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The Effect of In-Season, High-Intensity Interval Training in Soccer Players

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Abstract. Dupont, G., K. Akakpo, and S. Berthoin. The effect of in-season, high-intensity interval training in soccer players. *J. Strength Cond. Res. 18(3):584–589. 2004.*—The effects of in-season, high-intensity interval training on professional male soccer players' running performances were investigated. Twenty-two subjects participated in 2 consecutive training periods of 10 weeks. The first period was considered a control period and was compared with a period where 2 high-intensity interval training exercises were included in the usual training program. Intermittent runs consisted of 12–15 runs lasting 15 seconds at 120% of maximal aerobic speed alternated with 15 seconds of rest. Sprint repetitions consisted of 12–15 all-out 40-m runs alternated with 30 seconds of rest. Results from the high-intensity interval training have shown that maximal aerobic speed was improved (+8.1 ± 3.1%; $p < 0.001$) and that the time of the 40-m sprint was decreased (−3.5 ± 1.5%; $p < 0.001$), whereas no change in either parameters were observed during the control period. This study shows that improvements in physical qualities can be made during the in-season period.

Key Words. performance, intermittent exercise, field tests, repeated sprints

Introduction

For soccer players, training aims to improve technical, tactical, psychological, and physical qualities. During the preseason, training emphasizes physical fitness improvements, whereas during the in-season period the emphasis is mainly on making tactical and technical improvements while maintaining physical fitness. Indeed, as competition matches require a high energy expenditure, the training load is not increased in order to avoid excessive fatigue or the beginning of an overtraining syndrome.

During a soccer match, players perform different types of exercise such as running, kicking, jumping, and tackling. Soccer requires the repetition of runs alternated with short to long periods of recovery, which could be active or passive. Intensity and running periods can alternate at any time according to the demands of the match. In addition, goals or decisive actions are often preceded by accelerations, sprints, bursts, jumps, and shots. Consequently, one of the aims of training is to improve the ability to perform maximal and high-intensity exercise. Bangsbo (4) found that Danish first division players performed more high-speed and sprint runs than Danish second division players, indicating that the amount of sprints and high-speed running depends on the level of the competition. Soccer is also characterized by the introduction of new rules set forth by the International Football Associations Board, such as the 1992 rule against goalkeepers using their hands when their partners pass them the ball; the 1997 rule determining the limited time that goalkeepers may keep the ball in their hands; or the availability of balls around the pitch when a ball is kicked out of the field's limit, which aims to increase effective play time and thus to decrease recovery time. For high-level soccer players, this means being able to perform multiple sprints and high-intensity runs and to recover more quickly.

However, soccer performance is also dependent on players' aerobic capacity. Helgerud et al. (16) found that the enhancements of maximal oxygen uptake ($\dot{V}O_2max$) led to an improvement in soccer performance, substantiated as distance covered, level of work intensity, and number of sprints during a match. Thus, increasing a soccer player's fitness through training is a complex process that requires an increase both in aerobic and anaerobic qualities.

The purpose of this study was to determine the effects of an in-season, high-intensity interval training program. This specific training program was compared with a control period where participants performed the usual soccer exercises. We hypothesized that the specific program would allow soccer players to increase their aerobic and anaerobic qualities without decreasing the soccer team's performance.

Methods

Experimental Approach to the Problem

The participants were followed over a 20-week period that was divided into a control period (weeks 1–10) and a high-intensity interval training period (weeks 11–20). The control period was from August to October, whereas the high-intensity interval training period was from October to December. Before beginning the protocol, anthropometric measurements (height, mass, and percentage of body fat) were made, and a maximal graded test was performed. Field tests (maximal graded field test and 40-m sprint field test) and anthropometric measurements were carried out before the control period, after the control period (which corresponded to the beginning of the high-intensity interval training period), and at the end of the high-intensity interval training period. Field tests and training exercises were performed on a 400-m outdoor tartan track.

The total number of sessions was the same for the 2 programs. The duration of each session ranged between 1 hour 15 minutes and 1 hour 30 minutes. Before the tests, the procedures were explained to the participants. The tests were performed at the same time of the day and of the week. Before the tests, participants were required to rest on the day of the trial, consume their last meal at least 3 hours before the test, and were asked to refrain from smoking and consuming beverages containing caffeine.

Subjects

Twenty-two professional male soccer players participated in the study. Participants played at the national level and carried out 1 match and from 8 to 10 training sessions per week. Before entering the experimentation stage, age, height, and body mass of the participants were 20.2 ± 0.7 years, 178.0 ± 4.9 cm, and 71.3 ± 5.7 kg, respectively. All subjects were fully informed of any risks before giving their written informed consent to participate in these experiments. This study received approval from the Lille Consultative Committee for Human Protection in Biomedical Research (Ethical Committee for Human Research in Lille Area).

Anthropometric Measurements

Anthropometric measurements included height, body mass, and percentage of body fat. A wall stadiometer was used to measure height, and a calibrated bioelectrical impedence balance (Tanita TBF 543) was used to determine body mass and to estimate the percentage of body fat.

Maximal Treadmill Graded Test

The maximal treadmill graded test was preceded by a medical examination. It aimed to characterize the population and to determine the capacity to play at a high level. During this test, respiratory gas exchanges were measured breath-by-breath using a portable system (Cosmed K4b^2, Cosmed, Rome, Italy) in order to determine the maximal oxygen uptake ($\dot{V}O_2max$). This analyzer has previously been validated for measuring these parameters over a wide range of exercise intensities (21). Before each test, the O_2 and CO_2 analysis systems were calibrated using ambient air and with a gas mix of known O_2 and CO_2 concentrations. The calibration of the turbine flowmeter of the K4b^2 was performed using a 3-l syringe (Quinton Instruments, Seattle, WA). Respiratory gas exchanges and heart rate (HR; Polar Electro, Kempele, Finland) values were averaged every 15 seconds. The velocity at the first stage was set at 8 km·h^{-1} for 2 minutes, and then the velocity was increased by 1 km·h^{-1} per stage for 1 minute (6). Fingertip blood samples were obtained 3 minutes after each test in order to determine lactate concentrations ([La]) by spectrophotometric means (Dr. Lange, Berlin, Germany). The $\dot{V}O_2max$ corresponded to the highest $\dot{V}O_2max$ attained in 2 successive 15-second periods for the graded test. It was judged that participants had reached their $\dot{V}O_2max$ when 3 or more of the following criteria were met: (a) a plateau in $\dot{V}O_2$ despite increasing running speed; (b) a final respiratory exchange ratio (RER) higher than 1.1; (c) visible subject exhaustion; (d) an HR within 10 b·min^{-1} of age-predicted maximum HR; and (e) a lactate concentration higher than 9 mmol·L^{-1}.

Forty-Meter Sprint Test

The 40-m sprint test was preceded by a standardized warm-up consisting of a run at 10 km·h^{-1} for 15 minutes followed by 10-minute bursts of running and stretching. The time for the 40-m sprint test (t40m) was measured using photocells (Brower Timing Systems, South Draper, UT) placed at the start and at 40 m. When ready to sprint, the subjects decided themselves when to start the sprint test from a static position. Each participant had 3 trials separated by at least 5 minutes of rest, and the fastest time was recorded. A 40-m distance was chosen because Balsom (3) reported that the sprint distance covered by a soccer player was not longer than 40 m and that a 30- or 40-m sprint distance is generally chosen to measure a player's sprint performance (8, 16, 17).

Maximal Graded Field Test

The graded field test (20) was performed to determine the maximal aerobic speed (MAS; i.e., the lowest velocity that elicits $\dot{V}O_2max$ during a graded test; Ref. 7). The initial speed was set at 10 km·h^{-1} and was increased by 1 km·h^{-1} every 2 minutes. Red cones were set at 25-m intervals along the track (inside the first lane), whereas green cones were set 2-m behind the red cones. The running pace was dictated by audio signals, and the subjects had to be within 2-m of the red cones with each signal. When participants were behind a green cone 3 consecutive times, the test was terminated. A longer sound marked the changes in the running speed. The speed of the soundtrack was checked prior to the beginning of each session. The velocity at the last completed stage was increased by 0.5 km·h^{-1} if the participant was able to run a half stage, and this was assumed to represent the MAS. This test has previously been found to be a valid and reliable method of estimating the velocity associated with $\dot{V}O_2max$ (6, 19, 20). During the test, the participants were verbally encouraged to run as long as possible. Heart rate (Polar Accurex+, Polar Electro, Kempele, Finland) was measured continuously, and values were averaged over 15-second periods. Maximal HR (HRmax) corresponded to the highest measured value.

Team Performance Measurement

Team performance was assessed by computing the winning percentage in the championship (wins/total number of games) during each training period (11). Nine official matches were played during the control period, and eight official matches were played during the high-intensity interval training period.

Training Protocol

The two 10-week periods were performed without interruption. The control period consisted of technical and tactical skills, games, and matches. The high-intensity interval training period consisted of similar exercises but involved 2 high-intensity interval training exercises per week. These exercises were included in the usual sessions. During 2 sessions, the participants performed repeated sprints alternated with short recovery periods (Tuesday) and intermittent high-intensity runs (Thursday). The following sessions (Wednesday and Friday) consisted of light exercises.

For the repeated sprints, subjects were required to perform 12–15 sprints of 40 m with 30 seconds of passive recovery. During the first 5 weeks, the number of sprints was set at 12, and thereafter the number of repetitions was set at 15. All sprints were performed from a standing start. The participants were instructed to complete each sprint in the quickest time possible. This exercise was chosen because Balsom et al. (2) suggested that the contribution of aerobic metabolism increased with the repetitions, whereas it was classified primarily as anaerobic exercise.

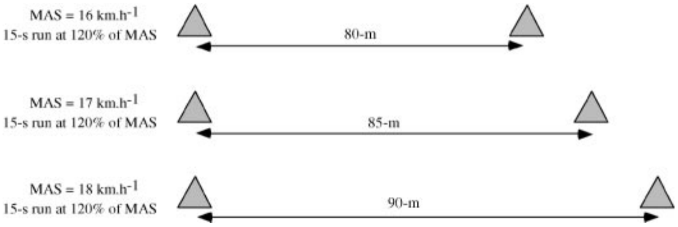

FIGURE 1. Track for intermittent exercise of 15 seconds at 120% of MAS alternated with 15 seconds of passive recovery. The soccer players must run between 2 cones in 15 seconds according to their own MAS. They must then stand near the cone for 15 seconds. At the end of the 15-seconds recovery period, they run for 15 seconds in the opposite direction, and so on.

Intermittent high-intensity runs were performed 48 hours after the repeated sprint session. These intermittent runs were individualized according to the MAS of each subject. They consisted of 2 series of 12–15 intermittent runs of 15 seconds at 120% of MAS alternated with 15 seconds of passive recovery. During the first 5 weeks, the number of repetitions per series was set at 12, and then the number of repetitions was increased to 15. The choice of the running velocity was justified by the fact that this kind of exercise allows participants to elicit and to maintain $\dot{V}O_2max$ (10). For these exercises, running paces were given by a manual timer producing a sound every 15 seconds from the start to the end of the exercise. During the 15-second exercise period, participants had to cover a distance determined according to their own MAS (Figure 1). Subjects covered different distances during the same time and at the same relative intensity (percentage of MAS). Participants were allowed to stop running within the 3-m distance after the stop line. After a 15-second rest, they started running again in the opposite direction for 15 seconds.

Statistical Analyses

Data are presented as means and standard deviations (mean ± *SD*). An analysis of variance (ANOVA) for repeated measures with Tukey's post hoc test was used to compare MAS, t40m, HRmax, mass, and body fat between different measurements. Regression analyses were used to examine the relationships between the MAS before the control period, after the control period, and after the high-intensity interval training period. Similarly, regression analyses were used to examine the relationships between the t40m before the control period, after the control period, and after the high-intensity interval training period. The level of significance was set at $p \leq 0.05$.

RESULTS

The $\dot{V}O_2max$, HRmax, RER, maximal ventilation, and [La] obtained during the treadmill test were 60.1 ± 3.4 $ml \cdot kg^{-1} \cdot min^{-1}$, 196.5 ± 6.1 $b \cdot min^{-1}$, 1.12 ± 0.04, 141.2 ± 16.0 $L \cdot min^{-1}$, and 10.9 ± 1.4 $mmol \cdot L^{-1}$, respectively. The anthropometric characteristics, t40m, MAS, and HRmax measured before the control period, after the control period, and after the high-intensity interval training period are presented in Table 1. The ANOVA revealed no significant time effect for anthropometric and HRmax measurements. A significant time effect was obtained for MAS and t40m. The Tukey post hoc test indicated that MAS (+8.1 ± 3.1%; $p < 0.001$) and t40m (−3.5 ± 1.5%; $p < 0.001$) were significantly improved after the high-intensity interval training period, whereas no changes were observed during the control period.

TABLE 1. Effects of the training program on body mass, body fat, sprint running (t40m), maximal aerobic speed (MAS), and maximal heart rate (HRmax).

	Before control period	After control period	After high-intensity interval training
Body mass (kg)	71.3 ± 5.7	71.8 ± 6.2	71.5 ± 5.9
Body fat (%)	14.7 ± 2.4	15.0 ± 2.6	14.6 ± 2.3
t40m (s)	5.56 ± 0.15	5.55 ± 0.15	5.35 ± 0.13*
MAS ($km \cdot h^{-1}$)	15.9 ± 0.8	16.1 ± 0.8	17.3 ± 0.9*
HRmax ($b \cdot min^{-1}$)	197.5 ± 6.9	195.8 ± 5.9	195.1 ± 5.1

* Significant different from other periods ($p < 0.001$).

The relationship between MAS values obtained before and after the control period is presented at the top of Figure 2, whereas the relationship between MAS obtained after the high-intensity interval training period and after the control period is presented at the bottom. Likewise, the relationship between t40m obtained before and after the control period is presented at the top of Figure 3, whereas the relationship between t40m obtained after the high-intensity interval training period and after the control period is presented at the bottom.

The team won 33.3% of its games during the control period and 77.8% of its games during the high-intensity interval training period.

DISCUSSION

The purpose of this study was to compare the effects of a specific training protocol based on sprint repetitions and high-intensity intermittent runs in comparison with a control period. It was hypothesized that the in-season high-intensity interval training period would allow soccer players to increase aerobic and anaerobic running performances. Results of this study confirm this hypothesis. Two training sessions per week over 10 weeks allowed soccer players to significantly improve the MAS and to decrease t40m. Moreover, soccer team performance did not appear to be adversely affected. In fact, during the control period, the team won 33.3% of its games compared with 77.8% during the high-intensity interval training period.

Siegler et al. (24) found similar improvements with female high school soccer players. A 10-week in-season plyometric, resistance training, and high-intensity anaerobic program significantly improved 20-m sprint times and time to exhaustion during a specific shuttle test. However, as the protocol and participants were different from those in the present study (sex and level), the results are not comparable. In the present study, the $\dot{V}O_2max$ (60.1 ± 3.4 $ml \cdot kg^{-1} \cdot min^{-1}$) measured on a treadmill at the beginning of the study was in the range (58.1 to 65.5 $ml \cdot kg^{-1} \cdot min^{-1}$) of those obtained for professional soccer players (9, 16, 27). Likewise, the t40m (5.56 ± 0.15 seconds) measured before the control period was in the range (5.56 ± 0.15 to 5.62 ± 0.19 seconds) of those obtained for 2 junior men's elite teams in Norway (18).

During the control period, participants maintained the initial levels for MAS and t40m. This control period

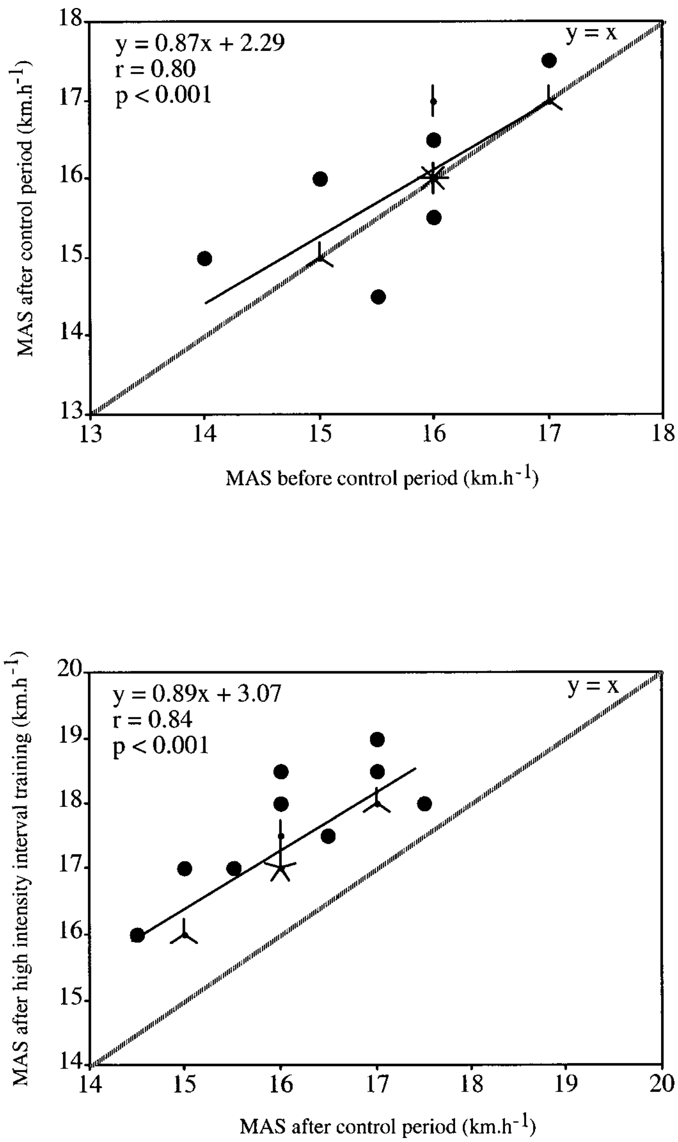

FIGURE 2. The relationship between the MAS measured before and after the control period (top) and the relationship between the MAS after the high-intensity interval training period and after the control period (bottom). The dotted line equals the identity line. When different points have the same coordinates, the number of subjects is indicated by the number of branches.

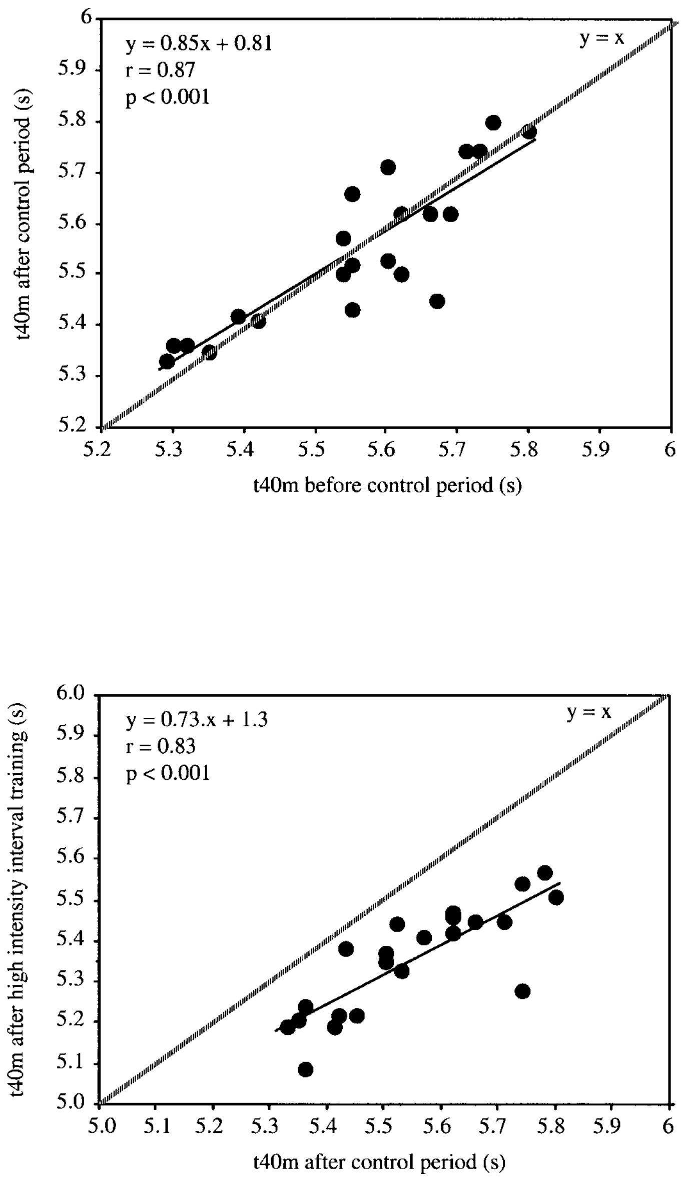

FIGURE 3. The relationship between the t40m measured before and after the control period (top) and the relationship between the t40m after the high-intensity interval training period and after the control period (bottom). The dotted line equals the identity line. When different points have the same coordinates, the number of subjects is indicated by the number of branches.

was based on technical and tactical skills and games. In soccer, these forms of exercise are often used during the playing season in order to improve technical and tactical qualities without decreasing soccer performances.

Between the beginning and the end of the high-intensity interval training period, MAS was increased significantly from 15.9 to 17.3 km·h^{-1}, which corresponded to an improvement of 8.1% ($p < 0.001$). Based on the assumption that the $\dot{V}O_2$max improvements require exercises eliciting and maintaining a high level of $\dot{V}O_2$max (1), short, intermittent exercises are often proposed in training programs to increase $\dot{V}O_2$max (13, 18, 26). Intermittent runs of 15 seconds at 120% of MAS alternated with 15 seconds of passive recovery were successful in eliciting and maintaining a high level of $\dot{V}O_2$ (10). Indeed, these intermittent runs of 15 seconds at 120% of MAS allowed $\dot{V}O_2$ to be sustained longer than intermittent runs of 15 seconds at 110, 130, and 140% of MAS or a continuous run at 100% of MAS (10). With similar intermittent exercises, Franch et al. (13) also found that short-interval training made up of 30–40 repetitions of 15-second runs alternated with 15 seconds of passive recovery performed 3 d·wk^{-1} over a 6-week period significantly increased ($p < 0.05$) the velocity associated with $\dot{V}O_2$max. In the present study, the high-intensity interval training program was not only based on intermittent runs of 15 seconds but also on the repetition of sprints alternated with 30 seconds of passive recovery. A single bout of this form of exercise is performed mainly via anaerobic pathways, but the relative contribution of aerobic metabolism to the total energy provision has been shown to increase when the exercise bouts are repeated with short recovery intervals (15). According to Balsom et al. (2), the $\dot{V}O_2$ attained at the completion of 15 bouts of 40 m alternated with 120-, 60-, and 30-second recovery periods corresponded to 52, 57, and 66 of $\dot{V}O_2$max, respectively. The repetition of 40-m sprints alternated with 30 seconds of passive recovery would result in a significant contribution of aerobic pathways to energy supply. To our knowledge, no study has shown the effects of a training program based on the repetition of 40-m sprints alternated with 30 seconds of recovery. Conversely, numerous training programs on a cycle ergometer based on the repetition of high-intensity exercise reported significant improvements in $\dot{V}O_2$max or maximal aerobic power (14, 22, 26). Our results indicate that intermittent high-intensity runs and sprint repetitions alternated with short recovery periods are useful to increase soccer players' aerobic performance (MAS) during the in-season.

Anaerobic performance was also improved during the high-intensity interval training period, whereas no modification occurred during the control period. The t40m decreased significantly from 5.56 to 5.35 seconds, which corresponded to a drop of 3.5% ($p < 0.001$). In comparison with submaximal or maximal intensities, high-intensity exercise can enable fiber recruitment to be elicited with specific physiological adaptations. Simoneau et al. (25) showed that a training program consisting mainly of a series of high-intensity exercises lasting 15–90 seconds allowed areas of types I and IIb fibers to be significantly increased, whereas a proportion of type IIa remained unchanged. Moreover, Tabata et al. (26) found that a 6-week training program based on short, intermittent exercise at high intensities alternated with short recovery periods allowed $\dot{V}O_2$max and the anaerobic capacity (i.e., measured as the accumulated O_2 deficit) to be significantly improved. Likewise, 9 weeks' training based on the repetition of four 30-second high-intensity exercises significantly improved aerobic and anaerobic performances (14), whereas 2-weeks' training based on the repetition of 15 seconds of all-out intensity alternated with 45-second rest periods plus a 30-second all-out repetition increased $\dot{V}O_2$max and the enzymatic activities of aerobic and anaerobic pathways (22). Conversely, when the training was based on exercises at submaximal intensity, sprint performance was not significantly increased. Indeed, after 8 weeks' specific aerobic interval training consisting of 4 × 4 minutes at 90–95% of maximal heart, Helgerud et al. (16) did not find a significant difference on the t40m between pre- and post-training (5.58 ± 0.16 seconds vs. 5.56 ± 0.15 seconds, respectively). In the present study, the training sessions based on sprint repetitions combined with intermittent runs at high intensity improved anaerobic performance. However, it seems difficult to determine the mechanisms responsible for the decrease in t40m as anaerobic performance improvements can be linked to numerous factors such as enzymatic adaptations (22), fiber hypertrophy, and/or neural improvements (23).

During the in-season, coaches often aim to increase technical and tactical qualities, whereas physical qualities are maintained through games and the usual tactical exercises. The present study shows that the usual exercises maintain physical fitness. However, during the in-season, coaches could also aim to improve physical fitness, without causing an overtraining syndrome, in order to improve the team's performance. In the present study, high-intensity interval training exercises were included in the habitual sessions (consisting of technical and tactical exercises and games), whereas the sessions following the high-intensity interval training sessions consisted of exercises at moderate intensities. The training volume (sessions per week) was kept constant, whereas the exercise load ranged from light to high intensities to prevent monotony (i.e., one of the possible factors leading to overtraining; Ref. 12). In addition, 1 of the intermittent exercises was individualized according to each subject's aerobic fitness.

Practical Applications

This study has shown that aerobic and anaerobic performances were increased during the in-season by a specific training program based on intermittent runs at high intensity and sprint repetitions. These results seem particularly interesting for soccer players because improvements in physical qualities are often emphasized before the beginning of competition. After this period, the objective of coaches is to maintain the level of physical qualities. The results obtained after the control period have shown that aerobic and anaerobic performances were maintained during the competition season. However, this study shows that improvements in physical qualities are also possible during the competition period without negatively affecting the soccer team's performance. Nevertheless, it is not appropriate to directly link physical performance to a soccer team's performance. Performance in soccer is determined by the players' technical, tactical, physiological, and psychological/social characteristics, and these factors are closely linked to each other (5).

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