Matching Physiological Demand of Competitive Soccer Matches with Comprehensive Complex Training for Soccer Players

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ABSTRACT

Treeraj A, Kamutsri T, Lawsirirat C, Intiraporn C. Matching Physiological Demand of Competitive Soccer Matches with Comprehensive Complex Training for Soccer Players. JEPonline 2016;19(6):94-103. The purpose of this study was to propose a comprehensive complex training program to meet energy demand of competitive games. Twelve male varsity soccer players (age, 20.58 ± 1.78 yrs; height, 172.50 ± 5.30 cm; weight, 67.83 ± 8.43 kg; body mass index, 22.81 ± 2.62 kg·m⁻²; VO₂ max, 54.55 ± 3.11 mL·kg⁻¹·min⁻¹) were recruited to perform three carefully designed complex training programs, which were a combination of clean pull lifts, vertical jumps, and a 20-m shuttle run. The study used a crossover design to administer the three programs. Subjects completed the three programs on three different days separated by 48 hrs to allow complete recovery and to control inter-subject variability. Blood lactate concentration was recorded immediately after the training and at every 3-min interval until 15 min after the training. Blood lactate clearance was calculated at every 3-min interval from minute 3 to minute 15 of recovery time. One way repeated measure was used to analyze the data. The average blood lactate concentrations at minute 0 (i.e., immediately after training) were 9.90, 8.53, and 7.94 mmol·L⁻¹ for Programs I, II, and III, respectively, which were close to the values reported in the literature. The findings indicate that Program I is recommended for coaches to train their varsity soccer players. Program I ensures that the players will get an adequate workout common to a competitive soccer match that requires a high blood lactate level.

Key Words: Complex Training, Physiological Demand, Varsity Soccer
INTRODUCTION

Soccer is a physical demanding sport that requires the repetition of many diverse activities such as jogging, jumping, running, and sprinting, and skill-related characteristics of players (e.g., strength, power, speed, agility, balance, stability, flexibility, and endurance) (4,9). The movements in a soccer match are performed at low and moderate to high intensities where players typically cover an average distance of 9 to 12 km with short distance movements of 15 to 20 m with changes in direction every 3 to 6 sec. The energy supply for these actions is provided from both aerobic and anaerobic metabolic pathways (14).

To improve aerobic endurance as well as anaerobic capacity, high intensity intermittent training (HIIT) is commonly used among soccer players (12). HIIT alternates between short intensity work outs (70 to 90% of maximum heart rate) and a short rest. As a result, energy demand from HIIT fluctuates from high to low level between work and rest (8). This pattern is similar to a soccer game where a player alternatively switches between using a short burst of energy in sprinting and a short rest during jogging or walking. HIIT is a one dimensional training exercise where it can only improve one functional capability (e.g., sprinting ability). However, soccer players also need sprinting, jogging, jumping, heading, and kicking. HIIT cannot address all diverse activities required in soccer players. A new training program that matches energy demands and activities during a soccer competition is essential and needed. To maximize the efficiency of one training session, the new training program must embed variety of activities for lower extremities while mimicking physiological demand of a soccer competition.

Complex training can be created to match the requirements for soccer players, and it is very popular for improving strength and explosive power. It is a combination of strength and plyometrics exercise in the same muscle groups. Complex training utilizes the concept of post activation potentiation (PAP) that is defined as an increase in force production following a maximal or near maximal muscle action due to phosphorylation of the myosin light chain (13). This phenomenon is defined by an increase of muscle contraction related to its previous contraction (5). As a result, complex training relies on anaerobic system and, therefore, can be used to train for improving lactate tolerance. Complex training is most effective when it is carefully design to address sport-specific movements in training exercise (2,6).

To our knowledge, complex training is designed to improve skill-related fitness such as speed, strength, and power, but no paper has designed a complex training program to match the physiological demands of soccer players. Yet, the matching of physiological demands for competition to a sport-specific complex training program is anticipated to help the athletes perform better.

Lighter workloads result in poor physical fitness and performance in competitions while heavier workloads may result in excessive fatigue and injury. Thus, the aim of this research was to develop a new complex training program for soccer players that can emulate energy and movement patterns during a competitive soccer match. By mimicking energy pattern, the program helps to ensure that soccer players have an adequate fitness level for a competitive match, while mimicking movement pattern allows the coaches to consolidate their various training programs to improve the lower extremities used by soccer players. It is anticipated that the new training program will help to reduce training period for soccer players.
METHODS

Subjects

Twelve healthy male varsity soccer players voluntarily participated in this study (age, 20.58 ± 1.78 yrs; height, 172.50 ± 5.30 cm; weight, 67.83 ± 8.43 kg; body mass index, 22.81 ± 2.62 kg·m$^{-2}$; VO$_2$ max, 54.55 ± 3.11 mL·kg$^{-1}$·min$^{-1}$). All subjects provided written, informed consent before taking part, which was approved by Mahidol University’s Institutional Review Board (MU-IRB), Thailand. A pre-participation questionnaire was administered to exclude subjects who smoked and/or had a history of cardiovascular disease, metabolic disease, and other dysfunctions.

Procedures

The experimental conditions consisted of 3 complex training programs. The subjects completed the training programs on three different days separated by 48 hrs to allow complete recovery and to control inter-subject variability. Upon arrival, each subject was equipped with a heart rate monitor (Polar FT01, China), gas analyzer (Oxycon mobile Unit, Germany) and, then, a fingertip blood sample was taken for blood lactate analysis before and during the recovery period. Prior to starting the program, the subjects had a 5-min rest period followed by a 10-min warm-up. After the warm-up session, the subjects were asked to perform 6 sets of complex training with a 3-min rest between each set. After finished training, the subjects were asked to sit down and wait for their blood lactate concentration testing. There were no cool down periods during the 15 min of recovery time in order to prevent any interferences of cool down to the complex training program. The complex training programs were performed on a soccer field where the ambient temperature and relative humidity were 28.24 ± 3.41°C and 55.76 ± 5.61%, respectively.

Experimental Approach to the Problem

This study developed a new complex training program matching energy demand of a soccer match using a combination of clean pull, vertical jump, and sprint shuttle run. These activities were used due to their employment of lower extremities and their direct relation to movement patterns in soccer. To match energy demand for a soccer match, blood lactate concentration, blood lactate clearance, and heart rate were measured. The study was a randomized and crossover study. The subjects were asked to attend the university on 4 separate occasions separated by at least 7 days. On the first visit, each subject completed a maximal incremental Bruce protocol test on a treadmill while breath-by-breath (VO$_2$) measurements were recorded using a gas analyzer (Oxycon mobile Unit, Germany). Peak oxygen uptake (VO$_2$ max) was recorded as the highest 30-sec average before volitional exhaustion. The subjects were also familiarized with test procedures. VO$_2$ max was used as inclusion criteria for the subjects. The cutoff point for VO$_2$ max was 51 mL·kg$^{-1}$·min$^{-1}$, which was the same cutoff point used for Thailand national soccer player selection (Figure 1). On the following 3 visits, the subjects completed 3 different complex training programs.
Complex Training Designs

The complex training programs consisted of a combination of clean pull (A), vertical jump (B), and shuttle run (C). Each subject was equipped with a heart rate monitor and gas analyzer (Figure 2). All designed complex training shared similar activities where the subjects were required to perform clean pull at 85% of their 1 RM followed by 6 vertical jumps at their maximum effort, and a 20-m (with 180° turn) sprint shuttle run. After the subjects finished their task, they had a 30-sec break before they began the next task. The difference among the three programs was the number of repetitions in clean pull and the break between a clean pull lift.

Program I required the subjects to perform a clean pull lift at 85% of 1 RM 6 times continuously. Program II required the subjects to perform a clean pull lift at 85% of 1 RM three times continuously. While Programs I and II asked the subjects to perform continuous clean pull lifts, Program III required the subjects to lift clean pull at 85% of 1 RM 6 times with a 15-sec rest between each clean pull lift. Figure 2 pictorially summarized the design of each program. The subjects were required to repeat a maximum of 6 clean pulls and 6 vertical jumps because 6 repetitions of high intensity workout improves strength, while a 20-m shuttle run was selected due to the frequent sprinting distance of soccer players. Program I was designed such that the subjects experienced the heaviest workload with shortest rest period. Program II was designed with the understanding that 6 repetitions of 85% of 1 RM were in the upper limits for strength training where the subjects exhausted their strength during the 6 clean pull lifts. The subjects may have had insufficient energy left to perform their next task. As a result, Program II was design to lesser the workload where the subjects were required to perform 3 clean pull lifts. Similarly, Program III was designed such that the subjects had a short rest of 15 sec after each clean pull lift.
One Repetition Maximum Measurement

Maximal strength in the leg extensors was measured as 1 RM in clean pull. Before the 1 RM clean pull test, subjects performed a standardized specific warm-up that consisted of 3 sets with gradually increasing load.

Blood Lactate Concentration Measurement

Blood samples were taken from fingertips and collected in heparinized capillary tubes immediately after training was completed and at 3-min intervals until 15 min after the training session (Figure 3). Blood lactate concentration was analyzed using a blood lactate analyzer (Lactate Scout, Germany). Lactate concentrations are expressed in millimole per liter (mmol·L⁻¹).
Blood lactate clearance indicated how well the subjects recovered from trainings and was calculated as:

\[ \text{Blood Lactate Clearance} = \frac{\text{blood lactate}_{\text{initial}} - \text{blood lactate}_{\text{delay}}}{\text{blood lactate}_{\text{initial}}} \times 100. \]

Statistical Analyses

All statistical analyses were performed using SPSS statistical software for Windows (Version 17.0, SPSS Inc., Chicago, IL, USA). Values are reported as mean ± SD and SEM. A repeated measures ANOVA for blood lactate concentration, blood lactate clearance, and heart rate was used to determine the significant difference among complex training programs and times of recovery. The Tukey’s post-hoc test was used to assess differences in the repeated measurement between trials. Statistical significance was set at P<0.05.

RESULTS

Table 1. Reported Blood Lactate Concentration and Blood Lactate Clearance at the Baseline, Immediately After Training or at Minute 0, and at Every 3 Minutes of Recovery Time from Minutes 3 to 15.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Program 1</th>
<th>Program 2</th>
<th>Program 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood lactate concentration (mmol·L(^{-1}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0th minute</td>
<td>9.90 ± 3.16*</td>
<td>8.53 ± 3.38</td>
<td>7.94 ± 2.53</td>
</tr>
<tr>
<td>3rd minute</td>
<td>10.47 ± 3.08**</td>
<td>8.62 ± 3.17</td>
<td>8.48 ± 3.12</td>
</tr>
<tr>
<td>6th minute</td>
<td>10.00 ± 4.18</td>
<td>8.36 ± 3.52</td>
<td>8.27 ± 2.56</td>
</tr>
<tr>
<td>9th minute</td>
<td>8.69 ± 3.28</td>
<td>7.83 ± 3.19</td>
<td>7.86 ± 2.61</td>
</tr>
<tr>
<td>12th minute</td>
<td>8.28 ± 3.14</td>
<td>7.59 ± 2.98</td>
<td>7.24 ± 2.16</td>
</tr>
<tr>
<td>15th minute</td>
<td>6.97 ± 2.56</td>
<td>6.83 ± 2.45</td>
<td>6.65 ± 2.45</td>
</tr>
<tr>
<td>Blood lactate clearance (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd minute</td>
<td>-7.95 ± 23.05</td>
<td>-3.32 ± 15.94</td>
<td>-5.83 ± 14.21</td>
</tr>
<tr>
<td>6th minute</td>
<td>0.25 ± 23.25</td>
<td>2.50 ± 8.07</td>
<td>-5.29 ± 17.80</td>
</tr>
<tr>
<td>9th minute</td>
<td>11.58 ± 20.32</td>
<td>7.47 ± 15.12</td>
<td>-0.82 ± 19.46</td>
</tr>
<tr>
<td>12th minute</td>
<td>14.43 ± 33.13</td>
<td>8.77 ± 19.50</td>
<td>5.54 ± 24.12</td>
</tr>
<tr>
<td>15th minute</td>
<td>29.68 ± 13.71</td>
<td>17.26 ± 19.02</td>
<td>11.43 ± 34.37</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.01 differences between program
Blood Lactate Concentration during Recovery Time

Resting blood lactate concentrations before training were 2.21 ± 1.23, 1.79 ± 0.91, and 1.80 ± 0.72 mmol·L⁻¹ for Programs I, II, and III, respectively. Table 1 presented the blood lactate concentration for the three complex training programs. Blood lactate concentration increased immediately after training and decreased gradually during the recovery period. The blood lactate concentration obtained in Program I was higher than Programs II and III immediately after exercise or at minute 0 of recovery time (P<0.05) and at minute 3 of recovery time (P<0.01). Additionally, at minute 3 of recovery time, Program I had the highest blood lactate concentration with a mean value of 10.46 ± 0.89 mmol·L⁻¹. There was no significant difference in blood lactate concentration among the three programs during any other recovery periods.

Blood Lactate Clearance during Recovery Time

Blood lactate clearance of Programs I, II, and III was an increasing function (Table 1). The slope of blood lactate clearance of Program I was greatest when compared to Programs II and III because blood lactate concentration of Program I was significantly higher than blood lactate concentration of Programs II and III at minutes 0 and 3 of recovery time. But, blood lactate concentration of Programs I, II, and III were similar to one another resulting in greatest difference in blood lactate concentration and, therefore, the greatest slope in blood lactate clearance in Program I. We found no significant difference among Programs I, II, and III in blood lactate clearance. Peak blood lactate clearance was found at minute 15 of the recovery time with mean values of 29.68% ± 13.71, 17.26% ± 19.02, and 11.43% ± 34.37 for Programs I, II, and III, respectively. There was no statistical difference in blood lactate clearance among the three programs at any other periods.

DISCUSSION

This study developed a complex training program that emulated energy demand in a soccer game by matching blood lactate concentration after training with blood lactate concentration endured by soccer players after a competitive match. The training programs can be used as an alternative training method for soccer players instead of HIIT to yield physiological benefits beyond sprinting.

Blood Lactate Concentration during Recovery Time

Blood lactate concentration is the ratio of blood lactate production rate and blood lactate removal rate, and it represents the intensity of work load of a training program. If the rate of production exceeds the removal rate, blood lactate concentration increases via lactate accumulation. This occurs during intense exercise when the body uses carbohydrates to produce energy during times of low oxygen levels. Agnevik (1) reported that the average blood lactate levels after a Swedish Division 1 soccer match was 10 mmol·L⁻¹ with peak values of 15 mmol·L⁻¹. Ekblom (7) found that blood lactate concentration increased to 9.75 and 7.2 mmol·L⁻¹ after first and second half of a soccer game in Division I of the Swedish league.
As seen in Table 1, the average blood lactate concentration at minute 0 of Programs I, II, and III (9.90, 8.53, and 7.58 mmol·L\(^{-1}\), respectively) was very close to the average blood lactate reported in the literature. High blood lactate concentration was seen in all complex training programs. According to Brooks et al. (3), high accumulation of blood lactate in the body occurs as a result of greater recruitment of type II fast twitch muscle fibers because fast twitch fibers produce greater amounts of lactate than slow twitch fibers. All three complex training programs were designed for the subjects to use their maximum effort by finishing each task within 30 sec. The subjects employed ATP and glycolysis system and utilized their type II fast twitch muscle fibers to create explosive power in order to keep up with the training procedure making their body to experience high blood lactate concentration matching with the blood lactate level occurred during a competitive soccer match. The average blood lactate of Program I was higher than Programs II and III because Program II had a lower load than program I, while Program III was created to have more rest periods than Program I. The lower work load and more rest intervals explain the difference between the blood lactate concentrations among Programs I, II, and III.

**Blood Lactate Clearance during Recovery Time**

After training, blood lactate clearance was gradually increasing after exercise until minute 15 of the recovery period. There was no significant difference in blood lactate clearance at any recovery time periods among the three programs. However, the average blood lactate clearance of Program I was initially lower than Programs II and III before it was higher than Programs II and III at minutes 9, 12, and 15 of the recovery time (Table 1). Program I induced high blood lactate concentration because of its heaviest load. Initially, after training had finished, the muscles continued producing blood lactate due to its inertia of previous strenuous training. Therefore, the blood lactate clearance of Program I was lower than that of Programs II and III (i.e., initially). After the muscles were fully at rest, it tried to eliminate blood lactate in the system as fast as possible. As a result, blood lactate clearance at minutes 9, 12, and 15 of Program I was higher than that of Programs II and III.

**Complex Training Program Selection for Varsity Soccer Players**

This study focused on developing a complex training program that efficiently stimulated energy demand in a competitive soccer match. As discussed earlier, the average blood lactate concentrations of the three complex training programs were between the blood lactate concentrations reported in the literature. As a result, all three of the carefully constructed complex training programs can be used to substitute for the traditional HIIT for varsity soccer players. Among these three complex training programs, Program I is recommended as a training program for varsity soccer players.

Program I offers several obvious advantages for varsity soccer players. First, the result of blood lactate concentration found from Program I was closer to the blood lactate concentration found from competitive soccer matches than the other two programs (9.90 mmol·L\(^{-1}\) in Program I to 10 mmol·L\(^{-1}\) from Agnevik (1) and 9.75 mmol·L\(^{-1}\) reported by Ekblom (7). Second, Program I results in the heaviest workload and, therefore, has the highest level of blood lactate concentration when compared to the other two programs. As a result of engaging in Program I, varsity soccer players will become acquainted with high blood lactate
concentration in their body systems, which should help produce a faster adaptation to the competitive matches than the other programs.

Maintaining performance when high blood lactate concentration occurs in the body system is very crucial for success, especially in sports with repetitive high-intensity activities (8, 10). Players are less likely to keep up their level of performance if they are never trained to endure high blood lactate (11). Finally, Program I trains the players for quicker blood lactate clearance that leads to a faster recovery time. After 15 min of training, blood lactate concentrations of Programs I, II, and III were comparable to one another even though blood lactate concentration of Program I was significantly higher than the other two programs. Program I challenges players to endure with high blood lactate accumulation and to quickly rid blood lactate from the body.

CONCLUSIONS

This study proposes a comprehensive complex training program for varsity soccer players that meet the physiological demands in a competitive soccer match. The proposed complex training program includes activities focusing on improving explosive power in lower extremity muscles that consists of clean pull lifts, vertical jumps, and a 20-m shuttle run with 180° turn. Program I is highly recommended for coaches to train their varsity soccer players. Program I ensures that the players get an adequate workout common to a competitive soccer match that requires a high blood lactate level. As a result, the players will get used to high blood lactate concentration and be able to maintain their performance throughout the game. Additionally, the subjects had quicker blood lactate clearance under Program I than under the other programs. This finding implies that the players under Program I will have a better recovery time. Therefore, Program I is suggested for coaches as an additional training program or as an alternative to traditional HIIT to incorporate all facets of soccer games.

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