ACTA GYMNICA, 2024, Volume 54, Article e2024.010
https://doi.org/10.5507/ag.2024.010

OPEN ACCESS

ORIGINAL RESEARCH

Effects of CrossFit training on muscular strength, speed, agility, and VO_{2max} in young soccer players

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Abstract

Background: Over the past few decades, CrossFit has become a very popular physical activity. However, there is little literature on its effect, as resistance training, on the performance of soccer players. **Objective:** This study examined the effects of 12 weeks of CrossFit training on muscular strength, speed, agility, and VO_{2max} in young male soccer players. **Methods:** Thirty-eight soccer players were divided randomly into the experimental group (n = 19, age 17.32 ± 1.02 years, body height 1.76 ± 0.15 m, body mass 63.24 ± 5.68 kg, body mass index 21.34 ± 1.32 kg/m^2) and control group (n = 19, age 17.21 ± 1.70 years, body height 1.74 ± 0.16 m, body mass 63.43 ± 5.21 kg, body mass index 21.45 ± 1.21 kg/m^2). Both groups underwent 12 weeks of the usual soccer training program, including physical exercises on a regular basis, three times a week. Additionally, in the experimental group, a training program based on high-intensity functional physical activity was added during each training session as part of the usual weekly training regimen. Pre- and post-intervention tests were performed to measure player performance, including 30-m sprint, Yo-Yo intermittent recovery test level 1, vertical jump, agility T-test, sit-ups, and push-ups during 60 s. **Results:** A significant group x time effect was found for all tests: 30-m sprint (p = .012, η_p^2 = .42), Yo-Yo test (p = .029, η_p^2 = .23), vertical jump (p = .002, η_p^2 = .46), T-test (p = .002, η_p^2 = .21), sit-ups (p < .001, η_p^2 = .55), push-ups (p = .001, η_p^2 = .25). The improvement was higher in the experimental group for all variables. **Conclusions:** CrossFit training is an effective strategy for improving the physical capacities in young soccer players.

Keywords: Fran CrossFit, high-intensity interval training, physical fitness, team sport, football

Introduction

Soccer is the most popular sport in the world regardless of origin and geographic region (Hammami et al., 2013). It is characterized by high-intensity critical events that are installed on an aerobic base of less intense activity and comfort (Hulton et al., 2022), where data indicate high competitiveness in soccer activities (Hammami et al., 2013) as a complex and inclusive team sport (Dolci et al., 2020). It has a large, high speed and fierce confrontation (Zhou et al., 2022). This means that physical ability is a necessary condition and a basic need for improving performance, which cannot be postponed or negotiated (Zhou et al., 2022).

In contemporary soccer, each player must be able to switch from a fast-attacking position to a defensive position. Physical factors and physiological abilities are also very important in soccer (Song et al., 2019) and, therefore development of physical fitness (Bonavolontà et al., 2021; Carvutto et al., 2021). Marín-Pagán et al. (2020) asserted that strength, speed, and agility are essential aspects of a soccer's performance, as they are the basis for performance of various movements such as high speed, short-motion (Hulton et al., 2022), change of direction (Di Domenico & D'Isanto, 2019), and variability (Hung et al., 2020). Many training techniques have been developed to increase fitness among soccer players, yet these training methods vary according to the goal of training (Lee & Joo, 2020). Saidi et al. (2020) emphasized that training programs must be tailored and address physical features such as aerobic capacity, strength, ability, and speed of direction change.

In recent years, CrossFit has been recognized as one of the fastest growing high-intensity job training modes in the world (Claudino et al., 2018; Mauring, 2021). Thus, it has gained increasing attention from the academic community as a means of combating limited athlete time and training availability (Mauring, 2021). In fact, CrossFit is a high-intensity functional physical activity (HIFT), which is characterized by varied training volume and intensity in different exercises (Teixeira et al., 2020). This training process relies on a pre-set time limit to complete a certain

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Article history: Received January 9 2024, Accepted September 9 2024, Published October 9 2024

number of repetitions with or without a recovery period (Sprey et al., 2016). It also aims to preserve and improve physical condition (Toledo et al., 2021). Therefore, HIFT was a combination of specific exercises, including aerobic exercise (i.e., running), gymnastics (i.e., exercises with body weight such as pull-ups, push-ups, squats, or box jumps), and weightlifting. According to previous research, HIFT training enhances a variety of physical qualities, including strength, endurance, and aerobic fitness (Toledo et al., 2021). Some literature suggests that CrossFit training may be effective in developing abilities that require maximum strength, long endurance, or mixed performance in short-term and long-term programs (Schlegel, 2020).

HIFT exercises may also increase VO_{2max} and improve body composition (Choi et al., 2017; Wagener et al., 2020), due to stress being performed and stimulation in muscle activation occurring (Wagener et al., 2020).

Therefore, the purpose of this study was to investigate the effect of 12-week CrossFit training on physical fitness variables (muscle strength, speed, agility, and VO2max) in young soccer players. According to previous studies (Teixeira et al., 2020; Toledo et al., 2021); we hypothesize that fitness will be significantly better after 12 weeks of adding HIFT compared to usual soccer training.

Methods

Participants

The study involved 38 young male Tunisian sub-elite soccer players who compete at a national U17-U18 level. They were all team soccer players from the same club in the second division Tunisian soccer league. Among the 38 participants, there were thirteen defenders, twelve midfielders, five wingers, and eight forwards. Players were divided randomly into two groups, the experimental group (EG; n = 19, age 17.32 ± 1.02 years, body height 1.76 ± 0.15 m, body mass 63.24 ± 5.68 kg, body mass index 21.34 ± 1.32 kg/m^2) and the control group (CG; n = 19, age 17.21 ± 1.70 years, body height 1.74 ± 0.16 m, body mass 63.43 ± 5.21 kg, body mass index 21.45 ± 1.21 kg/m^2). All players in the study who had a history of musculoskeletal injuries in the previous six months or cardiorespiratory diseases were excluded. The players reported that they did not use any ergogenic aids or medications that could affect their performance.

Participants and their parents signed written informed consent after explaining the purpose, potential risks, and study procedures. Each participant was required to obtain an official medical clearance from the government agency of the Ministry of Health as an indicator of positive health conditions and the possibility of participating in the training program. The players cannot participate in any other training during the study. The experimental protocol was approved by the local ethics committee of the Performance Optimization Laboratory (LR09SEP01), National Center of Medicine and Sports Sciences, Tunis, Tunisia. All procedures were implemented in accordance with the Helsinki Declaration (2013).

Experimental design

Twelve weeks of training program with two test sessions (pre-and post-training test) occured during the preparation period from July 2021 to October 2021 to control external factors and integrate them with the training system.

The two groups underwent 12 weeks of two different types of training programs with three sessions/week (Sunday, Tuesday, Thursday), 60 min/session. The exercise protocol included 10 min of technical instructions, 10 min of dynamic warm-up (low intensity running, stretching exercises), 10 to 20 min of technical exercises, 20 min of specific exercises (HIFT or usual training), and 5 min of calming exercises with stretching to return the body to its normal condition. During the 20 min of specific exercises (HIFT or usual training), the EG underwent specific exercises of HIFT as part of the usual weekly training regimen, without any adjustment of the CG. All training took place in an artificially lawn open-air soccer field and at a temperature-controlled gym.

Participants took part in both pre-and post-training tests, evaluated at the same time of day and under the same experimental conditions through three days separated by 24 hr:

1. the first session for anthropometrical measurements,
2. the second session for the agility T-test, 30-m sprint, and vertical jump test,
3. the third session for push-ups and sit-ups during 60 s and Yo-Yo intermittent recovery test level 1.

Players were asked to standardize and follow the same nutritional plan 24 hr before each testing session to minimize diet-related changes in performance.

Fran CrossFit style program

The CrossFit program was a combination of aerobic exercise (including cardio-exercise such as running), gymnastics (including exercises with body weight such as pull-ups, push-ups, squats, and box jumps), and weightlifting (deadlift and bench press at 50% of one-repetition maximum). The intensity of exercise, repetitions, sets, distance, and recovery were supervised by a specialist during all sessions. The training program focused on strengthening the muscles of the body in general and on some of the muscles most commonly used in soccer, such as the back, abdomen, chest, and thighs. All exercises were performed alternately for 3 rounds of 21, 15, and 9 repetitions for each round using Fran style workout (Zeitz et al., 2020).

Anthropometric measurements

Participants' body composition was measured before the start of the experiments in the morning, three hours after waking up, and in a fasting state. Body height was measured using a fixed stadiometer (seca 213, seca, Hamburg, Germany) to the nearest 0.5 cm. Body mass was measured using Tanita BC-418 MA (Tanita, Tokyo, Japan). The body mass index was calculated as body mass per body height squared (kg/m^2).

Speed – 30-m sprint

The sprint tests began with 10 min warm-up. A straight section 30 m long was defined by the examiner using paired photocells (Witty System, Microgate, Bolzano, Italy) to measure the time to the nearest 0.01 s. Players then ran for 30 m from a standing position at the starting photocell beam. Three trials were separated by 6–8 min recovery periods, and the examiner chose the best time for the analysis (Karsten et al., 2016).

Power – vertical jump

After 10 min warm-up, players were told to take to the same ready position, hold it for a short while, and then receive the countdown "3, 2, 1, Jump!", followed by a maximum height countermovement jump. The jump was performed with shoes and hands on the hips. All players performed three jump trials with a 60 s rest between each trial to choose the highest jump for analysis. The height of the jump was measured with wearable inertial measuring units (Sensor DX3.1, Humotion, Müenster, Germany) attached to a harness on the players' backs. All players performed their vertical jumps in the same order (Rahlf et al., 2020).

Agility – T-test

The test was performed on an outdoor soccer field using cones to specify each distance. The participant starts with a standing position behind a starting cone A. At the signal, the participant sprints 9.14 m to cone B and touches the base of the cone with their right hand, then turns left and alternates sideways, running 4.57 m to cone C, also touching its base with their left hand. Then runs 4.57 m sideways to the right to cone D and touches the base with the right hand. Then returns to cone B and touches it with the left hand, running backward to cone A. The time starts when passing through the time gates and stops when returning (Karahan, 2020). The time was recorded using a photocell timing system (Witty System, Microgate, Bolzano, Italy) to the nearest 0.01 second. The test was repeated twice with an active recovery period duration of 2 min, and the best performance was used for analysis.

Sit-ups

To assess abdominal muscle strength and endurance, the participant starts in a lying position on their back with knees bent, feet flat on the floor with an appropriate opening. The arms are crossed over the chest. The lower legs or ankles are held by a teammate or another player. On the "Go!" command, the participant raises the upper body forward until the elbows or forearms touch the thighs and then returns with a full torso to the ground until the shoulder blades touch the ground. The participant repeats the lifting and lowering as many times as possible correctly for 60 s. Throughout the test, the buttocks must stay in consistent contact with the floor; hopping and filling of the lower back are not permitted. Rest during the exercise is permitted in either the upper or lower position. The number of correct times during the test period was counted in two trials and the best trial was used as the test score (Abarghoueinejad et al., 2021).

Push-ups

To measure muscular strength for the arms and shoulders, the participant starts with plank position, hands and toes touching the floor, back and legs in a straight line, feet slightly apart, arms shoulder-width apart and extended at right angles to the body. When the starting signal is given, the participant proceeds to lower their bodies until their chest and thighs touch the ground and then return to the starting position with their arms outstretched. This procedure is repeated for 60 s. The number of correct times during the test period was counted in two trials, and the best trial was used as the test result (Cosgrove et al., 2019).

Yo-Yo intermittent recovery test level 1

To measure endurance and maximum oxygen consumption (VO_{2max}), the Yo-Yo intermittent recovery test level 1 consisted of running a 20-m shuttle back and forth between two lines, with a gradual increase in speed over time. A 5-m sprint recovery area was set behind the starting line, with participants given 10 s of recovery after each bout of the shuttle run. Playback speed was controlled by digital beeps from a laptop computer. The running speed of the first four bouts (0–160 m) was set at 10–13 km/h, and the subsequent seven bouts (160–440 m) were at 13.5–14 km/h. After the 11th bout, the running speed was increased in increments of 0.5 km/h every eight rounds (i.e., after 760 m, 1080 m, 1400 m, 1720 m, etc.). When subjects failed to reach the finish line in time on two occasions, the distance traveled was recorded and represented the final score. The test was administered only once. The expected maximum oxygen consumption for each participant was calculated by the formula (Hung et al., 2020):

distance in meters * 0.0084 + 36.4.

Statistical analysis

Data were expressed as mean values and standard deviations. IBM SPSS (Version 25; IBM, Armonk NY, USA) was used for all statistical tests. A statistical significance for all analyses was set at $p < .05$. Data distribution normality was confirmed using the Kolmogorov-Smirnov test. All parameters measured before and after the intervention (T1 vs. T2) and between the two groups (EG vs. CG) were compared with a two-way analysis of variance. Additionally, post hoc tests were computed using Bonferroni adjustments to identify group-specific changes over time in case of significant group-by-time interactions. Partial eta-squared (η_p^2) was used as the measure of the effect size for the simple main effects and interaction effect, respectively, and defined as small (.01), medium (.06), and large (.14; Hopkins et al., 2009). The relative change of all variables was also calculated to establish changes between pre- and post-tests using the formula:

(final value – initial value)/(initial value) * 100.

Results

All participants completed the study with 100% adherence to the procedures. No injuries were observed or reported

during the experimental period. The results of the statistical analysis are presented in Table 1.

Both groups presented significant improvement for all tests ($p < .05$); however, a significant group x time effect between the two groups on all tests was observed: 30-m sprint ($p = .012$, $\eta_p^2 = .42$), Yo-Yo test ($p = .029$, $\eta_p^2 = .23$), vertical jump ($p = .002$, $\eta_p^2 = .46$), T-test ($p = .002$, $\eta_p^2 = .21$), sit-ups ($p < .001$, $\eta_p^2 = .55$), push-ups ($p = .001$, $\eta_p^2 = .25$). Results showed higher improvement for all variables in the EG.

Discussion

The purpose of this study was to examine the effects of regular Fran CrossFit training, using the CrossFit program, on some physical fitness variables in young soccer players. A 12-week intervention using CrossFit was compared with a control group that performed only regular field training program sessions. In agreement with our research hypothesis, the main findings showed that the CrossFit exercisers provided significantly better results than the control group on all physical capacity tests after the intervention period. In addition, the within-group analysis showed that both groups significantly improved in all tests of physical fitness, with better results in the CrossFit group.

Muscle strength

With regard to the current study, the results of the physical fitness of the participants in the CrossFit program indicated an improvement in the muscular strength of the lower limb of the body (the explosive leg power) through the vertical jump test (24.38%), as well as a significant improvement in the endurance of the upper body seen in push-ups during 60 s (52.37%), and sit-ups during 60 s (46.68%). These changes can be explained by the nature of the exercises used in the HIFT program, such as squats and box jumps, which are excellent for building the strength of the leg muscles that give explosive power when performing, in addition to regular training for 12 weeks.

In the literature, these results are consistent with Söyler and Kayantaş (2020a). After ten weeks of CrossFit training for soccer players, a significant difference was determined in the vertical jump performance (21%), and a significant difference was found in the level of maximum strength. The results also showed in Adlof et al. (2018) that after eight weeks of CrossFit training, high school soccer players improved their vertical jump height significantly (7.3%). The results indicated that four weeks of CrossFit training significantly increased strength (19.4%) and muscular endurance (47.3%), and although the soccer players were elite and their fitness level was high, CrossFit training fit.

In other study for young adolescents, the eight-week CrossFit intervention program caused significant improvements in upper and lower-body muscular strength (Cataldi et al., 2021). The study of Eather et al. (2016) showed a significant improvement in the performance of vertical jump (explosive leg power) in 96 adolescents after applying the CrossFit training program for eight weeks. They indicated that through CrossFit, physical fitness parameters can be improved in a safe and effective way. Additionally, it is an interesting and engaging form of physical exercise for young people. The CrossFit training program is feasible and effective and has shown great success in improving muscular strength. Cosgrove et al. (2019) found a significant time effect for the effectiveness of participating in CrossFit on strength and muscular endurance of the upper and lower body for both sexes.

However, other studies reported that there was no improvement in vertical jump performance in active individuals after six weeks of CrossFit training (Barfield & Anderson, 2014; Goins, 2014).

Speed and agility

Most sports experts agree that speed, a basic motor ability, is essential for success in many sports (Di Domenico & D'Isanto, 2019). This requires trainers to work on improving it. The results of the current study indicated that the HIFT program led to improvements in speed through the 30-m sprint test at a rate of (–7.58%), as well as an improvement in agility through the T-test, with an improvement rate of (–7.78%). These changes can be explained by the fact that the training program included functional exercises such as the kettlebell swing and the overhead press, which contribute to improving speed and agility. This is consistent

Table 1 Physical performances before and after the 12 weeks program training

Variable	Experimental group ($n = 19$)			Control group ($n = 19$)			Time effect p (η_p^2)	Group effect p (η_p^2)	Group x time interaction p (η_p^2)
	Mean ± *SD*		Relative change (%)	Mean ± *SD*		Relative change (%)			
	Pre-test	Post-test		Pre-test	Post-test				
30-m sprint (s)	4.92 ± 0.20	4.54 ± 0.16***	–7.72	4.89 ± 0.22	4.72 ± 0.25***	–3.48	.001 (.48)	.003 (.23)	.012 (.42)
Agility T-test (s)	10.89 ± 0.37	10.04 ± 0.57***	–7.81	10.94 ± 0.58	10.70 ± 0.66**	–2.19	.001 (.37)	.060 (. 67)	.002 (.21)
Vertical jump (cm)	36.50 ± 5.61	45.40 ± 6.91***	24.38	36.85 ± 6.05	40.65 ± 5.58***	10.31	.001 (.62)	.003 (.21)	.002 (.46)
Push-ups 60 s (repetitions)	30.65 ± 6.41	46.70 ± 7.62***	52.37	30.25 ± 6.61	30.85 ± 7.00*	1.98	.001 (.43)	.030 (. 38)	.001 (.25)
Sit-ups 60 s (repetitions)	36.10 ± 6.05	52.95 ± 5.92***	46.68	36.90 ± 7.86	37.85 ± 6.80**	2.57	.001 (.24)	.040 (.47)	< .001 (.55)
Yo-Yo test (mL/min/kg)	46.46 ± 2.47	50.13 ± 2.42***	7.90	46.90 ± 2.40	48.50 ± 2.10***	3.41	.001 (.32)	.100 (.67)	.029 (.23)

Note. Yo-Yo test = Yo-Yo intermittent recovery test level 1. Asterisks indicate a statistically significant difference between pre-test and post-test: *$p < .05$, **$p < .01$, *$p < .001$.

with what was indicated by Baron et al. (2019), which is that improving functional status leads to an improvement in running speed and is associated with acceleration and other motor skills.

Looking at the literature in this field, we find that the results of the current study are consistent with what was confirmed by Söyler and Kayantaş (2020a), where a significant difference was found in the sprint variable (–13.4%), as well as in the agility variable (–12.4%). Adlof et al. (2018) showed that female soccer players in high school improved sprinting 40 yards (–6.8%) and agility (–6.5%). In a study on young soccer players (Carvutto et al., 2021), the results showed that eight weeks of high-intensity functional training improved agility. Still, the results of sprint performance were not consistent with the current study, as Carvutto's study showed no significant improvement of sprint performance.

As for studies on other disciplines, Yildiz et al. (2019) found in his study on tennis players that the functional training program for eight weeks showed significant improvements and increases in speed (–12%) as well as in the agility variable (–6.5%).

Maximal oxygen uptake

The high and low endurance of a person depends on the level of maximum oxygen capacity. The better the $VO_{2max,}$ the better their physical condition (Gumantan & Fahrizqi, 2020). Optimum training for soccer should, therefore, allow, among many goals, an optimization of maximum oxygen intake (Calandro et al., 2020). The results of the current study showed an improvement in the VO_{2max} variable (7.88%) after HIFT training.

These results are consistent with Söyler and Kayantaş (2020a), where a significant difference was found in the maximum oxygen consumption (8.2%) after 10 weeks of CrossFit high-intensity exercises training for female soccer players. As for studies on other disciplines, a study by Afandi and Wijaya (2022) aiming to determine the effect of Cindy's Cousin CrossFit exercise on the value of VO_{2max} showed that a period of 6 weeks with 18 training sessions led to a significant increase in the value of VO_{2max} for athletes. In addition, Borras et al. (2017) showed a significant improvement in VO_{2max} (8.6%) after eight weeks of CrossFit training in a group of young high school students aged 16–18 years. In a study by Söyler and Kayantaş (2020b) on sedentary male subjects, CrossFit training was conducted for 12 weeks, and statistically significant differences were observed in VO_{2max} (5.3%). Similarly, in a study by Brisebois et al. (2018), after 8 weeks of CrossFit training, results showed an improvement in VO_{2max} (5.5%) in physically inactive adults. Kliszczewicz et al. (2019) showed that CrossFit training favored a rapid physiological improvement in VO_{2max} following a four-week intervention in physically active participants. Goins (2014) also reported an 11% increase in VO_{2max} in recreationally active individuals after 6 weeks of CrossFit. The results of the current study are also consistent with the aerobic benefit of CrossFit reported by Sousa et al. (2016), who reported that participants in CrossFit training showed better performance in aerobic fitness and there were statistically significant differences in VO_{2max} evaluated the multistage shuttle run test (14.1%) compared to participants in resistance training. The results of this study were also consistent with those of Barfield and Anderson (2014), who indicated an improvement in aerobic capacity (6%) in participants in the CrossFit program versus a traditional resistance program.

The current study is inconsistent with the finding (Mauring, 2021) that eight weeks of CrossFit training did not improve VO_{2peak} in recreationally active men and women.

Limitations

There are some limitations to this study. The study only included male footballers, which makes it difficult to apply in practice to female footballers. Therefore, further research is needed to determine whether training with HIFT affects the fitness of female soccer players. The absence of physiological factors that could have offered a more convincing explanation for the difference between the CG and EG included cardiovascular responses (i.e., heart rate), muscle fatigue (i.e., blood lactate), and perceptual state (i.e., rate of perceived exertion) etc. Likewise, in order to understand morphological changes before and after training with or without HIFT, it is imperative that morphological variables (i.e., lean and fat mass, body mass index) are assessed.

Conclusions

According to study results, incorporating HIFT into soccer training programs was shown to improve physical capacities among young soccer players between the ages of 16 and 18. Thus, CrossFit training can be recommended as a successful program for improving and enhancing the performance of young soccer players.

Conflict of interest

The authors report no conflict of interest.

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