Effect of Preseason Concurrent Muscular Strength and High-Intensity Interval Training in Professional Soccer Players

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1Department of Physical Education, Hong Kong Baptist University, Hong Kong; 2Scientific Research Unit, “Evaluation, Sport, Health” at the National Centre of Medicine and Science in Sports, Tunis, Tunisia; 3Soccer National Team of Ivory Coast, Africa; and 4Department of Circulation and Medical Imaging, Faculty of Medicine, Norwegian University of Science and Technology, Norway

Abstract

Wong, P-L, Chaouachi, A, Chamari, K, Dellal, A, and Wisloff, U. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. J Strength Cond Res 24(3): 653–660, 2010—This study examined the effect of concurrent muscular strength and high-intensity running interval training on professional soccer players’ explosive performances and aerobic endurance. Thirty-nine players participated in the study, where both the experimental group (EG, n = 20) and control group (CG, n = 19) participated in 8 weeks of regular soccer training, with the EG receiving additional muscular strength and high-intensity interval training twice per week throughout. Muscular strength training consisted of 4 sets of 6RM (repetition maximum) of high-pull, jump squat, bench press, back half squat, and chin-up exercises. The high-intensity interval training consisted of 16 intervals each of 15-second sprints at 120% of individual maximal aerobic speed interspersed with 15 seconds of rest. EG significantly increased (p ≤ 0.05) 1RM back half squat and bench press but showed no changes in body mass. Within-subject improvement was significantly higher (p ≤ 0.01) in the EG compared with the CG for vertical jump height, 10-m and 30-m sprint times, distances covered in the Yo-Yo Intermittent Recovery Test and maximal aerobic speed test, and maximal aerobic speed. High-intensity interval running can be concurrently performed with high load muscular strength training to enhance soccer players’ explosive performances and aerobic endurance.

Key Words football, combined training, weight training, periodization, intermittent

Introduction

Numerous explosive activities are required in soccer, such as jumping, kicking, tackling, turning, sprinting, and changing pace (37). Improvement of these explosive performances have been reported after muscular strength training that increased the available force of muscular contraction in appropriate muscle groups (20,29). In addition, it has been reported that jump height (r = 0.78), 10 m (r = 0.94), and 30 m (r = 0.71) sprint performances are highly correlated with maximal muscular strength in professional soccer players (39). Muscular strength could be increased by 2 mechanisms: muscular hypertrophy and neural adaptation (20). The former increases the cross-sectional area of muscle and results in greater body mass, which is generally not desirable in soccer players because the extra weight may decrease overall performance (37). Alternatively, neural adaptation enhances muscle strength by recruiting more muscle fibers while causing minimal increase in body mass (20). Therefore, to maximize strength gains without an increase in body mass, the training program for soccer players who already have sufficient muscle mass should consist of high load and short repetition sets (i.e., 4–6RM) for 3–4 sets (20) with 2–5 minutes of rest in between sets (1).

Despite the importance of explosive performance, players also have to run 8–12 km during the 90-minute playing time of a match (11) and approximately 98% of total energy used by players during a game is derived from aerobic metabolism (37). To improve aerobic endurance capacity, prolonged continuous exercise traditionally has been used (21). However, this kind of exercise relies mainly on fat metabolism, which is not specific to the intermittent and high-intensity soccer activity pattern that requires both fat and carbohydrate oxidation (37). Specifically, it has been shown that during 90 minutes of intermittent exercise, fat oxidation was almost 3 times lower and carbohydrate oxidation was about 1.2 times higher compared with continuous exercise with same overall energy expenditure.
(5). Therefore, intermittent training protocols have been developed to cope with the specific physical requirement of soccer. In this context, a previous study of professional soccer players showed that repeated-sprint and high-intensity interval training performed once per week for 10 weeks significantly improved players’ 40-m sprint time and maximal aerobic speed (14). Moreover, high-intensity interval training has been reported to induce greater improvement in VO₂max compared with continuous training involving the same mechanical work and duration (19). Unlike recreationally trained and untrained individuals, it has been reported that further improvements in performance for trained individuals can only be achieved through high-intensity interval training (27).

Because explosive activities and aerobic endurance are important for soccer performance (37), it is of practical interest for coaches to simultaneously improve these capacities in their players. In this context, previous studies of concurrent muscle strength and aerobic endurance training have produced contradictory results; some studies have reported complementary effects (6,9,23), whereas others showed interference effects (13). Specifically, Chetara et al. (6) found that concurrent training significantly improved individual’s maximal oxygen uptake (VO₂max), maximal aerobic speed (MAS), and time to exhaustion at MAS compared with aerobic endurance training alone. It has also been reported that combining strength and endurance training results in greater performance improvement than single-mode training (23). In contrast, strength training has been reported to cause muscle hypertrophy, increased contractile protein, and contractile force (3,36), which has the potential negative effect of reducing mitochondrial density and decreasing the activity of oxidative enzymes, thus inhibiting the improvement of aerobic endurance (36). Unlike strength training, aerobic endurance training does not induce muscle hypertrophy but increases the mitochondrial content and oxidative capacity and converts muscle fiber characteristics from fast to slow twitch, which negatively affects explosive performances (35). However, to the best of our knowledge, there is no previous study examining the effect of concurrent muscular strength and high-intensity interval training in professional soccer players.

Therefore, the purpose of the present study was to examine the effect of 8 weeks of preseason concurrent muscular strength and high-intensity running interval trainings on professional soccer players’ explosive performances and aerobic endurance. It has been reported that strength training regimens aimed to enhance neural adaptation without muscle hypertrophy minimized the interference with aerobic endurance capacity (33). We hypothesized that concurrent training would improve both explosive performances and aerobic endurance of professional soccer players when appropriate training programs were selected.

**Methods**

**Experimental Approach to the Problem**

To examine the effects of preseason concurrent muscular strength and high-intensity running interval training on professional soccer players’ physical performance, all players participated in the pretest to measure their baseline performances. Specifically, all players participated in 2 test sessions separated by 4 days in the following sequence: Day 1—maximal vertical jump, ball-shooting, 30-m sprint, and Yo-Yo Intermittent Recovery Test (YYIRT); and Day 2—Vam Eval Test. These tests were conducted on the soccer pitch and all players wore soccer sportswear. Players had a 20-minute warm-up consisting of slow jogging and static and dynamic stretching prior to the test. There were 10-minute rests between tests for full recovery. Water breaks and extra rest time were allowed when requested by players. In addition, the maximal muscular strength test was conducted 5 hours after the Vam Eval Test. After the pretest, both the experimental group (EG, n = 20) and control group (CG, n = 19) received 8 weeks of preseason soccer training, with the EG receiving additional concurrent muscular strength and high-intensity interval training. The muscular strength training was performed on Monday and Thursday mornings, each lasting for 90 to 120 minutes, whereas the high-intensity interval training lasting for 8 minutes was performed on Monday and Thursday afternoons (~5 hours after the morning session) at the end of the 90-minute soccer training session. After 8 weeks of training, all players participated in the posttest, and these values were compared with those of the pretest to examine the concurrent training effects. All tests were performed at approximately the same time of the day, with similar environmental conditions (temperature: 31–33°C; humidity: 75–85%).

Performance tests that are specific to soccer match performance were used in the present study. In this regard, it has been shown that maximal vertical jump is the most discriminating explosive performance variable for soccer players (18). A 30-m sprint with 10-m lap time has been suggested as the standard sprint test for soccer players (37). Shooting is an important skill in soccer and is one of the ways to score goals, which could lead to team and individual success. The YYIRT is a soccer-specific test addressing both aerobic and anaerobic metabolism of players (4). Finally, the Vam Eval Test is a continuous maximal incremental running test that estimates the velocity associated with maximum aerobic speed (MAS) and has been used to assess soccer players (10,14). Therefore, in the present study, we examined players’ lower body strength (back half squat) and explosive performances (maximal vertical jump, ball shooting, and 30-m sprint with 10-m lap time), upper body strength (bench press), intermittent aerobic endurance (Yo-Yo Intermittent Recovery Test—level one), and continuous aerobic endurance (Vam Eval Test).
Subjects
Thirty-nine professional male soccer players competing at the highest level in Hong Kong participated in the study. Before the start of the league season, there were 8 weeks of preseason training after all players had returned from their ~45 days off-season holidays in which no soccer training or fitness training were performed. During the preseason phase, the players had 6 to 8 soccer training sessions per week, each lasting for ~90 minutes. Each training session generally consisted of a 10-minute warm-up, 30 minutes of technical training, 30 minutes of tactical training, 15 minutes of simulated competition, and a 5-minute cool-down. In contrast, players had 5 to 6 soccer training session per week, each lasting for ~90 minutes during the season, and 1 official game scheduled during each weekend. During the season, players had no more than 1 muscular strength training session per week to maintain their body strength. The first team consisted of a 6 to 8 soccer training sessions per week, each lasting for 90 minutes during the season, and 1 official game scheduled during each weekend. During the season, players had no more than 1 muscular strength training session per week to maintain their body strength. The first team served as the EG (n = 20) and the reserve team was the CG (n = 19); goalkeepers were excluded from this study. Their age, body mass, height, and body mass index are shown in Table 1. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Clinical Research Ethics Committee before the commencement of the assessments. Written informed consent was received from all players after a brief but detailed explanation about the aims, benefits, and risks involved with this investigation. Players were told they were free to withdraw from the study at any time without penalty. During the study course, all players were instructed to maintain normal daily food and water intake, and no dietary interventions were undertaken.

Procedures
Maximal Muscular Strength. 1RM half squat and bench press strength was recorded as the maximal weight subjects were able to raise as described by Marques et al. (30). In the present study, a free weight squat exercise was performed, allowing players to bend their knees to reach half-squat position (~90-degree angle in the knee joint between femur and tibia) with the barbell held over the shoulders (back squat). The bar position for the free weight bench press exercise began in the up position at full elbow extension, moved to chest level for a momentary pause, and finished back at the starting position. No bouncing of the bar off the chest was allowed. Hand and foot positions were determined for each subject during familiarization and were held constant during all testing. Repetitions performed incorrectly were not included in the count. Prior to the test, players performed 2 warm-up sets each of 8 repetitions at ~65 to 75% of their perceived maximal loads. To determine the maximal strength, loads of 5-kg increments for back half squat and 2-kg increments for bench press were subsequently added until players failed to finish 6 repetitions with proper technique (1,37). There were 3-minute rests between sets. Maximal strength (1RM) of back half squat and bench press were determined by 6RM using the formula (i.e., 6RM = 85% of 1RM) as suggested by the USA National Strength and Conditioning Association (1). Maximal muscular strength was determined for no more than 4 sets for all players. The first author monitored the test session to ensure proper exercise technique and safety.

Maximal Vertical Jump. Players in barefoot condition started from an upright standing position. Players were required to perform a countermovement jump vertically with arm swing. Jump height was determined by the portable platform (Just Jump System, M-F Athletic Company, Cranston, RI, USA), based on the flight time (40). Each player performed 3 jumps each separated by a 1-minute rest, and the best (highest) jump was used for analysis (39).

Ball Shooting. Players performed maximal velocity instep place kicks of a stationary ball. A ball of FIFA standard size and inflation was kicked 4 m toward a 1 × 1 m target (40). Players were asked to shoot the ball as hard as possible, and 5 shots were allowed for each player with 1-minute rests in-between (40). Ball speed was measured by a radar gun (Sports Radar Gun SRA 3000, Precision Training Instrument, IL, USA) located 0.3 m from the stationary ball and pointed toward the target as directed by the instruction manual. The shot that hit the target and produced the highest ball speed was selected for analysis.

Table 1. Players’ physical characteristics before and after the 8 weeks of training.

<table>
<thead>
<tr>
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<th>Experimental group (n = 20)</th>
<th>Control group (n = 19)</th>
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<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
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<tr>
<td>Age (year)</td>
<td>24.6 ± 1.5</td>
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<tr>
<td>Body mass (kg)</td>
<td>71.4 ± 1.9*</td>
<td>71.1 ± 1.8</td>
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<td>Height (m)</td>
<td>1.76 ± 0.02</td>
<td>1.76 ± 0.02</td>
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<td>Body mass index (kg·m⁻²)</td>
<td>23.1 ± 0.4</td>
<td>23.0 ± 0.4</td>
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Values are mean ± SEM.
*Significant difference between groups at p ≤ 0.05.
30-m Sprint. Players were asked to complete a 10-minute specific warm-up including jogging, static and dynamic stretching, and several accelerations. Players stood 0.5 m behind the starting gate before every sprint (31), and sprint time was measured with infrared photoelectronic cells (Speedtrap II Wireless Timing System, Brower Timing System, Australia) positioned at 0 m, 10 m, and 30 m from the starting line at a height of 1 m. There were 3 trials in total (31), and a 3-minute recovery time was allowed between each trial. The best (fastest) 30-m sprint time and the associated 10-m sprint time were selected for analysis.

Yo-Yo Intermittent Recovery Test. Because playing soccer includes high-intensity, intermittent bouts of exercise, which stresses the anaerobic and aerobic metabolic pathways, the YYIRT protocol mimics the soccer-specific exercise pattern (4). The YYIRT consists of 2 × 20 m bouts of shuttle-running performed at increasing speed, interspersed by 10 seconds of active recovery (slow jog or walk), that are directed by the prerecorded acoustic signals. In this test, the running speed is progressively increased from 10 to 19 km h⁻¹ with a maximum total distance that can be covered during the test of 3,640 m (4). The test was terminated when the player was unable to maintain the required speed, and the distance covered in the shuttles was recorded for analysis (4).

Vam Eval Test. The continuous test began at the running speed of 8 km h⁻¹ with consecutive speed increases of 0.5 km h⁻¹ per minute until exhaustion (10). Players adjusted their running velocity to auditory signals at 20-m intervals, delineated by visual marks along the soccer pitch (14). A longer sound marked the changes in the running speed. The maximal aerobic speed (MAS) is the velocity in km h⁻¹ of the last 1-minute stage completed by the player. The uncompleted 1-minute stages were not taken into account. The greatest distance covered (MASdistance) in this test was recorded. Heart rate was measured continuously (Polar, Lempele, Finland), and values were averaged over 5-second periods. The highest value recorded during the Vam Eval Test was considered to be the maximal heart rate (HRmax) (14).

Muscular Strength Training. One of the investigators, who is a Certified Strength and Conditioning Specialist (CSCS) from the U.S. National Strength and Conditioning Association (NSCA), designed and supervised the training program throughout the study. The following exercises were performed in a straight set (i.e., 1 exercise after another) for 4 sets each with 6RM and ~3-minute rest between sets to maximize strength gains by neural adaptation (1): high-pull, jump squat, bench press, back half squat, and chin-up. The loads were increased each time the player successfully completed the work load of the previous training with 5-kg increments for jump squat and back half squat and 2 kg increments for high-pull, bench press, and chin-up (1,37). This type of strength training has been reported to induce minor muscular hypertrophy (25) and did not interfere with the development of aerobic endurance (33). In addition to these exercises, players performed a plyometric sit-up throwing a 3-kg medicine ball for 3 sets each with 15 repetitions to strengthen their core muscles.

High-Intensity Interval Training. During the 15-second work period, players had to cover a predetermined distance according to their own MAS (14). After a 15-second passive rest, they started running again in the opposite direction for 15 seconds (14). The distance was individualized according to the MAS of each player (120% of their MAS). This running

<table>
<thead>
<tr>
<th>Table 2. Effects of 8 weeks of concurrent muscular strength and high-intensity interval training on physical performances.</th>
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<tr>
<td><strong>Experimental group (n = 20)</strong></td>
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<tr>
<td>Vertical jump height (cm)</td>
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<td>Ball-shooting speed (km h⁻¹)</td>
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<td>10-m sprint time (s)</td>
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<td>YYIRT (m)</td>
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<td>MASdistance (m)</td>
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<td>HRmax (beat-min⁻¹)</td>
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Values are mean ± SEM.
*Significant difference between pretests and posttests at p ≤ 0.05.
†Significant difference between groups at p ≤ 0.05.
Yo-Yo Intermittent Recovery Test; MAS = maximal aerobic speed; MASdistance = distance coverage during MAS test; HRmax = maximal heart rate.
speed was selected because this intensity has been shown to increases players' maximal oxygen uptake (15). More intervals (i.e., 16) were run in the present preseason study compared with that of a previous in-season study using 12 to 15 intervals (14) because improvement in fitness is a major concern during preseason compared with maintenance during the season.

**Statistical Analyses.** Data are expressed as mean ± SEM. Independent sample t-tests were used to examine the differences between the 2 groups (EG and CG) at pretest, revealing significant initial group differences in body mass, ball-shooting speed, and 10-m sprint time. Therefore, analysis of covariance (ANCOVA) controlling for pretest values was then used. This analysis creates an adjusted mean for posttest values of the EG and CG. In addition, the repeated measures ANOVA (2 × 2) were used to examine the differences between the 2 groups over the 2 tests. Between-subject differences were assessed by post hoc test (with Bonferroni alpha control). Within-subject effects were further analyzed using a paired sample t-test. Furthermore, within-subject percentage changes were calculated, and the differences between EG and CG were examined by independent sample t-tests. Statistical power was also calculated for independent parameters. Significant level was defined as p ≤ 0.05.

The reliability of each test was assessed by intraclass correlation coefficient (ICC) and SEM as suggested by Weir (38). The results showed that these tests were highly repeatable: maximal vertical jump (ICC = 0.99; SEM ≤ 1.4), ball shooting (ICC > 0.98; SEM ≤ 1.9), and 30-m sprint (ICC > 0.98; SEM ≤ 0.03). The test-retest coefficient of variance for the YYIRT has been reported as 4.9% (24), and the Vam Eval Test has previously been found to be a valid and reliable method of estimating the velocity associated with VO₂max (2). Reliability of estimating maximal muscular strength from multiple repetitions has been reported to be high in back half squat (ICC = 0.95) and bench press (ICC = 0.95) (30).

**RESULTS**

After 8 weeks of concurrent training, 1RM back half squat increased from 123.0 ± 1.5 kg to 148.0 ± 1.9 kg (+ 25 kg, p ≤ 0.05) and 1RM bench press increased from 65.3 ± 1.5 kg to 70.4 ± 1.1 kg (+ 5.1 kg, p ≤ 0.05) in the EG. In addition,
no differences were observed in height, body mass, or body mass index in both groups compared to the pretest ($p > 0.05$) (Table 1). The EG showed significant within-subject improvement in vertical jump height ($+2.5$ cm, $p \leq 0.05$), $10$ m ($-0.11$ seconds, $p \leq 0.05$) and $30$ m ($-0.12$ seconds, $p \leq 0.05$) sprint times, YYIRT ($+298$ m, $p \leq 0.05$), MAS ($+0.5$ km h$^{-1}$, $p \leq 0.05$), and $\text{MAS}_{\text{distance}}$ ($+298$ m, $p \leq 0.05$) following the concurrent training, whereas CG showed significant improvement only in YYIRT ($+137$ m, $p \leq 0.05$) and $\text{MAS}_{\text{distance}}$ ($+56$ m, $p \leq 0.05$) (Table 2) over the same training period.

After $8$ weeks of training, the EG had a higher percentage improvement in vertical jump height, $10$ m and $30$ m sprint times (Figure 1), YYIRT, MAS, and $\text{MAS}_{\text{distance}}$ compared with that of the CG (Figure 2). Statistical power analysis indicated strong effects ($>0.8$) of concurrent training on vertical jump height, $10$ m and $30$ m sprint times, MAS, and $\text{MAS}_{\text{distance}}$, but only a moderate effect on YYIRT and a small effect on ball-shooting speed (Table 2).

**DISCUSSION**

The results of the present study supported our hypotheses that concurrent training would improve both explosive performances and aerobic endurance of professional soccer players. This study showed that professional soccer players concurrently trained with muscular strength and high-intensity interval (EG) had significantly ($p \leq 0.05$) higher percentage improvement in vertical jump height, $10$ m and $30$ m sprint times, YYIRT, MAS, and $\text{MAS}_{\text{distance}}$ compared with soccer training alone (CG) (Figure 1 and 2). Moreover, after $8$ weeks of concurrent training, the body mass of the EG was similar to the pretest ($p > 0.05$, Table 1), which could be explained by the strength training protocol selected in the present study (4 sets of $6$RM) that prevents muscle hypertrophy. Therefore, the potential negative effect of muscular strength training on aerobic endurance (reduced mitochondrial density and decreased oxidative enzymes activity) caused by muscle hypertrophy was minimized (36).

Maximal muscular strength (back half squat and bench press) increased significantly after $8$ weeks of muscular strength training in EG and corresponds to significant higher percentage improvement in vertical jump height, $10$ m and $30$ m sprint times (Figure 1) as compared with soccer training alone (CG). This agreed with previous studies, which reported high correlations between muscular strength and explosive performances (39). However, ball-shooting speed was not changed in the EG after muscular strength training in the present study. A previous study reported that ball-shooting speed was positively associated with leg strength (28), but another study found no significant relationship between ball-shooting speed and any of the strength parameters (32). Furthermore, it has been reported that shooting is a multijoint activity, which is highly dependent on timing and transfer of energy between the involved body segments (26). Correlation between kicking performance and knee extension in high angular velocity ($r = 0.90$) was found to be higher than that of low angular velocity ($r = 0.61$) (22).

The muscular strength exercises used in the present study did not focus on the development of movement speed and transfer of force (except for jump squat), which could explain the absence of improvement in the shooting performance of the EG.

The present study is the first to use high-intensity interval training together with muscular strength training for soccer players. The high-intensity interval training significantly improved aerobic endurance as evidenced by the enhancement in YYIRT, MAS, and $\text{MAS}_{\text{distance}}$, whereas soccer training alone developed YYIRT and $\text{MAS}_{\text{distance}}$ only. Furthermore, the within-subject improvement of the EG was significantly greater for YYIRT, MAS, and $\text{MAS}_{\text{distance}}$ compared with that of the CG. Therefore, high-intensity interval training could be considered to be an alternative to continuous aerobic training for concurrent training. This supports a previous study on concurrent muscular strength training and aerobic interval training, which improved aerobic capacity in physically active individuals (6). However, in this study by Chtara et al. (6) muscular endurance and explosiveness were trained in $2$ separate phases. In addition, the muscular strength training they used incorporated short rest interval ($20–30$ seconds), and the total duration of the training was short ($\sim 30$ minutes), which has been shown to have little effect on muscular strength and explosive performance (1). Docherty and Sporer (12) proposed an interference model of concurrent muscular strength training and aerobic endurance training. They stated that muscle hypertrophy-type training, together with high-intensity aerobic interval training, has the greatest interference effect. Specifically, hypertrophy-type strength training increases contractile protein but has a negative effect on mitochondrial density and the oxidative enzymes, which subsequently inhibits aerobic endurance (3,36), whereas continuous aerobic endurance training increases the mitochondrial content and oxidative capacity and converts muscle fiber characteristics from fast to slow twitch, which affect developing explosive performance (35). Contrarily, muscular strength programs with high loads of $3$ to $6$RM, concurrently with high-intensity interval training, reduce the interference effect. This is because this type of muscular strength training stresses the neural system but does not place metabolic demands (i.e., protein synthesis) on the working muscles. Consequently, the activated muscles could increase their oxidative capability as a training response to the aerobic interval training without affecting neural adaptation, thus improving aerobic endurance.

High-intensity interval training has several advantages over continuous aerobic training. It has been reported that improvements in maximal cardiac output and skeletal muscle mitochondrial oxidative capacity were observed with interval training but not during continuous training. This suggests that interval training can maximize both peripheral muscle and...
central cardiorespiratory adaptation and develop functional improvement (7,8). In addition, the players in the present study expressed their preference for interval training rather than for sustained continuous aerobic exercise, and they reported that they were more motivated doing high-intensity intervals. Long-duration aerobic training usually lasts for >30 minutes, whereas high-intensity interval sessions are typically much shorter (i.e., 8 minutes), which could be considered a time-efficient training method. Moreover, the exercise pattern and intensity of high-intensity intervals is much closer to the type of effort required during a soccer match than that of continuous training (4). From our observation in the present study, however, the professional players were exhausted during the first 2 weeks of the interval training, and a lower number of intervals may be needed if the same protocol is used for amateur or younger soccer players. It is suggested that the concurrent muscular strength and supramaximal interval (120% of MAS in this study) training should be carried out during the preseason period rather than in-season because the high training load induced by the concurrent training together with the competitive match schedule may result in insufficient recovery/rest time or overreaching (17). Alternatively, to perform the concurrent training during the season, it has been suggested that alternating hard–easy training days reduces training monotony and prevents overreaching and overtraining in athletes (17). In addition, it has been reported that a longer duration and lower-intensity dribbling interval training (4 x 4 minutes at 90–95% of HR_{max}, with 3-minute recovery) during the season elevate aerobic capacity with no negative interference on explosive performances (31).

In designing interval training, several factors, such as mode of recovery, work/rest duration, and speed, induce different physiologic responses. In this context, Dellal et al. (10) examined the mode of recovery and showed that during 30-second interval training at 100% of MAS (1:1 work/rest ratio), active recovery (slow jog) induced ~9% higher heart rate response compared with passive recovery. In another study using cycle ergometers, it was reported that active recovery resulted in significantly faster declines in muscle oxyhemoglobin and shorter time to exhaustion than passive recovery during intermittent exercise (16). Price and Moss (34) investigated the effect of work/rest (passive) duration with the same work/rest ratio (1:1.5) and the same total duration (~20 minutes) on intermittent exercise at 120% of MAS. They found that with their long protocol (24:36 seconds), blood lactate was significantly higher, and blood pH was significantly lower, compared with their short protocol (6:9 s). Dupont et al. (15) examined the effect of running speed on intermittent running and found that 130% of MAS induced higher heart rate and blood lactate responses compared with 110%, or 120% of MAS. In addition, they reported that running at 120% of MAS induced higher VO_{2}peak values and a longer period of exercise at >95% of VO_{2}max, which lead to greater improvements in aerobic capacity. Although results can be logically deduced from the present study and from the relevant scientific literature, future studies combining muscular strength training with different interval running programs are required to provide empiric evidence that supports the supposition.

**Practical Application**

During the preseason period, strength and conditioning specialists can concurrently use muscular strength training and high-intensity interval running to enhance professional soccer players’ explosive performances and intermittent and continuous aerobic endurance. Specifically, to minimize the interference effect of the aforementioned concurrent training modes, high load and less repetition (6RM for 4 sets, with 3 minutes of rest between sets) are recommended in muscular strength training to stress the neural adaptation and to avoid muscle hypertrophy for soccer players who already have sufficient muscle mass. Furthermore, high-intensity interval running for 15:15 seconds (120% of maximal aerobic speed and passive recovery) could be used to effectively improve aerobic endurance. High-intensity interval running is a time-efficient training method that enhances aerobic capacity as compared with traditional continuous aerobic endurance training. However, the modes of recovery, work/rest duration, and speed have to be considered prior to the interval training because they induce different physiologic responses. We also suggest performing the concurrent training in the preseason period rather than in-season because the high training load induced by the concurrent training together with scheduled competitive matches may result in insufficient recovery/rest or overtraining. Alternatively, to perform the concurrent training during the season, it has been suggested that alternating hard–easy training days reduces training monotony and prevents overreaching and overtraining in athletes (17).

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