The Anaerobic Endurance of Elite Soccer Players Improved After a High-Intensity Training Intervention in the 8-Week Conditioning Program

Goran Sporis, Lana Ruzic, and Goran Leko

Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia

Abstract

The purpose of this study was to evaluate changes in anaerobic endurance in elite First-league soccer players throughout 2 consecutive seasons, in 2 phases, with and without high-intensity situational drills. Eighteen soccer players were tested before and after the 8-week summer conditioning and again in the next season. The measured variables included 300-yard shuttle run test, maximal heart rate, and maximal blood lactate at the end of the test. During the first phase of the study, the traditional sprint training was performed only 2 × weeks and consisted of 15 bouts of straight-line sprinting. In the second year the 4 × 4 min drills at an intensity of 90–95% of HRmax, separated by periods of 3-minute technical drills at 55–65% of HRmax were introduced. Statistical significance was set at $P \leq 0.05$. The traditional conditioning program conducted during the first year of the study did not elicit an improvement in anaerobic endurance as recorded in the 300-yard shuttle run test. After the intervention, the overall test running time improved significantly (55.74 ± 1.63 s vs. 56.99 ± 1.64 s; $P < 0.05$) with the maximal blood lactate at the end of the test significantly greater (15.4 ± 1.23 mmol·L^{-1} vs. 13.5 ± 1.12 mmol·L^{-1}. $P < 0.01$). As a result, this study showed some indication that situational high-intensity task training was more efficient than straight-line sprinting in improving anaerobic endurance measured by the 300-yard shuttle run test.

Key Words 300-yard shuttle run test, maximal blood lactate, situational high-intensity training

Introduction

The high level of the anaerobic capacities in soccer players enables them to perform high-speed runs, which in the end may have a crucial impact on match results (24). Soccer is a predominantly aerobic game (5,20,37,39) and anaerobic energy is essential to performance in sprints, high-intensity runs, and duel plays, all of which may contribute to the final outcome of the game (23). Top-class soccer players are able to perform more high-intensity running than moderate professional soccer players (28).

It has been proven previously that interval training enhances aerobic endurance in soccer players by increasing distance covered, enhancing work intensity, and increasing the number of sprints and involvements with the ball during a match (17) The players spend 1–11% of the game sprinting (4,5,32), which represents 0.5–3.0% of effective time with ball in play (1,4,29). For example, a midfielder sprints more than 1.1 km of total 10.9 km covered during the match (39). For this reason, it is extremely important to incorporate anaerobic training into overall conditioning training protocols.

The incorporation of sport-specific speed training in the early phase of conditioning should contribute to the improvement of specific anaerobic performance components: acceleration, maximal speed, and agility (23). All of the aforementioned components influence the performance during the various shuttle-run sprint tests. Because the repeated sprint ability field tests showed high reliability and validity (27,30,43), high reproducibility, and sensitivity (21), they may represent a valid measure of anaerobic soccer performance. Also, it has been shown that high-intensity sprint ability represents one of the measures for match-related physical performance in top level professional soccer players (28,31) and some tests also were validated to be accurate predictors of player match performance (35). Although previous studies have proven the correlation of sprint ability and player performance (11,28) as well as effects of high-intensity runs on anaerobic capacities (22,30), there is a lack of scientific studies examining the effects of high-intensity specific movement patterns on anaerobic capacities of soccer players (36).

The preparation period in Croatian soccer teams at the beginning of the season typically encompasses low volume of anaerobic sprint training and a high volume of aerobic training eliciting the improvement of aerobic capacities (40). Because the variance between maximal oxygen uptake and

Address correspondence to Lana Ruzic, lana.ruzic@kif.hr.

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total sprint time is only 12% (4), any further improvement in aerobic fitness will is expected to contribute only marginally to improvement in repeated sprint performance. The sprint training usually practiced by Croatian soccer teams during the first period of preparation consists mainly of straight-line runs (12,40) and does not take into account the many abrupt changes in direction that occur in an actual game situation. Therefore, the purpose of this longitudinal 2-year study was to examine the effects of redesigned high-intensity situational sprint training on anaerobic performance of elite soccer players.

Methods

Experimental Approach to the Problem

There were 2 experimental phases completed in this study. In the first phase of the study (summer 2002), the players completed their traditional 8-week preseason conditioning according to the training program used during several

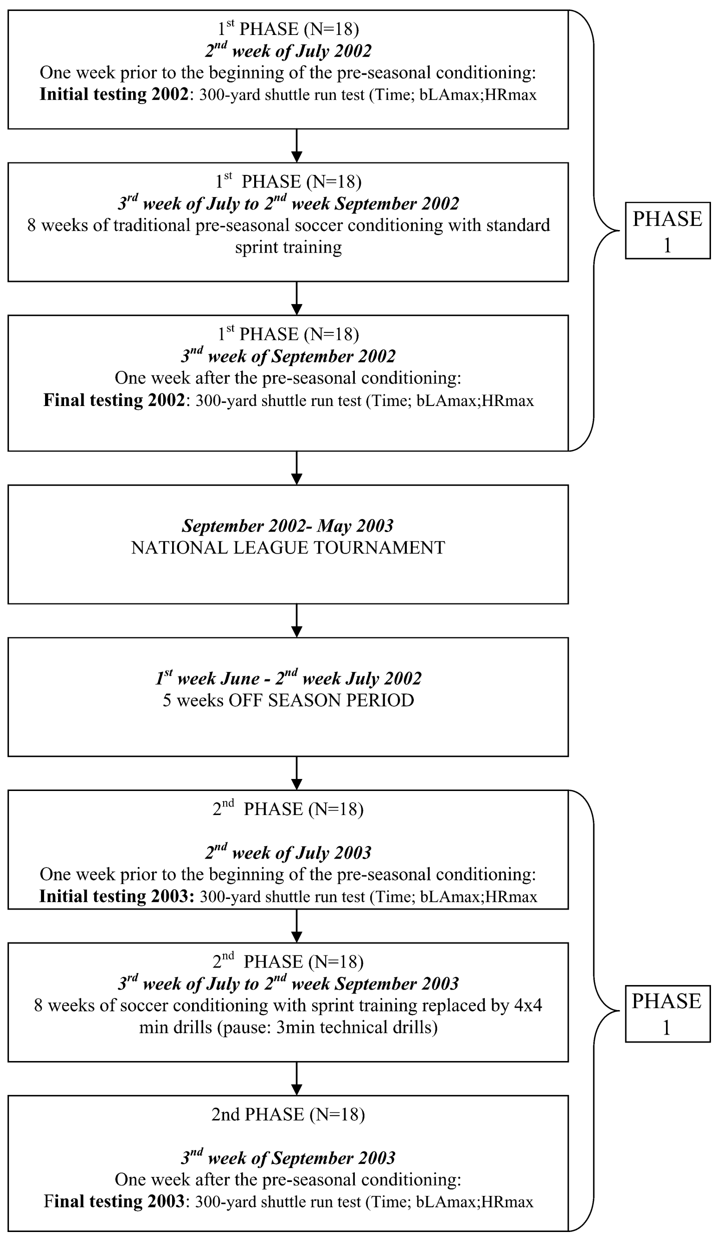

Figure 1. Time line flow chart of the experimental design. Wk, week; bLAmax, maximal blood lactate concentration; HRmax, maximal heart rate at the end of the test; Time, time needed to complete the 300-yard test.

previous seasons. In the second phase of the study (summer 2003), the high-intensity situational training was introduced instead of the standard sprint training. The repeated sprint ability test (300-yard shuttle run test) was used to determine the effects of both conditioning programs on anaerobic endurance (Figure 1). The physical load was assessed by measurements of blood lactate concentrations and maximal heart rate at the end of the test. Changes in body weight and body fat percentage were also monitored.

Subjects

Eighteen elite male soccer players, members of the First league team, volunteered to participate in the study. Six of the subjects were also members of the Croatian National Team, and the remaining players played in one of the 3 highest-ranked teams in Croatia. All of the participants provided written consent after they were informed of test protocol without being informed of the aim of the study. The protocol of the study was approved by the Ethical Committee of the Faculty of Kinesiology, University of Zagreb, according to the revised Declaration of Helsinki. The sample comprised 5 defenders, 10 midfield players, and 3 forwards with all goalkeepers excluded. The main characteristics of the sample are presented in Table 1.

Procedures

The study took place in 2 phases, during the precompetitive periods of 2002/2003 and the season of 2003/2004. In the summer of 2002 and the summer of 2003, the preseason training program was administrated for the duration of 8 weeks. Technical, tactical, and strength training was performed in the same manner during both phases (Table 2). The subjects trained 8–10 sessions per week for 90–105 minutes per session. Strength training was conducted in a gym twice a week in 90 min durations (30 minutes' warm up; 40 minutes' circular training; 20 minutes' stretching exercises). The investigator, who was also a conditioning adviser for the team, supervised all sessions. After the first phase of the study the subjects played the National First Soccer League season. Before the beginning of the second phase, the subjects were free for 5 weeks (off-season period), which probably caused a certain level of detraining. Therefore, it was important to test for differences between the results of initial measurements in 2002 and initial measurements in 2003.

The main difference between the programs in preparation period 2002 and preparation period 2003 was in the way the sprint training was performed. During the first phase of the study the traditional sprint training was performed only 2 times a week and consisted of 15 bouts of straight-line sprints (5×20 m; 5×40 m; 5×60 m) with no situational drills. In between the sprints, the subjects performed stretching exercises and walked back at a slow pace for the duration of 90 seconds (30).

In the second year of the study, the situational training intervention was included in the preseason training period. The intervention consisted of introducing the newly designed high-intensity situational training instead of the traditional sprint training described previously. The high-intensity intervention consisted of 4×4 min maximal running with different drills (Figure 2) at an exercise intensity of 90–95% maximal heart rate, separated by "rest" periods of 3-minute technical drills at 55–65% maximal heart rate. During the 3-minute technical drills, the subjects were required to work in pairs and perform inside-of-the-foot passes (first drill), receive the passed ball with the chest (second drill), and perform head kicks and head receiving (third drill). The described interval training was administrated as an extension of regular training, three times a week over an 8-week period on alternate days from the strength-training sessions.

Anaerobic Performance Test

Anaerobic endurance was tested at the beginning and end of the preparation period using a 300-yard shuttle run test (2,19) as a test to measure anaerobic endurance. The test protocol requires measuring and marking reference points that are 25 yards apart on a flat grass surface. During the test the subject must run to the 25-yard mark, touch it with his foot, turn and run back to the start. This is repeated 6 times without stopping. The test is a quick and easy way of indirect determination of anaerobic performance, and improvements in anaerobic performance, during and after periods of conditioning training.

During the test each player was instructed and verbally encouraged to apply maximal effort. Tests were performed in the afternoon between 2 and 4 pm, on a natural grass soccer pitch, and the subjects wore soccer kits. Times were recorded in 100ths of a second by an electronic time

Table 1. General descriptive parameters of the sample at the beginning of the study.

	Age	Height (cm)	Weight (kg)	Body fat (%)	HRmax (treadmill)*	$\dot{V}O_2$max* (mL min^{-1})	Years in training
Mean ± SD	26.4 ± 3.3	182.1 ± 6.0	78.1 ± 7.6	10.7 ± 2.2	179 ± 2.1	58.9 ± 3.1	13.1 ± 2.8

*The maximal oxygen uptake ($\dot{V}O_2$max) and maximal heart rate (HRmax) were measured by a progressive treadmill test to exhaustion.

TABLE 2. General conditioning program overview for summer 2002 and summer 2003 (wk-week).

Mesocycle	Introductory	Multilateral	Basic	Specific	Precompetition	Competition	Total
Calendar duration	Third week of July	Fourth week of July	First week of August	Second week of August	Third week of August	Fourth week August and first and second weeks of September	
Conditioning vs. technical-tactical training (%)	20/80	60/40	30/70	15/85	10/90	15/85	
Duration (days)	7	7	5	8	7	26	60
Days of training and/or matches	6	6	5	8	6	24	55
N of trainings	8	9	9	9	7	25	67
N of matches	1	1	0	4	0	7	13
Hours of training	14.5	14.5	13.5	11.5	10.5	36	100.5
Hours of matches	1.5	1.5	–	6	–	10.5	19.5
Extensity of training days	2.41	2.41	2.7	1.4	1.75	2.33	2.16
Intensity (% HRmax)	70–75%	80%	85%	90%	90%	90–95%	85%
Rest days between the cycles	1	1	0	1	0	1	4

keeping device (Photo-cell system by RS, Croatia). After the completion of the test, subjects underwent measurements of maximal blood lactate concentration using the simplified blood lactate test meter (Arkray Lactate Pro™ LT-1710, Japan). The physical load as a percentage of maximal heart rate was monitored using heart rate monitors (Polar Team

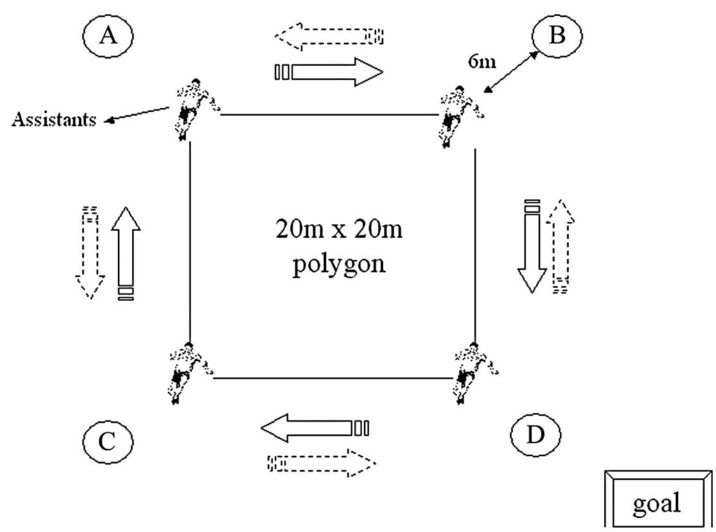

Figure 2. The intensity situational training was performed on several marked polygons. The subjects performed 4-minute runs with clockwise and counter-clockwise changes of direction after each lap. The assistants (who were not the subjects in this study) stood at the angles of the square with the ball and were required to pass the ball to the players as they reached them at the marked 6m distances. The subject had to complete four different assignments during the runs at each station: return the ball with his left leg (A), return the ball with his right leg (B), return the ball towards the assistant's chest (C), and perform a shot at goal (D).

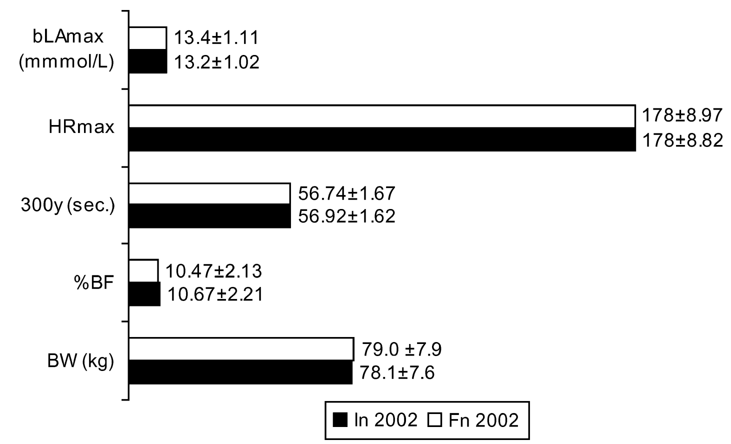

Figure 3. Mean values and standard deviations for measured parameters in summer 2002. In 2002, initial testing in 2002; Fn 2002, final testing in 2002; bLAmax, maximal blood lactate concentration; HRmax, maximal heart rate at the end of the test; 300y, time needed to complete the test; %BF, percentage of body fat; BW, body weight.

System, Finland), whereas the body fat percentage was determined by skinfold method in the morning hours of the testing day (Harpenden Skinfold Caliper, UK). During the test the air temperature ranged from 21°C to 24°C. The researchers were responsible for all measurements that were performed.

Statistical Analyses

The statistical Package for Social Sciences SPSS (v11.5, SPSS Inc., Chicago, IL) was used for statistical analyses. Descriptive statistics were calculated for all experimental data. The Kolmogorov-Smirnov test was used to test the normal distribution of the data. Statistical power and effect size were calculated using the GPower software (13,14). The reliability of the 300-yard shuttle run test was determined using the reliability analysis (alpha) and the test re-tests method (Pearson correlation coefficient). Interclass correlation coefficient was calculated to determine the reliability of dependant variable (300-yard shuttle run test). For comparison between the 2002/2003 and 2003/2004 seasons, in the initial and final measurements, we used the Paired Sample Test. Results were accepted as significant at $P \leq 0.05$.

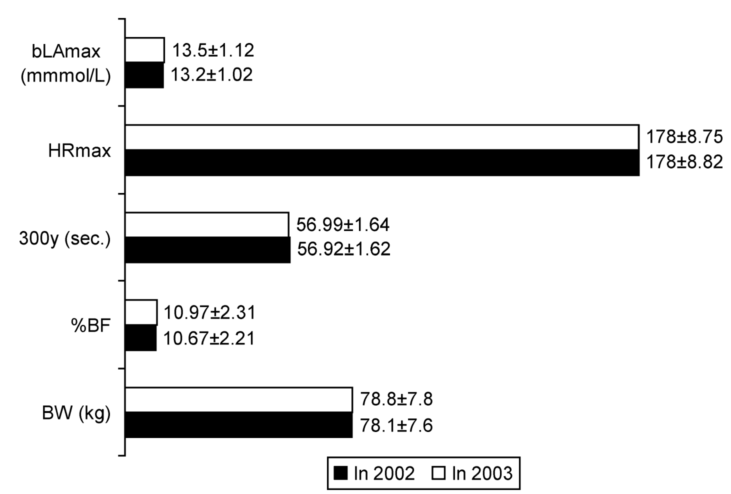

Figure 4. Mean values and standard deviations for measured parameters at the beginning of the 2 seasons. In 2002, initial testing in 2002; In 2003, final testing in 2003; bLAmax, maximal blood lactate concentration; HRmax, maximal heart rate at the end of the test; 300y, time needed to complete the test; %BF, percentage of body fat; BW, body weight. **Significant at level of $P < 0.01$; *significant at level of $P < 0.05$.

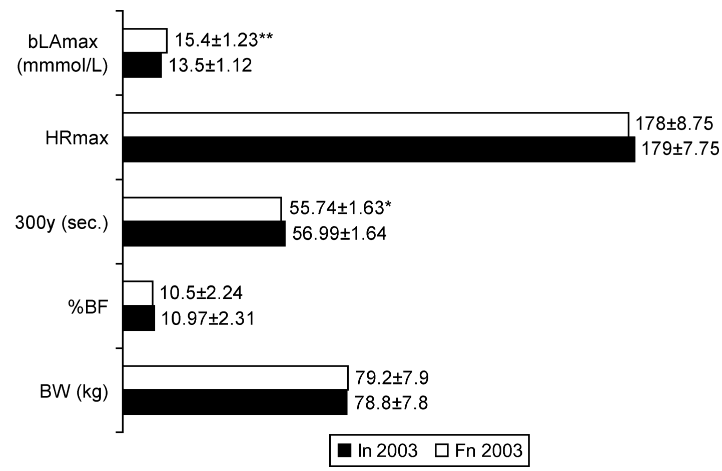

Figure 5. Mean values and standard deviations for measured parameters in summer 2003. In 2003, initial testing in 2003; Fn 2003, final testing in 2003; bLAmax, maximal blood lactate concentration; HRmax, maximal heart rate at the end of the test; 300y, time needed to complete the test; %BF, percentage of body fat; BW, body weight.

Results

Initial Testing vs. Final Testing in 2002

No significant differences were observed for 300-yard shuttle run test result, maximal blood lactate, and maximal heart rate. That was regarded as not satisfactory in terms of improvement in anaerobic endurance of the players. Body weight and percentage of fat tissue also did not change significantly. The mean values and standard deviations for the pre- to post training results in the first season (after the traditional soccer conditioning) are given in Figure 3.

Initial Testing in 2002 vs. Initial Testing in 2003

The fact that the18 players who were the subjects during the first year stayed with the team in the second season enabled us to continue the study. At the start of the second season the initial measurements were repeated on the same subjects and no statistically significant differences were recorded in any of the measured variables between the initial measurements in 2002 and 2003 (Figure 4), which was a necessary precondition for the study to continue.

Initial Testing vs. Final Testing in 2003

After the completion of the redesigned training program in the second year of the study, all of the tests were repeated and the effects of the new program on measured variables were examined. The means and standard deviations for measured parameters in the second year of the study are presented in Figure 5. We observed a statistically significant increase in maximal blood lactate from 13.5 ± 1.12 pretraining to 15.4 ± 1.23 mmol·L^{-1} post-training ($P = 0.0021$; 0.16 effect size), and the improvement in overall test performance (55.74 ± 1.63 vs. 56.99 ± 1.64 s; $P = 0.032$; 0.16 effect size). The reliability coefficient α for 300-yards shuttle run test was 0.96 while the test re-test method showed high ICC values (ICC = 0.93; range 0.83–0.97; $P < 0.0031$). No significant differences between the tests were observed in maximal achieved heart rate, body fat and body weight. The calculated statistical power for this study was 0.168.

Discussion

The primary finding of the study was observed in the second year of the study, after the intervention program. The 4 × 4-minute high-intensity drill training designed to influence anaerobic endurance can provide improvements in the shuttle run anaerobic test. The subjects significantly improved the overall 300-yard running time, which was not the case in the season before. Also, maximal lactate production was significantly higher (the blood lactates make a significant contribution to total energy expenditure in endurance-type training (34)). Consequently, we can conclude that players performed better and were able to sustain higher blood lactate concentrations in a shorter test time. The high-intensity interval drill training that led to improvement of anaerobic endurance might contribute to improvement in match performance (25,28,31).

The greater lactate concentrations, together with better running time, could be attributed to the increase of the buffering capacity (22) and peripheral skeletal muscle adaptations (42). As described earlier, the 4 × 4-minute program intervention targeted lactic anaerobic energy systems but required the high work rate of aerobic pathways as well. As described previously (7), the glycolytic lactic and oxidative pathways should be viewed as linked and not alternative processes, because lactate, the product of one pathway, is the substrate for the other. Also, as explained by Robergs et al. (33), if muscle did not produce lactate, acidosis and muscle fatigue would occur more quickly, so we may presume that the greater levels of lactate delayed the fatigue and improved overall test performance.

The 4-minute duration of the drills resulted in high lactate accumulation and the incorporated high intensity bouts were aimed at maximal lactate production intensity zones in order to increase the buffering capacities of the muscles (8,15,41). However, because the muscle buffering capacity was not controlled in present study, it remains to be confirmed. Unfortunately, the extent of this study was limited by the very same factor that represented the main advantage of the study, and that was a representative sample of the elite First League and National Squad soccer players.

The present study provided complementary findings to the study of McMillan et al. (26) when similar training intervention was found to be effective in improving maximal aerobic capacity over a short period of time, but the influence on blood lactate and sprint ability was not monitored. In their paper the 4 × 4-minute bouts were dribbling activities at moderate intensity, whereas in our study the players performed high intensity runs during the 4 × 4-minute bouts.

The traditional conditioning program conducted during the first year of the study did not elicit the desired changes in anaerobic endurance (Figure 3) and the time needed to complete the 300-yard shuttle run test did not improve. In addition, lactate production during the test did not increase significantly. Blood lactate concentration is an indirect parameter pointing to the engagement of anaerobic glycolytic processes and is related to the amount of work performed prior to testing (25). The lack of changes in produced lactate during the test might lead to the conclusion that the traditional soccer-conditioning program did not target the anaerobic-glycolytic energy pathways because of the too short straight-line sprinting duration included in the traditional program (12,40). During the traditional soccer conditioning in the first year of the study the players performed short, straight-line sprints, mostly using their phosphate energetic pathways (16,33) Considering that during a 90-minute game, soccer players run about 10 km at an average intensity close to the anaerobic threshold, for example, 80–90% of maximal heart rate (37), results after the first season preparation period were less than satisfactory.

It is known that the high-intensity sprints that a player has to complete in each soccer match (6,23,38) are much shorter in duration than the time needed to complete a 300-yard shuttle run test. Despite that, the modern soccer game tends to accumulate a number of repeated sprints and there often exists a 1-minute period with several sprints for the same player. That is why an improvement in 300-yard shuttle run test may be a good anaerobic performance indicator in soccer. The test may be a useful addition to the battery of soccer-specific field tests that estimate soccer related physiological characteristics like aerobic fitness-related field tests (10,27), or aerobic-anaerobic field tests (9,18).

Practical Applications

Usually, the easiest and the least time-consuming way to incorporate high-intensity workout in conditioning soccer programs is straight-line or zigzag sprinting. The present study examined the influence of complex, high-intensity training, with incorporated drills into standard preseason conditioning of top-level soccer players. We found that the presented 4 x 4 min high-intensity drills resulted in a better overall time on the 300-yard shuttle run test accompanied with a better ability of the players to sustain greater lactate concentrations. On the contrary, the standard short straight-line sprints that were administrated in the first season did not produce similar improvements. These differences between the programs appear to be due to the longer duration of the high-intensity drills in the new program. The conditioning coaches may wish to apply an extra effort to organize the polygons in the above-described manner, implementing high-intensity 4 × 4-minute drills with 3-minute low-intensity active rests. A simple way of measuring improvement in anaerobic endurance with the 300-yard shuttle run test can be used by coaches to adjust the training program settings and evaluate the results. According to the early findings of this study, changes have already been incorporated into the current season programs of three First League Croatian Soccer teams. Initiatives of this kind might also be applicable in conditioning of handball or basketball players.

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