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Research article

Physiological and Biochemical Adaptations to a Sport-Specific Sprint Interval Training in Male Basketball Athletes

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Abstract

The present study compared the effects of incorporating traditional sprint interval training (SIT) or basketball-specific SIT (SSIT) into typical off-season training of male basketball players. Adaptations to and effect size (EF) of interventions on aerobic fitness [evaluated using Yo-Yo intermittent recovery test level-1 (Yo-Yo IR1)], change of direction [T-test (TT) and Illinois agility test (IAT)], vertical jump (VJ), standing long jump (SLJ), linear speed, maximal strength [one repetition maximum test in leg press ($1RM_{LP}$)], and hormonal status were examined. Male athletes (age = 25.7 ± 2.0 years; height = 188.1 ± 7.9 cm; body mass = 85.9 ± 8.0 kg) were randomly assigned to one of three groups of SIT (n = 10): three sets of 10 × 15 sec *all-out* intervals with 1:1 recovery between bouts and a 3-min recovery between sets; SSIT (n = 10): the same intervals as SIT + basketball-specific ball drills while running; and CON (n = 10): two sessions per week of regular basketball technical and tactical drills. SIT and SSIT resulted in significant changes compared with baseline in maximal oxygen uptake (4.9%, ES = 2.22 vs. 6%, ES = 2.57), TT (-1.8%, ES =-0.46 vs. -2.7%, ES = -1.14), IAT (-4.5%, ES = -2.01 vs. -5.4%, ES = -1.93), VJ (7.5%, ES = 0.58 vs. 12%, ES = 0.95), linear sprint time (-2.9%, ES = -0.32 vs. -4.3%, ES = -0.69), Yo-Yo IR1 (18.5%, ES = 2.19 vs. 23.7%, ES = 2.56), serum testosterone (28%, ES = 1.52 vs. 29.7%, ES = 1.59), and cortisol (-6.53%, ES = -0.37 vs. -12.06%, ES = -0.64). Incorporating SIT and SSIT into typical off-season basketball training triggers adaptive mechanisms that enhance aerobic and anaerobic performance in male basketball players. The effect size values indicate more significant effects of SSIT than SIT in most physiological and sport-specific adaptations. Such a superior effect could be attributed to the more basketball-specific movement pattern of the SSIT. Such interventions can be used by the coaches and athletes for designing the training load and for better training adaptations throughout the training seasons and competition periods.

Key words: Interval training, team sport, hormonal changes, aerobic power, athletic performance.

Introduction

Physical conditioning plays a vital role in training strategies designed to improve the fitness levels of basketball players (Balčiūnas et al., 2006). Conditioning programs are designed with specific interventions tailored to the characteristics of the discipline in which the athlete competes (Laursen and Buchheit, 2019; Sheykhlouvand et al., 2018a; Balčiūnas et al., 2006). Basketball is a high-intensity intermittent team sport requiring activities with maximal or near-maximal efforts (García et al., 2020). The game is characterized by high anaerobic glycolytic and aerobic oxidative demands, repeated change of direction (COD) challenging neuromuscular system, accelerations, decelerations, short distance sprints, jumps, physical contacts, and sport-specific skills (García et al., 2020; Heishman et al., 2020; Sekine et al., 2019; Hernández et al., 2018; Ben Abdelkrim et al., 2007). According to the literature, basketball players perform an average of 105 high-intensity runs with short duration (2-6 seconds) with 21 seconds rest intervals (Figueira et al., 2022). To achieve high-performance levels in repetitive high-intensity actions throughout basketball games, the energy demands rely on both anaerobic and aerobic energy metabolism while during low-intensity activities such as jogging, walking, and standing, aerobic energy metabolism is dominant (Arslan et al., 2022). Hence, improving both anaerobic and aerobic metabolic system is crucial for enhancing basketball performance.

Various sport-specific interventions have been introduced to improve these qualities in basketball players. High-intensity interval training (HIIT) is proven effective for enhancing metabolic capacities. Like the nature of HIIT, a basketball match involves periods of intensive sprinting, followed by short periods of moderate-to-low-intensity running (Garcia et al., 2020). Hence, HIIT could be considered a sport-specific conditioning approach for basketball players (Engel et al., 2018).

Many studies have developed sport-specific interval interventions, such as small-sided games, which are tailored to the unique requirements of basketball game dynamics and have compared them with traditional running-based HIIT (Arslan et al., 2022; Klusemann et al., 2012). Researchers believe that when exercise mimics movement patterns specific to the game, it brings about the simultaneous enhancement of technical skills under demanding physical conditions. Such approach motivates athletes to engaging in basketball-specific conditioning than conventional training methods, leading to the better transmission of physiological adaptations (Klusemann et al., 2012; Delextrat and Martinez, 2014). However, there are limitations to such interventions in question.

While these methods imitate basketball-specific movement patterns, they primarily aim to enhance athletes' skills under high-intensity exercise rather than directly focusing on athlete's conditioning. Although game-based interval interventions enhance aerobic and anaerobic training, their adaptive responses cannot be compared with traditional HIIT, given that the running distance and total work are rate different, making matching exercise loads difficult. More importantly, different numbers of high-

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intensity activities performed during the game-based interventions result in an inter-individual difference in the adaptations and prevent uniform adaptive response to the training (Castagna et al., 2011; Matthew and Delextrat, 2009; Ben Abdelkrim et al., 2007). Accordingly, in this study, we aimed to examine the effects of sprint interval training (SIT) program, known as one of the practical models of HIIT capable to induce positive improvement in performance capacity and skeletal muscle energy metabolism (Bayati et al., 2011; Sheykhlouvand et al., 2018b), using basketball-specific drills with a ball (SSIT). We directly compare it with a traditional running-based SIT program without ball using a research design that matched groups concerning total time commitment and repetitions, training frequency (2 sessions a week), and training duration (6 weeks) but differed in modality (running vs. running + ball drills). The effects on aerobic and anaerobic performance and hormonal changes were examined. Identifying a sport-specific SIT mimicking the game while imposing the same training load as traditional SIT to improve basketball-specific performance would be of value. Given the combination of ball drills with SIT and greater motivation of athlete's during sport-specific movement causing to enhance and maintain intensity and increase the athlete's physiological response (Aguiar et al., 2012), we hypothesized SSIT may result in more sport-specific adaptations than traditional SIT.

Methods

Participants

Following communication with a professional club and explaining the details of study, especially positive effects of SIT on aerobic and anaerobic performance, thirty male basketball players (age = 25.7 ± 2.0 years; height = 188.1 ± 7.9 cm; body mass = 85.9 ± 8.0 kg) gave written informed consent and voluntarily participated (Table 1). Participants were randomly assigned to SIT (n = 10), SSIT (n = 10), or control group [CON (n = 10)]. As they were members of a male team, we recruited only male participants. Participants of each group were matched based on their positions (guard, forward, and center). All athletes were familiar with basic interval and SIT interventions but hadn't performed SIT over the past three months. Before participation, all participants completed a questionnaire examining their medical history, injury background, and performance levels. The study's inclusion criteria specified that participants must meet three requirements: (a) having no history of injuries to the upper or lower body, (b) not having had any lower limb reconstructive surgery or unresolved musculoskeletal disorders in the past two years, and (c) not using ergogenic aids. All procedures followed the principles outlined in the Declaration of Helsinki and approved by the Institutional Ethics Review Committee for the Sichuan University of Science & Engineering, China.

Study design

Figure 1 illustrates a summary of the study design. The present study employed a randomized-controlled method with two experimental and one control group. The research took place over six weeks, during the team's off-season phase of the annual training cycle, and involved two weekly training sessions. One week before the baseline testing, the researchers conducted a laboratory familiarization with all

Table 1. Characteristic of the participants.

	SIT (n=10)			SSIT (n=10)			CON (n=10)		
	mean	±	SD	mean	±	SD	mean	±	SD
Age (y)	25.3	±	1.8	25.7	±	2.5	26.2	±	1.7
Height (m)	1.89	±	0.07	1.88	±	0.08	1.86	±	0.08
Weight (kg	87.0	±	7.6	85.9	±	9.5	85.0	±	7.6
Training experience (y)	8.5	±	2.1	8.7	±	1.4	8.1	±	1.8

SIT: sprint interval training, SSIT: sport-specific SIT, CON: control group

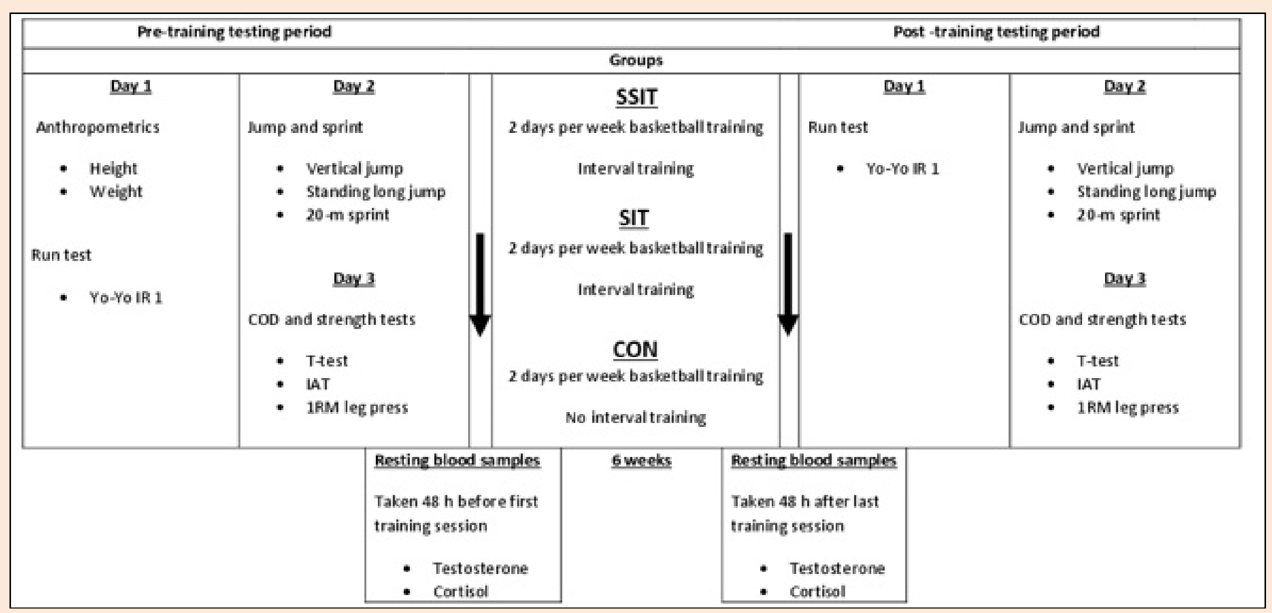

Figure 1. Overview of experimental protocol.

participants ensuring they became familiar with the testing procedures and training protocols. Participants visited the laboratory three times with 24 hours of rest between each visit, during which anthropometric measurements, performance metrics, and biochemical markers were evaluated. Following the anthropometric measurements at the first session, participants' aerobic power was evaluated using Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1). Vertical jump, standing long jump, and 20-m sprint abilities were measured during the second session with a 2-hour recovery between the tests. The third testing session evaluated COD and maximal strength, with a 2-hour relief between dedicated tests. The fasting blood sample was collected in the morning, two days before the initial and two days after the final training session. To control diurnal performance effects, the test sessions were completed at the same time of the day (i.e., afternoon). The participants were asked to avoid rigorous physical activity, stick to their regular diet 24 hours before the test, and abstain from caffeine and alcohol (Gharaat et al., 2020; Barzegar et al., 2021). 96 h after the completion of the preliminary test sessions, the participants commenced a 6-week training intervention, and 96 h after the final training session, they underwent the same testing sessions with the same conditions and testing order as pre-training.

Anthropometric measures
Height was assessed employing a stadiometer affixed to the wall (Seca 222, Terre Haute, IN), with measurements recorded to the closest 0.1 cm. Concurrently, body mass was determined using a medical scale (Tanita, BC-418MA, Tokyo, Japan) that measured the nearest 0.1 kg.

Muscular strength
Using a leg press machine (Body Solid, Model GLPH 1100, USA), one repetition maximum in leg press ($1RM_{LP}$) was measured to determine lower body maximal strength according to the guidelines of Kraemer and Fry (1995). After a standardized weight lifting warm-up, participants performed 3 - 5 sets of weight lifts until one repetition set with 4 min of recovery between sets. The heaviest load lifted by the participant with proper exercise technique was considered to represent his 1RM (Earle, 2006). The participants were required to obtain a knee angle of 90° as the benchmark. The test-retest reliability of $1RM_{LP}$ was 0.94.

Jumping test
Jumping ability was evaluated using the vertical jump (VJ) and standing long jump (SLJ) tests. The VJ was measured by a Vertec vertical jump tester (Power System, Knoxville, Tennessee) fixed in the basketball court. After completing a standardized warm-up (Stevanovic et al., 2019), participants performed three maximal VJs with a self-selected countermovement depth and a 30-sec rest interval between the attempts. For the SLJ, the subjects were instructed to perform maximal jump horizontally as far as possible with countermovement and arm swing. Participants completed three maximal SLJs with a 3-min relief interval between the efforts. The point at which the ground was touched by the heel of the leg being tested was measured to determine the distance of each jump. The highest displacement in VJ and SLJ was recorded for further analysis. The test-retest reliability of VJ and SLJ were 0.95 and 0.97, respectively.

Sprint test
A 20-m linear sprint test on an indoor track basketball court determined the athletes' maximal sprint speed. After a self-selected warm-up, participants completed three maximal sprints in the 20-m track with a 2-min rest between the efforts. Participants were instructed to move expeditiously between electronic timing gates while standing, and commenced their movement from the first gate. They were encouraged to run between electronic timing gates (JBL Systems, Oslo, Norway), and the running time was measured to the nearest 0.01 s. The fastest sprint time was selected for analysis, and the test-retest reliability of the 20-m sprint test was 0.92 (Rimmer and Sleveret, 2000).

Change of direction (COD) tests
The T-test (TT) and Illinois Agility test (IAT) were applied to measure COD. Figure 2 and Figure 3 indicate TT and IAT procedures, respectively. The tests were conducted according to Miller and colleagues (2006). Following a self-selected warm-up and 2-3 trials in TT and IAT, participants completed three trials with maximal effort with a 3-min rest between the trials. The time was recorded using the above-mentioned timing gates fixed at the start and finish lines. The fastest time was recorded for further analysis. The test-retest reliability of TT and IAT were 0.98 and 0.97, respectively.

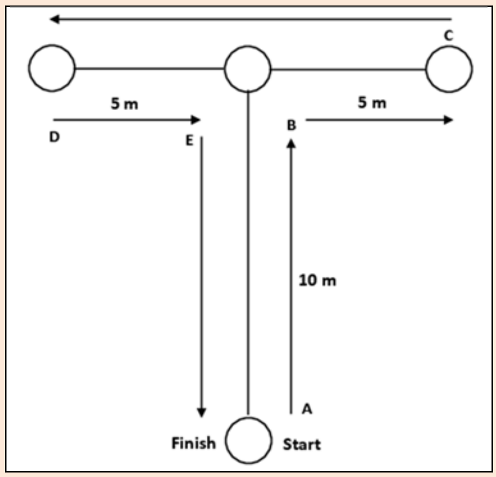

Figure 2. T-test procedure.

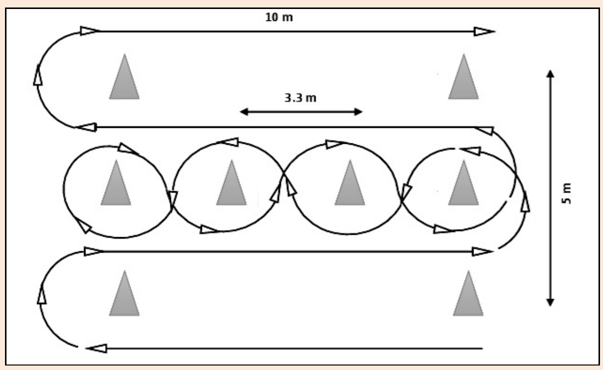

Figure 3. Illinois agility test procedure.

this study (SIT: 7.5%; SSIT: 12%) was in conjunction with previous studies employing different SIT regimens (Arslan et al., 2022; García-Pinillos et al., 2017). However, some researchers failed to show the positive effects of SIT on VJ (Aschendorf et al., 2018). The observed disparities in the outcomes might stem from variations in the duration of the training, gender, fitness levels of the participants, and the specific mode of training employed. Enhanced explosiveness in VJ could be attributed to parameters such as reactive strength and muscular power (Panoutsakopoulos and Bassa, 2023). However, neither SIT nor SSIT enhanced $1RM_{LP}$, indicating that enhanced neuromuscular adaptations such as increasing rate of force development and firing rate of muscles (Buchheit and Laursen, 2013) and anaerobic power production of plantar flexors and knee extensors (Maffiuletti et al., 2002) could be a possible explanation for improved VJ. We can speculate implementing SSIT, involving sport-specific drills such as dribbling, passing, and shooting exercises, resulted in more significant neuromuscular adaptations than regular SIT, leading to greater training effects with an effect size of 0.95 vs. 0.58. Nonetheless, further investigations are necessary to elucidate the specific adaptations achieved through this approach.

Regarding the sprint performance, both SIT and SSIT groups enhanced this locomotor ability after six weeks. An increase in sprint acceleration and velocity due to interval intervention involves fast-twitch muscle fiber and also improvements in stride length resulting in sprint gains (Lee et al., 2020). Our finding is in accordance with previous studies reporting a positive transfer of SIT to sprint performance (Clemente et al., 2022). SSIT indicated greater changes in the 20-m sprint than SIT (medium vs. small ES). The possible mechanism explaining such a difference could be the enhanced acceleration component of the maximal sprint test due to sport-specific movements during SSIT (Arslan et al., 2022). Both SIT and SSIT significantly diminished TT and IAT time. In addition, the changes in IAT were significantly greater in the SSIT than in the SIT. Likewise, Arslan and colleagues (2022) have shown small vs. moderate training effects of HIIT and small-sided games on these parameters. COD presents a key attribute in basketball. A quick COD requires rapid force development and high power generation by the lower extremities (Miller et al., 2006). In COD ability tasks, the leg extensor muscles undergo swift transitions between eccentric and concentric muscle actions, accompanied by minimal ground contact time (Miller et al., 2006; Clemente et al., 2022). Effect size results indicate a greater impact of SSIT on COD, which could be attributed to the sport-specific drill during SSIT (i.e., forward, dribbling, and CODs). By challenging the neuromuscular system and decision-making ability through basketball-specific drills, such movements may indirectly benefit the ultimate COD better than linear running (Arslan et al., 2022).

Both SIT interventions were associated with an increase in TEST levels and a decrease in serum CORT concentrations. Our results corroborate previous findings (Sheykhlouvand et al., 2016b; Ambroży et al., 2021), indicating anabolic-type effects of intensive interval training. Typically, elevations in resting TEST with reductions in CORT show an anabolic environment and increase performance capacity in athletes. Enhanced resting TEST levels represent a favorable hormonal environment when attempting to maximize performance adaptations.

This study possesses certain limitations that warrant consideration when interpreting its findings. Firstly, the study exclusively involved male subjects, which restricts the generalizability of our results to the broader population. Gender-based differences in physiology and responses to interventions may exist, and further research with diverse participant groups is necessary to ascertain the applicability of our findings to women.

Secondly, the study acknowledges the potential influence of external factors outside of the intervention, such as dietary habits, sleep patterns, and overall training load. While we tried to control these variables and maintain consistency among participants, we cannot entirely exclude the impact of these factors on the observed outcomes. Future research could employ more rigorous control measures or investigate these external factors as variables of interest to understand their effects on the studied intervention better.

Conclusion

In conclusion, the results in the present study support the hypothesis that incorporating SIT and SSIT into typical basketball training of male basketball players during the off-season phase of the athletes' annual training program can induce more significant improvements in aerobic fitness, anaerobic performance, and hormonal adaptations. Specifically, the post-training analysis indicated that both interventions were linked with enhanced aerobic fitness, VJ, COD, linear speed, and anabolic hormonal status. The effect size values indicated more significant effects of SSIT than SIT in most physiological and sport-specific adaptations. Such a superior effect could be attributed to the more basketball-specific movement pattern of the SSIT. We speculate technical drills and tactical exercises related to a team's success influence the players' motivation to enhance and maintain intensity and increase the athlete's physiological response. Moreover, sport-specific practices may impose more challenging movements mimicking the game and cause more significant gains than SIT performed on a direct track.

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Key points

- Incorporating SIT and SSIT into typical off-season basketball training triggers adaptive mechanisms that enhance aerobic and anaerobic performance in male basketball players.
- The effect size values indicate more significant effects of SSIT than SIT in most physiological and sport-specific adaptations. Such a superior effect could be attributed to the sport-specific movement pattern of the SSIT.
- The observed alterations in hormonal responses indicate an anabolic adaptation to this intervention, signifying a positive and advantageous training response.
- The integration SIT into routine basketball training offers athletes and coaches an opportunity to harness its potential to optimize training quality and efficiency of their training. This integration stimulates favorable physiological changes, culminating in notable enhancements in athletic performance.

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