
Pre-training
Post-training


VCO2 (l/min)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Rest
Max
Rest
Max
Pre-training
Post-training


RER (VCO2/VO2)
1.2
1
0.8
0.6
0.4
0.2
0
Rest
Max
Rest
Max
Pre-training
Post-training


VEGF pg/ml
40
35
30
25
20
15
10
5
0
Rest
Max
Rest
Max
Pre-training
Post-training

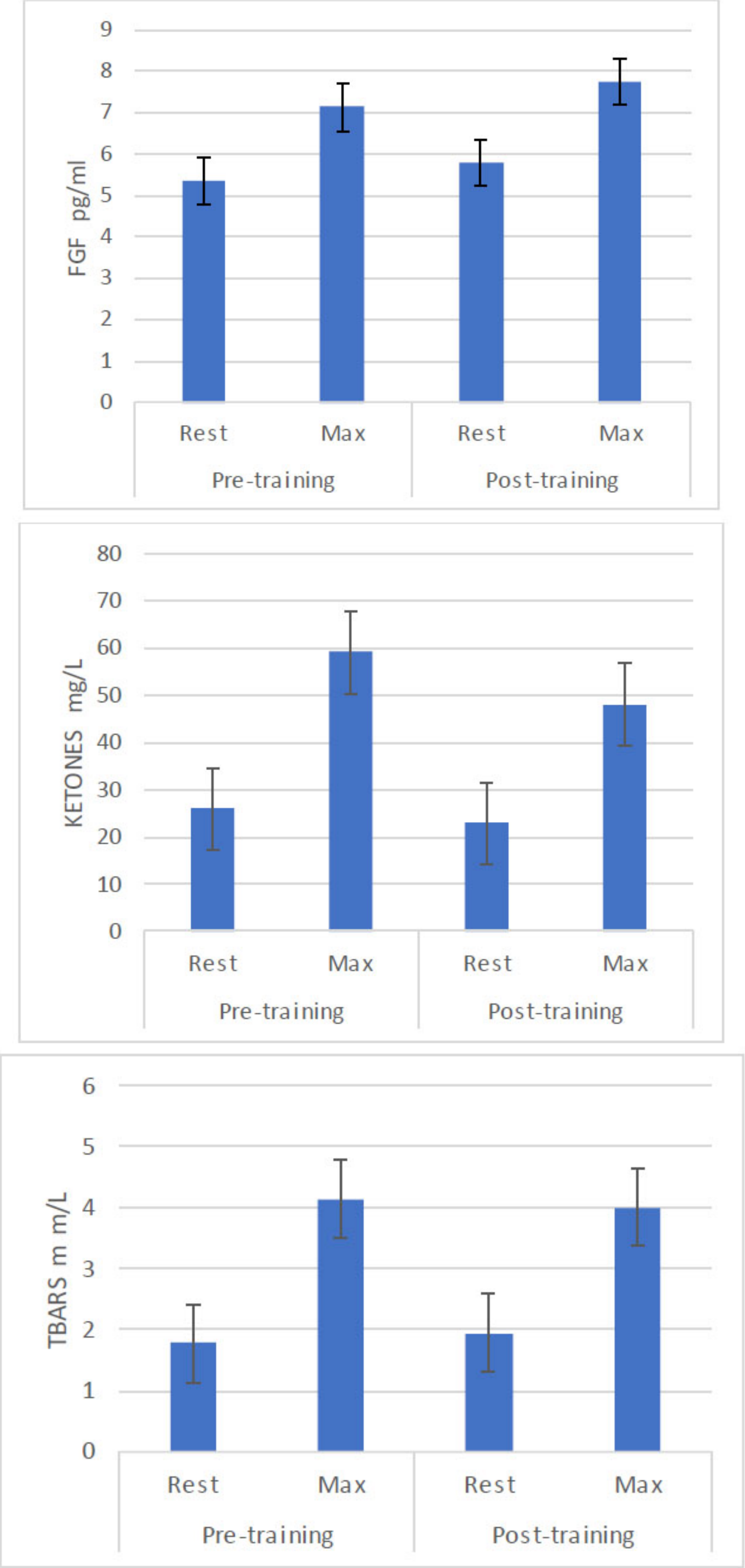


Fig. (2). Pre- and post-values of aerobic endurance, vascular endothelial growth factors, and ketones before and after training intervention.

4. DISCUSSION

The main results of the investigation showed that the implementation of basketball-specific HIIT sessions improved the aerobic performance of young female basketball athletes. In addition, several performance-related parameters, such as sprint time were improved in the HIIT group. The present investigation revealed that 5 weeks of HIIT can significantly ($P<0.005$) increase the physical fitness variables [VO2max (5.6%) and VCO2 (8.4%)] among young players. It has been documented that eight weeks of high-intensity interval training (HIIT) can significantly ($P<0.001$) raise the muscle damage indices (LDH (15.0%), CK (14.4%), cortisol (9.4%), inflammatory markers (IL-6 (15.7%), TNF-α (18.2%)], antioxidant indicators (MDA (29.5%), GPx (0.4%)], and physical fitness variables (VO2max (13.6%), Wpeak (11.6%), VJ (11.2%)] as well as physically fit variables (VO2max (13.6%), Wpeak (11.6%), and VJ (11.2%) [29].Our results showed statistically significant differences between the two measurements at rest and after the exercise before and after the programme in all physiological variables investigated. The reason for this study is that when the body exerts itself physically, it needs more energy than normal to do the same tasks. As a result, all of the body's systems have to work harder than usual to fulfill the body's demands for the energy it needs during the physical effort. An increase in breathing times per minute was brought on by an increase in cardiac payment rates and energy consumption. This increased the amount of oxygen that entered the lungs and was carried throughout the body by the blood. Additionally, there is a direct correlation between the quantity of oxygen consumed and, therefore, the amount of carbon dioxide the lungs produce and the volume of pulmonary ventilation. Interpretation of the data is made possible by a greater comprehension of the variations in basketball players' physiological states during certain actions. The results of studies on how basketball players' bodies changed physiologically throughout certain exercises aligned with the understanding that physiological change parameters are linked to the impact of different activities [29-31]. So, it is possible to associate the exercises by changing their parameters. The conducted research combines the current ideas in this direction since it is conceivable to organise the exercises used in basketball players' training based on the analysis of the immediate training effects of basketball players' specialised workouts. Consequently, more information has been discovered on how to enhance the basketball player's training regimen [32, 33].

The oxygen pulse, which is defined as the ratio of oxygen consumption to heart rate, shows how much oxygen is evacuated from the ventricles during each ventricular contraction. It was shown that a vigorous warm-up including 80% maximal heart rate resulted in greater O2 pulse max values than a gentle warm-up. Skeletal muscle seems to have improved oxygen transport and delivery after a substantial warm-up because of its increased stroke volume, capillary and mitochondrial density, and greater oxygen intake by active muscle. Consequently, the O2 pulse max is elevated [34-36]. According to our research, the rest and maximum O2 pulse values were (3.91–12.58) and (12.58–13.66) correspondingly, from pre– to post–testing. This is because the cardiovascular system is now more efficient and adaptable to physical exertion as a result of high-intensity exercise. After the programme, this led to an increase in the oxygen pulse rate, which shows that more oxygen was getting to the tissues with each heartbeat. As the respiratory system's ability to draw oxygen from the surrounding air and the circulatory system's ability to transmit and use it inside the body increased, so did oxygen consumption rates and maximum relative oxygen consumption [34]. Because of the production of new capillaries brought about by the repeated repetitions of physical activity, as well as the opening of some closed or inactive capillaries, regular sports training increases the density of the capillaries surrounding the air sacs of the lungs. The player's respiratory efficiency is increased by the flat surface of gas exchange between those capillaries and the lungs' alveoli [37]. Maximal oxygen uptake (VO2max) is considered by most writers to be the best measure of an organism's aerobic capacity and the strongest sign of an athlete's physical prowess. The purpose of the research was to evaluate differences in VO2max capacity depending on the kind of sport performed by participants in order to determine their physical capabilities. The players' reported VO2 max was 48.06 ml/kg/min, which is consistent with our results that show an average of 41.33 ml/kg/min for max VO2. With a minimum of 800 metres and a maximum of 1880 metres, the participants covered a total distance of 1456.67 metres. The player with the most speed (17.37 km/h) was the post/power forward [38].

During exercise, VEGF is primarily produced in the muscles and not only increases in the periphery but may also cross the blood-brain barrier. While some studies have shown no effect at all or even a net decrease in VEGF levels, others have indicated that physical exercise increases the quantity of circulating VEGF. A number of factors might be responsible for these differences, such as variations in the experimental process, significant interindividual variability in VEGF response, and the heightened sensitivity of highly trained individuals to physical activity in terms of VEGF production. Wahl *et al*. discovered that whilst low-intensity/high-volume training did not raise circulating VEGF, both acute and chronic high-intensity interval training did. According to their theory, high-intensity interval training boosts mechanical and metabolic stimulation, which causes muscles to release more VEGF into the bloodstream [39-42]. Oestrogen may be a key mediator of this angiogenesis *via* the VEGF/eNOS/Akt [23, 24] signalling pathway, which is sensitive to the endothelium's ER-α and ER-β. The availability of ligands is a prerequisite for the essential activation of VEGF in angiogenesis processes.FGFs may be released by active carrier proteins, or they may operate on target cells. When HLGAGs are FGFs may bind present, receptor tyrosine kinases. When FGFs bind at this level, they cause receptor dimerization and activate several signal transduction pathways that lead to downstream signalling cascades [26] Together with oestrogens, FGF signalling is essential for the formation of angiogenesis [27]

Our findings showed no statistically significant variations between the two measurements taken before and after the exercise programme in the urea variable. Exercise increases the rate at which muscles rupture and the breakdown of most different types of proteins in the body to produce energy. This leads to an increase in the rates at which the body must quickly eliminate toxic ammonia, which equalizes the urea variable's building and demolishing processes. Moreover, our findings revealed statistically significant variations in the variable of ketones between the two assessments before and after the program. This is because the training program reduced the breakdown of lipids to release the energy required for physical effort, resulting in ketones, which delayed the sensation of exhaustion. It has been observed that increasing the liver's responsiveness and adaptability to physical effort leads to a large rise in its activity in glycogen storage, whether in the liver or in the muscles, allowing it to continue physical exertion for a longer amount of time. When you continue to exercise, glycogen decomposes to produce glucose, which is the fastest and preferred source of energy for the body during exercise, which reduces the release of energy from fatty substances and thus the rate of ketones that result from the breakdown of fatty substances to produce the energy needed for physical exertion [39]. In all evolutionary areas of life, ketones are important sources of fuel. In the event that there is no supply of carbohydrates, the body may get energy from ketones. Between 5% and 20% of the energy used by the human body is made up of ketones. Fatty acids are changed by the liver into ketone bodies, which are then transported by blood to other organs. This procedure is particularly crucial when a person's blood glucose levels have dropped and they need to keep their organs, including the brain, supplied with energy. The oxidation and use of ketone bodies by mitochondria, particularly in organs with high energy demands, is known as ketone metabolism [39]. Our findings suggest that young female basketball players may improve their aerobic capacity by doing high-intensity interval training with both short and long intervals over the season.

CONCLUSION

All the cardiovascular system-related variables that have been evaluated have higher rates of high-intensity physical exercise. The development of the physical fitness parameters that are considered for basketball players is positively impacted by qualitative activities. Basketball players' skill development is positively impacted by certain routines. Exercises tailored to high intensities increase cardiac impulse and oxygen consumption rates (oxygen consumption: the highest relative oxygen consumption, the rate of change in respiration, the amount of carbon dioxide generated, and the oxygen pulse). Particularly intense physical activities positively influence antioxidant levels. Metabolism indicators for energy consumption (urea-ketones) are positively impacted by high-intensity specialised exercise. Exercises with high intensities that target certain cardiac impulses and oxygen consumption rates enhance the body's energy-gathering capacity more so than fat and protein breakdown.

LIST OF ABBREVIATIONS

FGF = Fibroblast Growth Factor
RER = Respiratory Exchange Ratio
VEGF = Vascular Endothelial Growth Factor
HIIT = High-intensity Interval Training
TG = Training Group
SJ = Squat Jumping
SLJ = Long Jump Standing

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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