The impact of CrossFit training on body composition, muscle strength, physiological adaptations, and the development of rebounding and footwork skills in basketball players

El impacto del entrenamiento CrossFit en la composición corporal, la fuerza muscular, las adaptaciones fisiológicas y el desarrollo de habilidades de rebote y juego de pies en jugadores de baloncesto

Authors

Ahmed K. Hassan [1]

[1] King Faisal University, Al-Ahsa, Saudi Arabia

Corresponding author:
Ahmed K. Hassan
amohhamed@kfu.edu.sa

How to cite in APA

Hassan, A. (2025). The impact of CrossFit training on body composition, muscle strength, physiological adaptations, and the development of rebounding and footwork skills in basketball players. *Retos*, *70*, 788–804. https://doi.org/10.47197/retos.v69.115399

Abstract

Introduction: CrossFit training can mirror on a physical and technical basketball species improving explosive power, trunk stability, and agility, which are the main performance characteristics of basketball games.
Objective: The study aims to evaluate the impact of an eight-week CrossFit-based training course will influence body composition, strength, aerobic and anaerobic capacity, rebounding, and footwork among male players.
Methodology: The sample in the study was 32 Al-Ahsa, Saudi Arabian players. Two groups were randomly assigned: experimental, which consisted of 16 players, and control, which also consisted of 16 players. The implementation of an experimental eight-week program was conducted with both groups. The primary stage of the training session included CrossFit exercises in the experimental group.
Results: The experimental group demonstrated better results as compared to the control group, with an improvement level of 5.85 to 18.20. ($p < 0.001$; ES = 0.23-0.94).
Discussion: The data obtained indicates improvements in body composition, muscle strength, and aerobic and anaerobic capacity, as well as basketball-specific skills (rebounding, footwork) increased in the group of participants (experimental group, EG) in the eight-week CrossFit training program, and the findings are higher compared to the control group (CG).
Conclusion: The experimental program, which was implemented, had a positive effect on body composition, where a lower proportion of fat and more muscular mass was recorded. Owing to the incorporation of cross-fit training, muscular strength was also boosted, and some physiological variables were also strengthened, consequently making the participants enhance their rebounding and footwork abilities.

Keywords

CrossFit; Vo2max, fat mass, rebounding, footwork, Battle Ropes; Trx; weightlifting, plyometric.

Resumen

Introducción: El entrenamiento de CrossFit puede reflejarse en la práctica física y técnica del baloncesto, mejorando la potencia explosiva, la estabilidad del tronco y la agilidad, principales características de rendimiento en este deporte.
Objetivo: El estudio busca evaluar el impacto de un curso de entrenamiento de ocho semanas basado en CrossFit en la composición corporal, la fuerza, la capacidad aeróbica y anaeróbica, el rebote y el juego de pies en jugadores masculinos.
Metodología: La muestra del estudio estuvo compuesta por 32 jugadores del equipo Al-Ahsa de Arabia Saudita. Se asignaron aleatoriamente dos grupos: experimental, compuesto por 16 jugadores, y control, también compuesto por 16 jugadores. Se implementó un programa experimental de ocho semanas con ambos grupos. La fase principal de la sesión de entrenamiento incluyó ejercicios de CrossFit en el grupo experimental.
Resultados: El grupo experimental mostró mejores resultados en comparación con el grupo control, con un nivel de mejora de 5,85 a 18,20 ($p < 0{,}001$; ES = 0,23-0,94).
Discusión: Los datos obtenidos indican mejoras en la composición corporal, la fuerza muscular, la capacidad aeróbica y anaeróbica, así como en las habilidades específicas del baloncesto (rebote, juego de pies), en el grupo de participantes (grupo experimental, GE) del programa de entrenamiento CrossFit de ocho semanas, y los resultados son superiores en comparación con el grupo control (GC).
Conclusión: El programa experimental implementado tuvo un efecto positivo en la composición corporal, registrándose una menor proporción de grasa y un mayor porcentaje de masa muscular. Gracias a la incorporación del entrenamiento CrossFit, también se incrementó la fuerza muscular y se fortalecieron algunas variables fisiológicas, lo que permitió a los participantes mejorar sus habilidades en el rebote y el juego de pies.

Palabras clave

CrossFit; Vo2max, masa grasa, rebote, trabajo de pies, Battle Ropes; Trx; levantamiento de pesas, pliométrico.

Introduction

Basketball is an intermittent, high-intensity team sport that requires the combination of anaerobic power, muscular strength, agility, and quick footwork, combined with efficient rebounding skills and tactical awareness (Li et al., 2024; Altavilla & Raiola, 2014). The demands of the game in terms of physical and physiological aspects require that well-programmed training regimens should be utilized to optimize performance with a reduced risk of injury (Ryadova et al., 2023). Because of this, novel training practices have been pursued in greater detail to maximize general fitness and sport-specific basketball abilities. Basketball is defined by stop-and-go high-intensity work, and players must be at their best concerning physical condition and resilience to injuries. As a result, sport-specific training programs have risen in prominence due to their capacity to improve performance measures, which include increases in aerobic capacity, agility, and anaerobic power. Studies have already indicated that intensity-modulated training, such as High-Intensity Interval Training (HIIT), could vastly enhance VO2 max by up to 13.3 percent more than conventional endurance training (Shamim, 2021). Borkar and Badwe (2023) conducted a randomized controlled trial and showed that sports-specific training lasting 12 weeks produced clinically important positive changes in speed, agility, and anaerobic performance in basketball players. Likewise, more well-organized agility training with plyometric exercises and resistance-based methods has been observed to be beneficial in improving primary movement patterns used in basketball playing, such as quick direction changing and reactive footwork (Li et al., 2024). The results of this study are relevant to emphasize the need to include scientifically supported, functional training modes in basketball conditioning programs.

In this context, interest has emerged in functional training methodologies such as CrossFit, given their potential to integrate multiple physical abilities into a single session. CrossFit, which involves the combination of many movements associated with weightlifting, plyometrics, gymnastics, and aerobic conditioning to improve physical capacity in total (Feito et al., 2018). This practice has drawn major concern in sports science. It has been able to increase body composition, muscular strength, and cardiorespiratory fitness which are major contributors of sports performance in basketball and other games (Ningrum et al., 2025; Alsharab et al., 2024; Cabrera Linares et al., 2024; Perna et al., 2016). Here, crossfit can be considered as an entire training regime that has the potential of accommodating many forms of physical demands at the same time, and because of this, it is especially applicable to sports that necessitate explosive power, agility, and endurance.

Although research on the overall benefits of CrossFit has become increasingly more present, there is little research done on its specific effects on basketball-related skills, e.g., rebounding and footwork. They are essential skills in competition, but little is known about how to improve them through specific training programs such as Crossfits. This deficiency points to a potential research effort to investigate the effects of CrossFit on a greater scale of physiological adaptations beyond that of examining its potential ability to make sport-specific adaptations. Additionally, the research indicates that CrossFit exercise can improve the maximum oxygen capacity (VO2 max), anaerobic force, along with work capacity, which are closely linked to the long-term achievement in-competitive basketball games (Putro et al., 2025; Ponce-García et al., 2024; Meier et al., 2023A; Dexheimer et al., 2019). The effects on vertical jump height and lower-body power necessary to jump back successfully (de Alemida et al., 2023; Ramos de Amorim et al., 2023; Feito et al., 2018; Perciavalle et al., 2016) could also be achieved through CrossFit with its emphasis on explosive and multi-joint exercises, but evidence regarding how systematic CrossFit programs can help in such areas is lacking.

CrossFit, a methodology of high intensity functional training (HIFT) involves blending various movement patterns including weightlifting, plyometrics, gymnastics, and aerobic training to all-round physical fitness. The technique has attracted the interest of sports science because of its effectiveness in enhancing the body composition, muscular strength, cardiorespiratory efficiency, and anaerobic capacity, which are essential factors in the performance of competitive basketball and other sports (Alsharab et al., 2024; Cabrera Linares et al., 2024; Bendo et al., 2024; Stanković et al., 2023; Feito et al., 2018). They directly correlate to athleticism as agility, and trunk stability in basketball, two of which are fundamental aspects of CrossFit multifaceted training (Corredor-Serrano & Garcia-Chaves, 2023; Martínez-Gómez et al., 2020).

Studies show that CrossFit training can indeed lead to a considerable improvement in physiological factors connected to basketball such as maximal oxygen uptake (VO2) anaerobic power, and able-bodied force (Shamim, 2021; Martínez-Gómez et al., 2020). To give an example, there are studies demonstrating that CrossFit interventions in basketball players result in increasing the vertical jump ability, sprint speed, and agility following regulated exercises (Elkeky et al., 2020). Comparatively, plyometric and circuit-based exercise, which forms the basis of the CrossFit activities, have been demonstrated to increase explosive power and reactive agility that are fundamental in the skills of rebounds and footwork (Hoyos-Manrique et al., 2024; Moscatelli et al.,2023; Ricart Luna et al., 2020; Saini, 2019). These modifications are also facilitated by the alterations in body composition including gaining lean mass and decreasing the proportion of fat tissue, which improve acceleration, jumping performance, and the efficiency of movements (Cordredor-Serrano & Garcia-Chaves, 2023).

Despite the multiple benefits attributed to CrossFit, there is a gap in the literature regarding its effect on basketball-specific motor skills such as rebounding and footwork, which are crucial for competitive performance. Although the physiological aspects of enhancement are well described, the specific link to sport-genuine skills has not been adequately explored (Yogavarthini et al., 2024). To fill this gap, the current study offers an eight-week program (based on CrossFit training) aimed at examining its impact on the main physical and physiological variables as well as basketball-specific ones. These are body composition, muscular strength, aerobic and anaerobic capacity, and skills such as rebounding and footwork. Through this combination, the research will therefore yield a clearer picture of how to employ CrossFit to achieve the specific needs of basketball and therefore offer possible alternatives in the form of practical advice to coaches and players who might be pursuing optimizing performance through innovative training approaches.

Nevertheless, the careful introduction of CrossFit programming should be emphasized because it is a high-impact style of training that is linked to the higher risk of musculoskeletal injuries, especially in the shoulders, lower back, and knees (Oliver-Lopez et al., 2022; Gianzina & Kassotaki, 2019). Besides, cases of exertional rhabdomyolysis are reported, and the need to use individualized strategies and pay close attention during an extreme conditioning program is obvious (Montalvo et al., 2017). Adjusting the CrossFit exercise to suit the needs of basketball specifically, i.e., vertical jumps, side sprints, and rapid acceleration, would increase its relevance when applied on the youth and amateur level (Besada & Pizarro, 2024).

Method

Participants

The sample was determined by the formula of Thompson's finite population [15]. First, the general formula to use when dealing with an infinite population was used with 95 percent confidence level ($Z = 1.96$), a 5 percent margin of error ($d = 0.05$), and an estimated proportion of 0.5 ($p = 0.5$). Nevertheless, the total target population was composed of only 35 residents of Al-Ahsa, and hence the sample was corrected by applying the finite population correction formula. The study involved 32 male basketball players who were divided into an experimental and a control group (16 participants in each group) randomly (see Table 1). The random allocation was done to produce a balance in the groups before the intervention.

Procedure

Research variables were measured to test the homogeneity of the two groups before the beginning of the training program over three days, to establish a baseline comparability. The criteria used to select the participants included the following: (a) male gender, (b) minimum five-year experience in regular basketball training and competition, (c) ability to train four times per week, and (d) no previous history of chronic pathologies or use of any medications that might have an impact on the physiological or performance results of the study. Moreover, the next exclusion criteria were conducted to keep scientific integrity and reduce the number of confounding factors: Presence of cardiovascular or respiratory disorders that can impede exercise tolerance, Failure to attend training, or to conform to testing procedures.

Study Design

During the intervention period, the players engaged in CrossFit training sessions at the Al-Adalah basketball court located in Al-Ahsa, Saudi Arabia. Pre-assessments were collected from the 2nd of January to the 4th of Januall4, for the application of the tests for all the individuals. The experimental group was subjected to a CrossFit based training program. The program was implemented from the 6th of January 2024 to the 29th of February 2024. The control group followed an identical training program on frequency and duration but without any CrossFit activities. Post-measures for the experimental and the control groups were implemented from the 2nd of February to the 4th of February 2024, using the same procedures and conditions as the pre- and post-measurements. The participants were first briefed about the potential risks of the study and completed informed consent forms to confirm their consent to participate. The Ethics Committee of King Faisal University approved the research study under the reference KFU-REC-2023-FEB-ETHICS622.

Instrument

Assessment of Body Composition

Anthropometric measurements were done to assess the body composition through standardized and reliable ways. The heights of participants were assessed with Martin Anthropological Scale, which is the validated tool commonly used both in clinical and research practices (Kolachahi, Elmieh, & Talebi, 2020). As part of the measurement procedure, measurement participants were asked to stand straight with feet together and crossed arms on their chests and make sure that their heels, buttocks, and upper back were touching the vertical surface of the measuring device. They were also requested to ensure they close their eyes and inhale deep to have perfect posture. The stadiometer was set up vertically and measured height to nearest 0.1 cm.

The body weight and body composition parameters were evaluated with the help of the InBody 720 bioelectrical impedance analyzer (InBody Co., Seoul, South Korea), which is an accurate and highly reproducible instrument that is thoroughly used in the research studies (Stankovic, Capric, & Djordjevic et al., 2023; Gonzalez et al., 2019). To get trustworthy outcomes, we recommended that the participants fast at least four hours before the test and not use caffeine or alcohol during a 24-hour period before the examination and avoid any intense physical activity 12 hours before the assessment. The parameters of body composition allocated were Body Mass Index (BMI), Body Fat Percentage (BFP%), Fat Mass (FM), Fat-Free Mass (FFM) and Body Fat Index (BFI). Such measurements were also done to determine baseline body composition data, and to check the change of the body composition before and after the intervention.

Physiological Assessments

To fully review the physiological changes elicited by the CrossFit-style training program, important parameters such as aerobic capacity, anaerobic power and maximum oxygen uptake (VO 2 max) were measured in a controlled laboratory environment.

VO2 max and Aerobic Capacity Evaluation

A progressive treadmill test to volitional exhaustion was used to measure maximal oxygen consumption (VO2 max) on a Lode Valiant Ultra 300 treadmill (Groningen, The Netherlands), which was interfaced with a Cortex MetaMax 3B cardiopulmonary gas analysis system (Leipzig, Germany). The method using this system makes it possible to measure oxygen uptake and carbon dioxide production breath-by-breath with high accuracy and reliability (Zhang et al., 2023; Schutte et al., 2016).

Participants undertook a graded exercise test (GXT) beginning at a speed of 7-12 km/h with 1 percent inclination and then increments of 1km/h every 3 minutes until voluntary exhaustion. Continuous monitoring of Heart rate, perception of effort (Borg Scale), and expired gases were done during the test. The oxygen uptake (VO 2) was averaged during the last 60 seconds of every stage, and the peak VO 2 before the termination was considered VO 2 max (Goenarjo et al., 2021). All subjects were asked to Abstain from caffeine, alcohol, and stimulants, at least 12 hours before testing. Avoid extreme physical exercise 24 hours before the test. Come in fast condition (at least 4 hours after the last meal). The test sessions were carried out between 8.00 AM and 11.30 AM to limit the effects of diurnal changes in performance and physiology. The environmental conditions were kept constant at a temperature of 18 24 °C and humidity of 30 - 60 percent, with all the variables being continuously monitored during the test period.

Anaerobic Power Testing

Anaerobic power has been measured by Margaria-Kalamen Staircase Test (MK Test) which is a well-known field test to measure Maximum lower extremity power during short efforts (Beitia et al., 2022; Haff & Dumke, 2018). During this test, the test subjects were to walk up a staircase composed of 9 steps (each 17.5 cm high) as fast as they could after warming up lightly, and their performance was timed by a digital watch or various electronic gate timers. The formulae used to calculate power output was Power (Watts) = (Body mass (kg) x Vertical distance (m) x g)/Time (s) and g is a gravitational terminal velocity (9.81 m/s 2). Although this test is among the best tests to measure peak anaerobic power, it is mainly used to measure mechanical Maximum lower extremity power during short tasks.

Muscle Strength, Core Stability and Skill Assessment

On the second day, muscle strength was measured using the Vertec® Jump (VJ) test, the Medicine Ball Javelin Quadrathlon (MBQJ) test, and the plank (P) test to determine trunk stability. All the participants warmed up for 10 minutes before the tests, which involved both running and walking for five minutes and dynamic stretching for five minutes. Rebounding and footwork skills were tested on the third day, and the warm-up was as follows: five minutes of running/walking, five minutes of dynamic stretching, and five minutes of shooting and rebounding the ball (see Appendix A).

Vertec® Vertical Jump Test (VJ): The lower-body power was measured via the vertical jump test (VJ) because this is especially important in basketball performance, especially during rebounding movements. It was performed with the use of the Vertec® device (Jump USA, Sunnyvale, CA, USA), which is a valid and reliable instrument to measure the vertical jump height using a set of adjustable and rotating plastic vans (Buckthorpe, Morris, & Folland, 2012; Selvamoorthy, Macgregor, Donald, & Hunter, 2024). The subjects were asked to complete the test in standardized conditions after a dynamic warm-up that included light jogging, mobility work, and submaximal jumps. All the participants were tested under the Vertec® in the same position (dominant shoulder over the top of the vanes). They stood about 10 cm in front of the device, with their faces toward the vanes, their feet flat on the ground, and then jumped. To provide the greatest effort, they were asked to bend their knees and swing their arms back during the countermovement part. Then, hips, knees, and ankles straight away, swing the dominant arm upwards. Feel and move the highest vanes you can know of the highest jump. Each participant was tested three times, with 30 seconds of rest between the attempts to exclude the influence of fatigue. Each trial was measured, and the maximum displacement of the vans was recorded and analyzed by transferring the values into centimeters. Statistical evaluation was done using the best score out of the three attempts. The mode of calculation offers a reasonably convenient and field-tested gauge of the lower-body power, which is especially appropriate in measuring adaptation when the training involves high-intensity functional training like CrossFit.

MBQT: Medicine Ball Javelin Quadrathlon Test was taken to measure the upper-body power. The dynamic throwing movement that was tested using a medicine ball mimicked a javelin-like throw in a standing position (Zhao et al., 2023; Hassan et al., 2023). The instruction to the participants was to assume a position with the feet somewhat shoulder-width apart, in parallel to one another, and to a slight extent staggered in the direction of the throw. The medicine ball was held with two hands, cupped in front of the body at the chest level and the throw was started with a whole-body coordinated mechanic: hip rotation, trunk extension, and arm extension. In the three-step throwing technique, the participants were required to start with their feet together and were allowed to take up to two steps before throwing the ball in the throwing box. The last action was taken once the ball was released so that it would have optimum forward movement. Throwing distance was calculated between the release point (which was calculated by the position of the front foot at the time of release) and the point where the ball initially hit the ground. All trials were recorded with a measuring tape by an assistant, and everyone threw three times maximum with a one-minute rest period between throws to ensure the minimal influence of fatigue. Statistical analysis was done with the best score (longest distance). The test offers a valid and practical measure of upper-body explosive strength and kinetic chain coordination.

Plank Test (P): Core muscle endurance was measured using the plank test, as it is an essential element of postural stability, balance, and force transfer during basketball-specific movements (cutting, jumping, and landing). This is a test of how long the trunk musculature, comprising rectus abdominis, transversus abdominis, obliques, and erector spinae can hold an isometric contraction in a stationary position (Tong, Wu, & Nie, 2014; Buckthorpe, Morris, & Folland, 2012). Participants were prone on the floor with their elbows at 90 deg on the floor directly under the shoulders. The forearms were parallel to each other, and the body was raised onto the toes, so that the head and heels made a right angle. Feet were held together, the hips were raised to make the body a firm, horizontal plane, neither sagging nor tipping forward too much. When the participant had reached the right posture (neutral spine, no lumbar hyper-extension or pelvic tilt) the test started, and a digital stopwatch was used to measure the time. The participants were asked to hold on to this position as long as possible, but the head must be facing down and not up or forward. The test ended when one of the following happened: The hips of participant touched the ground. Compensatory movement (e.g., arching of the back or dropping of the shoulders) was observable. The subject verbally stated that they were no longer able to keep a proper form. Each subject carried out two trials with a 3-minute rest period in between, and the highest performance (maximum time maintained in a correct position) was used in analysis.

Basketball Rebound Test: Basketball rebound test was generated to determine the capability of the participants to accomplish a maximal vertical jump and by maintaining a sport-specific task, catching a basketball that received a bounce off a fixed height. The test involved the use of the Basketball Rebound Height Tester Model GA-5503 (Changsha, Hunan Province, China) with vertically adjustable backboard which has got a mechanism to release the ball to standard height of vertical drop. The participants started in a marked start line which was 1 meter in front of the equipment. They were sent off at a running start by hearing the auditory start signal, where they would run over to tester and jump vertically (or as high as possible) to receive the ball as soon as it came bouncing. All subjects performed three maximum trials and the time rest between trials was set to 90 seconds to allow enough recovery and reduce the effects of fatigue. The maximum rebound height by the participant was automatically recorded when he/she used built-in sensors on the equipment and the best score out of three trials was analyzed statistically.

Modified T-test (footwork skill): The Modified T-Test was utilized to measure the important aspects of the basketball-specific footwork that involves the lateral speed of the feet, change-of-direction capability, and reactive agility, which are all critical in performing quick directional changes when playing offense and defense in basketball. The test involves a combination of pre-programmed movement patterns and reactivity with the FITLIGHT TM Trainer System, which increases its validity and reliability in testing sport-specific motor skills (Hassan et al., 2022). The following equipment was necessary due to the testing protocol: a measuring tape and marker cones to set up the course, the FITLIGHT™ Trainer System (a wireless, light-based reaction training device), an ordinary basketball, and a digital stopwatch with a precision of 0.01 seconds. The course was in the form of a modified T, as four cones designated A to D, where Cone A was the starting point, Cones B, C, and D were located 5 yards (4.57 m) horizontally (to the right or left) of Cone A and 10 yards (9.14 m) ahead. A FITLIGHT™ unit, which provided visual stimuli (flashing lights) was attached to each cone and the participants were required to respond to these stimuli by touching or swiping the light to switch it off. The starting position was at cone A in a ready position where the feet were shoulder-width apart and facing forward. They were instructed to run to Cone B where the FITLIGHT unit was set on an auditory start signal. The subjects were asked to reach out and touch the light with the right hand to turn it off, followed by a lateral shuffle to Cone C turning off the light with the left hand. These then made a lateral move to Cone D, touching the light with the right hand, and then back to Cone A, never taking their hands off the body or losing the flow of movement in the sequence. Every subject performed three successful trials, and the break between the attempts was two minutes to provide a recovery and stable performance level. The trials were considered invalid when the subject crossed one foot in front of the other when shuffling, did not deactivate the right FITLIGHT unit, or did not follow the marked route. Only valid attempts were counted and the fastest time (in seconds) of the three trials was employed in statistical analysis. The test is an excellent and valid measure of dynamic footwork performance which includes measures of acceleration, deceleration, direction change, and response to visual stimuli.

Experimental Procedures

Experimental training intervention was planned and carried out during eight weeks and improvement in the targeted physical and physiological factors was the major aim of the training program i.e., the improvement in the following factors: muscle strength, cardiorespiratory fitness, anaerobic capacity as well as improving basketball specific skills including Rebounding technique and the model footwork agility (see Appendix B). This program was designed around CrossFit-inspired functional movements, adjusted in such a manner that they became more basketball-specific. The experimental group was frequency of four times a week (Saturday, Monday, Wednesday, and Thursday), during which each set lasted between 90 and 120 minutes, ending after 32 sessions. All the sessions included four standardized phases and their duration in the experimental group: Warm-up (15 minutes), Functional Strength and Conditioning (30-50 minutes), Skill Development Phase (20-45 minutes), and a Cool-down/ Recovery (10 minutes).

1) Functional Strength and Conditioning (30- 50 minutes)

This portion consisted of a blend of multi-joint, compound motions based on CrossFit methodology, but altered to the needs of basketball. These exercises were designed to work large muscle groups, increase explosive power, muscular endurance, and metabolic conditioning, (Weightlifting: Power cleans, overhead presses, Plyometrics: Box, jumps, lateral bounds, Suspension Training: TRX rows, TRX lunges, Kettlebell Drills: Swings, goblet squats, Battle Rope Workouts). The exercises were carried out within 6-10 repetitions, 3-5 sets, with breaks between sets 30-80 seconds, and 40-55 seconds between various exercises. The strength of this block was calculated as a combination of parameters: Percentage of 1RM during weightlifting exercises (75-90% of the heaviest weight), Heart rate evaluation during metabolic conditioning blocks (75-90 percent of the maximal heart rate), Rating of Perceived Exertion (RPE) scale (7-9 with a scale of 1-10). This prevented controlling the intensity systematically and justified the principle of progressive overload application, which also reduced the risks of injury in case of appropriate monitoring and individual adjustments (Gianzina & Kassotaki, 2019).

2) Skill-building Stage (20- 45 minutes)

The technique of rebounding and footwork in basketball. Drills that involved fast changes of direction, body control, space awareness, and timing were involved when the participants had to bounce back. These exercises were incorporated into work in the agility ladder, working with cones, and FITLIGHT reactive tasks to promote sport-specific coordination and decision-making during movement. The sessions were all standardized with certified coaches. Increasing levels of intensity and complexity were incorporated gradually over the eight weeks to minimize the possibility of plateaus and injury or constant adaptation. The control group underwent more of a classic basketball conditioning regimen, but without CrossFit elements.

Data analysis

The IBM-SPSS 26 (Chicago, IL, USA) software was used to analyze the data obtained in this work. Several statistical estimates were generated, such as the mean, standard deviation, coefficient of variation, confidence interval (95% CI, lower and upper limits), and effect size, to guarantee the rigidity and dependability of the results. Inferential analyses were only run after determining the normality of data distribution based on skewness, kurtosis, and Shapiro-Wilk test to ensure that assumptions used in parametric analyses were met. The mean difference calculations between the experimental group and control group then followed by an independent t-test analysis. In this study, statistical significance was set at a reference value of $p < .05$ and this made the results meaningful and reliable.

Results

Tables 1.2 indicate descriptive statistical properties of the experimental group (EG) and the control group (CG) participants by their age, height, weight, years of experience, the body composition (BMI, physical performance index, and percent of body fat), muscle strength (vertical jump, plank test, and quad medicine ball javelin throw), physiological adaptations (VO2max, Margaria-Calamin test), basketball-specific skills (Rebounding, footwork), and Figure 1 indicates pre- and post-intervention descriptive statistics for the experimental and control groups.

Table 1. Descriptive statistics.

	EG				CG			
	Mean	Std.	Min	Max	Mean	Std.	Min	Max
Age	18.84	0.70	18.00	20.00	18.94	0.66	18.00	20.00
Height	175.38	1.02	174.00	177.00	175.56	1.21	174.00	178.00
WIGHT	76.06	2.79	70.00	80.00	76.38	2.31	72.00	80.00
Training	5.81	0.54	5.00	7.00	5.75	0.45	5.00	6.00

Table 1 shows the descriptive statistics of demographic and training variables that describe the two groups (experimental group (EG) and control group (CG)) as well as their characteristics. Age, height, weight, and experience in training of the two groups did not vary significantly. The average age of the two groups was nearly 18.84-18.94 years, with a very small standard deviation (0.70 and 0.66 in EG and CG, respectively). This is implied that the age of participants is very close. Likewise, there was no significant variance in height as well as weight between the groups, where the mean height was 175.38 cm and 175.56 cm, respectively, of the experimental and control groups, and the mean weight of means of the groups was 76.06 kg and 76.38 kg, respectively. Years of training also demonstrated similar values, 5.81 (EG) and 5.75 (CG), as shown in the mean. The similarities implied that the groups were well matched at baseline, thus there are fewer chances of confounding variables in the study findings.

Figure 1. Descriptive statistics of experimental and control groups.

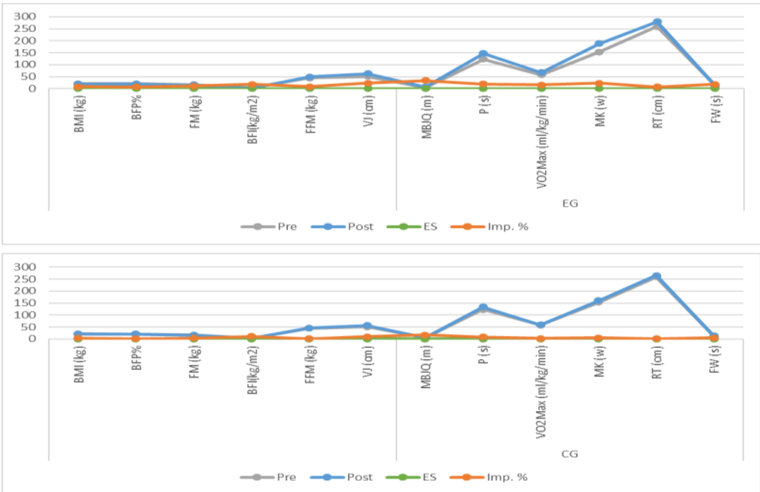

Table 2. Descriptive statistics of experimental and control groups in Body composition, muscle strength, physiological adaptations, rebounding, and footwork skills

Group	Outcome measures	Pre			Post			ES	Sig.	Imp. %
		Mean	Std.	CV %	Mean	Std.	CV %			
EG	BMI (kg)	21.48	1.51	7.03	19.47	0.78	4.01	0.43	<0.01	9.36
	BFP%	20.86	1.33	6.38	19.23	0.84	4.37	0.36	<0.01	7.81
	FM (kg)	16.77	0.74	4.41	14.97	0.51	3.41	0.68	<0.01	10.73
	BFI (kg/m²)	3.88	0.32	8.25	3.14	0.07	2.23	0.74	<0.01	19.07
	FFM (kg)	45.06	0.59	1.31	49.23	0.45	0.91	0.94	<0.01	9.25
	VJ (cm)	51.47	1.10	2.14	63.24	1.68	2.66	0.95	<0.01	22.87
	MBJQ (m)	5.57	0.16	2.87	7.46	0.14	1.88	0.98	<0.01	33.93
	P (s)	123.05	1.12	0.91	147.54	1.82	1.23	0.99	<0.01	19.90
	VO2Max (ml/kg/min)	58.08	1.43	2.46	67.58	1.27	1.88	0.93	<0.01	16.36
	MK (w)	153.13	4.38	2.86	188.00	6.91	3.68	0.91	<0.01	22.77
	RT (cm)	259.88	11.24	4.33	280.38	8.05	2.87	0.54	<0.01	7.89
	FW (s)	13.26	0.33	2.49	10.86	0.25	2.30	0.95	<0.01	18.10
CG	BMI (kg)	21.70	1.53	7.05	20.95	1.37	6.54	0.07	<0.01	3.46
	BFP%	20.67	1.17	5.66	20.27	1.12	5.53	0.03	<0.01	1.94
	FM (kg)	16.77	0.74	4.41	16.14	0.75	4.65	0.16	<0.01	3.76
	BFI(kg/m²)	3.89	0.31	7.97	3.45	0.34	9.86	0.33	<0.01	11.31
	FFM (kg)	45.06	0.59	1.31	45.83	0.45	0.98	0.37	<0.01	1.71
	VJ (cm)	51.30	1.09	2.12	56.67	1.17	2.06	0.86	<0.01	10.47
	MBJQ (m)	5.57	0.16	2.87	6.51	0.17	2.61	0.90	<0.01	16.88
	P (s)	123.05	1.12	0.91	134.42	3.73	2.77	0.82	<0.01	9.24

VO2Max (ml/kg/min)		1.42	2.44	59.92	0.61	1.02	0.43	<0.01	3.15
MK (w)	153.06	4.46	2.91	160.06	3.42	2.14	0.45	<0.01	4.57
RT (cm)	259.94	9.20	3.54	265.25	8.45	3.19	0.09	<0.01	2.04
FW (s)	13.26	0.33	2.49	12.64	0.32	2.53	0.50	<0.01	4.68

Key: EG—Experimental Group; CG—Control Group; Min—Minimum; Max—Maximum; BMI— Body fat index; BFP%—Body fat percentage; FM—Fat mass; BFI— Body fat index; FFM—Fat-free mass; VO2Max —maximal aerobic capacity; MK—Margaria-Kalamen (MK) Staircase Test; MBJQ—Medicine Ball Javelin Quadrathlon; P—Plank test; RT—Rebound test; FW—footwork; CV—coefficient of variation; ES— Effect size; Imp. % — improvement percent.
P < 0.01.

The descriptive data findings, visibly reported in Table 2 reveal the strong advances in body composition and performance outcome measurements in the experiment group (EG) against the control group (CG). The EG reported a significant improvement in all variables that it measured with percent improvement from 7.81% (BFP%) to 33.93% (MBJQ), and most effect sizes (ES > 0.43) had immense practical significance. Remarkably, the EG indicated significant improvements in BMI (9.36%), percent body fat (7.81%), fat mass (10.73%), and fat-free mass (9.25%), vertical jump height (22.87%), and aerobic capacity (16.36%), and Anaerobic Power (MK) (22.77%). On the same note, basketball-specific skills like rebounding (7.89%) and speed of footwork (18.10%) also increased tremendously. Conversely, the CG showed small effects with a shorter effect size and lack of practical importance, especially in physiological adaptations (VO2Max 3.15%) and skill-associated results (RT 2.04%). These results support that the intervention given to the EG had positive influences in leading to measurable changes in body composition, muscle strength, physiological transformations, and basketball-specific skills than those of the CG.

Table 3. The results consisted of the F-statistic from analysis of variance (ANOVA) of the main effects: measurement and group, as well as ηp2 for the Interaction (measurement group). According to Bonferroni's post hoc test the increment in all the variables was significantly higher in the experimental group compared to control group. The ANOVA details are obtained as follows in Table 3 below. To sum up, the results of the investigation were as follows: Since p-value < 0. 05, there were significant effects obtained in relation to all the study variables.

Table 3. Post-hoc analyses incorporated analysis of variance (ANOVA) as well as the ηp2 values for Measurement, Group, and the Interaction (Measurement Group).

Outcome measures	Measurement			Group			Intercept			Group ×Time Interaction		
	F	P	ηp^2	F	P	ηp^2	F	P	ηp^2	F	P	ηp^2
BMI (kg)	41.77	<0.01	0.580	2.32	0.139	0.072	8819.53	<0.01	0.997	17.70	<0.01	0.370
BFP%	117.31	<0.01	0.796	1.189	0.284	0.038	10856.288	<0.01	0.997	42.98	<0.01	0.589
FM (kg)	361.62	<0.01	0.923	6.21	0.018	0.172	18879.84	<0.01	0.998	84.45	<0.01	0.738
BFI(kg/m²)	209.63	<0.01	0.875	3.11	0.088	0.094	6231.01	<0.01	0.995	13.23	<0.01	0.306
FFM (kg)	662.06	<0.01	0.957	116.08	<0.01	0.795	342691.38	<0.01	0.999	314.29	<0.01	0.913
VJ (cm)	485.63	<0.01	0.942	118.87	<0.01	0.798	120328.25	<0.01	0.999	222.09	<0.01	0.881
MBJQ (m)	336.20	<0.01	0.918	110.46	<0.01	0.786	60305.45	<0.01	0.999	148.98	<0.01	0.832
P (s)	2604.49	<0.01	0.989	63.97	<0.01	0.681	69946.29	<0.01	0.999	363.71	<0.01	0.924
VO2Max (ml/kg/min)	1871.76	<0.01	0.984	111.13	<0.01	0.787	77261.94	<0.01	0.999	212.41	<0.01	0.876
MK (w)	1163.17	<0.01	0.975	126.26	<0.01	0.808	204357.97	<0.01	0.999	155.89	<0.01	0.839
RT (cm)	309.04	<0.01	0.912	5.49	0.026	0.155	27514.46	<0.01	0.999	106.99	<0.01	0.781
FW (s)	670.83	<0.01	0.957	91.68	<0.01	0.753	73177.45	<0.01	0.999	229.74	<0.01	0.884

Key: BMI= Body fat index; BFP%= Body fat percentage; FM= Fat mass; BFI= Body fat index; FFM= Fat-free mass; VO2Max= maximal aerobic capacity; MK= Margaria-Kalamen (MK) Staircase Test; MBJQ= Medicine Ball Javelin Quadrathlon; P= Plank test; RT= Rebound test; FW= footwork; ηp^2 = eta squared.
P < 0.01.

Post-hoc outcomes described in Table 3 demonstrate significant effects on several outcome measures and were documented by large F-values and low p-values (<0.01) of Measurement, Group, and Interaction effects. The effect sizes (ηp2) show high practical significance, especially in the Measurement and Interaction effect, and the degree of the results was moderate to very large (0.580 in the case of BMI and 0.989 in the case of VO2Max). It is worth mentioning that the values of Group x Time Interaction effect sizes were quite high in all (0.738 and 0.924 in the case of FM and VO2Max, respectively), indicating that the changes over time were significantly larger in the experimental group than in the control one. Also, the importance of the interceptions was very significant (p < 0.01) and therefore represented the consistency at the baseline of the measured items. These results suggest that the intervention was effective in causing significant changes in body composition (BMI, BFP%, FM, FFM), muscle strength (VJ, MBJQ, P) and inception on the perspicacity of physiological adaptations (VO2Max, MK), basketball-specific skills (RT, FW) with the interaction effects driving the competent influence of the intervention on the experimental group compared to the control group.

Statistical differences of the dimensional measurements and the improvement rates between the experimental and control groups in Figure 2.

Figure 2. Differences between experimental and control groups.

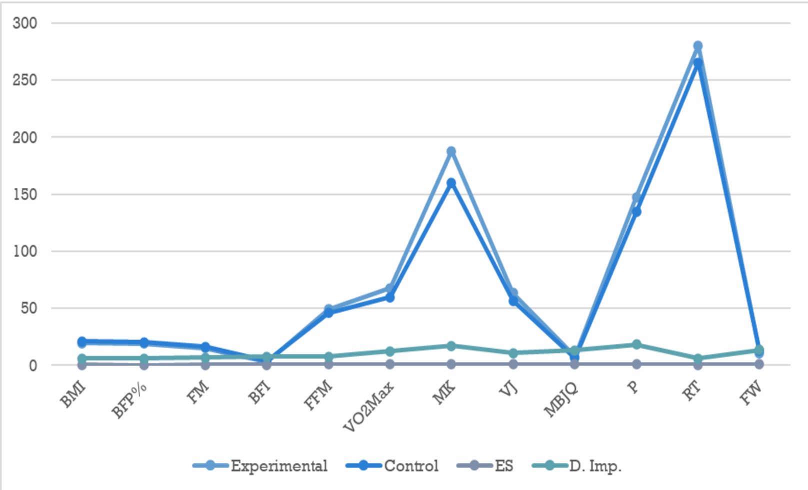

Table 4. Mean, standard deviation, and percentage of improvement in post-test measurements of experimental and control groups.

Outcome measures	Experimental		Control		ES	D. Imp.	CI		P
	Mean	Std. Deviation	Mean	Std. Deviation			Lower	Upper	
BMI	19.47	0.78	20.95	1.37	0.32	5.9%	-2.280	-0.670	<0.01
BFP%	19.23	0.84	20.27	1.12	0.23	5.87%	-1.751	-0.320	<0.01
FM	14.97	0.51	16.14	0.75	0.47	6.97%	-1.634	-0.711	<0.01
BFI	3.14	0.07	3.45	0.34	0.29	7.76%	-0.489	-0.131	<0.01
FFM	49.23	0.45	45.83	0.45	0.94	7.54%	3.082	3.727	<0.01
VO2Max	67.58	1.27	59.92	0.61	0.94	12.4%	6.945	8.383	<0.01
MK	188.00	6.91	160.06	3.42	0.88	17.05%	24.003	31.872	<0.01
VJ	63.24	1.68	56.67	1.17	0.85	10.66%	5.526	7.616	<0.01
MBJQ	7.46	0.14	6.51	0.17	0.91	13.21%	0.840	1.065	<0.01
P	147.54	1.82	134.42	3.73	0.84	18.2%	11.005	15.246	<0.01
RT	280.38	8.05	265.25	8.45	0.47	5.85%	9.167	21.083	<0.01
FW	10.86	0.25	12.64	0.32	0.91	13.42%	-1.976	-1.566	<0.01

D. Imp. — Differences in improved percent.

The data provided in Table 4 shows that in all the outcomes that were measured, the experimental group (EG) has shown significant improvements in comparison to the control group (CG) with the percentage of improvement (D. Imp.), effect sizes (ES), and statistical significance (P < 0.01). In body composition measures, the experimental group differences in rates of improvement with the control group are significant, and these measures include body mass index (BMI, 5.9%) body fat percent (BFP%, 5.87%), fat mass (FM, 6.97%), and fat-free mass (FFM, 7.54%), with effect sizes large on FFM (ES = 0.94) and FM (ES = 0.47). Equally, physiological improvements observed in Maximal aerobic capacity (VO2Max, 12.4%) and anaerobic power (MK, 17.05%) demonstrated large improvements and high effect sizes (ES > 0.88). Other variables associated with performance also changed significantly, including the height of the vertical jump (VJ, 10.66 percent), medicine ball javelin quadrathlon (MBJQ, 13.21 percent), and plank test duration (P, 18.2 percent), which indicates the success of the intervention. Moreover, basketball-specific skills such as rebounding (RT, 5.85 percent) and footwork (FW, 13.42 percent) displayed significant improvements that were accompanied by medium-sized effect sizes (ES > 0.47). The reliability of these findings is also supported by their confidence intervals (CI), and the ranges in which they fall do not overlap, so the differences between the groups are evident. Overall, these findings support the effectiveness of the intervention in increasing both physical and performance-related characteristics of the experimental group compared to the control one.

Discussion

The study showed that an eight-week Cross-Fit-based exercise program had significant effects on major aspects of body composition, muscular power, physiological adjustments, and basketball-related skills. In particular, the parameters of body composition, which include Body Mass Index (BMI), body fat percentage (BFP), fat mass (FM), body fat index (BFI), and fat-free mass (FFM), were improved. Also, muscular power indices of vertical jump (VJ), medicine ball throw (MBQJ), and plank test (P)improved considerably. The physiological adaptations, like the maximal oxygen consumption (VO2 max) and anaerobic power (measured through Margaria-Kalamen test [MK]), also increased in a significant manner. Moreover, characteristic basketball skills were observed in such areas as rebounding and footwork and showed significant improvement. Statistical tests have shown that all the tested variables had significant differences when comparing within-groups (pre- and post-test processes) and between-groups (experimental group and control group). The results of post-hoc ANOVA showed large effect sizes ($p < 0.001$) and demonstrated that the experimental group performed better than the control one on all measures. These results are consistent with those of other studies, including that of Alsharab et al. (2024), who have found that young soccer players improved significantly in body composition indices (BMI, BFP, FFM) after 12 weeks of CrossFit training. Analogously, the current study specifies the usefulness of CrossFit to drop the body fat with higher fat-free mass, which plays a crucial role in upgrading athletic performance and sport-related efficiency.

These findings correspond to the previous studies, which also proved that people who are involved in CrossFit have more evident changes in their anthropometrical parameters than those who have been training in classical programs and either resistance or endurance training (Ningrum et al., 2025; Kicanovic et al., 2022; Menargues-Ramirez et al., 2022; Camacho-Cardenosa et al., 2020). Improvements in lean tissue and adiposity loss were demonstrated, pointing to the CrossFit potential as a better way of approaching body composition rather than the alternative methods, making it an excellent choice in conditioning programs related to sports activities such as basketball. The changes made also seem to be informed by the structured incorporation of functional movements under high-intensity, weightlifting, plyometrics, and metabolic conditioning. These elements are very important to improve cardiac performance, lung performance, and metabolism. As an example, repeated high-intensity exercise consistently improves cardiac output, systemic delivery of oxygen to peripheral tissues, and VO2 max, which play an important role in maintaining performance during stop-and-go sports such as basketball (Meier et al., 2023B; Fabrin et al., 2023). This shows the efficiency of such training regimens in modifying physiological adaptation directly translatable to the sport-related requirements.

Besides body composition and aerobic adaptations, muscular power was also improved significantly, as shown by the study. The experimental group performed better in vertical jumps, medicine ball throws, and sprint tests in comparison with the control group. The results are in line with those of previous research that had demonstrated CrossFit training as one of the most effective training methods to build explosive power, upper-body strength, trunk stability, all of which are potent capabilities in basketball-specific movements that include rebounding and making sudden shifts in direction (Cui, 2024; Costa et al., 2021). In addition, the variety and scale of CrossFit activities are proven to provide the equivalent or even better results in contrast to the conventional resistance or endurance exercise regimes (Alzohary et al., 2024; Costa et al., 2021).

In addition to physical results criteria, the research highlights the applicability of CrossFit training to a more diverse range of populations and situations. In another example, the area with high school students taking part in distance CrossFit training demonstrated considerable enhancement of the core endurance, muscle strength, and overall stamina based on the improvements in the plank holds and squats (Vypasniak et al., 2024). Likewise, students at the universities with no age or training conditions found improvements in functional fitness, flexibility, and cardiovascular health after interventions involving

CrossFit (Pryimakov et al., 2023). The above results document the multidimensional adaptability of CrossFit as a system of training that can cover a wide range of fitness objectives on top of promoting systemic metabolic wellness and muscle endurance (Alsharab et al., 2024; Cui, 2024).

Finally, the synergistic interaction between physiological adaptations and sport-specific performance further validates the utility of CrossFit in athletic training (Borkar & Badwe, 2023; Hodžić et al., 2023). By combining compound movements with progressive overload, CrossFit enhances neuromuscular activation, increases oxygen delivery to muscles, and improves exercise tolerance—all of which contribute to superior performance in sports requiring intermittent high-intensity efforts, such as basketball (Zhang & Miao, 2023; Gianzina & Kassotaki, 2019). Collectively, these results reinforce the potential of CrossFit as an effective approach for optimizing general fitness levels and technical execution in basketball athletes (Yakoviv & Melnyk, 2023; Posnakidis et al., 2022).

Implications for sport Institutions

The practical consequences of the investigation are of great help to athletic trainers, coaches, and basketball players in defining an effective training program to improve physical and physiological performance. The results show that including the training methodologies based on CrossFit can lead to significant advances in the most important areas that are vital to basketball performance. In the first place, the whole program resulted in significant improvements in body composition, among them being a significant decrease in body fat percentage (BFP) and an elevation in fat-free mass (FFM). The basketball players must pay special attention to these changes since they directly affect power-to-weight ratios, agility, and general mechanical efficiency on the court. Specifically, reduced body fat levels lead to more acceleration and deceleration rates when the direction must be changed quickly, whereas high lean body mass helps to perform explosive activities, like jumping or sprinting.

Secondly, the study showed that the indicators of muscular power increased significantly (vertical jump height and medicine ball throw performance). These modifications are necessary to build skills that are unique to basketball, including rebounding, shot swatting, and rapid defensive reconfiguration. Through the incorporation of exercises such as Olympic lifts, plyometrics, and functional training in training programs, the body will be able to build neuromuscular coordination and capacity to deliver power during high-intensity maneuvers during games. Thirdly, the intervention led to an improvement of physiological adaptations such as a higher maximal oxygen uptake (VO2 max) and an increase in respiratory capacity. These results are important in maintaining high-level repeated activities during a basketball match. Increased aerobic and anaerobic capacities enable the players to recuperate faster during periods of intensive activity and to sustain their performance level better throughout the game event and adverse effects of fatigue. What is more, the blend of aerobic and anaerobic fitness in CrossFit can be well complemented by the intermittent style of basketball, in which the game follows the pattern of high-intensity work and brief break spurts.

Moreover, the study also pointed to enhanced motor skills, especially rebounding and footwork. Such skills are the most vital part of the game called basketball and demand some of the power, balance, coordination, and agility. Coaches can achieve this more by using sports-specific drills, as well as the use of functional training aids, which include the TRX suspension systems, kettle weights, and plyometrics. As an example, TRX exercises help to improve core stability and upper-body strength, which are essential to achieve stability in contact situations or to challenge the rebounds. On the same note, kettlebell training and functional jump achieve the same benefits by enhancing lower-body explosiveness and dynamic movement skills, which allow players to make quick lateral moves and explosive jumps through the game. Finally, this outcome stresses the need to design CrossFit programs considering basketball necessities. Although the CrossFit exercise system provides a flexible and intense conditioning program, one should consider the specificities of the kind of sports, which include, but are not limited to, vertical jumping power, lateral speed, and injury prevention. To evade the risk of musculoskeletal injury, coaches should thoughtfully plan workouts that primarily focus on multi-joint compound exercises, simulate game-related conditions, and progressively overtrain players. Additional safety and effectiveness can be achieved by introducing such elements as mobility work, flexibility training, and individualization.

Study Limitations and Future study

Although the findings of this study provided good evidence of positive changes in the variables of interest, there are a few limitations that need to be noted in the accurate interpretation of the study and careful generalization. First, the sample size used to conduct the study was quite small, as there were only 32 participants. It is also possible that this small sample can impact statistical strength of findings as well as limit the possibility of generalizing the findings to generalize the findings to a wider group of basketball players. The next research is the expansion of the sample and its diversity to increase the reliability and external validity of the findings. Second, all the subjects of the study were males, thereby limiting the generalizability of the results to women athletes. Given the difference between the genders in terms of physiology and performance, it is vital to come up with more studies that involve both men and women to identify whether the same response to training can be seen between genders. Third, the length of the intervention was rather short and was eight weeks long. Although major improvements have been noted over this period, it is still not evident how the incorporation of CrossFit training in basketball will change over the long run. Future studies are needed to examine the effects of long-term training to define whether long-term exposure to CrossFit results in long-term or even further physiological and performance changes.

Fourth, environmental and lifestyle influences that may have some interference with physical performance and adaptation, such as diet, sleep quality, stress levels, and overall mental health, were not controlled in the paper. The study might have involved these variables, and they have the possibility of biasing the results because they are not controlled. In future studies, more stringent measures on these factors must be adopted to evaluate the effect of the training program. Lastly, the participants sampled were within one geographic location (Al-Ahsa, which restricts the geographical and cultural variety of a sample. This local app tends to decrease the generalizability of findings in other populations, which may not share some environmental, cultural, or training experiences. Inclusion of participants in future study whose region of origin would be included in a range of other regions would present an incentive to gain a broader picture of the program behavior by its contexts of use in the different regions. In short, the study is a rich source of information on the advantages of CrossFit in basketball players; however, the limitations described can be considered when further scholars research to improve their depth, scope, and generalizability by eliminating the mentioned issues.

Conclusions

This study proved that CrossFit training could be used as one of the effective tools in enhancing physical and physiological performance in basketball players, and it was therefore an asset to athletic training regimen. Within eight weeks, the program has shown a great enhancement in a variety of factors, such as body composition, along with musculature power and even physiological changes. It also played a huge part in the formation of basketball-specific skills like rebounding and footwork. Moreover, the diversity of the exercises included in this regimen, being a complex of weight training, plyometrics, and aerobics, offers comprehensive stimulation to the body and mind, resulting in improvements in the performance of the entire athlete. Moreover, the research highlighted the necessity of making special training programs, which must be adjusted to the requirements of kinds of sports. To illustrate, by homing in on vertical jumps, side lunges, and quick acceleration, the player can directly affect the performance in basketball. Moreover, the usage of tools (TRX, kettlebells, and functional training) could be helpful to increase the efficiency of dynamic movements on the court. Nevertheless, these results need to be interpreted through several weaknesses, including the insignificant sample size, the fact that only males were included, and the comparatively short term that the intervention lasted. These constraints allow introducing the future in studying the effect of long-term programs, their application to greater and more heterogeneous samples, such as females, as well as determining the effects of environmental and psychological aspects on performance. Overall, the current research is serious scientific proof that CrossFit may be used as a powerful means of enhancing overall fitness and sports performance in basketball. Nevertheless, coaches and practitioners are to plan their programs to consider the specific needs of each player and minimize the chance of the emergence of potential injuries as well as enhance long-term adaptation.

Acknowledgements

The author would like to thank all the individuals who contributed to the success of this study. I also extend my sincere gratitude to King Faisal University, which provided me with the necessary financial support, without which I would not have been able to complete this research.

Financing

This study was funded by the Deanship of Scientific Research at King Faisal University, Saudi Arabia, grant number (GRANT KFU252306).

References

Alsharab, O., Triki, R., Jebabli, N., Khalfoun, J., Zouhal, H., & Ben Abderrahman, A. (2024). Effects of a CrossFit training program on body composition and hematological parameters in young soccer players. Advances in Social Sciences Research Journal, 11 (3), 283–294. https://doi.org/10.14738/assrj.113.16543

Altavilla, G., & Raiola, G. (2014). Global vision to understand the game situations in modern basketball. Journal of Physical Education and Sport (JPES), 14 (4), 493–496. https://doi.org/10.7752/jpes.2014.04075

Alzohary, A., Al-Sayed Abdel Aal, M., & Salim, E. (2024). The effects of CrossFit training on the development of some elements of physical and functional fitness and the level of performance on the floor movement apparatus. Mağallat Taṭbīqat ʿUlūm Al-Riyāḍaẗ, 14 (2), 15–23. https://doi.org/10.21608/jass.2024.290637.1006

Beitia, P., Stamatis, A., Amasay, T., & Papadakis, Z. (2022). Predicting firefighters' physical ability test scores from anaerobic fitness parameters & mental toughness levels. International Journal of Environmental Research and Public Health, 19 (22), 15253. https://doi.org/10.3390/ijerph192215253

Bendo, A., Brovina, F., Bushati, S., Salllaku, D., Bushati, M., & Papa, E. (2024). The effect of high interval intensity training (HIIT) on the performance of basketball players 10–15 years old. *Retos, 62,* 627–636. https://doi.org/10.47197/retos.v62.109315

Besada, I., & Pizarro, D. (2024). Efectos del Crossfit© en la educación física durante la educación secundaria obligatoria: Una revisión sistemática. *Retos, 62* , 1072–1084. https://doi.org/10.47197/retos.v62.107737

Borkar, P., & Badwe, A. N. (2023). A study to determine the effect of 12 weeks sports specific training program on physical and physiological variables in amateur basketball players – A randomized controlled trial. International Journal of Health Sciences and Research , 13 (7), 280–289. https://doi.org/10.52403/ijhsr.20230740

Buckthorpe, M., Morris, J., & Folland, J. P. (2012). Validity of vertical jump measurement devices. Journal of Sports Sciences , 30 (1), 63–69. https://doi.org/10.1080/02640414.2011.624539

Cabrera Linares, J. C., Latorre Román, P. Á., Párraga Montilla, J. A., Martínez Salazar, C., & Espinoza Silva, J. M. (2024). Is high intensity interval training (HIIT) a feasible method for improving anthropomorphic and cardiometabolic parameters in preschool children? *Retos , 61 ,* 792–800. https://doi.org/10.47197/retos.v61.107878

Camacho-Cardenosa, A., Timón, R., Camacho-Cardenosa, M., Guerrero-Flores, S., Olcina, G., & Marcos-Serrano, M. (2020). Six months of CrossFit improves metabolic efficiency in young trained men. Cultura, Ciencia y Deporte , 15 (45), 421–427. https://doi.org/10.12800/CCD.V15I45.1519

Corredor-Serrano, L. F., & García-Chaves, D. C. (2023). Composición corporal, fuerza explosiva y agilidad en jugadores de baloncesto profesional. *Retos, 49*, 189–195. https://doi.org/10.47197/retos.v49.96636

Costa, F., Parodi Feye, A. S., & Magallanes, C. (2021). Efectos del entrenamiento de sobrecarga tradicional vs CrossFit sobre distintas expresiones de la fuerza. *Retos, 42,* 182–188. https://doi.org/10.47197/retos.v42i0.86132

Cui, L. (2024). The effects of CrossFit training program on promoting physical fitness towards a training program for Guangdong University Basketball League players . International Journal of Education and Humanities , 14 (3), 334–338. https://doi.org/10.54097/8ycfrv95

De Alemida, R. M. M., Barreto, B. C. T., Bolognese, A. M., de Castro, A. C. R., de Araújo, L. F. C., & de Souza, M. M. G. (2023). CrossFit, Olympic weightlifting, powerlifting and strongman: High-intensity sports and their relationship with the stomatognathic system. Observatório de la Economía Latinoamericana , 21 (7), 6612–6630. https://doi.org/10.55905/oelv21n7-043

Dexheimer, J. D., Schroeder, E. T., Sawyer, B. J., Pettitt, R. W., Aguinaldo, A. L., & Torrence, W. A. (2019). Physiological performance measures as indicators of CrossFit® performance. Sports , 7 (4), 93. https://doi.org/10.3390/sports7040093

Elkeky, A., Ayman, M., Esmail, M., Mohamed, H., & Alkhaldy, F. (2020). The effect of using cross training on improving some of the physical abilities of basketball players and its relationship to the biochemical variables. Journal of Advanced Sport Sciences , 10 (1), 120–133. https://doi.org/10.21608/JASS.2021.63020.1029

Fabrin, S., Palinkas, M., Evandro, Fioco, M., Gomes, G. G. C., Regueiro, E. M. G., Gabriel, da Silva, P., Siéssere, S., Verri, E. D., & Regalo, S. C. H. (2023). Functional assessment of respiratory muscles and lung capacity of CrossFit athletes. Journal of Exercise Rehabilitation, 19 (1), 67–74. https://doi.org/10.12965/jer.2244594.297

Feito, Y., Heinrich, K. M., Butcher, S. J., & Poston, W. S. C. (2018). High-intensity functional training (HIFT): Definition and research implications for improved fitness. Sports, 6 (3), 76. https://doi.org/10.3390/sports6030076

Gianzina, E. A., & Kassotaki, O. A. (2019). The benefits and risks of the high-intensity CrossFit training. Sport Sciences for Health , 15 (1), 21–33. https://doi.org/10.1007/s11332-018-0521-7

Goenarjo, R., Dupuy, O., Fraser, S., Berryman, N., Perrochon, A., & Bosquet, L. (2021). Cardiorespiratory fitness and prefrontal cortex oxygenation during Stroop task in older males. Physiology & Behavior , 242 , 113621. https://doi.org/10.1016/j.physbeh.2021.113621

Gonzalez, M. C., Orlandi, S. P., & Santos, L. P. (2019). Body composition using bioelectrical impedance: Development and validation of a predictive equation for fat-free mass in a middle-income country. Clinical Nutrition , 38 (5), 2175–2179. https://doi.org/10.1016/j.clnu.2018.09.012

Haff, G. G., & Dumke, C. (2018). Laboratory manual for exercise physiology (2nd ed.). Human Kinetics. ISBN: 978-1-4925-3694-9

Hassan, A. K., Alhumaid, M. M., & Hamad, B. E. (2022). The effect of using reactive agility exercises with the FITLIGHT Training System on the speed of visual reaction time and dribbling skill of basketball players. Sports , 10 (11), 176. https://doi.org/10.3390/sports10110176

Hassan, A. K., Bursais, A. K., Alibrahim, M. S., Selim, H. S., Abdelwahab, A. M., & Hammad, B. E. (2023). The impact of core complex training on some basketball-related aspects of physical strength and shooting performance. European Journal of Investigation in Health, Psychology and Education , 13 (9), 1624–1644. https://doi.org/10.3390/ejihpe13090118

Hodžić, D., D'Hulst, G., Leuenberger, R., Arnet, J., Westerhuis, E., Roth, R., Schmidt-Trucksäss, A., Knaier, R., & Wagner, J. (2023). Physiological profiles of male and female CrossFit® athletes. bioRxiv , 1–29. https://doi.org/10.1101/2023.10.11.561828

Hoyos-Manrique, J. E., Arango Paternina, C. M., & Patiño Villada, F. A. (2024). Motivos para la práctica de CrossFit en los usuarios de un centro afiliado. Cuadernos de Psicología del Deporte , 24 (2), 180–192. https://doi.org/10.6018/cpd.607291

Kicanovic, L. J., Živanović, B., Vukadinović Jurišić, M., & Obradović, J. (2022). Effects of CrossFit training program and traditional gym training on morphological characteristics of men. Exercise and Quality of Life , 14 (2), 13–19. https://doi.org/10.31382/eqol.221202

Kolachahi, S. A., Elmieh, A., & Talebi, M. (2020). The effect of TRX exercises on serum levels of IGF-1 and cortisol and some health-related physical factors in active women. Medical Science Journal of Islamic Azad University - Tehran Medical Branch, 30 (4), 432–442. https://doi.org/10.29252/IAU.30.4.432

Li, W., Liu, Y., Deng, J., & Wang, T. (2024). Basketball-specific agility: A narrative review of execution plans and implementation effects. Medicine, 103 (6), e37124. https://doi.org/10.1097/md.0000000000037124

Martínez-Gómez, R., Valenzuela, P. L., Alejo, L. B., Gil-Cabrera, J., Montalvo-Pérez, A., Talavera, E., Lucia, A., Moral-González, S., & Barranco-Gil, D. (2020). Physiological predictors of competition performance in CrossFit athletes. International Journal of Environmental Research and Public Health , 17 (10), 3699. https://doi.org/10.3390/ijerph17103699

Meier, N., Schlie, J., & Schmidt, A. (2023A). Physiological effects of regular CrossFit® training and the impact of the COVID-19 pandemic—A systematic review. Frontiers in Physiology, 14 , 1146718. https://doi.org/10.3389/fphys.2023.1146718

Meier, N., Schlie, J., & Schmidt, A. (2023B). CrossFit®: "Unknowable" or predictable? A systematic review on predictors of CrossFit® performance. Sports, 11 (6), 112. https://doi.org/10.3390/sports11060112

Menargues-Ramírez, R., Sospedra, I., Holway, F. E., Hurtado-Sánchez, J. A., & Martínez-Sanz, J. M. (2022). Evaluation of body composition in CrossFit® athletes and the relation with their results in official training. International Journal of Environmental Research and Public Health, 19 (17), 11003. https://doi.org/10.3390/ijerph191711003

Moscatelli, F., Messina, G., Polito, R., Porro, C., Monda, V., Monda, M., Scarinci, A., Dipace, A., Cibelli, G., Messina, A., & Valenzano, A. (2023). Aerobic and anaerobic effect of CrossFit training: A narrative review. Sport Mont Journal , 21 (1), 123–128. https://doi.org/10.26773/smj.230220

Ningrum, D. T. M., Hafizah, H., Setyawan, D. A., & Mahyudi, Y. V. (2025). Effect of structured physical activity programs on physical fitness and body composition among junior high school students: A randomized controlled trial. *Retos, 68* , 249–257. https://doi.org/10.47197/retos.v68.111620

Oliver-López, A., García-Valverde, A., & Sabido, R. (2022). Summary of the evidence on responses and adaptations derived from CrossFit training: A systematic review. Retos: Nuevas Tendencias En Educación Física, Deportes y Recreación, 46, 309–322. https://doi.org/10.47197/retos.v46.93442

Perciavalle, V., Marchetta, N. S., Giustiniani, S., Borbone, C., Perciavalle, V., Petralia, M. C., Buscemi, A., & Coco, M. (2016). Attentive processes, blood lactate and CrossFit®. Physician and Sportsmedicine , 44 (4), 403–406. https://doi.org/10.1080/00913847.2016.1222852

Perna, S., Bologna, C., Agosti, I., & Rondanelli, M. (2016). High-intensity CrossFit training compared to high-intensity swimming: A pre-post trial to assess the impact on body composition, muscle strength and resting energy expenditure. Asian Journal of Sports Medicine, 9 (1), e13843. https://doi.org/10.5812/asjsm.13843

Ponce-García, T., García-Romero, J., Carrasco-Fernández, L., Castillo-Domínguez, A., & Benítez-Porres, J. (2024). The association of whole and segmental body composition and anaerobic performance in CrossFit® athletes: Sex differences (Unpublished manuscript). Preprints, 2024072029. https://doi.org/10.20944/preprints202407.2029.v1

Posnakidis, G., Aphamis, G., Giannaki, C. D., Mougios, V., & Bogdanis, G. C. (2022). The addition of high-load resistance exercises to a high-intensity functional training program elicits further improvements in body composition and strength: A randomized trial. Sports, 10 (12), 207. https://doi.org/10.3390/sports10120207

Pryimakov, O., Prysiazhniuk, S., Korobeynikov, G., Oleniev, D., Polyvaniuk, V., Mazurok, N., & Omelchuk, O. (2023). Improvement of students' physical fitness in physical education classes using CrossFit means. Physical Education of Students, 27 (2), 71–78. https://doi.org/10.15561/20755279.2023.0203

Putro, B. N., Cahyanto Wibawa, J., Ayubi, N., Dafun Jr, P. B., & Wen Ming, J. (2025). Physiological concept of plyometric training to improve physical fitness of basketball players: A systematic review. *Retos, 66,* 1000–1010. https://doi.org/10.47197/retos.v66.113684

Ramos de Amorim, L., Dudel Mayer, B. L., & Claudino, R. (2023). Raising plantar pressures in CrossFit® practitioners: Assessment before and after training. Ibero-American Journal of Podology, 5 (1), E0652023-1. https://doi.org/10.36271/iajp.v5i1.65

Ricart Luna, B., Monteagudo Chiner, P., Pérez Puchades, V., Cordellat Marzal, A., Roldán Aliaga, A., & Blasco Lafarga, C. (2020). Cambios en fuerza explosiva y agilidad tras un entrenamiento online en jóvenes jugadores de baloncesto confinados por COVID-19. *Retos, 41,* 256–264. https://doi.org/10.47197/retos.v41.83011

Ryadova, L. O., Rozhkov, V. O., Shuteev, V. V., Tikhonova, A. O., Yevarnytskyi, I. A., & Kramarenko, V. I. (2023). General characteristics and historical aspect of the establishment of the game of basketball on the territory of Ukraine. Scientific Journal of Mykhailo Drahomanov Ukrainian State University, 6 (166), 139–144. https://doi.org/10.31392/NPU-nc.series15.2023.6(166).30

Saini, H. K. (2019). Relationship of plyometric and circuit training with explosive strength and agility of Punjab state basketball players. International Journal of Physical Education, Sports and Health, 4 (1), 36–38. https://www.journalofsports.com/archives/2019/vol4/issue1/3-2-294

Schutte, N. M., Nederend, I., Hudziak, J. J., Bartels, M., & de Geus, E. J. (2016). Twin-sibling study and meta-analysis on the heritability of maximal oxygen consumption. Physiological Genomics, 48 (3), 210–219. https://doi.org/10.1152/physiolgenomics.00117.2015

Selvamoorthy, R., Macgregor, L. J., Donald, N., & Hunter, A. M. (2024). Dryland performance tests are not good predictors of world aquatics points in elite male and female swimmers. Sports, 12 (4), 104. https://doi.org/10.3390/sports12040104

Shamim, P. (2021). The impact of high-intensity interval training (HIIT) on basketball-specific performance and physiological adaptations. International Journal of Physiology, Nutrition and Physical Education , 6 (1), 435–441. https://doi.org/10.22271/journalofsport.2021.v6.i1g.2966

Stanković, M., Čaprić, I., Đorđević, D., et al. (2023). Relationship between body composition and specific motor abilities according to position in elite female soccer players. International Journal of Environmental Research and Public Health, 20, 1327. https://doi.org/10.3390/ijerph20021327

Tong, T. K., Wu, S., & Nie, J. (2014). Sport-specific endurance plank test for evaluation of global core muscle function. Physiotherapy Theory and Practice, 15 (1), 58–63. https://doi.org/10.1016/j.ptsp.2013.03.003

Vypasniak, I., Nesen, O., & Jagiello, M. (2024). Enhancing physical fitness through CrossFit for 15–16-year-old high school students. Physical Culture, Recreation and Rehabilitation, 3 (1), 10–15. https://doi.org/10.15561/physcult.2024.0102

Yakoviv, V., & Melnyk, S. A. (2023). Development of strength qualities of throwers in track and field athletes using CrossFit tools. Naukovij Časopis Nacional'nogo Pedagogìčnogo Universitetu Imenì M.P. Dragomanova, 4 (163), 216–221. https://doi.org/10.31392/npu-nc.series15.2023.04(163).40

Yogavarthini, S. T., Jothilingam, M., Murugan, P. V., & Anbarason, A. (2024). Effect of CrossFit training during post-season of track and field athletes. Indian Journal of Physiotherapy & Occupational Therapy - An International Journal, 18 (5), 243–248. https://doi.org/10.37506/mx67tf31

Zhang, M., Miao, X., Rupčić, T., Sansone, P., Vencúrik, T., & Li, F. (2023). Determining the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting accuracy in professional female basketball players. Applied Sciences, 13 (15), 8624. https://doi.org/10.3390/app13158624

Zhao, K., Siener, M., Zhao, Y., & Hohmann, A. (2023). Physical fitness and motor competence performance characteristics of Chinese elite youth athletes from four track and field throwing disciplines—a cross-sectional study. Frontiers in Physiology, 14, 1267804. https://doi.org/10.3389/fphys.2023.1267804

Author and translators' details:

Ahmed K. Hassan	amohhamed@kfu.edu.sa	Author