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ORIGINAL ARTICLE

Effects of high intensity interval training combined with plyometrics on vertical jump and repeated sprint ability in young soccer players

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ABSTRACT

The aim of this study was to examine the effects of High Intensity Interval Training (HIIT) combined with plyometric exercises on vertical jump (VJ) and repeated sprint ability (RSA) in young soccer players. Eighteen U19 players were participated in this study, and were divided into two groups, experimental group (EG) and control group (CG). Players performed the 30-15 Intermittent Fitness Test (IFT), Repeated Sprint ability (RSA) test, Sargent Jump Test (SJT), and the Rating of Perceived Exertion (RPE) for data collection. A significant improvement was observed in VJ height and peak power within the EG (p = .044, moderate effect) compared to CG (p = .661, trivial effect). Time × group interaction for these variables was not significant (p = .275, moderate effect). RSA_{mean} significantly improved in EG (p = .005, large effect), while a significant decline was observed in CG (p = .006, large effect). RSA_{best} significantly declined in CG (p = .042, small effect). In contrast, no significant differences were found in RSA_{best} in EG. Both groups showed no significant improvement in RSA_{dec} (p > .05). Only RSA_{mean} showed a significant interaction effect (p = .000, large effect), indicating a greater improvement in the EG than the CG. The study shows that HIIT combined with plyometric exercises for 8 weeks improved both VJ and RSA_{mean}. The authors suggest integrating HIIT with plyometric exercises to improve VJ and RSA_{mean} for soccer players.

Keywords: Performance analysis, High intensity interval training, Plyometrics, Vertical jump, Power, Anaerobic capacity.

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INTRODUCTION

Soccer is an intermittent sport characterized by high-intensity efforts (Stølen et al., 2005), requiring players to perform repeated sprints of maximal or near-maximal intensity over short durations, interspersed with brief recovery periods involving low- to moderate-intensity activities (Alves et al., 2010). It also involves a variety of movements with fluctuating intensity, including running, jumping, turning, and sprinting (Rampinini et al., 2007). The energy system used in soccer is broadly divided into aerobic and anaerobic components, and most athletes train to meet the specific demands of their sport. Soccer requires athletes to repeatedly perform maximal or submaximal actions over distances of less than 30 meters for up to 90 minutes (Alves et al., 2010). The ratio of aerobic to anaerobic fitness in soccer players is approximately 30–70%. For these reasons, soccer training typically includes physical exercises designed to improve both aerobic and anaerobic fitness.

RSA is the ability to produce the best possible average sprint performance over a series of sprints (≤10 seconds), separated by short (≤60 seconds) recovery periods) (Girard et al., 2011). This ability is a complex quality to be related to both neuromuscular (determining maximal sprint speed, e.g., neural drive, motor unit activation, or muscle strength) and metabolic sprint ability (involved in the ability to repeat sprints, e.g., oxidative capacity for phosphocreatine (PCr) recovery, lactate-H+ buffering or Na + /K + transport capacity) (Girard et al., 2011). It also discriminates against professional soccer players from amateurs (Rampinini et al., 2009). In addition, players with greater lower-body power tend to perform better in sprints, change of direction, and VJ (Aloui et al., 2022). Strength is relevant to soccer players; therefore, it is recommended to include different training strategies to improve their physical attributes (Ramírez-Campillo et al., 2015).

Given the importance of both aerobic and anaerobic systems in soccer, HIIT has been widely implemented in athletic programs. It is defined as intense bouts of exercise that elicit >80 % of maximal heart rate, interspersed by periods with rest or low-intensity exercise periods (Gibala et al., 2012). Or incomplete recovery (MacInnis & Gibala, 2017). The exercise intensity of HIIT sets is near maximum, with the maximum oxygen uptake (VO_{2max}) being between 50% and 75% at rest (Laursen & Jenkins, 2002b). It has been widely used to improve several health and performance indicators (Gibala et al., 2012; Laursen & Jenkins, 2002a). It is well-known that HIIT is an exercise model that has been shown to result in similar muscular and cardiovascular adaptations compared to other traditional endurance exercise models. HIIT is proposed as an effective training method for trained athletes and improve their VO_{2max} (Marterer et al., 2020). VO_{2max} is the main indicator for measuring athlete performance and cardiovascular fitness and adaptation to training loads (Marta et al., 2013).

Alongside HIIT, plyometric training for improving muscle performance is now an integral part of a professional soccer player's overall fitness program (Ramírez-Campillo et al., 2015). It is aimed at increasing explosive strength by utilizing the stretch-shortening cycle (Markovic & Mikulic, 2010). Plyometric training is used to improve athletes' neuromuscular function and improve performance in sports in which explosive strength and endurance are expressed (Ramírez-Campillo et al., 2015). The plyometric program is a specialized high-intensity training process used to develop motor skills (Bedoya et al., 2015), and it includes exercises such as horizontal jumps and VJ, drop jump DJ, countermovement jump (CMJ), and hurdle exercises.

Given the increasing use of HIIT and plyometric exercises in soccer-specific training, this study aims to investigate the combined effects of HIIT and plyometric training on VJ and RSA in young soccer players. Understanding how these two training modalities interact can help optimize training programs for developing both explosive power and anaerobic endurance in youth athletes.

METHOD

Participants

Eighteen U19 Algerian amateur soccer players voluntarily participated in this study (mean ± SD: age = 18.8 ± 0.6 years, body height = 173.7 ± 5.4 cm, body weight = 64.9 ± 6.9 kg, BMI = 21.5 ± 2.2). The participants were divided into two groups: EG (n = 9) and CG (n = 9). Before starting the experiment, the authors confirmed that all players were free from diseases and informed them about the study's objectives, duration, and potential risks. All players provided written informed consent to participate in the study. The study adheres to the Declaration of Helsinki (World Medical Association, 2013). Table 1 presents the characteristics of the participants.

Table 1. Characteristics of the participants.

	EG (n = 9) (Mean ± SD)	CG (n = 9) (Mean ± SD)	*p*-value
Age (years)	18.9 ± 0.6	18.6 ± 0.6	.332
Height (cm)	170.8 ± 5.06	176.5 ± 4.2	.013*
Weight (kg)	63.1 ± 9.1	66.7 ± 3.4	.279
BMI (kg/m2)	21.5 ± 2.6	21.4 ± 1.6	.969

*Note. * : p < .05.*

Design and procedures

The aim of the research was to determine the effectiveness of in-season 8-week training program aimed at developing VJ and RSA in young soccer players. This is done by implementing a HIIT program combined with plyometric exercises. The study followed a pretest-posttest control group design. Players were first randomly assigned to the two groups (9 players per group). Pre-tests were then conducted for both groups. The EG performed the proposed training program, while the CG continued with its usual training routine. The warm-up, technical, and tactical training remained the same for both groups throughout the experiment. After 8 weeks, the tests were repeated to analyze the results.

Data collection

Rating of perceived excretion

The Rating of Perceived Exertion (RPE) scale proposed by Foster et al., (2001) was used, consisting of a numerical scale ranging from 0 to 10. Each number represents a specific level, starting from "*rest*" (0) to "*maximum intensity*" (10). This scale was employed in this study to determine the training load of the program. After completing each training session, players were asked about their perceived level of difficulty using the question: "*What was the difficulty level you felt during the exercise?*" The average of the players' responses was then calculated and multiplied by the duration of the exercise to determine the load for that exercise, expressed in Arbitrary Units (A.U.).

30-15 intermittent fitness test

The protocol for soccer players was followed (Figure 1). The initial running velocity was set at 8km/h and subsequently increased by 0.5 km/h following the conclusion of each 30-second stage. Players were instructed to complete as many stages as possible, with the termination of the test coinciding with the individual either being unable to maintain the required running speed or falling short of the 3 m 'safety zone' following the audio signal on 3 consecutive instances. A player's resultant end test velocity (V_{IFT}) was determined as the last stage they completed successfully (Buchheit, 2010). The results of this test were used to program HIIT training sessions to determine the distance each player runs.

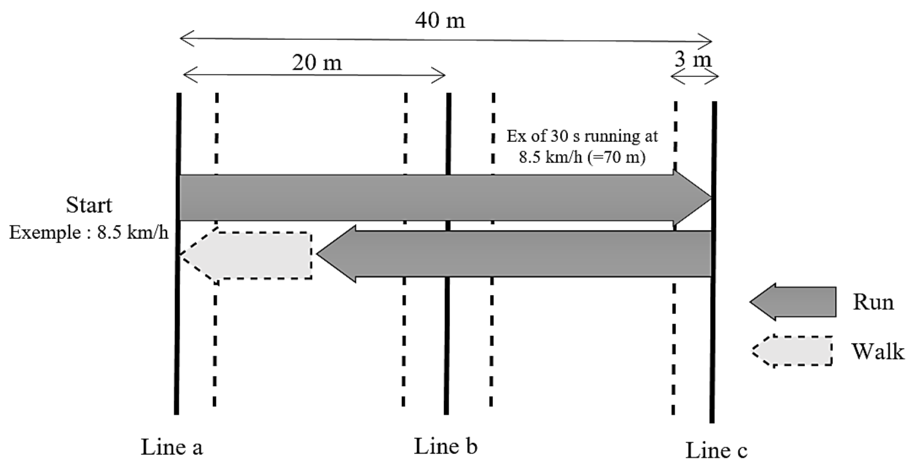

Figure 1. Protocol of 30-15 intermittent fitness test.

Repeated sprint ability test

Immediately after the 10-minute warm-up, each player completed a single 40-m (20 m + 20 m) shuttle sprint test (Figure 2). This sprint trial was used as the criterion score during the subsequent 6×40m RSA sprint test (Rampinini et al., 2007). Participants were then rested for 5 min before the start of the RSA test. The RSA test consisted of six 40-m (20 m + 20 m) shuttle sprints separated by 20 seconds of passive recovery. This test was designed to measure both repeated sprint and change in direction abilities. The athletes started from a line, sprinted for 20 m, touched a cone with a hand, and then returned to the starting line as fast as possible. The best performance (RSA_{best}), average performance (RSA_{mean}), and percentage decrement (RSAdec) were recorded for statistical analysis.

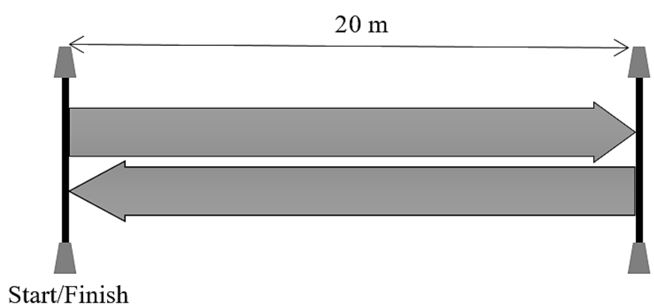

Figure 2. Protocol of RSA test (6×40 m shuttle sprints).

Sargent jump test

This test aims to assess VJ performance and lower limb power. Players had their right-hand fingers marked with orange chalk. While standing flat-footed next to a wall on their right side, with their right arm extended above their head, the players marked the highest point they could reach on the wall. Just before the jump, the players were allowed to freely flex their lower limbs and prepare their upper limbs for a sudden upward thrust to achieve the highest VJ possible. At the peak of the jump, the players extended their right hand against the wall to mark the maximum height reached. The jump height was calculated as the difference between the two points marked on the wall. Each volunteer performed three jumps, with a minimum interval of 45 seconds between jumps, and only the highest jump was considered (De Salles et al., 2012). Peak power was inferred from this test using the Sayers et al., (1999) equation:

$$\text{Peak power (W)} = 60.7 \times \text{VJ (cm)} + 45.3 \times \text{mass(kg)} - 2055$$

Intervension

The training program was developed based on the method of alternating between work and rest. It was structured using two variables: time and the type of exercises. Regarding time, very short-duration HIIT training was adopted (15"/15", 10"/20", 5"/25"). As for the type of exercises, a combination of running and plyometric exercises (horizontal and vertical) were used (Table 2 and Figure 3).

Table 2. Summary of training load progression.

W	S	Type (W/R)	Plyometrics Intensity	Running Intensity (%V_{IFT})	Blocks and Sets	Load (A.U)
1	1	15”/15”	Low Plyos (H)	100%	3 Sets	183.30
	2	5”/25”	Low Plyos (H)	120%	3 Sets	166.95
2	3	10”/20	Low Plyos (H)	110%	3 Sets	186.60
	4	5”/25”	Low Plyos (H)	120%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	410.48
3	5	15”/15”	Low Plyos (H)	105%	3 Sets	183.30
	6	5”/25”	Low Plyos (H)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	416.64
4	7	10”/20”	Low Plyos (H)	110%	3 Sets	219.78
	8	5”/25”	Low Plyos (H)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	485.16
5	9	15”/15	Vigorous Plyos (V)	105%	3 Sets	163.20
	10	5”/25”	Moderate Plyos (V)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	497.28
6	11	10”/20”	Vigorous Plyos (V)	110%	3 Sets	106.50
	12	5”/25	Vigorous Plyos (V)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	282.88
7	13	15”/15”	Moderate Plyos (V)	105%	3 Sets	129.90
	14	5”/25”	Vigorous Plyos (V)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	323.44
8	15	10”/20”	Moderate Plyos (V)	110%	3 Sets	186.60
	16	5”/25”	Vigorous Plyos (V)	125%	2 Blocks: Block 1: 2 Sets Block 2: 2 Sets	416.00

Note. W = Week, S = Session, H = Horizontal, V = Vertical, W/R = Work/Rest, A.U = Arbitrary Unis, VIFT = Velocity for the Intermittent Fitness Test, Plyos = Plyometrics.

Data analysis

The data in this study were expressed as mean ± SD. First, the normality of the data distribution was verified using the Shapiro-Wilk test. A comparison of the pre-test results between EG and CG was conducted using an independent samples t-test. Within-group comparisons (pre-test vs. post-test) were performed using a paired samples t-test, along with the percentage of change (pre-post) to assess the difference. Hedges' g effect size (ES) was calculated to determine the magnitude of the difference, with thresholds for interpretation as follows: small (0.2), moderate (0.5), and large (0.8). A two-way ANOVA was conducted based on two factors: time (pre-post) and group (EG and CG). Post-hoc comparisons were performed using the Bonferroni adjustment if a significant time × group interaction was observed. Partial eta-squared (η^2) was used to evaluate the magnitude of differences between the groups, with thresholds interpreted as small (0.01–0.06), moderate (0.06–0.14), and large (>0.14). Statistical significance was set at $p < .05$.

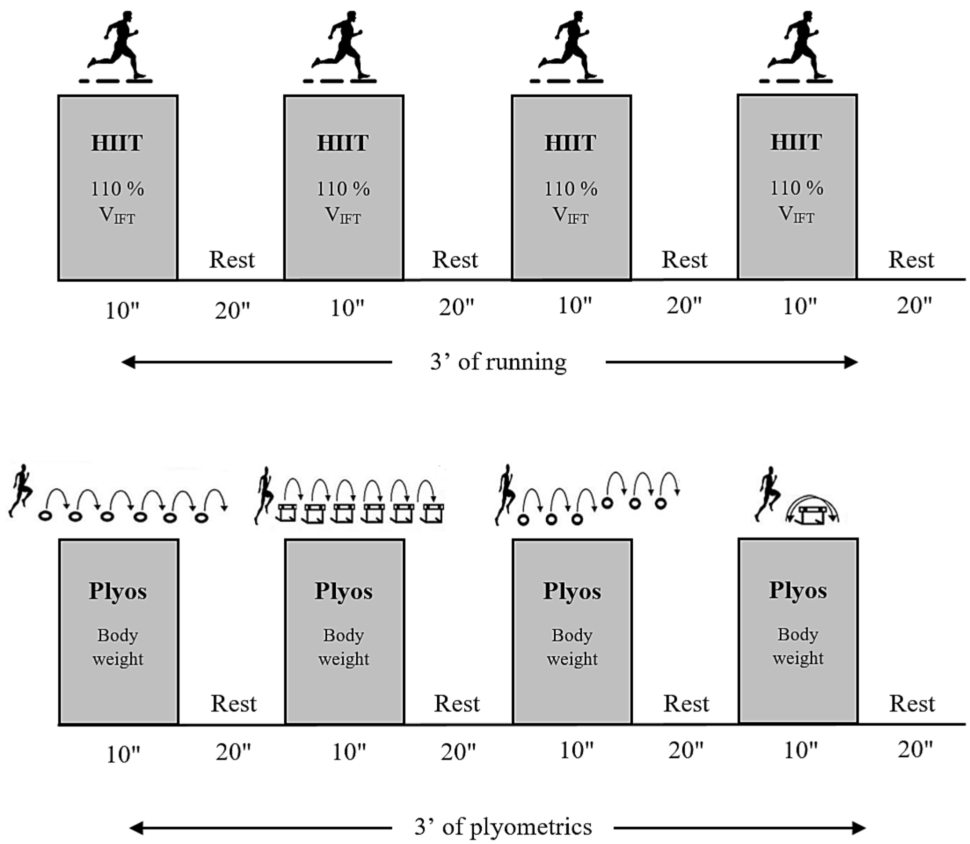

Figure 3. An example of a training session (10”/20”), showing how to alternate between high-intensity running and plyometric exercises.

RESULTS

Table 3 presents the pre-test and post-test results for the EG and CG across various performance variables.

A significant improvement was observed in VJ height and peak power within the EG (p = .044, moderate effect), whereas the CG showed no significant changes (p = .661, trivial effect). However, the time × group interaction for these variables was not statistically significant (p = .275, moderate effect), indicating similar trends in both groups over time.

For RSA, RSA_{mean} significantly improved in EG (p = .005, large effect), while a significant decline was observed in CG (p = .006, large effect). However, the interaction effect was significant (p = .000, large effect), indicating a greater improvement in the EG compared to CG. RSA_{best} significantly declined in CG (p = .042, small effect). In contrast, no significant differences were found in RSA_{best} in EG. Both groups showed no significant improvement in RSA_{dec} (EG: p = .794; CG: p = .232).

Table 3. Comparison of Changes in VJ and RSA between EG and CG groups

Variables	EG (n = 09)			CG (n = 09)			Main time effect	Time x group
	Pre-test	Post-test	*p*-values [g] Magnitude	Pre-test	Post-test	*p*-values [g] Magnitude	*p*-values [η²] Magnitude	*p*-values [η²] Magnitude
	Mean ± SD			Mean ± SD				
VJ (cm)	42.66 ± 4.89	45.44 ± 6.16	**.044*** [0.499] Moderate	39.44 ± 4.55	40.11 ± 6.13	.661 [0.124] Trivial	.084 [0.175] Large	.275 [0.074] Moderate
Peak power (W)	3393.80 ± 526.38	3562.41 ± 511.42	**.044*** [0.324] Moderate	3364.31 ± 312.05	3404.77 ± 399.53	.661 [0.112] Trivial	.084 [0.175] Large	.275 [0.074] Moderate
RSA_{best} time (s)	7.65 ± 0.95	7.45 ± 0.35	.183 [0.279] Small	7.69 ± 0.33	7.77 ± 0.36	**.042*** [0.231] Small	.414 [0.042] Small	.064 [0.199] Large
RSA_{mean} time (s)	8.15 ± 0.21	7.95 ± 0.23	**.005**** [0.908] Large	8.03 ± 0.24	8.21 ± 0.29	**.006**** [0.676] Large	.783 [0.005] Small	**.000#** [0.630] Large
RSA_{dec} (%)	6.50 ± 2.67	6.91 ± 3.99	.794 [0.120] Trivial	4.52 ± 2.45	5.25 ± 2.61	232. [0.288] Small	.495 [0.030] Small	.850 [0.002] Small

*Note. No statistically significant were observed in between groups pre-test comparison; EG: Experimental group; CG: Control group; g: Hedges' g effect size; η2: Partial eta-squared; *: significant difference between pre- and post-tests (p < .05); ** p < .01; #: significant time x group.*

DISCUSSIONS

This study aimed to investigate the effect of HIIT combined with Plyometrics on VJ and RSA in Young Soccer Players across an 8-week in-season period. To the best of the authors' knowledge, this is the first study that investigates the effects of HIIT combined with Plyometrics on VJ and RSA in Young Soccer Players. The main findings indicated an improvement in these two attributes VJ and RSA after implementing the training program utilizing the HIIT combined with Plyometrics. As for the type of exercises, a combination of running and plyometric exercises (horizontal and vertical) were used in Table 2 and Figure 3. Our results are in line with those of Sáez De Villarreal et al., (2015), who reported significant increases in VJ performance following combined plyometric-speed training and technical drills work in U15 male youth soccer players. Sedano et al., (2011) reported that plyometrics performed on elite soccer players three times a week for 10 weeks increases their jumping ability more than from general physical training. In a systematic review by Bedoya et al., (2015), in which seven studies on the effect of plyometric training for youth soccer players were reviewed, six of the seven reported that plyometrics improved CMJ. Jump performance augmentation could be the result of neuromuscular adaptations such as greater neural drive of agonist muscles, changes in mechanical stiffness of tendons, size changes and/or the architecture of muscles, and changes in the mechanics of single fibres. This is because it uses the stretch-shortening cycle (SSC) muscle action (Markovic & Mikulic, 2010; Meylan & Malatesta, 2009).

According to Markovic & Mikulic, (2010), the SSC enhances the ability of the neural and musculotendinous systems to produce maximal force in the shortest amount of time, prompting the use of plyometric training as a bridge between strength and speed. The purpose of plyometric training is to increase the power of subsequent movements by using both natural elastic components of muscle and tendon and the stretch reflex (Meylan & Malatesta, 2009). In other words, plyometric training can strengthen the elastic properties of connective tissue, improve the mechanical characteristics of the muscle-tendon complex, and optimize cross-bridge mechanics and motor unit activation (Markovic & Mikulic, 2010; Ramírez-Campillo et al., 2015). These adaptations are associated with increased joint stiffness, improved muscle strength, increased contraction speed, and improved dynamic stability and neuromuscular control (Markovic & Mikulic, 2010; Ramírez-Campillo et al., 2015).

Our results revealed that for RSA, RSA_{mean} significantly improved in EG and a significant decline was observed in CG. Also, a greater improvement in the EG compared to CG were observed. Our results are in line with those of Michailidis et al., (2023), authors found that a 4-week training program HIIT improved RSA_{mean}, and their study supports that a short-term HIIT program can improve acceleration, agility, and RSA performance. Aloui et al., (2022) found that the combined plyometric and short sprint training for 8 weeks during the season improved all RSA parameters except the fatigue index in U15 elite youth soccer players. As previously stated, plyometrics revealed a meaningful improvement in jumping performance, which may transfer into improved running economy and enhance aerobic performance (Marta et al., 2013). A study conducted by Negra et al., (2020) found that RSA_{best} and RSA_{total} showed greater performance enhancements after training in the Plyometric Jump Training group [Δ = 1.8% and 1.2% for RSA_{best} and RSA_{total}, respectively], compared with the CG [Δ = -1.6 and 1.3% for RSA_{best} and RSA_{total}, respectively].

The improvement in VJ reflects an enhancement (as with the RSA_{mean}) in the ability to utilize the stored elastic energy and indirectly assists in the first phase of the force-time curve initiated by the rate of force development occurring in the first 180-250 ms in leg extensors within the training group. The improvement in VJ could be further explained by findings from other studies where speed, leaping power, and strength have been reported to affect each other if an improvement in any one of them occurs (Stølen et al., 2005).

The nature of the exercises included in the HIIT training program combined with Plyometrics improves VO_{2max}. HIIT is widely used to improve VO_{2max} (Marterer et al., 2020), and it has the effect of increasing VO_{2max}. Theoretically, the increase in VO_{2max} can be attributed to improvements in physiological thickening of the left ventricular myocardial heart so that the strength and ability of the heart to pump blood each contraction increases thereby reducing the number of beats per minute, all contributing to a greater stroke volume (Costigan et al., 2016), and peripheral adaptations, which enhance the muscles' ability to extract oxygen and generate adenosine triphosphate (ATP) aerobically (Daussin et al., 2007). It is likely that HIIT can improve both mechanisms within a relatively short time frame. Also, Ramírez-Campillo et al., (2015) founded that soccer players who practiced plyometrics had better endurance test results compared with soccer players who did not. However, one advantage of HIIT is that it may concurrently develop other factors like the rate of PCr resynthesis, and can actually reduce the decrease in muscle H+ during the recovery from supramaximal exercise (Bishop et al., 2008) and muscle buffer capacity (Edge et al., 2006), These factors help in Recovery between sprints during RSA. Thus, plyometrics not only improves jumping ability in soccer players but also improves a range of physical fitness attributes, such as agility and endurance (Hammami et al., 2016; Meylan & Malatesta, 2009; Negra et al., 2020). However, jumping ability, agility, and endurance are elements that are included in physical fitness.

The present study supports the theory that aerobic capacity is an important factor influencing recovery from RSA in soccer, and There is a relationship between RSA and relative VO_{2max} (Jones et al., 2013), which has been reported to be moderately correlated ($0.62 < r < 0.68$; $p < .05$) with RSA (both mean sprint performance and sprint decrement) (Rampinini et al., 2009). It has previously been proposed that an individual's RSA may be aided by their aerobic capacity as an enhanced aerobic capacity may increase the ability to tolerate, remove, and buffer H+ from the working muscle (Sahlin & Henriksson, 1984) and also enhance PCr and ATP resynthesis from inorganic phosphates post6exercise (Harris et al., 1976). The results of Bishop & Edge, (2006) in their study indicate that VO_{2max} contributes to performance during repeated-sprint efforts, and has a superior ability to resist fatigue during these exercises, especially during the latter stages of a repeated-sprint test when subjects may reach their VO_{2max} (McGawley & Bishop, 2008). This suggests that improving VO_{2max} may allow for a greater aerobic contribution to repeated sprints, potentially improving RSA.

In contrast with the results of this study, some studies have reported that VO_{2max} is a poor indicator of RSA (r = 0.09–0.03) (Aziz et al., 2000). However, research also indicates that there is not a linear relationship between VO_{2max} and various repeated-sprint fatigue indices (Bishop et al., 2003). This may be explained by differences in the type of protocol used for the RSA test (Da Silva et al., 2010) where VO_{2max} has not been reported to be related to RSA when sprints of less than 40 meters or 6 seconds have been used, also the results of Da Silva et al., (2010) study demonstrated that RSA is more strongly correlated with Velocity at the Onset of Blood Lactate Accumulation (vOBLA) and Velocity at Maximal Oxygen Uptake (vVO_{2max}) than the more commonly measured VO_{2max}. In Aziz et al., (2000) study, there was only a modest relationship between VO_{2max} and RSA performance indices, and this demonstrated that, while aerobic fitness does play a role in the performance of activities whose metabolic demand is similar to that of RSA type of exercise protocol, its contribution or benefits during such high intensity intermittent performance may be limited.

As confirmed by Aziz et al., (2007) in a study, which concluded that the lack of association between measured VO_{2max} and aerobic endurance performance in the 20-m multistage shuttle run with performance in the RSA suggests that aerobic fitness itself is poorly associated with performance in the RSA in elite young soccer players. Furthermore, RSA may also be influenced by the training status of the players. Rampinini et al., (2007) concluded in their study, that using the median split technique, it was found that the group that reached the higher peak speed during the incremental test covered significantly more total distance, high intensity running, and very high intensity running in comparison with the group that reached the lower peak speed during the same test. The best group in RSA_{mean} (time below the median value) covered more very high intensity running and sprinting distances compared to players with times above the median value. The discrepancy between the results of the present study and the results of previous studies appears to be due to differences in the methods applied (prepubertal soccer players vs. adolescent soccer players, period of the season [pre-season vs. season], training background of the players [trained vs. highly trained], and total soccer training load per week.

Our study revealed a significantly declined RSA_{best} in CG and no significant differences were found in EG, and Both groups showed no significant improvement in RSA_{dec} ($p > .05$), The previous investigation of Kargarfard et al., (2020) reported no improvements in RSA following combined plyometric and short sprint training in male U19 soccer players. Also, a study conducted by Hammami et al., (2016) revealed no significant differences in RSA parameters after 8 weeks of plyometrics training in adolescent soccer players. This discrepancy could be due to the active control groups, which either maintained regular specific training (Miranda et al., 2022) or combined resistance training with regular specific training (Kobal et al., 2017). Regular specific training alone or in combination with other methods can influence RSA which is largely dependent on the extent of PCr resynthesis (Bogdanis et al., 1996) and the removal of H^+ from the muscle during recovery between bouts.

The improvement in RSA_{mean} and VJ performance in the current study may be due to the significant enhancement in the outcome of high-intensity actions (HIIT combined with Plyometrics) after training. Particularly, the observed improvements were most likely a result of enhancements in explosive power through improvements in motor unit synchronization, stretch-shortening cycle efficiency, or musculotendinous stiffness (Harris et al., 2007).

Limitations

This study has certain limitations. The small sample size limits the generalizability of the findings to the wider youth population. Future studies are encouraged to include a larger sample to enhance the external validity of the results. Additionally, although the researchers provided guidelines regarding sleep duration and nutritional intake, these factors could not be strictly controlled and therefore may have influenced the outcomes of the study.

CONCLUSIONS

In conclusion, this is the first study that investigates the effects of HIIT combined with Plyometrics on VJ and RSA in Young Soccer Players. It was demonstrated that HIIT combined with Plyometrics improved VJ and RSA_{mean}. This suggests that the increase in RSA_{mean} after the 8-week intervention is most likely due to the increase in muscle strength, where speed, leaping power, and strength have been to affect each other if an improvement in any one of them occurs. Authors suggest combining these exercises to enhance performance of young soccer players.

Practical implications

The findings of this study will enable coaches to select appropriate training methods to enhance the performance of young players. Since RSA reflects both aerobic and anaerobic fitness, combining HIIT with plyometric training is recommended to improve this quality and enhance explosive performance in football. This integrated approach may also contribute to better match outcomes and reduced injury risk among youth players.

AUTHOR CONTRIBUTIONS

Amar Mouissa: conducted the fieldwork, field tests, and intervention program, and also wrote the article. Lilia Kebaili: reviewed the article before submission. Oussama Kessouri: performed statistical analysis of the data and made some revisions during the writing process.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Aloui G, Hermassi S, Bartels T, Hayes LD, Bouhafs EG, Chelly MS, Schwesig R. Combined Plyometric and Short Sprint Training in U-15 Male Soccer Players: Effects on Measures of Jump, Speed, Change of Direction, Repeated Sprint, and Balance. Front Physiol. 2022 Feb 18;13:757663. https://doi.org/10.3389/fphys.2022.757663

Alves Maio JM, Rebelo AN, Abrantes C, Sampaio J. Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. J Strength Cond Res. 2010 Apr;24(4):936-41. https://doi.org/10.1519/JSC.0b013e3181c7c5fd

Astorino TA, Edmunds RM, Clark A, King L, Gallant RA, Namm S, Fischer A, Wood KM. High-Intensity Interval Training Increases Cardiac Output and V˙O2max. Med Sci Sports Exerc. 2017 Feb;49(2):265-273. https://doi.org/10.1249/MSS.0000000000001099

Aziz AR, Chia M, Teh KC. The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. J Sports Med Phys Fitness. 2000 Sep;40(3):195-200. PMID: 11125761.

Aziz AR, Mukherjee S, Chia MY, Teh KC. Relationship between measured maximal oxygen uptake and aerobic endurance performance with running repeated sprint ability in young elite soccer players. J Sports Med Phys Fitness. 2007 Dec;47(4):401-7. PMID: 18091678.

Bedoya AA, Miltenberger MR, Lopez RM. Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review. J Strength Cond Res. 2015 Aug;29(8):2351-60. https://doi.org/10.1519/JSC.0000000000000877

Bishop D, Edge J. Determinants of repeated-sprint ability in females matched for single-sprint performance. Eur J Appl Physiol. 2006 Jul;97(4):373-9. https://doi.org/10.1007/s00421-006-0182-0

Bishop D, Edge J, Thomas C, Mercier J. Effects of high-intensity training on muscle lactate transporters and postexercise recovery of muscle lactate and hydrogen ions in women. Am J Physiol Regul Integr Comp Physiol. 2008 Dec;295(6):R1991-8. https://doi.org/10.1152/ajpregu.00863.2007

Bishop D, Lawrence S, Spencer M. Predictors of repeated-sprint ability in elite female hockey players. J Sci Med Sport. 2003 Jun;6(2):199-209. https://doi.org/10.1016/S1440-2440(03)80255-4

Buchheit M. The 30-15 Intermittent Fitness Test : 10 year review The 30-15 Intermittent Fitness Test : 10 year review. November. 2010.

Buchheit M, Ufland P. Effect of endurance training on performance and muscle reoxygenation rate during repeated-sprint running. Eur J Appl Physiol. 2011 Feb;111(2):293-301. https://doi.org/10.1007/s00421-010-1654-9

Costigan SA, Eather N, Plotnikoff RC, Hillman CH, Lubans DR. High-Intensity Interval Training for Cognitive and Mental Health in Adolescents. Med Sci Sports Exerc. 2016 Oct;48(10):1985-93. https://doi.org/10.1249/MSS.0000000000000993

da Silva JF, Guglielmo LG, Bishop D. Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. J Strength Cond Res. 2010 Aug;24(8):2115-21. https://doi.org/10.1519/JSC.0b013e3181e34794

Daussin FN, Ponsot E, Dufour SP, Lonsdorfer-Wolf E, Doutreleau S, Geny B, Piquard F, Richard R. Improvement of VO2max by cardiac output and oxygen extraction adaptation during intermittent versus continuous endurance training. Eur J Appl Physiol. 2007 Oct;101(3):377-83. https://doi.org/10.1007/s00421-007-0499-3

de Salles PG, Vasconcellos FV, de Salles GF, Fonseca RT, Dantas EH. Validity and reproducibility of the sargent jump test in the assessment of explosive strength in soccer players. J Hum Kinet. 2012 Jun;33:115-21. https://doi.org/10.2478/v10078-012-0050-4

Edge J, Bishop D, Goodman C. The effects of training intensity on muscle buffer capacity in females. Eur J Appl Physiol. 2006 Jan;96(1):97-105. https://doi.org/10.1007/s00421-005-0068-6

Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. J Strength Cond Res. 2001 Feb;15(1):109-15. PMID: 11708692. https://doi.org/10.1519/00124278-200102000-00019

Gibala MJ, Little JP, Macdonald MJ, Hawley JA. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol. 2012 Mar 1;590(5):1077-84. https://doi.org/10.1113/jphysiol.2011.224725

Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability - part I: factors contributing to fatigue. Sports Med. 2011 Aug 1;41(8):673-94. https://doi.org/10.2165/11590550-000000000-00000

Hammami M, Negra Y, Aouadi R, Shephard RJ, Chelly MS. Effects of an In-season Plyometric Training Program on Repeated Change of Direction and Sprint Performance in the Junior Soccer Player. J Strength Cond Res. 2016 Dec;30(12):3312-3320. https://doi.org/10.1519/JSC.0000000000001470

Harris N, Cronin J, Keogh J.. Contraction force specificity and its relationship to functional performance. In J Sports Sci. 2007 25(2). https://doi.org/10.1080/02640410600630910

Harris RC, Edwards RH, Hultman E, Nordesjö LO, Nylind B, Sahlin K. The time course of phosphorylcreatine resynthesis during recovery of the quadriceps muscle in man. Pflugers Arch. 1976 Dec 28;367(2):137-42. https://doi.org/10.1007/BF00585149

Jones RM, Cook CC, Kilduff LP, Milanović Z, James N, Sporiš G, Fiorentini B, Fiorentini F, Turner A, Vučković G. (2013). Relationship between repeated sprint ability and aerobic capacity in professional soccer players. Scientific World Journal. https://doi.org/10.1155/2013/952350

Kargarfard M, Tajvand S, Rabbani A, Clemente FM, Jalilvand F. Effects of combined plyometric and speed training on change of direction, linear speed, and repeated sprint ability in young soccer players: A pilot study. Kinesiology. 2020, 52(1), 85-93. https://doi.org/10.26582/k.52.1.11

Kobal R, Loturco I, Barroso R, Gil S, Cuniyochi R, Ugrinowitsch C, Roschel H, Tricoli V. Effects of Different Combinations of Strength, Power, and Plyometric Training on the Physical Performance of Elite Young Soccer Players. J Strength Cond Res. 2017 Jun;31(6):1468-1476. https://doi.org/10.1519/JSC.0000000000001609

Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. Sports Med. 2002a;32(1):53-73. https://doi.org/10.2165/00007256-200232010-00003

Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. Sports Med. 2002b;32(1):53-73. https://doi.org/10.2165/00007256-200232010-00003

MacInnis MJ, Gibala MJ. Physiological adaptations to interval training and the role of exercise intensity. J Physiol. 2017 May 1;595(9):2915-2930. https://doi.org/10.1113/JP273196

Markovic G, Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med. 2010 Oct 1;40(10):859-95. https://doi.org/10.2165/11318370-000000000-00000

Marta C, Marinho DA, Barbosa TM, Izquierdo M, Marques MC. Effects of concurrent training on explosive strength and VO(2max) in prepubescent children. Int J Sports Med. 2013 Oct;34(10):888-96. https://doi.org/10.1055/s-0033-1333695

Marterer N, Menz V, Amin S, Faulhaber M. 6-week High-intensity Interval Training (HIIT) of the Lower Extremities Improves VO2max of the Upper Extremities. Int J Sports Med. 2020 Jun;41(6):380-390. https://doi.org/10.1055/a-1073-8016

McGawley K, Bishop D. (2008). Anaerobic and aerobic contribution to two, 5 x 6-s repeated-sprint bouts. Coaching and Sport Science Journal, 3(2), 52.

Meylan C, Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. J Strength Cond Res. 2009 Dec;23(9):2605-13. https://doi.org/10.1519/JSC.0b013e3181b1f330

Michailidis Y, Ganotakis C, Motsanos N, Metaxas T. The effects of an HIIT program on young soccer players' physical performance. Int Sport Coach J. 2023; 18(4). https://doi.org/10.1177/17479541221102530

Miranda C, Rago V, Silva JR, Rebelo A. Effects of traditional vs. complex strength training added to regular football training on physical capacities in U19 football players: a team study. Sport Sci Health. 2022; 18(3). https://doi.org/10.1007/s11332-021-00833-9

Negra Y, Chaabene H, Fernandez-Fernandez J, Sammoud S, Bouguezzi R, Prieske O, Granacher U. Short-Term Plyometric Jump Training Improves Repeated-Sprint Ability in Prepuberal Male Soccer

Players. J Strength Cond Res. 2020 Nov;34(11):3241-3249. https://doi.org/10.1519/JSC.0000000000002703

Ramírez-Campillo R, Burgos CH, Henríquez-Olguín C, Andrade DC, Martínez C, Álvarez C, Castro-Sepúlveda M, Marques MC, Izquierdo M. Effect of unilateral, bilateral, and combined plyometric training on explosive and endurance performance of young soccer players. J Strength Cond Res. 2015 May;29(5):1317-28. https://doi.org/10.1519/JSC.0000000000000762

Rampinini E, Bishop D, Marcora SM, Ferrari Bravo D, Sassi R, Impellizzeri FM. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. Int J Sports Med. 2007 Mar;28(3):228-35. https://doi.org/10.1055/s-2006-924340

Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, Coutts AJ. Repeated-sprint ability in professional and amateur soccer players. Appl Physiol Nutr Metab. 2009 Dec;34(6):1048-54. https://doi.org/10.1139/H09-111

Sáez de Villarreal E, Suarez-Arrones L, Requena B, Haff GG, Ferrete C. Effects of Plyometric and Sprint Training on Physical and Technical Skill Performance in Adolescent Soccer Players. J Strength Cond Res. 2015 Jul;29(7):1894-903. https://doi.org/10.1519/JSC.0000000000000838

Sahlin, K, Henriksson J. Buffer capacity and lactate accumulation in skeletal muscle of trained and untrained men. Acta Physiologica Scandinavica. 1984; 122(3). https://doi.org/10.1111/j.1748-1716.1984.tb07517.x

Sayers SP, Harackiewicz DV, Harman EA, Frykman PN, Rosenstein MT. Cross-validation of three jump power equations. Med Sci Sports Exerc. 1999 Apr;31(4):572-7. https://doi.org/10.1097/00005768-199904000-00013

Sedano S, Matheu A, Redondo JC, Cuadrado G. Effects of plyometric training on explosive strength, acceleration capacity and kicking speed in young elite soccer players. J Sports Med Phys Fitness. 2011 Mar;51(1):50-8. PMID: 21297563.

Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med. 2005;35(6):501-36. https://doi.org/10.2165/00007256-200535060-00004

World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013 Nov 27;310(20):2191-4. https://doi.org/10.1001/jama.2013.281053