Introduction

Aerobic fitness is important for soccer players. A high maximal aerobic power (V\text{\textsubscript{O2max}}) has been correlated with work-rate during a game and a high aerobic capacity is reported to aid recovery during high-intensity intermittent exercise, typical of soccer performance and training [35]. Furthermore, an increase in the capacity of the oxygen transport system leads to a higher aerobic contribution to the energy expended, taxing the anaerobic energy system less and, consequently, reducing fatigue through sparing glycogen and preventing the decrease of muscle pH [5,6,8,10,41]. The relevance of aerobic fitness for soccer players has been also confirmed by some studies showing a relationship between aerobic power and competitive ranking, team level, and distance covered during the match [1,13,27,39,45]. For these reasons, soccer training programmes commonly include aerobic conditioning.

Abstract

The aim of this study was to compare the effects of specific (small-sided games) vs. generic (running) aerobic interval training on physical fitness and objective measures of match performance in soccer. Forty junior players were randomly assigned to either generic (n = 20) or specific (n = 20) interval training consisting of 4 bouts of 4 min at 90–95% of maximum heart rate with 3 min active rest periods, completed twice a week. The following outcomes were measured at baseline (Pre), after 4 weeks of pre-season training (Mid), and after a further 8 weeks of training during the regular season (Post): maximum oxygen uptake, lactate threshold (Tlac), running economy at Tlac, a soccer-specific endurance test (Ekblom’s circuit), and indices of physical performance during soccer matches (total distance and time spent standing, walking, and at low- and high-intensity running speed). Training load, as quantified by heart rate and rating of perceived exertion, was recorded during all training sessions and was similar between groups. There were significant improvements in aerobic fitness and match performance in both groups of soccer players, especially in response to the first 4 weeks of pre-season training. However, no significant differences between specific and generic aerobic interval training were found in any of the measured variables including soccer specific tests. The results of this study showed that both small-sided games and running are equally effective modes of aerobic interval training in junior soccer players.

Key words
Small-sided games · aerobic fitness · match analysis · football · interval training

Physiological and Performance Effects of Generic versus Specific Aerobic Training in Soccer Players

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Bibliography
The importance of aerobic training in soccer has been recently confirmed by Helgerud and co-workers [22] who trained a group of junior soccer players twice a week for 8 weeks at the beginning of the competitive season, using a 4 x 4 min running interval training conducted at 90–95% of maximal heart rate (HR\(_{\text{max}}\)). Resting periods between bouts were 3 min of active recovery. After this training intervention VO\(_{2}\text{max}\), lactate threshold, and running economy at lactate threshold improved by 11, 16, and 7%, respectively. Similarly, the distance covered during a match increased by 20% and the average exercise intensity during matches increased by 5%. Furthermore, the number of sprints doubled and involvements with the ball during a match increased by 23%.

Although Helgerud et al. [22] demonstrated the effectiveness of running interval training, other authors have proposed sport-specific exercises, such as small-sided games, as an alternative mode of aerobic training [4,9,11,12,18,37]. Using this training mode is possible to reach exercise intensities within the range shown by Helgerud et al. [22] to be effective for improving aerobic fitness and soccer performance (90–95% of HR\(_{\text{max}}\)) [4,23]. Furthermore, small-sided games-based training should ensure the activation of muscle groups as they are engaged during actual match-play [4,9,11,12]. Additionally, as technical and tactical skills are involved and trained in conditions similar to actual match-play, this sport-specific training should promote an effective transfer to the competitive environment [43]. For these reasons, the inclusion of small-sided games as part of soccer training is quite common in soccer clubs at all levels [37].

Despite the growing interest of coaches and sport scientists in soccer-specific aerobic training, no experimental evidence of its effectiveness has been reported. Therefore, the aim of this study was to compare the effects of small-sided drills and running interval training regimens on aerobic fitness and match performance in soccer players, with particular attention to the control of the aerobic training stimulus. We hypothesized that specific and generic aerobic training were equally effective in improving VO\(_{2}\text{max}\) and other physiological parameters of aerobic fitness, but that specific training was superior in enhancing performance in soccer-specific endurance capacity and actual match-play.

**Methods**

**Subject recruitment and eligibility**

Volunteers were recruited among two teams competing in the same championship (Campionato Berretti) but in different groups. This championship includes the junior teams of professional football clubs. No differences in physical fitness level were found between the two teams (data not shown). In order to be included in the study subjects had to 1) ensure regular participation in all the training sessions, 2) have competed regularly during the previous competitive season, and 3) possess medical clearance. Goalkeepers were excluded from the investigation. The study protocol was approved by the Institutional Review Board and by the soccer clubs involved. An informed consent signed by the subjects and by their parents was required prior to participation in the study.

**Study design and randomization**

A parallel two-groups, matched, randomized, longitudinal (pretest-midtest-posttest) design was used. It is well established that the physiological characteristics of soccer players and their physical performance during the match (total distance and high intensity running) are role-dependent [19]. Furthermore, starter players could have different training responses compared to non-starters [10,11]. Therefore, subjects within each team were matched according to their role (defender, midfielder, and forward) and starter/non-starter condition. Allocation to either the specific or generic training group within each pair was performed by tossing a coin. The training intervention lasted 18 weeks (from August to December) and consisted of two weeks of tests (pre-test), four weeks of pre-season training (from August to September), two weeks of tests (mid-test, during which the first two matches of the official season took place), further eight weeks of training followed by two weeks for testing (post-test) before the winter break.

**Training programmes**

During the pre-season summer period, all subjects trained five days a week performing 1 to 2 training sessions a day (90–120 min per session). Both teams were also involved in pre-season tournaments consisting of 30-min games. During the regular competitive season all subjects trained four times a week (from Monday to Thursday with sessions of 90–120 min in duration) with the official games usually taking place on Saturday. Twice a week part of the training sessions was devoted to aerobic interval training consisting of 4 bouts of exercise lasting 4 min with 3 min active recovery (60–70% of HR\(_{\text{max}}\)), as suggested by Helgerud et al. [22]. The mode of exercise in the generic training group (GTG) was running around the regular soccer pitch at an intensity corresponding to 90–95% of HR\(_{\text{max}}\). In the specific training group (STG) training mode was different small-sided games selected based on previous experience and pilot studies in which mean exercise intensity responses of traditional drills suggested by previous authors [4,9] were controlled using HR monitors [34]. Field dimensions, coach indications, and rules were manipulated in order to determine exercise intensities similar to interval-running criteria. During the small-sided games the ball was always available by prompt replacement when out. The small-sided games selected were:

- 3 vs. 3, with goalkeeper, 2–3 ball-touches, 25 x 35 m field dimension;
- 4 vs. 4, with goalkeeper, 2 ball-touches, 40 x 50 m field dimension;
- 4 vs. 4 and 5 vs. 5 according to Bangsbo (p. 166 and 176 of reference [9]);
- 4 vs. 4 and 5 vs. 5 according to Bangsbo (p. 52 of reference [12]);
- 4 vs. 4 and 5 vs. 5 according to Balsom (p. 45 of reference [4]).

To limit confounding variables no strength, power, or plyometric exercises were included in the training sessions during the study.

**Aerobic training stimulus control**

Aerobic training HR was recorded using short-range telemetry systems (Vantage NV, XTrainer, S610 and S710 models, Polar, Kempele, Finland). Heart rate was recorded every 5 s. Recent studies demonstrated that the HR method provides reasonably
Tests were always performed in the same order: laboratory test, outcome measures (CR10-scale [16]), and has been recently applied and validated in quantification of global training load (training interventions plus field test, and match-play analysis). Tests were performed at the same time of the day, with operators unaware of the subjects’ allocation to the different training modes. Tests were always performed in the same order: laboratory test, field test, and match-play analysis.

Outcome measures

Before each testing session, subjects were instructed not to eat for at least three hours before testing, not to drink coffee or beverages containing caffeine for at least eight hours before physical testing. Players were also asked to follow a nutritional plan developed to ensure an adequate carbohydrate intake in the week before testing (~60% of total energy intake). The assessments were performed at the same time of the day, with operators unaware of the subjects’ allocation to the different training modes. Tests were always performed in the same order: laboratory test, field test, and match-play analysis.

Aerobic fitness

Lactate threshold and \( \dot{V}O_{2\text{max}} \) were determined using a two-phase treadmill incremental protocol similar to that suggested by Helgerud et al. [22]. After a 10 min warm-up consisting of running at 9 km·h\(^{-1} \), the treadmill (RunRace, Technogym, Gambettola, Italy) speed was increased by 1 km·h\(^{-1} \) every 5 min (3% inclina- tion). According to Helgerud et al. [22], lactate threshold (Tlac) was considered as the exercise intensity eliciting a 1.5 mmol·l\(^{-1} \) increase in blood lactate concentration [La] above exercise baseline values (50–60% of \( \dot{V}O_{2\text{max}} \)). Capillary blood samples were taken at the end of each 5-min step. Once capillary [La] was elevated above 4 mmol·l\(^{-1} \), players performed a 6-min active rest at 9 km·h\(^{-1} \), after which the treadmill speed was increased by 0.5 km·h\(^{-1} \) every 30 s until exhaustion, usually reached within 5–8 min. Achievement of \( \dot{V}O_{2\text{max}} \) was considered as the attainment of the following criteria: a plateau in \( \dot{V}O_{2} \) with increasing speeds and a respiratory exchange ratio above 1.10. The highest HR measured during the test was used as maximum reference value. Running economy (RE) at Tlac was expressed as ml·kg\(^{-0.75} \)·m\(^{-1} \) according to Helgerud et al. [22]. Expired gases were analysed using a breath-by-breath automated gas-analysis system (VMAX29, Sensormedics, Yorba Linda, CA). Flow, volume, and gas concentrations were calibrated before each test using routine procedures. Capillary blood samples (25 µl) were collected from an ear lobe and immediately analyzed using an enzymatic technique (YSI® 1500 Sport, Yellow Springs Instruments, Yellow Springs, OH). Before each test the analyzer was calibrated following the instructions of the manufacturer using standard lactate solutions of 5, 15, 30 mmol·l\(^{-1} \). Heart rate was recorded every 5 s using HR monitors (VantageNV, Polar Electro, Kempele, Finland).

The reliability expressed as coefficient of variation of \( \dot{V}O_{2\text{max}}, \) Tlac, and running economy has been reported to be about 3, 1.5, and 2.5% (e.g. [24,38]).

Soccer specific endurance

To obtain a measure of soccer-specific endurance, the circuit suggested by Ekblom [3] was used. Ekblom’s test consisted of completing a soccer-specific circuit 4 times as quickly as possible. The circuit includes several activities typical of soccer performance such as changes in direction, jumping, running backwards, and lateral running. Before the commencement of the soccer-specific test, the players underwent 10 min of warm-up consisting of low intensity running. Soccer players were familiarized with the test in the week before the start of the study performing the circuit at low to moderate intensity.

Match performance and intensity

In order to examine the effects of the training interventions on selected match performance variables [22] match-analyses were performed. Match-play was monitored during 11-a-side soccer matches performed by STG against GTG within each team, as the level of opposing teams might influence the physiological demands and activity pattern of competition [19,31]. In fact, the matching procedures performed in the present study ensured that the competitive level of the two teams was similar. In order to further control for influencing match-plays variables, the investigators asked coaches not to change the tactical play over the three matches. Players were observed during three matches played pre-, mid-, and post-training interventions. A total of six matches, three for each team, were analyzed.

Match-play analysis was performed with a time-motion procedure similar to that used in several descriptive studies by others [7,13,15,26,27,31,40]. In the original procedure each video camcorder filmed only one player. In the present study 20 soccer players were video-filmed at the same time, using 6 video digital camcorders (Samsung® and Sony® models) to capture match activities. Each half-pitch match activities were video-filmed by two fixed camcorders with the two remaining camcorders used for whole-pitch coverage and actions involving the ball, respectively. The videotapes were subsequently downloaded onto a personal computer hard disk. The videos of each of the two half-pitches were replayed using commercially available video-editing software on two 32 inch monitors for computerized coding of the activity categories according to Mohr et al. [31]. For categorization purposes, the players were asked to reproduce the activity categories along a track of 20 m delimited by photocells. This enabled the individual mean velocity to be determined for each match activity. Sprints were divided into those below and above 2 s. The mean speed of the two sprint categories was determined using the speed-time relationship obtained by means of a radar system (Stalker ATS, Applied Concepts Inc, Plano, TX) during 30-m sprints in which players wore a reflector to improve radar data acquisition. The activity categories and their corresponding mean velocities were: standing (0 km·h\(^{-1} \)), walking (including backward and side-ways, 5.2 km·h\(^{-1} \)), jogging (including low-intensity, sideways and backwards running, 7.6 km·h\(^{-1} \)), low-speed running (10.2 km·h\(^{-1} \)), moderate-speed running (13.9 km·h\(^{-1} \)), high-speed running (17.1 km·h\(^{-1} \)), running sprint (26.7 km·h\(^{-1} \)), sprints below 2 s (17.8 km·h\(^{-1} \)), sprints...
The soccer players’ body mass, height, and body composition were also assessed using standard anthropometric technique. Before each laboratory session of testing, players completed the Profile of Moods State questionnaire for the detection of overreaching state symptoms and to measure the subjective response to training of the two intervention-groups. The total mood disturbance index (TMD) was determined as the difference between negative moods (Tension, Depression, Anger, Fatigue, Confusion) and Vigor scores plus 100 [33].

Other measures

Exercise intensity during match-play was assessed using HR. Exercise intensity was expressed as percent of HR_{max} and classified in four intensity zones: <80%, 80–90%, 90–95%, and >95%. The maximum HR reached during the laboratory incremental treadmill-test was used as reference.

Results

Subjects

Forty-four subjects were assessed for eligibility but only 40 were randomly assigned to treatment after screening and matching. Eleven out of these forty subjects (30%) were lost to the follow-up or excluded from the final analysis. The flow-chart of participants is represented in Fig. 1 [30]. Thus, only 29 subjects (age 17.2 ± 0.8 years, body mass 69.1 ± 4.7 kg, height 178.1 ± 5.8 cm, estimated body fat 8.0 ± 2.1 %, soccer experience 9.6 ± 1.5 years) were included in the final analysis. The baseline anthropometric and outcome measures of drop-outs were not significantly different from those who completed the study. The proportion of defenders, midfielders, attackers in GTG (5, 6, and 4, respectively) was not different from STG (5, 5, and 4, respectively). Similarly, the proportion of starters and non-starters in GTG (1: 0.66) was not different from STG (1: 0.75). Playing time was not different between groups (data not shown). Body mass and estimated percent of body fat values did not change significantly from the start to the end of the study (data not shown).

Aerobic training load

Time spent in training sessions, tournaments, and official matches during the pre-season and the further 8 training weeks corresponded to about 2491 and 3979 minutes, respectively.
During the 4 weeks of pre-season training, players underwent 9 training intervention sessions corresponding to 144 min of controlled aerobic training stimulus (6% of total training time). During the 8 weeks of the mid-to-post training period, there were 15 intervention sessions corresponding to about 240 min of controlled aerobic training stimulus (7% of total training time).

About 1 min was necessary to reach the target exercise intensity (> 90% of HRmax) as already shown by Hoff et al. [23]. The average exercise intensity expressed as % of HRmax during the interval-running sessions was not different from that reached during small-sided games sessions (90.7 ± 1.2% vs. 91.3 ± 2.2%, respectively). In Fig. 2 the mean training time spent by the two groups in various intensity zones, including the recovery phases (3 × 3 min), during the 12 weeks of training is presented. No differences between groups were found in time spent in the selected HR zones, except for the >95% of HRmax intensity zone where STG spent 29.4 s per training session more than GTG.

No significant group differences were found in the mean weekly training load, determined using the session-RPE method, during the pre- to mid-training period (3605 ± 210 vs. 3475 ± 249 AU in GTG and STG, respectively). Similarly, no significant difference between groups in the mean weekly training loadotalled during the mid- to post-training period was found (2875 ± 335 vs. 2798 ± 322 AU in GTG and STG, respectively). Pre-season mean weekly training load was significantly higher than that accumulated during the mid- to post-training period for both training groups.

Total mood disturbance calculated from the POMS before the three testing sessions showed no difference between groups. The mean values of TMD in GTG were 105 ± 10, 102 ± 8, 103 ± 7 AU for pre-, mid-, and post-testing session, respectively. The mean values of TMD in STG were 102 ± 11, 104 ± 9, 102 ± 9 AU for pre-, mid-, and post-testing session, respectively. None of the players showed individual changes in TMD larger than 26.8%, suggested as the individual minimal detectable change [2].

**Effect on aerobic fitness**

Laboratory measurements of aerobic fitness at baseline and follow-up test are shown in Table 1. There were no significant group × time interactions in any measures of aerobic fitness (V\(\dot{O}_2\)max, Tlac, RE at Tlac). There were, however, significant main effects for time for V\(\dot{O}_2\)max and velocity at Tlac and V\(\dot{O}_2\) at Tlac. Post-hoc analysis showed significant differences between pre- and mid-training values, but no significant differences between mid- and post-values, except for velocity of Tlac and V\(\dot{O}_2\) of Tlac which increased by further 5% from mid- to post-training. The main factor for time was close to significance (\(p=0.07\)) for RE at Tlac, which decreased by 1% from pre- to mid-training and by 2% from pre- to post-training. There was a non significant decrease of maximum HR (from 196 ± 8 to 193 ± 8 b·min⁻¹). Using the same respiratory data scaled by body mass⁻⁰.⁷⁵ similar results were obtained (data not shown).

**Effect on soccer specific endurance**

Performances in the Ekblom’s test are shown in Table 1. No significant group × time interactions were found while the main effect for time was significant. Post-hoc analysis of pooled data showed significant pre- to mid-training, and mid- to post-training improvements.

**Effects on match performance and intensity**

The effective playing time was 64.2, 65.1, and 63.8 min for the pre-, mid-, and post-training matches, respectively. Similarly to laboratory and field test results, no significant group × time interactions were found for the indices of soccer performance (total distance covered, standing, walking, low-intensity activity, and high-intensity activity) (Table 2). The main effect for time
Table 1 Effects after 4 weeks (Mid) and a further 8 weeks (Post) of generic vs. specific aerobic interval training on soccer players’ aerobic fitness and soccer-specific endurance (Ekblom’s test)

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Mid</th>
<th>Post</th>
<th>Interaction#</th>
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<tbody>
<tr>
<td>Maximal values</td>
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<tr>
<td>GTG (n = 15)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>– VO_{2max} (l·min^{-1})</td>
<td>3.883 ± 0.306</td>
<td>4.143 ± 0.378</td>
<td>4.163 ± 0.387</td>
<td>p = 0.80</td>
</tr>
<tr>
<td>– VO_{2max} (ml·kg^{-1}·min^{-1})</td>
<td>55.6 ± 3.4</td>
<td>59.7 ± 4.1</td>
<td>60.2 ± 3.9</td>
<td>p = 0.81</td>
</tr>
<tr>
<td>– HR_{max} (b·min^{-1})</td>
<td>197.7 ± 9.5</td>
<td>196.2 ± 10.0</td>
<td>194.1 ± 7.2</td>
<td>p = 0.99</td>
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<tr>
<td>STG (n = 14)</td>
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<tr>
<td>– VO_{2max} (l·min^{-1})</td>
<td>3.960 ± 0.383</td>
<td>4.200 ± 0.417</td>
<td>4.203 ± 0.437</td>
<td></td>
</tr>
<tr>
<td>– VO_{2max} (ml·kg^{-1}·min^{-1})</td>
<td>57.7 ± 4.2</td>
<td>61.4 ± 4.6</td>
<td>61.8 ± 4.5</td>
<td></td>
</tr>
<tr>
<td>– HR_{max} (b·min^{-1})</td>
<td>194.5 ± 7.1</td>
<td>192.9 ± 8.2</td>
<td>192.7 ± 8.9</td>
<td></td>
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<tr>
<td>Lactate threshold</td>
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<tr>
<td>GTG (n = 15)</td>
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</tr>
<tr>
<td>– VO_{2} at Tlac (l·min^{-1})</td>
<td>3.150 ± 0.348</td>
<td>3.386 ± 0.338</td>
<td>3.515 ± 0.270</td>
<td>p = 0.98</td>
</tr>
<tr>
<td>– VO_{2} at Tlac (ml·kg^{-1}·min^{-1})</td>
<td>45.1 ± 3.8</td>
<td>48.7 ± 3.3</td>
<td>50.9 ± 2.9</td>
<td>p = 0.94</td>
</tr>
<tr>
<td>– % VO_{2max}</td>
<td>81.0 ± 4.3</td>
<td>81.7 ± 3.1</td>
<td>84.6 ± 3.4</td>
<td>p = 0.94</td>
</tr>
<tr>
<td>– Vel at Tlac (km·h^{-1})</td>
<td>11.2 ± 0.6</td>
<td>11.6 ± 0.5</td>
<td>12.2 ± 0.4</td>
<td>p = 0.42</td>
</tr>
<tr>
<td>– RE at Tlac (ml·kg^{-0.75}·m^{-1})</td>
<td>0.72 ± 0.03</td>
<td>0.71 ± 0.04</td>
<td>0.70 ± 0.04</td>
<td>p = 0.53</td>
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<tr>
<td>STG (n = 14)</td>
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</tr>
<tr>
<td>– VO_{2} at Tlac (l·min^{-1})</td>
<td>3.242 ± 0.407</td>
<td>3.465 ± 0.247</td>
<td>3.592 ± 0.281</td>
<td></td>
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<tr>
<td>– VO_{2} at Tlac (ml·kg^{-1}·min^{-1})</td>
<td>47.3 ± 4.9</td>
<td>50.7 ± 3.2</td>
<td>52.4 ± 2.8</td>
<td></td>
</tr>
<tr>
<td>– % VO_{2max}</td>
<td>81.5 ± 4.3</td>
<td>82.2 ± 3.6</td>
<td>84.7 ± 5.1</td>
<td></td>
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<tr>
<td>– Vel at Tlac (km·h^{-1})</td>
<td>11.3 ± 0.7</td>
<td>11.9 ± 0.7</td>
<td>12.4 ± 0.5†</td>
<td></td>
</tr>
<tr>
<td>– RE at Tlac (ml·kg^{-0.75}·m^{-1})</td>
<td>0.73 ± 0.03</td>
<td>0.72 ± 0.02</td>
<td>0.71 ± 0.03</td>
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<tr>
<td>Ekblom’s test</td>
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<tr>
<td>GTG (n = 15)</td>
<td></td>
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<tr>
<td>– time (s)</td>
<td>704 ± 42</td>
<td>618 ± 49</td>
<td>603 ± 17</td>
<td>p = 0.57</td>
</tr>
<tr>
<td>STG (n = 14)</td>
<td></td>
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<tr>
<td>– time (s)</td>
<td>723 ± 47</td>
<td>629 ± 36</td>
<td>609 ± 33</td>
<td></td>
</tr>
</tbody>
</table>

GTG, generic training group; STG, soccer-specific training group; RE, running economy; Tlac, lactate threshold; VO_{2max}, maximum oxygen uptake; #, group × time interaction of a 2×(3) ANOVA

Table 2 Effects after 4 weeks (Mid) and a further 8 weeks (Post) of generic vs. specific aerobic interval training on physical soccer performance

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Mid</th>
<th>Post</th>
<th>Interaction#</th>
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<tbody>
<tr>
<td>GTG (n = 15)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Standing (s)</td>
<td>583 ± 177</td>
<td>528 ± 99</td>
<td>534 ± 10</td>
<td>p = 0.23</td>
</tr>
<tr>
<td>Walking (s)</td>
<td>3071 ± 263</td>
<td>2771 ± 262</td>
<td>2784 ± 229</td>
<td>p = 0.75</td>
</tr>
<tr>
<td>Low-intensity activity (s)</td>
<td>1395 ± 183</td>
<td>1668 ± 171</td>
<td>1649 ± 166</td>
<td>p = 0.11</td>
</tr>
<tr>
<td>High-intensity activity (s)</td>
<td>351 ± 67</td>
<td>432 ± 79</td>
<td>431 ± 75</td>
<td>p = 0.70</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>9330 ± 425</td>
<td>9958 ± 330</td>
<td>9924 ± 331</td>
<td>p = 0.29</td>
</tr>
<tr>
<td>STG (n = 14)</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Standing (s)</td>
<td>563 ± 129</td>
<td>517 ± 65</td>
<td>611 ± 150</td>
<td></td>
</tr>
<tr>
<td>Walking (s)</td>
<td>2981 ± 253</td>
<td>2755 ± 294</td>
<td>2736 ± 217</td>
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<td>Low-intensity activity (s)</td>
<td>1477 ± 215</td>
<td>1675 ± 251</td>
<td>1581 ± 170</td>
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<tr>
<td>High-intensity activity (s)</td>
<td>377 ± 60</td>
<td>452 ± 82</td>
<td>473 ± 89</td>
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<tr>
<td>Total distance (m)</td>
<td>9527 ± 444</td>
<td>10036 ± 510</td>
<td>9926 ± 404</td>
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</tbody>
</table>

Walking includes backward walking and sideways walking; Low-intensity activity includes jogging, low-intensity running, backwards running; High-intensity activity includes moderate, high-intensity running and sprinting. GTG, generic training group; STG, soccer-specific training group; #, group × time interaction of a 2×(3) ANOVA
was significant for total distance, walking, low-intensity activity, and high-intensity activity but not for standing. Total distance covered during the matches by the two groups (pooled data) increased from 9.425 ± 0.438 km (pre) to 9.996 ± 0.420 km (mid) and 9.890 ± 0.400 km (post).

In Table 3 the exercise intensity of the three matches classified in five HR zones relative to the two training groups are presented. No significant group × time interactions were found, while the main factor for time was significant for all the exercise intensity categories except for time spent at 80–90% of HRmax. Post-hoc analysis revealed significant pre- to mid-training and pre- to post-training differences, only. Also no significant group × time interactions were found for average match exercise intensity expressed as % of HRmax (p=0.97), while the main effect for time was significant. Average match-intensities for the pre-, mid-, and post-training matches were 82.8 ± 4.2, 84.8 ± 2.7, and 85.0 ± 2.8% of HRmax, respectively (pooled data). Both groups showed a significant decrease of mean exercise intensity during the second half (data not shown).

### Relationships between outcome measures

Significant and consistent correlations were found between VO2max and both the total distance covered during the matches and the time spent in high-intensity activities (mean r = 0.55 and r = 0.45, respectively; p < 0.05). Significant correlations were also found in all the three test sessions between VO2max and the soccer-specific endurance test suggested by Ekblom (mean r = -0.54, p < 0.05). No significant correlations were found between changes in the selected soccer performance variables and changes in VO2max, Tlac, RE at Tlac, and Ekblom’s tests.

Pre-training VO2max scores were not significantly correlated to mid and post absolute VO2max changes both in GTG (r = -0.23 [p = 0.23] and r = -0.07 [p = 0.72], respectively) and STG (r = -0.04 [p = 0.84] and r = -0.31 [p = 0.10], respectively).

### Discussion

#### Aerobic fitness

In agreement with our hypothesis, soccer-specific aerobic training performed using small-sided games was as effective as interval running in enhancing aerobic fitness in junior soccer players. In particular, these two aerobic training modes produced improvements in both aerobic power and capacity after the pre-season training period. Additional aerobic training during the competitive season only resulted in a moderate but significant increase in running velocity at Tlac (∼5%). These results partially confirmed those reported in a previous training study [22]. However, the 7%, 10%, and 2% improvements in VO2max, Tlac, and RE at Tlac found after 14 weeks of aerobic training in the present study were lower than the corresponding 10%, 16%, and 7% increase found by Helgerud et al. [22] after 8 weeks of interval training completed at the beginning of the regular season. Furthermore, different from the study of Helgerud et al. [22], the positive effects of aerobic training found in our study mainly occurred as a consequence of the pre-season training period, that is with players resuming training after at least 6 weeks of post-competitive season detraining. During the 8 weeks of training at the beginning of the competitive season, i.e the same period of the study of Helgerud et al. [22], we did not find any increase in VO2max and only a small improvement in Tlac intensity. The reason for the discrepancies between the results of the present study and the investigation by Helgerud et al. [22] is not apparent as the starting fitness level of the players and the quantity, duration, and intensity of interval training were similar. The only possible explanation could be that the players’ fitness level and the training program employed by Helgerud et al. [22] before the start of the regular season were different compared to the present study. However, the data relative to the pre-season period were not reported by Helgerud et al. [22].

In contrast with our results, Bangsbo [10] reported no change in VO2max after a pre-season training period in seven professional soccer players, while the speed corresponding to a blood lactate concentration of 3 mmol·l⁻¹ was found to be increased significantly. The lack of improvement in aerobic power found by
Bangsbo [10] could be due to the shorter summer break typical of professional soccer teams (2 – 3 weeks) compared to the longer detraining period of the junior players used in the present study. In fact, Bangsbo and Mizuno [14] showed that this relatively short-term training intermission was not sufficient to cause a significant decrease in VO2max, while muscle oxidative enzymes decreased rapidly and a longer time was required to restore them to the pre-detraining levels. Specifically, Bangsbo and Mizuno [14] showed in a group of semi-professional soccer players, that 4 weeks of high-intensity training were not sufficient to restore the levels of citrate synthase and β-hydroxy acyl CoA dehydrogenase found before a detraining period of 3 weeks [14]. This could explain why we found the highest increase of Tlac after 12 weeks of high-intensity aerobic training, while VO2max improvements were evident after 4 weeks of the pre-season training period. There is a general consensus that VO2max is limited mostly by the ability of the cardiovascular system to transport O2 to active muscles, and lactate threshold by the peripheral ability to utilize O2 and, in particular, by mitochondrial enzyme activity. In our study, the long summer break was probably sufficient to cause a decrease in both VO2max and Tlac [32]. However, while central factors (i.e. VO2max) were restored rapidly in a relatively shorter time (4 weeks), peripheral factors (i.e. muscle oxidative enzymes) probably required a longer time to improve (a further 8 weeks).

Similarly to the present study, Bangsbo [10] reported an increase in VO2max in eleven professional soccer players after seven weeks of training before a Champions Cup match (the current Champions League), but he did not find further improvement in VO2max during the season after this match, while a significant decrease of blood lactate at various sub-maximal running speeds was found both after the seven weeks of pre-match training and during the season. Casajus et al. [17] found improvement in ventilatory threshold without any change in VO2max during the competitive season in a Spanish professional soccer team. These studies and the results of our investigation seem to suggest that sub-maximal indices of aerobic fitness such as Tlac could be more sensitive to training than VO2max, in the physiological assessment of aerobic training outcomes in soccer, particularly when the “aerobic base” has been established. Furthermore, there was no evidence of the ceiling effect in very fit players suggested by some authors [23,44], as no significant correlations were found between pre-training VO2max and VO2max training-induced changes within both STG and GTG.

Soccer-specific endurance
Contrary to our hypothesis, our results did not show a superiority of soccer-specific aerobic training over interval running, in the performance variables and the soccer-specific tests selected for the investigation. Of the several soccer-specific aerobic endurance tests proposed in the literature we used the one proposed by Ekblom [3] because it integrates several activities typical of soccer performance such as changes in direction, jumps, sideways and backwards running. Similarly to the laboratory measures of aerobic fitness, no group × time interaction was found. The observed pre- to mid-training 13% improvement in this soccer-specific test was similar to the 15% reported by Ekblom [3] after a pre-season training period in a Swedish semi-professional soccer team. After the following 8 weeks of training, we did not find further improvements in the time to complete the Ekblom circuits. Although less popular than other field assessments, the results of our study suggested that this soccer-specific aerobic endurance test can be useful in practical settings. In fact, moderate but significant and consistent correlations were found between this field test and VO2max. The mean HR found during this test was about 95% of HRmax indicating that the aerobic mechanisms are heavily taxed during this integrated measure of soccer performance. Besides, midfielders tended to perform the test better than attackers and defenders (p = 0.09).

Match performance
After the pre-season period significant changes were found in the objective measures of match performance selected in this study for both training groups. In particular, the time spent during low- and high-intensity activities increased by 14 and 18%, while walking time decreased by 10%. Similarly, the total distance covered during match-play increased by 6%. However, no further changes were found after training during the competitive period. The 571-m increase of total distance found in the present study was lower than the 1716-m increase reported by Helgerud et al. [22] after 8 weeks of interval training. The mean total distance covered by players during the three matches (9425 – 9996 m) was within the 8000 – 12000 m commonly reported for soccer players [36]. However, the total distance covered during a match is considered a weak indicator of soccer performance as it does not reflect how much players tax their maximal aerobic power [42]. On the other hand, the high-intensity activity was suggested to be a better measure of physical performance during a soccer game [15,27,31]. Furthermore, Mohr et al. [31] have reported that top-level professional soccer players covered only 5% more distance in total but 28% more distance at high intensity than lower-level professional players. Consequently, the most important training effect on the selected objective measures of match performance found in the present study was the 18% increase in high-intensity activity. A similar increment during actual match-play was reported by Krustup and Bangsbo [26] in soccer referees after aerobic intermittent training. In particular, they found unaltered total distance covered but 23% greater distance covered at high intensity. In the same study VO2max did not change, while blood lactate response to running at 14 km·h−1 during an incremental treadmill test (90% of VO2max) significantly decreased.

Similarly to the results of Helgerud et al. [22], the mean exercise intensity of the matches expressed as percent of HRmax increased significantly from 83% in the pre-training match to 85% in the post-training match as a consequence of more time spent above 90% of HRmax and less time below 80% of HRmax. These changes seemed to reflect the higher external work performed at high speed during the matches after training. While we found significant correlation between VO2max and both the total distance covered and the time spent in high-intense activity during the three matches, we did not find relationships between changes in laboratory parameters of aerobic fitness and changes in physical variables of soccer performance. It is possible that the improvements in performance could be related to other physiological adaptations induced by aerobic training not measured in the present study. For example, Laursen and Jenkins...
[28] reported that high-intensity aerobic training could increase the muscles’ buffering capacity and it might also enhance Na+-K+-ATPase pump density.

Again, the different aerobic training mode did not result in different changes in match performance. This could be partially explained by the relative small difference in time spent at different training modes between the STG and GTG which was 6% of total training time. However, further differentiation of training by including more specific and generic aerobic interval training would decrease the external validity of the present study. In fact, more than two training sessions of aerobic training would be difficult to propose to soccer players and to incorporate in a regular training programme during the competitive season.

Training exercise intensity
The average exercise intensities during the interval running and small-sided games sessions were not significantly different from each other (90.7% and 91.3% of HRmax, respectively) and were within the target intensity (90–95% of HRmax) thought to be effective in enhancing aerobic fitness and soccer performance [22]. A more detailed analysis of training HR distributions showed that, during the 12 weeks of training, STG players spent 29.4 s more per session than GTG subjects in the 95–100% of HRmax intensity zones (p = 0.034). Consequently, the physiological strain produced by specific and generic high-intensity aerobic training was slightly different but not enough to cause different training outcomes, at least for the physiological and performance variables selected in this investigation.

Apart from the training time spent on physical conditioning, the remaining soccer training time commonly consisted of several technical and tactical exercises that could lead to further training stimuli. Even if these exercises are usually performed at low intensity, we controlled the global training load using the session-RPE [21] and no significant difference between groups was found. Furthermore, the global training load imposed upon these junior soccer players did not induce symptoms of overreaching as shown by unaltered TMD.

Conclusion
This study clearly demonstrates that small-sided games can be used as an effective training mode to enhance aerobic fitness and match performance in soccer players. Because no differences were found between specific and generic aerobic interval training, the choice of the aerobic training mode should be based mainly on practical necessity. For example, small-sided games can be useful for training aerobic fitness and tactical-technical components concurrently [4,9]. This can be an advantage especially for young soccer players, as the improvement of sport-specific motor skills is related to the frequency of practice sessions [43]. Moreover, the use of small-sided games increases players’ motivation and makes high-intensity aerobic training more acceptable. Further studies should investigate the effects of other training variables (intensity, frequency, and duration) and different combinations of aerobic with technical/tactical training on soccer performance.

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