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ORIGINAL RESEARCH

Effects of speed-agility-quickness training and sprint interval training on physiological and physical performance, and sports enjoyment in young soccer players

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Abstract

Sports enjoyment is crucial for young athletes as it influences both their immediate willingness to engage in sports and their long-term commitment and development. Therefore, understanding the effects of different training methods on sports enjoyment is essential. This study aimed to compare the effects of speed-agility-quickness training (SAQT) and sprint interval training (SIT) on young soccer players preparing to return after rehabilitation, investigating their impact on physiological and physical performance, as well as on sports enjoyment. A total of 56 adolescent soccer players (age, 15–17 years) were randomly assigned to either the SAQT (n = 28) and SIT (n = 28) groups and underwent training according to the group allocation twice weekly for 8 weeks. A graded exercise test for peak oxygen uptake (VO_2 peak), isokinetic knee strength tests (peak torque, average power), and agility tests (Illinois agility test, Agility *T*-test) were used to assess physical factors. The Sports Commitment Questionnaire-2 (SCQ-2) was used to evaluated sports enjoyment. VO_2 peak, isokinetic knee strength, and agility significantly improved in both groups after the 8 weeks of intervention. In between-group comparisons, it was found that SIT was more effective in enhancing VO_2 peak ($p < 0.05$), anaerobic threshold (AT) ($p < 0.05$), and knee strength ($p < 0.05$), whereas SAQT was associated with greater enhancements in Illinois agility test (IAT) ($p < 0.05$) and Agility *T*-test (ATT) ($p < 0.05$) performance times, as well as in sport enjoyment scores ($p < 0.05$). In conclusion, it appears that SAQT may substantially enhance agility and quickness, which are crucial for optimal in-game performance, while SIT may improve other vital components such as cardiorespiratory fitness and muscle strength. Particularly for youth soccer players who are recovering from injuries, SAQT could be instrumental in fostering more positive affective responses and enhancing sport enjoyment.

Keywords

Speed-agility-quickness training; Agility; Sports commitment; Strength; Youth; Injury

1. Introduction

The optimal performance of soccer players across all levels is influenced by various technical, physical, physiological, tactical and psychological factors [1]. Physical interventions, such as speed-agility-quickness training (SAQT), significantly influence soccer players' performance by affecting their ability to respond quickly and effectively in the field [2]. Developing these traits in young soccer players lays the foundation for a successful future career, so the choice of training method can have a significant impact [3].

In addition to the required physical attributes, young soccer players face various psychological challenges associated with participation in sports, such as the demands of schoolwork, family, and relationships with peers and coaches [4–7]. In particular, coaches' competence-supportive behaviors can influence young athletes' intentions to continue participating in sport [4]. However, despite some positive influences, the cumulative burden of these challenges can have negative effects, contributing to a decrease in sports enjoyment and ultimately causing some young athletes to drop out of sports activities [5]. This situation underscores the critical role of sports enjoyment in the athletic development of young athletes. Defined as the positive emotional experience derived from participating in sports, sports enjoyment is crucial for young athletes as it not only influences their immediate willingness to engage in and persist with sports activities but also impacts their long-term commitment and development [8]. Enjoyment in sports, characterized by feelings of pleasure, satisfaction and fulfillment, is a significant motivator that encourages young athletes to continue participating and exerting effort despite challenges [9].

Furthermore, young athletes may have relatively low motivation and competitive spirit compared to professional adult athletes, and may exhibit low sports commitment [10, 11]. According to De Muynck *et al.* [10], compared to adult athletes, young athletes place greater emphasis on the unique roles of coaches and parents in their motivation function, resulting in relatively lower levels of autonomous motivation and participation. As the probability of dropping out of sports is relatively high among individuals faced with various challenges, it is therefore crucial that interventions to elicit positive affective responses be implemented [12]. Positive affective responses are defined as emotional reactions beneficial to an individual's psychological state [13, 14]. These responses are not only indicators of an athlete's current enjoyment and satisfaction but also predictors of future sports participation and perseverance [14]. Therefore, understanding the effects of different training methods on enjoyment of sports in young athletes is crucial. Positive affective responses increase players' enjoyment, motivation, and commitment to sports, ultimately contributing to long-term engagement and improved performance [8]. Hence, it is necessary to investigate whether specialized training methods can significantly affect sports enjoyment and the physiological and physical abilities of young soccer players.

Among the various training interventions, sprint interval training (SIT) and SAQT have garnered considerable attention because they potentially improve physiological and physical abilities [15, 16]. SIT consists of periodic short sprints (within 45 seconds) of "all-out" maximal effort, interspersed with active rest intervals, and has been proven to improve aerobic and anaerobic performance, as well as overall exercise capacity, in a relatively short period of time [15, 17]. In contrast, SAQT focuses on improving the movement patterns and reaction times of athletes, which are vital for agility and speed. Moreover, it emphasizes the development of neuromuscular control, motor efficiency, and explosive functions required for sports performance, using various drills designed to improve acceleration, deceleration, direction change and reaction time [18].

Although previous studies have evaluated the effects of these training methods on physiological and physical abilities, their impact on sports enjoyment in young athletes has not been fully explored. Moreover, injuries not only weaken athletes' performance but also significantly influence their engagement and enjoyment of sports. Addressing these issues is crucial, as maintaining sports enjoyment during recovery is linked to better rehabilitation outcomes and a quicker return to sports [19]. Therefore, this study aimed to compare the effects of SAQT and SIT in young soccer players preparing to return after rehabilitation and investigate the impact of each training method on sports-related performance and sports enjoyment. Building on this, the study assumes that structured training programs like SAQT and SIT can enhance the physical and physiological capacities of these athletes, particularly those recovering from injuries. It also posits that such improvements are crucial for increasing sports enjoyment and overall performance, which are essential for the holistic development of the athletes.

2. Materials and methods

2.1 Study procedure and participants

Participants were recruited using the bulletin board of the rehabilitation center. The young soccer players and their legal guardians provided written informed consent to participate in this study.

G*Power 3.1 (Universität Düsseldorf, Düsseldorf, Germany) was used to calculate the sample size for an effect size (dz) = 0.5, α error = 0.05, and power ($1 - \beta$ err prob) = 0.80. Data analysis was performed using Wilcoxon signed-rank test. Fifty-six young male soccer players (age, 15–17 years) with healthy were analyzed (SAQT group, n = 28 and SIT group, n = 28) (Fig. 1). Participants were athletes performing elite sports in the first division youth league. The preferred condition for players to return to play after an injury is to receive a doctor's examination. Through this process, athletes must have no pathological problems and be pain-free. Next is muscle function. The deficit of muscle strength must be within 10%. Furthermore, psychologically, there is no fear of injury, recurrence, or participation in the game [20, 21]. This study included only athletes who were confirmed through this process by doctors and sports medicine specialist.

2.2 Cardiorespiratory fitness test

A graded exercise test using a treadmill was performed to measure the peak oxygen uptake (VO_2 peak) using a gas analyzer (Vmax229, Sensormedics Co., Linda, CA, USA). Anaerobic threshold (AT) and resting heart rate were measured concomitantly. According to the test recommendations, maximum exercise capacity can be measured between 8 and 12 minutes, and the Bruce protocol was adopted considering that these athletes have relatively excellent exercise abilities. The incline and speed of the treadmill were gradually increased every 3 minutes [22]. Oxygen uptake through the respiratory system was recorded as the average value of 10 seconds of Breath-by-Breath. Based on test recommendations, maximum exercise capacity can be determined between 8 and 12 minutes, and the Bruce protocol was adopted considering that the participants had high exercise capacity [23]. The treadmill started at a 10% incline and a speed of 1.7 mph, and every 3 minutes, the incline increased by 2% and the speed increased by 0.8 mph. Oxygen uptake through the respiratory system was recorded as a 5-second breath-by-breath average. A mask equipped with sensors that measure ventilation, O_2 and CO_2 amounts was used. The measurer checked several things before the test. Treadmill experience, current health condition for maximum capacity test, cardiac history, and fit of mask and face before test were confirmed. When the test reached its maximum state, the participant stopped by raising his or her hand or pressing the stop button, and recovered by sitting or lying down until the resting heart rate fell below 100 bpm.

An electrocardiogram analyzer (Case8000, GE Marquette Co., Fairfield, CT, USA) was used to continuously monitor

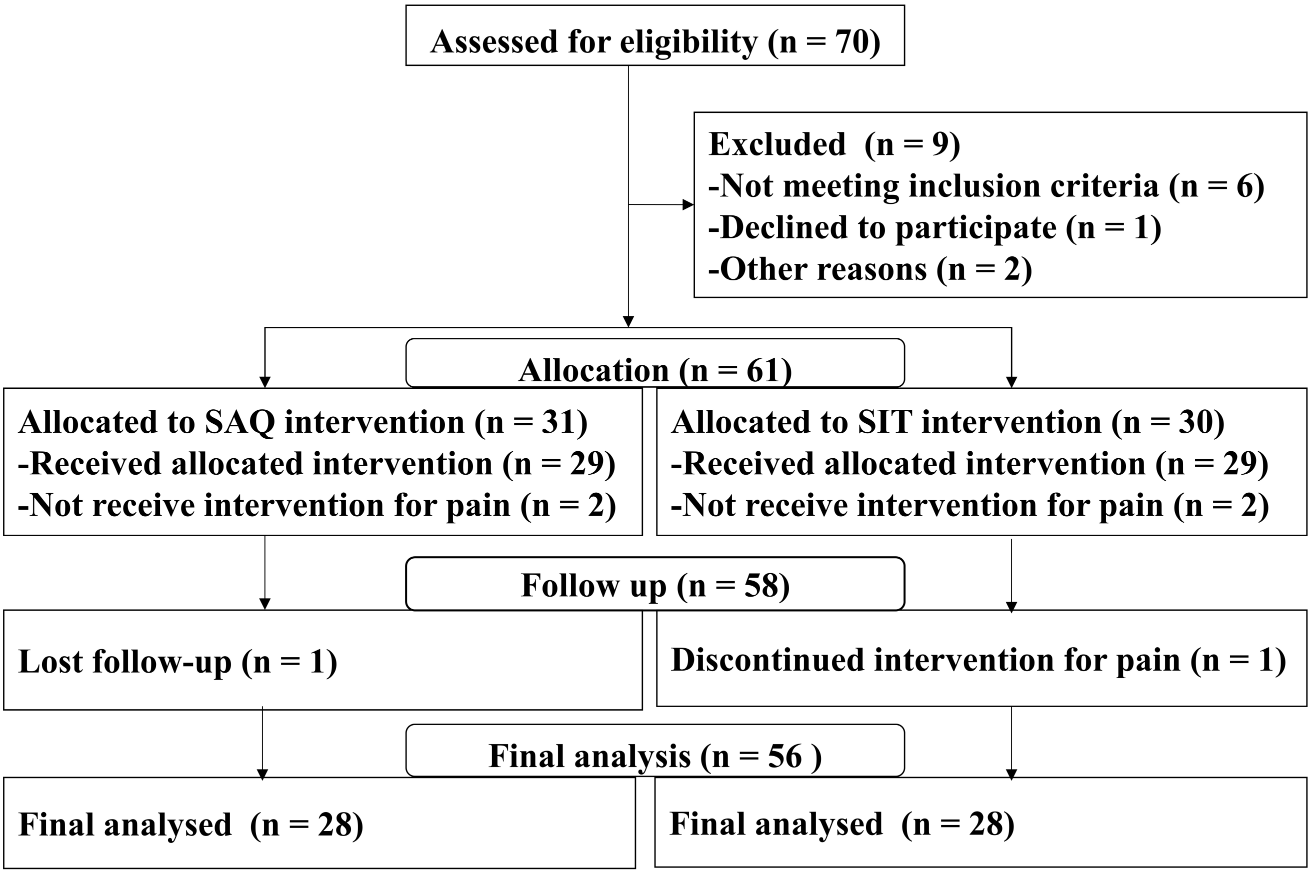

FIGURE 1. Flow chart for inclusion and exclusion of participants. SAQ: speed-agility-quickness training; SIT: sprint interval training.

the participants' condition to ensure safety and prevent sudden cardiac risks during the examination. During the test, blood pressure was checked at minute intervals, and the rating of perceived exertion and measured values were recorded every 3 minutes. The test aimed to measure the maximal exercise capacity, but was discontinued if participants felt pain (visual analog scale score ≥6) and requested to stop or when abnormalities were observed on the electrocardiogram. VO_2 peak was defined as the measured VO_2 when the respiratory exchange ratio reached ≥1.10, and AT was defined as the point at which VO_2 and ventilation increased suddenly.

2.3 Isokinetic knee strength test

The examiner clearly explained and demonstrated the required movements to the participants, and two trial exercises were conducted prior to the test. Isokinetic knee strength was measured while performing concentric contractions at 60°/s and 180°/s angular velocities, using an isokinetic dynamometer (Humac Norm, CSMi, Stoughton, MA, USA). In a previous study, the intraclass correlation coefficient of the Humac Norm isokinetic dynamometer for measuring knee strength was reported to range from 0.74 to 0.89, showing excellent reliability [24]. Maximum muscle strength (Nm) was measured at 60°/s, and muscle power (Watt) was measured at 180°/s [25]. The participant sat on the examination chair, and the axis of the dynamometer was matched with the anatomical axis of rotation of the knee joint (lateral epicondyle of the femur). The range of knee flexion and extension for the test was set at 0–90°, and the maximum knee extension was set to 0°. First, the knee was bent to 90° and the participant waited for a verbal signal. Extensor muscle strength was measured first with the start signal, and flexor muscle strength was measured with the next signal. The participant performed the motion four times at an angular velocity of 60°/s and ten times at an angular velocity of 180°/s. The absolute values of the measured muscle strength and power were normalized by dividing the weight by the percentage, and the relative values for the extensors and flexors were summed and analyzed to evaluate knee strength.

2.4 Agility tests

Agility was assessed using the Illinois agility test (IAT) and Agility *T*-test (ATT) [26]. Although traditionally agility includes a response to an unexpected stimulus [27], in this study, agility tests are defined as those assessing a player's ability to change direction rapidly and efficiently. The IAT specifically evaluates soccer players' ability to quickly change direction [28], while the ATT measures lateral movement, speed, and body control by simulating a scenario in which a player must react swiftly to a dynamic situation, such as chasing an opponent [29]. This definition reflects the sport-specific demands of soccer, where rapid changes of direction are critical, even though they do not always involve a response to an unexpected stimulus [30]. All participants performed a dynamic warm-up for 15 minutes before the test to prevent injury. The examiner explained and demonstrated the test procedure to the participants, and practiced it once.

For IAT, eight cones were installed on a course (length: 10 m; width: 5 m) (Fig. 2A). The participants lay face down on the floor, with their heads facing the starting line and their hands directly adjacent to their shoulders. At the examiner's "Go" command, they got up as quickly as possible, quickly ran forward for 10 m, circled around the cone, and then ran 10 m in the opposite direction. Subsequently, the participants quickly passed the slalom course with four cones and returned and ran 10 m up and down quickly to cross the finish line.

For the ATT, four cones were arranged in a T-shape (Fig. 2B). The distance between cones 1 and 2 was 9.14 m, while cones 2, 3 and 4 were placed 4.57 m apart [29]. Upon receiving the "Go" command from the examiner, participants sprinted quickly from cone 1 to cone 2 and touched the cone with the right hand. Then, they quickly sidestepped toward cone 3, touched it with their left hand, moved laterally toward cone 4, and touched it with their right hand. Finally, the participants moved to the side again to cone 3, touched it with their left hand, and ran quickly with a backstep to pass cone 1. Both the IAT and ATT were performed twice, and the time from start to finish was measured using a stopwatch. Inspectors were provided with several rounds of training and practice in advance to ensure accurate measurements, and were instructed to strictly follow the protocol. For both tests, a smaller value was recorded for the time required to complete the test.

2.5 Sport enjoyment score

The Sports Commitment Questionnaire-2 (SCQ-2) was used to evaluate psychometric parameters and subjectively measure the participant's enjoyment of the sport. SCQ-2 is a self-report questionnaire that measures an athlete's commitment to a specific sport [31]. This questionnaire provides insights into the cognitive, emotional and behavioral aspects of an individual's commitment to sports. In previous studies, the overall reliability of the SCQ-2 was >0.80, and the composite reliability ranged from 0.71 to 0.92 [32].

The SCQ-2 includes a series of questions that respondents are required to self-evaluate on the designated scale and comprises nine individual subscales related to sports commitment. Among the SCQ-2 questions, the four items of interest in this study were "sport enjoyment", "constrained commitment", "desire to excel-mastery achievement" and "valuable opportunities". In particular, the "Sport Enjoyment" source includes the following five items: "Playing this sport is fun", "I like playing this sport", "I love to play this sport", "Playing this sport is very pleasurable" and "Playing this sport makes me happy". Each item is rated on a 5-point Likert scale, with possible scores ranging from 1 (strongly disagree) to 5 (strongly agree). Respondents could express their degree of agreement or disagreement with each question using this range.

2.6 Intervention training

The training programs were conducted twice per week for eight weeks (16 sessions, approximately 30 min per session) for each group. During all training sessions, the heart rate was monitored in real time using an electronic heart rate monitoring device (Polar H10, Polar Electro, Bethpage, NY, USA) to control exercise intensity. Before initiating training, all participants warmed up with light running for 10 min at moderate intensity, corresponding to 50–60% of their maximal heart rate (HR_{max}). After completing the training, the participants cooled down for 10 min, maintaining the heart rate within the same range as that during the warm-up. Both training sessions took place on the same day of the week (Tuesday and Thursday), and each session was conducted at the same time (15:00–17:00 PM).

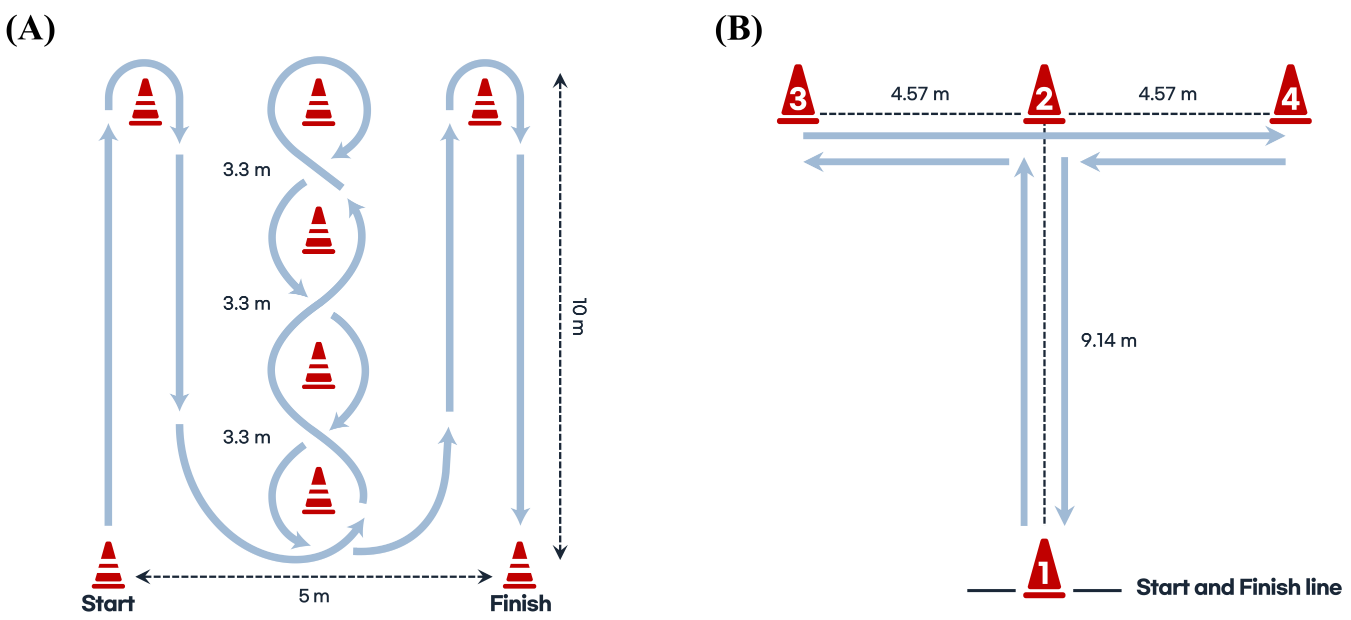

FIGURE 2. Agility tests. (A) Illinois agility test. (B) Agility *T*-test.

2.6.1 Speed, agility and quickness training

The SAQT program was based on the short stints of SAQT drills reported by Trecroci *et al.* [2]. Training sessions were held in the field and each session lasted approximately 20 minutes. The training volume and exercise intensity were adjusted using sports drills, work volume and rest, and the training volume was gradually increased every two weeks. In the 1st and 2nd weeks of training, participants performed basic footwork exercises (line drills, split-steps, multiple hops, skipping, in & out drills) and agility drills (short sprints with 2–3 changes of direction at 30 and 45 degrees over 10 m) without equipment. During the 3rd and 4th weeks, these exercises and drills incorporated an agility ladder. Weeks 5 and 6 focused on advanced footwork exercises (hip twist, icky shuffle, foot exchange) and agility drills (short sprints with 4–5 changes of direction at 30, 45 and 90 degrees over 10 m), also using an agility ladder. Finally, weeks 7 and 8 combined basic and advanced agility training over 15 m with both basic and advanced footwork training.

2.6.2 Sprint interval training

For SIT, the sprint interval running program described by Kelly *et al.* [33] was used. The SIT protocol included four sets of maximal intensity sprints, interspersed with short intra-set recovery periods and longer inter-set recovery periods. All training sessions were conducted on a 400 m track. After a 10-minute light warm-up, participants sprinted 200 m from the start line (midpoint of the straightaway) to the finish line (midpoint of the opposite straightaway). Each sprint was followed by an active recovery during which participants jogged 200 m back to the start line. Each sprint repetition and recovery period lasted 120 seconds. Participants completed each sprint in 30 seconds and were allowed a 90-second intra-set recovery period.

A single set consisted of three sprints, with an inter-set recovery period of 2–3 minutes allowed between each set at an intensity of 50–60% of HR_{max}. During training sessions in weeks 1 and 2, participants performed three sets, totaling nine sprints, with a 3-minute inter-set recovery period after each set. In weeks 3 and 4, the number of sets remained the same as before, but the recovery period between sets was reduced to 2 minutes. In weeks 5 and 6, participants performed four sets, totaling 12 sprints, with a 3-minute inter-set recovery period after each set. In weeks 7 and 8, the number of sets remained the same as before, but the recovery period between sets was reduced to 2 minutes.

2.6.3 Resistance training

The SAQT and SIT groups participated in the same resistance training program, conducted on the same days as each intervention training, twice a week for eight weeks. The program consisted of weight training, focusing on optimizing participants' training participation and preventing muscle loss. Participants performed three sets of 12 repetitions at 80% of their one-repetition maximum to improve strength [34]. Weight training included performing leg extension, leg curl, leg press, shoulder press, chest press, butterfly, pull-down, long pull, arm curl, abdominal, hip abduction, and inner thigh exercises using machines. For resistance training, the participants determined the order of use of each machine and moved to the next machine after completing the target muscle group exercise.

2.7 Data analysis

IBM SPSS 25.0 Statistics software for Windows (IBM Corp., Armonk, NY, USA) was used for the data analysis. Numerical data were presented as means and standard deviations, whereas categorical data were expressed as numbers and percentages. The Shapiro-Wilk test was used to determine normality. Because the main variables analyzed in this study were not normally distributed, non-parametric analysis was performed. The Wilcoxon signed-rank test was performed before and after intragroup comparisons, and the Mann-Whitney U test was used for intergroup comparisons. Statistical significance was set at $p < 0.05$.

3. Results

3.1 General characteristics of the SAQT and SIT groups

Table 1 shows the general characteristics of the participants according to group. No statistically significant differences in age, height, weight, body mass index, or injury site were observed between the SAQT and SIT groups.

3.2 Graded exercise test

VO_2 peak and AT improved significantly after training in both SAQT (p = 0.042 and p = 0.038) and SIT (p = 0.018 and p = 0.025) groups. The SIT group showed significantly improved VO_2 peak and AT after training compared with the SAQT group (p = 0.041 and p = 0.031) (Table 2).

3.3 Isokinetic knee strength and agility tests

Peak torque and average power at angular velocities of 60°/s and 180°/s significantly improved after training in the SAQT (p = 0.024 and p = 0.039) and SIT (p = 0.016 and p = 0.031) groups. No significant difference between the groups after training was observed at an angular velocity of 60°/s. However, after the intervention, the average power was significantly higher in the SIT group than in the SAQT group at an angular velocity of 180°/s (p = 0.020).

The IAT and ATT performance times were significantly reduced after training in both SAQT (p = 0.012 and p = 0.025) and SIT (p = 0.028 and p = 0.028) groups. However, in the comparison between groups, the SAQT group showed significantly more reduced IAT and ATT performance times after training than the SIT group (p = 0.041 and p = 0.031) (Table 3).

3.4 Sports enjoyment score

Table 4 shows the scores for the individual subscales of the SCQ-2. Scores for sport enjoyment (p = 0.015), constrained commitment (p = 0.005), desire to excel-mastery achievement (p = 0.002), and valuable opportunities (p = 0.006) increased

TABLE 1. Characteristics of participants in the SAQT and SIT groups.

Variables	SAQT (n = 28)	SIT (n = 28)	t or χ^2	E.S	p
Age, yr	16.3 ± 0.8	15.9 ± 0.9	1.336	0.469	0.189
Height, cm	174.2 ± 6.7	174.3 ± 5.9	−0.055	0.015	0.956
Weight, kg	65.0 ± 8.3	64.7 ± 7.2	0.110	0.038	0.913
BMI, kg/m^2	21.3 ± 1.5	21.2 ± 1.4	0.188	0.068	0.852
Player career, yr	4.5 ± 2.2	4.2 ± 2.8	0.195	0.119	0.878
Injury site, n					
Foot	4	5			
Knee	22	20	0.406	0.085	0.816
Hip	2	3			

$p < 0.05$; SAQT: speed-agility-quickness training; SIT: sprint interval training; BMI: body mass index; E.S: effect size (Cohen's d or Cramer's v).

TABLE 2. Results on graded exercise test in the SAQT and SIT groups.

Variables	Group	Pre	Post	Diff (%)	E.S	p
VO_2 peak, mL/kg/min						
	SAQT	47.7 ± 6.7	52.2 ± 8.9	9.4	0.571	0.042
	SIT	48.1 ± 7.4	55.3 ± 7.5	15.0	0.966	0.018
	p	0.524	0.041			
VO_2 peak, L/min						
	SAQT	3.10 ± 0.20	3.39 ± 0.22	9.4	1.379	0.028
	SIT	3.11 ± 0.17	3.57 ± 0.20	14.8	2.478	0.019
	p	0.488	0.039			
Anaerobic threshold, L/min						
	SAQT	2.21 ± 0.14	2.57 ± 0.19	16.3	2.157	0.038
	SIT	2.19 ± 0.10	2.66 ± 0.16	21.5	3.522	0.025
	p	0.495	0.031			

$p < 0.05$; SAQT: speed-agility-quickness training; SIT: sprint interval training; Diff: difference between pre- and post-training; E.S: effect size (Cohen's d); VO_2 peak: peak oxygen uptake.

significantly only in the SAQT group after training. Comparisons between groups also showed significant differences in all scores after training.

4. Discussion

Soccer requires high physiological capacity due to the high intensity and long playing time, and optimal cardiorespiratory fitness is essential to maintain energy provided throughout the game [35]. On the other hand, most situations that have a decisive impact on the outcome of a game are activities that require explosive power, such as short intense sprints, high jumps, and quick changes of direction [36]. These are crucial elements of performance in soccer. Traditional training methods to improve these skills are generally high-intensity and very difficult, so they can have negative effects, such as reduced sports participation and withdrawal, in youth who lack motivation to devote themselves to sports [37]. Therefore, intervention is needed to strengthen the positive affective response that youth athletes feel through sports and enable them to actively participate in training. This study explored the effects of an intervention using SAQT and SIT on performance-related functional parameters and sport enjoyment in youth soccer players preparing to return after injury.

VO_2 peak and AT improved significantly after training in both groups, indicating that both SAQT and SIT are effective interventions to improve cardiorespiratory fitness. SAQT includes high-intensity interval and agility training that contributes to improved aerobic fitness by increasing heart rate and oxygen consumption [38]. In contrast, SIT involves repeated bouts of maximal or near-maximal effort sprints with short recovery periods, which can significantly improve VO_2 peak [39]. In particular, adolescents tend to be more sensitive to various training stimuli because they possess relatively higher adaptability than adults [40]. Owing to this sensitive training-induced adaptation, the 8-week training program conducted in this study might be sufficient to improve cardiorespiratory fitness in adolescent athletes despite being a relatively short-term intervention. However, in between-group comparisons, both VO_2 peak and AT improved significantly more in the

TABLE 3. Results on isokinetic knee strength and agility test in the SAQT and SIT groups.

Variables	Group	Pre	Post	Diff (%)	E.S	*p*
60°/s, Nm/kg, %						
	SAQT	487.8 ± 127.1	532.5 ± 120.4	9.2	0.361	0.024
	SIT	477.6 ± 116.0	538.3 ± 110.2	12.7	0.536	0.016
	p	0.724	0.724			
180°/s, Watt/kg, %						
	SAQT	618.3 ± 127.0	642.1 ± 135.7	3.8	0.181	0.039
	SIT	607.6 ± 139.1	669.8 ± 120.2	10.2	0.478	0.031
	p	0.629	0.020			
Illinois agility test, sec						
	SAQT	16.5 ± 2.14	14.8 ± 1.75	−10.3	0.869	0.012
	SIT	16.4 ± 2.05	15.8 ± 1.68	−3.7	0.320	0.028
	p	0.524	0.041			
Agility *T*-test, sec						
	SAQT	11.4 ± 1.88	10.3 ± 1.50	−9.6	0.646	0.025
	SIT	11.3 ± 2.12	10.9 ± 2.00	−3.5	0.194	0.028
	p	0.495	0.031			

$p < 0.05$; SAQT: speed-agility-quickness training; SIT: sprint interval training; Diff: difference between pre- and post-training; E.S: effect size (Cohen's d).

TABLE 4. Results on the sport commitment questionnaire-2 in the SAQT and SIT groups.

Variables	Group	Pre	Post	Diff (%)	E.S	*p*
Sport enjoyment						
	SAQT	4.17 ± 0.8	4.66 ± 0.6	11.8	0.692	0.015
	SIT	4.10 ± 0.7	4.23 ± 0.5	3.2	0.213	0.138
	p	0.495	0.031			
Constrained Commitment						
	SAQT	3.83 ± 1.2	4.53 ± 0.5	18.3	0.761	0.005
	SIT	3.81 ± 1.1	4.00 ± 0.6	5.0	0.214	0.159
	p	0.589	0.015			
Desire to Excel-Mastery Achievement						
	SAQT	4.05 ± 0.9	4.61 ± 0.4	13.8	0.804	0.002
	SIT	4.00 ± 0.8	4.10 ± 0.5	2.5	0.149	0.210
	p	0.671	0.024			
Valuable opportunities						
	SAQT	4.15 ± 0.7	4.53 ± 0.8	9.2	0.505	0.006
	SIT	4.11 ± 0.7	4.21 ± 0.6	2.4	0.153	0.319
	p	0.941	0.025			

$p < 0.05$; SAQT: speed-agility-quickness training; SIT: sprint interval training; Diff: difference between pre- and post-training; E.S: effect size (Cohen's d).

SIT group. These differences in effectiveness may be due to training specificity. SIT is performed primarily through the anaerobic energy system, where repeated high-intensity sprints with minimal recovery periods lead to adaptations that improve the body's ability to tolerate and buffer lactic acid, which is a key component of improved anaerobic performance [41]. Furthermore, SIT combined with the relatively short duration of the training sessions may have played a pivotal role. Because SIT repeatedly compels the body to operate near its maximal capacity, it effectively improves anaerobic capacity and enables performance at higher intensities without the accumulation of a large amount of lactic acid [33]. Although SAQT improves aerobic capacity, it may be less effective than SIT for overall VO_2 peak improvement because it focuses on agility and speed. Therefore, SIT, which focuses on both aerobic and anaerobic conditioning, may be more suitable for improving both VO_2 peak and AT in soccer players who perform high-intensity sprints and require rapid recovery during matches.

Knee strength is a very important factor in soccer players because it directly affects various aspects of performance, injury prevention, and player longevity [42]. It improves essential performance-related attributes, including kicking power, jumping ability, agility, and turning. Additionally, it enhances balance and control, joint stabilization, and fatigue resistance [43]. Therefore, considering the physical demands and potential injury risk related to soccer, increasing knee strength is important for optimizing performance and preventing injury. In the isokinetic knee strength test, peak torque and average power significantly improved after training in both groups. However, compared with the SAQT group, the SIT group achieved a higher average power at an angular velocity of 180°/s. The differences in results may be attributed to various factors related to the specific characteristics of each training method. Bagley *et al.* [44] reported that SIT improves muscle strength and power because it focuses on high-intensity, explosive muscle contractions for the fast and powerful leg movements required for sprinting. Herbert *et al.* [45] reported that high-intensity interval training promotes the release of hormones, such as testosterone and growth hormone, which are associated with muscle growth and power development. Another training modality, SAQT, includes explosive movements such as drills and quick turns, which require fast and powerful muscle contractions [46]. The emphasis on explosive power development was consistent with the improvements in maximal strength at an angular velocity of 60°/s observed in the SAQT group. In addition, SAQT incorporates sports-specific movements such as cutting, pivoting, and accelerating. Because these movements require rapid changes in muscle force, they can contribute to improving muscle strength [47]. In addition, both SIT and SAQT can promote neuromuscular adaptations, including increased recruitment of motor units and synchronization of muscle contractions. These adaptations are essential for generating fast and powerful muscle contractions and contribute to improvements in muscle power [48, 49]. Although both training modalities can improve strength, the SIT group achieved better strength-related outcomes. Importantly, although SAQT improves physical characteristics, such as agility and quickness, it does not physiologically prioritize rapid force production to the same extent as SIT. Therefore, our findings suggest that SIT is more effective in developing specific types of muscle power required for explosive actions in sports, such as sprinting.

Regarding the agility test results, IAT and ATT performance times were significantly shortened after training in both groups. These results highlight several important factors that are associated with training-induced improvements in agility. SAQT emphasizes precise footwork and rapid changes in direction, which are directly related to agility [38]. SIT, which focuses on explosive sprints, also requires high coordination and body control [50]. Both training methods potentially improve the efficiency of neuromuscular pathways, and as participants adapt to the training program, they may become more adept at initiating and executing rapid movements essential for agility. Furthermore, the results of the isokinetic knee strength test in this study demonstrated that SAQT and SIT can improve lower-body strength and power through different mechanisms. These improvements can promote faster and more powerful directional changes, which is a fundamental aspect of agility. Although both training methods effectively improved agility, the better outcomes in the SAQT group provided insight into the importance of considering training specificity, emphasis and biomechanical differences. SAQT was specifically designed to improve agility, quickness and change-of-direction skills and the training program included drills that mimic the agility requirements of soccer, such as ladder drills, cone drills and zig-zag movements [2]. This training directly targeted the skills measured in agility tests. Additionally, SAQT focuses on improving soccer-specific movement patterns and skills needed for agility [51]. SIT primarily focuses on improving sprint speed and aerobic and anaerobic performance [17]. Although sprinting is an important element of soccer, agility requires more complex movements, including quick changes in direction and precise footwork [52]. Compared to the levels of specificity and agility provided by SAQT, those provided by SIT are limited. These results suggest that the benefits of skill-focused training that mimics real game situations can be significant for adolescent athletes who develop basic movement skills during growth.

Sports enjoyment and positive affective responses play pivotal roles in adolescent athletes' involvement and participation [53]. MacDonald *et al.* [54] used a questionnaire to investigate the role of enjoyment and motivational environment in team sports in 510 young athletes. Their results confirmed that positive experiences in sports increase the likelihood of long-term participation, induce the desire to return to the playing field, and contribute to sports dedication. Additionally, personal fulfillment and enjoyment within sports strengthen players' intrinsic motivation and improve their commitment to training and competing [55]. Based on a latent profile analysis of 313 young sportspersons, Gardner *et al.* [56] reported that those who truly enjoyed their sport were more dedicated and invested the required time and effort in training, practice and skill development. These efforts are essential to achieve long-term success in sports. In the present study, the score of the sports enjoyment component of the SCQ-2, which evaluates subjective sports enjoyment, significantly improved only in the SAQT group. This suggests that SAQT can elicit a more positive affective response in young soccer players than

SIT can. SAQT includes drills involving quick successions of movements that provide immediate positive reinforcement [38].

Athletes may experience a sense of accomplishment and enjoyment as they observe noticeable improvements in agility, quickness and change-of-direction skills during SAQT sessions. Furthermore, SAQT programs include a variety of elements that make training sessions more interesting and enjoyable [57]. Although the physical demands of SIT are systematic and scientific, they can cause considerable strain and fatigue in athletes [58]. Adolescents who are still physiologically and physically underdeveloped may find SIT physically challenging, which could potentially reduce their enjoyment of the training programme. Additionally, unlike SAQT, which focuses on skill development, SIT, which primarily targets sprinting speed and anaerobic performance, shows limited immediate effects on skill mastery and a sense of accomplishment that induce positive feelings. This effect may account for the lack of significant change in enjoyment in the SIT group. High levels of stress and pressure or low enjoyment are associated with a risk of burnout, which can lead to early dropout in young athletes [59]. Developing enjoyment and positive emotions can act as protective factors against burnout and help to retain athletes. Therefore, recognizing these differences in psychological responses to different training modalities can help coaches and trainers adjust their training programs to better fulfill the needs and preferences of young athletes. This could ultimately create more enjoyable and sustainable sports experiences.

This study has some limitations in terms of participant characteristics. As the participants were young male soccer players, the findings may not be generalizable to female athletes or athletes of other age groups. Although various physiological and psychological aspects are involved, this study only measured cardiorespiratory endurance, lower extremity muscle strength, and sports enjoyment. In this study, it was not possible to fully control other training (*e.g.*, individual training) of athletes excepting the intervention training. Differences in individual ability, severity of injury, and length of time away from team training were not taken into account. In particular, an exercise intensity monitoring system that takes individual differences in ability into account was not applied (*e.g.*, heart rate monitoring). Future research should include more scalability. In order to confirm the and efficiency of SAQT, it should be compared with other training, and the items should also be more diverse. Because it is unknown how long the positive results identified in this study will last after returning to the field, more long-term research is required. In this study, the Bruce protocol was used in graded exercise test (GXT). There are some opinions that this protocol is appropriate for adolescents [23], but there are also studies that suggest that the Oslo-protocol is more appropriate [60]. This means that different protocols may produce different results, and it would be very meaningful in future studies to conduct comparative analyzes using different protocols and compare rates at oxygen threshold, ventilatory-anaerobic threshold, and respiratory compensation point. This means that different protocols may produce different results, and it would be very meaningful in future studies to conduct comparative analyzes using different protocols and compare rates at oxygen threshold, ventilatory-anaerobic threshold, and respiratory compensation point. In addition, research on the psychological difficulties that athletes experience and overcoming them after returning will be able to provide future athletes with deep insight into not only the importance of physical ability but also psychological recovery. One interesting topic is that deeper analysis based on physiological test data will further support the effectiveness of training. Since women's participation in sports has been increasing recently, working to develop effective training for women will be an interesting topic.

5. Conclusions

In this study, participants who engaged in either SAQT or SIT for eight weeks demonstrated significant improvements in the outcomes of graded exercise test, isokinetic knee strength test, and agility tests post-training. Upon comparing the two groups, it was found that SIT was more effective in enhancing VO_2 peak, AT and knee strength, whereas SAQT was associated with greater enhancements in IAT and ATT performance times, as well as in sport enjoyment scores. Consequently, it appears that SAQT may substantially enhance agility and quickness, which are crucial for optimal in-game performance, while SIT may improve other vital components such as cardiorespiratory fitness and muscle strength. Particularly for youth soccer players who are recovering from injuries, SAQT could be instrumental in fostering more positive affective responses and enhancing sport enjoyment.

ABBREVIATIONS

SAQT, Speed, agility, and quickness training; SIT, Sprint interval training; SCQ-2, Sport Commitment Questionnaire-2; AT, Anaerobic threshold; VO_2 peak, Peak oxygen uptake; IAT, Illinois agility test; ATT, Agility T-test; HR_{max}, Maximal heart rate.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on request from the corresponding author.

AUTHOR CONTRIBUTIONS

YK and YP—conceptualization, supervision. CYD and YK—methodology, formal analysis, review and editing. YP—investigation. CYD and YP—original draft writing. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee of the Gangneung-Wonju National University (2021-13). Informed consent was obtained from all the participants and their legal guardians.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Klingner FC, Huijgen BC, Den Hartigh RJ, Kempe M. Technical–tactical skill assessments in small-sided soccer games: a scoping review. International Journal of Sports Science & Coaching. 2022; 17: 885–902.

[2] Trecroci A, Cavaggioni L, Rossi A, Moriondo A, Merati G, Nobari H, *et al*. Effects of speed, agility and quickness training programme on cognitive and physical performance in preadolescent soccer players. PLOS ONE. 2022; 17: e0277683–e0277698.

[3] McBurnie AJ, Dos' Santos T, Johnson D, Leng E. Training management of the elite adolescent soccer player throughout maturation. Sports. 2021; 9: 170–189.

[4] Wekesser MM, Harris BS, Langdon J, Wilson CH. Coaches' impact on youth athletes' intentions to continue sport participation: the mediational influence of the coach–athlete relationship. International Journal of Sports Science & Coaching. 2021; 16: 490–499.

[5] Le Bars H, Gernigon C, Ninot G. Personal and contextual determinants of elite young athletes' persistence or dropping out over time. Scandinavian Journal of Medicine & Science in Sports. 2009; 19: 274–285.

[6] Dugdale JH, Sanders D, Myers T, Williams AM, Hunter AM. Progression from youth to professional soccer: a longitudinal study of successful and unsuccessful academy graduates. Scandinavian Journal of Medicine & Science in Sports. 2021; 31: 73–84.

[7] Fuhre J, Øygard A, Sæther SA. Coaches' criteria for talent identification of youth male soccer players. Sports. 2022; 10: 14–23.

[8] Bandura CT, Kavussanu M. Authentic leadership in sport: its relationship with athletes' enjoyment and commitment and the mediating role of autonomy and trust. International Journal of Sports Science & Coaching. 2018; 13: 968–977.

[9] Gardner LA, Vella SA, Magee CA. Continued participation in youth sports: the role of achievement motivation. Journal of Applied Sport Psychology. 2017; 29: 17–31.

[10] De Muynck G-J, Morbée S, Soenens B, Haerens L, Vermeulen O, Vande Broek G, *et al*. Do both coaches and parents contribute to youth soccer players' motivation and engagement? An examination of their unique (de) motivating roles. International Journal of Sport and Exercise Psychology. 2021; 19: 761–779.

[11] Sevil-Serrano J, Abós Á, Diloy-Peña S, Egea PL, García-González L. The influence of the coach's autonomy support and controlling behaviours on motivation and sport commitment of youth soccer players. International Journal of Environmental Research and Public Health. 2021; 18: 8699–8710.

[12] Newman TJ, Lower-Hoppe LM, Burch M, Paluta LM. Advancing positive youth development-focused coach education: contextual factors of youth sport and youth sport leader perceptions. Managing Sport and Leisure. 2021; 26: 326–340.

[13] Strauch UG, Wäsche H, Jekauc D. Coach competences to induce positive affective reactions in sport and exercise—a qualitative study. Sports. 2019; 7: 16–30.

[14] Rhodes RE, Kates A. Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. Annals of Behavioral Medicine. 2015; 49: 715–731.

[15] Boullosa D, Dragutinovic B, Feuerbacher JF, Benítez-Flores S, Coyle EF, Schumann M. Effects of short sprint interval training on aerobic and anaerobic indices: a systematic review and meta-analysis. Scandinavian Journal of Medicine & Science in Sports. 2022; 32: 810–820.

[16] Milanović Z, Sporiš G, Trajković N, Sekulić D, James N, Vučković G. Does SAQ training improve the speed and flexibility of young soccer players? A randomized controlled trial. Human Movement Science. 2014; 38: 197–208.

[17] Gist NH, Fedewa MV, Dishman RK, Cureton KJ. Sprint interval training effects on aerobic capacity: a systematic review and meta-analysis. Sports Medicine. 2014; 44: 269–279.

[18] Lee YS, Lee D, Ahn NY. SAQ training on sprint, change-of-direction speed, and agility in U-20 female football players. PLOS ONE. 2024; 19: e0299204–e0299228.

[19] Weiss WM. Applying the sport commitment model to sport injury rehabilitation. Journal of Sport Rehabilitation. 2020; 30: 242–247.

[20] Meierbachtol A, Obermeier M, Yungtum W, Bottoms J, Paur E, Nelson BJ, *et al*. Injury-related fears during the return-to-sport phase of ACL reconstruction rehabilitation. Orthopaedic Journal of Sports Medicine. 2020; 8: 2325967120909385.

[21] Hsu C, Meierbachtol A, George SZ, Chmielewski TL. Fear of reinjury in athletes. Sports Health. 2017; 9: 162–167.

[22] Currie KD, Soave KM, Slade JM. Reliability of blood pressure responses used to define an exaggerated blood pressure response to exercise in young healthy adults. Journal of Human Hypertension. 2023; 37: 56–61.

[23] DiBella JA, Johnson EM, Cabrera ME. Ramped *vs.* standard bruce protocol in children: a comparison of exercise responses. Pediatric Exercise Science. 2002; 14: 391–400.

[24] Habets B, Staal JB, Tijssen M, van Cingel R. Intrarater reliability of the Humac NORM isokinetic dynamometer for strength measurements of the knee and shoulder muscles. BMC Research Notes. 2018; 11: 15.

[25] Costa DC, Valente-dos-Santos J, Celis-Moreno JM, Sousa-e-Silva P, Martinho DV, Duarte JP, *et al*. Learning effect on an isokinetic knee strength test protocol among male adolescent athletes. PLOS ONE. 2023; 18: e0288382–e0288391.

[26] Negra Y, Chaabene H, Hammami M, Amara S, Sammoud S, Mkaouer B, *et al*. Agility in young athletes: is it a different ability from speed and power? Journal of Strength and Conditioning Research. 2017; 31: 727–735.

[27] Sheppard JM, Young WB. Agility literature review: classifications, training and testing. Journal of Sports Sciences. 2006; 24: 919–932.

[28] Negra Y, Chaabene H, Amara S, Jaric S, Hammami M, Hachana Y. Evaluation of the Illinois change of direction test in youth elite soccer players of different age. Journal of Human Kinetics. 2017; 58: 215–224.

[29] França C, Gouveia É, Caldeira R, Marques A, Martins J, Lopes H, *et al*. Speed and agility predictors among adolescent male football players. International Journal of Environmental Research and Public Health. 2022; 19: 2856–2865.

[30] Chaalali A, Rouissi M, Chtara M, Owen A, Bragazzi NL, Moalla W, *et al*. Agility training in young elite soccer players: promising results compared to change of direction drills. Biology of Sport. 2016; 33: 345–351.

[31] Huhtiniemi M, Sääkslahti A, Watt A, Jaakkola T. Associations among basic psychological needs, motivation and enjoyment within finnish physical education students. Journal of Sports Science & Medicine. 2019; 18: 239–247.

[32] Scanlan TK, Chow GM, Sousa C, Scanlan LA, Knifsend CA. The development of the sport commitment questionnaire-2 (English version). Psychology of Sport and Exercise. 2016; 22: 233–246.

[33] Kelly DT, Cregg CJ, O'Connor PL, Cullen BD, Moyna NM. Physiological and performance responses of sprint interval training and endurance training in Gaelic football players. European Journal of Applied Physiology. 2021; 121: 2265–2275.

[34] Ratamess N. ACSM's foundations of strength training and conditioning. 2nd edn. Lippincott Williams & Wilkins: Philadelphia, PA. 2021.

[35] Marcos MA, Koulla PM, Anthos ZI. Preseason maximal aerobic power in professional soccer players among different divisions. The Journal of Strength & Conditioning Research. 2018; 32: 356–363.

[36] Jovanovic M, Sporis G, Omrcen D, Fiorentini F. Effects of speed, agility, quickness training method on power performance in elite soccer players. The Journal of Strength & Conditioning Research. 2011; 25: 1285–1292.

[37] Merkel DL. Youth sport: positive and negative impact on young athletes. Open Access Journal of Sports Medicine. 2013; 4: 151–160.

[38] Brown L, Ferrigno V. Training for speed, agility, and quickness. 3rd edn. Human Kinetics: Philadelphia, PA. 2014.

[39] Liang W, Liu C, Yan X, Hou Y, Yang G, Dai J, *et al*. The impact of sprint interval training versus moderate intensity continuous training on blood pressure and cardiorespiratory health in adults: a systematic review and meta-analysis. PeerJ. 2024; 12: e17064–e17087.

[40] Stricker PR, Faigenbaum AD, McCambridge TM, LaBella CR, Brooks MA, Canty G, *et al*. Resistance training for children and adolescents. Pediatrics. 2020; 145: e20201011–e20201023.

[41] Hall AJ, Aspe RR, Craig TP, Kavaliauskas M, Babraj J, Swinton PA. The effects of sprint interval training on physical performance: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research. 2023; 37: 457–481.

[42] Otsuki R, Benoit D, Hirose N, Fukubayashi T. Effects of an injury prevention program on anterior cruciate ligament injury risk factors in adolescent females at different stages of maturation. Journal of Sports Science & Medicine. 2021; 20: 365–372.

[43] Jones PA, Dos'Santos T, McMahon JJ, Graham-Smith P. Contribution of eccentric strength to cutting performance in female soccer players. The Journal of Strength & Conditioning Research. 2022; 36: 525–533.

[44] Bagley L, Al-Shanti N, Bradburn S, Baig O, Slevin M, McPhee JS. Sex comparison of knee extensor size, strength, and fatigue adaptation to sprint interval training. The Journal of Strength & Conditioning Research. 2021; 35: 64–71.

[45] Herbert P, Hayes L, Sculthorpe N, Grace FM. HIIT produces increases in muscle power and free testosterone in male masters athletes. Endocrine Connections. 2017; 6: 430–436.

[46] Abdulhussein AI, Faraj Al Abdullha JS. The effect of SAQ and (MetCon) training to developing some motor abilities, explosive ability and defensive foot movements for young basketball players. Indian Journal of Forensic Medicine & Toxicology. 2021; 15: 4782–4793.

[47] Falch HN, Haugen ME, Kristiansen EL, van den Tillaar R. Effect of strength *vs*. plyometric training upon change of direction performance in young female handball players. International Journal of Environmental Research and Public Health. 2022; 19: 6946–6961.

[48] Kinnunen JV, Piitulainen H, Piirainen JM. Neuromuscular adaptations to short-term high-intensity interval training in female ice-hockey players. The Journal of Strength & Conditioning Research. 2019; 33: 479–485.

[49] Hammami M, Negra Y, Billaut F, Hermassi S, Shephard RJ, Chelly MS. Effects of lower-limb strength training on agility, repeated sprinting with changes of direction, leg peak power, and neuromuscular adaptations of soccer players. The Journal of Strength & Conditioning Research. 2018; 32: 37–47.

[50] Dransmann M, Koddebusch M, Gröben B, Wicker P. Functional high-intensity interval training lowers body mass and improves coordination, strength, muscular endurance, and aerobic endurance of inmates in a German prison. Frontiers in Physiology. 2021; 12: 733774–733783.

[51] Milanović Z, Sporiš G, Trajković N, James N, Šamija K. Effects of a 12 week SAQ training programme on agility with and without the ball among young soccer players. Journal of Sports Science & Medicine. 2013; 12: 97–103.

[52] Trajković N, Sporiš G, Krističević T, Madić DM, Bogataj Š. The importance of reactive agility tests in differentiating adolescent soccer players. International Journal of Environmental Research and Public Health. 2020; 17: 3839–3848.

[53] Løvoll HS, Røysamb E, Vittersø J. Experiences matter: positive emotions facilitate intrinsic motivation. Cogent Psychology. 2017; 4: 1340083–1340097.

[54] MacDonald DJ, Côté J, Eys M, Deakin J. The role of enjoyment and motivational climate in relation to the personal development of team sport athletes. The Sport Psychologist. 2011; 25: 32–46.

[55] Timo J, Sami YP, Anthony W, Jarmo L. Perceived physical competence towards physical activity, and motivation and enjoyment in physical education as longitudinal predictors of adolescents' self-reported physical activity. Journal of Science and Medicine in Sport. 2016; 19: 750–754.

[56] Gardner LA, Magee CA, Vella SA. Social climate profiles in adolescent sports: associations with enjoyment and intention to continue. Journal of Adolescence. 2016; 52: 112–123.

[57] Lockie RG, Schultz AB, Callaghan SJ, Jeffriess MD. The effects of traditional and enforced stopping speed and agility training on multidirectional speed and athletic function. The Journal of Strength & Conditioning Research. 2014; 28: 1538–1551.

[58] Gillen JB, Gibala MJ. Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? Applied Physiology, Nutrition, and Metabolism. 2014; 39: 409–412.

[59] DiFiori JP, Benjamin HJ, Brenner JS, Gregory A, Jayanthi N, Landry GL, *et al*. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. British Journal of Sports Medicine. 2014; 48: 287–288.

[60] Fredriksen P, Ingjer F, Nystad W, Thaulow E. Aerobic endurance testing of children and adolescents—a comparison of two treadmill-protocols. Scandinavian Journal of Medicine & Science in Sports. 1998; 8: 203–207.

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