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ORIGINAL ARTICLE

Differences in physical fitness among indoor and outdoor elite male soccer players

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Abstract This study compared anthropometric (body height, body mass, percent body fat, fat-free body mass) and physical fitness characteristics (vertical jump height, power-load curve of the leg, 5 and 15 m sprint running time and blood lactate concentrations ($[La]_b$) at submaximal running velocities) among 15 elite male indoor soccer (IS) and 25 elite male outdoor soccer (OS) players. IS players had similar values in body height, body mass, fat-free body mass and endurance running than OS players. However, the IS group showed higher ($P < 0.05$–0.01) values in percent body fat (28%) and sprint running time (2%) but lower values in vertical jump (15%) and half-squat power (20%) than the OS group. Significant negative correlations ($P < 0.05$–0.01) were observed between maximal sprint running time, power production during half-squat actions, as well as $[La]_b$ at submaximal running velocities. Percent body fat correlated positively with maximal sprint time and $[La]_b$, but correlated negatively with vertical jump height. The present results show that compared to elite OS players, elite IS players present clearly lower physical fitness (lower maximal leg extension power production) characteristics associated with higher values of percent body fat. This should give IS players a disadvantage during soccer game actions.

Keywords Muscle strength · Muscle power · Endurance · Anthropometry · Soccer

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Introduction

Five-a-side indoor soccer (IS) (official name: Futsal), the indoor version of outdoor soccer (OS), is an intermittent high-intensity strenuous team sport played worldwide (12 million players in more than 100 countries) that places heavy emphasis on running speed and endurance and requires substantial strength levels to kick, tackle, turn, change pace and sprint during game actions. IS is played on a 38–42 m × 18–25 m pitch during two 20-min clock time halves, with the clock stopped for some events that can result in a total duration game of 70–80 min (Barbero-Alvarez et al. 2008). Teams can request one time-out (1 min) in each half and there is a break of 10 min between halves (Barbero-Alvarez et al. 2008). An IS team comprises five players and an unlimited number of substitutions are permitted (Barbero-Alvarez et al. 2008).

As in the case of IS, OS is also an intermittent high-intensity strenuous team sport that places heavy emphasis on strength, running speed and endurance. However, some significant differences exist between IS and OS soccer because OS is played on a bigger surface (100–110 m × 64–75 m) for a longer time (two 45-min periods) and with the clock stopped for very few events, which can result in a game whose total duration can be between 90 and 100 min. Teams cannot request a time-out during the game and there is a break of 15 min between halves. In addition, an OS team comprises 11 players and only three substitutions are allowed throughout the game.

As a consequence of the different characteristics of IS and OS, it has been argued that different physical fitness and anthropometric characteristics should exist between IS and OS players. Only a few studies have analyzed some anthropometric (Barbero-Alvarez et al. 2008; Castagna et al. 2008) and aerobic power (Castagna et al. 2008) characteristics of

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elite IS players. Despite its popularity, it is somewhat surprising to find no information concerning the strength, muscle power and aerobic capacity characteristics of current world class elite IS players. The majority of the great number of studies that have analyzed anthropometric and physical fitness characteristics of OS players have found that elite OS players must posses superior strength, power and endurance characteristics (Arnason et al. 2004; Casajus 2001; Davis et al. 1992; Stolen et al. 2005; White et al. 1988; Wisloff et al. 1998, 2004). In addition, the main physical differences in elite compared with lower level OS players seem to be a faster sprint velocity (Davis et al. 1992) and higher leg extensor power (Arnason et al. 2004).

To our knowledge no studies have analyzed if some differences exist in physical fitness and anthropometric characteristics among IS and OS players. Knowledge of the anthropometric and physiological characteristics of elite IS players is of great importance because: (1) little is known at present about these characteristics in this population, and (2) this knowledge should allow indoor coaches to verify and modify strength/power and endurance training programs to adapt their players to the physiological requirements of their sports.

Therefore, the aim of this study was to investigate the anthropometric, strength, muscle power and aerobic capacity characteristics of current world class elite IS players and to compare them with those of elite OS players. Second, it was interesting to examine the relationships between leg extension power production, endurance capacity and percent body fat in both groups of soccer players.

Considering that IS and OS soccer places heavy emphasis on strength and power-related actions, data were collected to test the following hypothesis. First, taking into account the physiological characteristics of players competing in relatively similar playing areas and competition times in sports such as basketball and handball (Gorostiaga et al. 2005; McInnes et al. 1995; Pers et al. 2002), we hypothesized that elite IS players should present lower endurance capacity and higher strength and muscle power values compared to elite OS players. Second, as has been observed in elite OS players (Arnason et al. 2004; Ekblom 1986; Hoff and Helgerud 2004; Stolen et al. 2005; Wisloff et al. 1998, 2004) and other team sports players (Hoff and Almasbakk 1995), associations between lower extremity muscle power and sprint running performance should be observed in elite IS players. Third, considering that anthropometric profile is an important selective factor for success in sport (Rienzi et al. 2000), it was hypothesized that low levels of body fat should be associated with higher physical fitness values in both groups of soccer players.

Methods

Subjects

One elite OS team ($n = 25$, age 25.2 ± 3 years) and one elite IS team ($n = 15$, age 26.2 ± 4 years), both teams including the goalkeepers, participated in the study. The OS can be considered an elite team because: (1) it finished fourth in the First Division Spanish Outdoor Soccer League in the previous season, (2) six of their players were or have been internationals, and (3) it was runner-up in the Spanish Outdoor Soccer Cup in the previous season. The IS can also be considered an elite IS team because: (1) it played in the First Division Spanish Indoor Soccer League, (2) it was a semi-finalist in the Spanish Indoor Soccer Cup in the previous season, (3) four of their players were or have been internationals and (4) the Spanish Indoor Soccer League is considered one of the best leagues in the world because in previous years the National Spanish Indoor Soccer Team has reached the final of the European and World Indoor Soccer Championships. This study was carried out in September, 1 week after the end of the 7- to 5-week pre-competitive mesocycle. During the 7-week pre-competitive mesocycle, OS players had an average of 47 training sessions (6.7 training sessions per week) for a total average duration of 3,165 min. During the 5-week pre-competitive mesocycle IS players had an average of 38 training sessions (7.6 training sessions per week) for a total average duration of 3,180 min. The physical characteristics of the subjects are presented in Table 1.

Before starting the study, players had a physical examination by the team physician and each was cleared of any medical disorders that might limit their full participation. The subjects and coaches were informed in detail about the experimental procedures and the possible risks and benefits of the project, which was approved by the Institutional

Table 1 Physical characteristics of outdoor and indoor soccer teams

	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)	Fat-free body mass (kg)
Outdoor soccer team ($n = 25$)	25.2 (3.2)	180.6 (5.7)	76.6 (5.8)	6.9 (1.5)*	71.3 (5.2)
Indoor soccer team ($n = 15$)	26.2 (4.1)	176.7 (7.6)	76.9 (10.0)	9.7 (2.5)	69 (7.8)

Significant difference (*$P < 0.05$) compared to indoor soccer team

Review Committee of the Instituto Navarro de Deporte y Juventud, and carried out according to the Declaration of Helsinki. The subjects were not taking exogenous anabolic-androgenic steroids or other drugs or substances expected to affect physical performance. No tests for any banned substance were positive in any of the subjects during several in or out of competition doping control tests. The subjects were not taking any medications that would have an impact on the results of the study.

Experimental design

A comparative study was conducted to determine if anthropometric and physical fitness parameters are different between male IS and OS players. Two distinct groups of soccer players were identified: outdoor and indoor male soccer players. These groups were tested and compared with an analysis of variance (ANOVA) to determine if anthropometric and physical fitness parameters distinguished any of the groups. All the subjects were familiarized with the testing protocol, as they have been previously tested on several occasions in previous years with the same testing procedures. The test–retest intraclass correlation coefficients of the testing procedure variables used in this study were >0.91 and the coefficients of variation ranged from 0.9 to 7.3%.

Testing schedule

All the players in a given team were assessed on the same day, and the tests were performed in the same order and in the same facilities. Testing was conducted over three separate sessions, separated by at least 2 days. During the first testing session, each subject was subjected to anthropometrical measurements. In the second test session, each subject was subjected to muscle power measurements. In the third testing session, vertical jump, and sprint and endurance running tests were measured. The goalkeepers did not perform the endurance running test. Due to injuries, some players did not perform the muscle power ($n = 7$ in OS), the sprint ($n = 3$ in OS; $n = 1$ in IS) or the endurance running ($n = 3$ in OS) tests. Testing was integrated into weekly training schedules.

Physical characteristics

The anthropometric variables of body height (m), body mass (kg), skinfold thickness (%) and fat-free body mass (kg) were measured in each subject. Height and weight measurements were made on a levelled platform scale (Año Sayol, Barcelona, Spain) with an accuracy of 0.01 kg and 0.001 m, respectively. Percentage of body fat was calculated from measurements of skinfold thickness (Jackson and Pollock 1978). Site selection and location were standardized for the measurements because small differences in location can produce significant differences (Rienzi et al. 2000). Fat-free body mass (kg) was calculated as the difference between body mass and body fat.

Jumping test

On an indoor court, the subjects undertook the jumping test after a non-standardized 15-min warm-up period. Jumping consisted of four maximal jumps on a contact platform (Newtest OY, Oulu, Finland). The subjects were asked to perform a maximal jump (CMJ) from standing position with a preparatory movement from the extended leg position down to a 90° knee flexion followed by a subsequent concentric action. A detailed description of the jumping test procedure can be found elsewhere (Bosco et al. 1983). The jumping height was calculated from the flight time (Bosco et al. 1983). The maximal jumps were recorded interspersed with approximately 10 s rest between jumps. The best reading was used for further analysis.

Sprint and endurance running test

Ten minutes after completion of the jumping test and after a non-standardized warm-up period that included low-intensity running, several acceleration runs and stretching exercises, the subjects undertook a sprint running test consisting of three maximal sprints of 15 m, with a 90-s rest period between each sprint, on an indoor court. 15 m was chosen because this is the average distance run by elite soccer players at high intensity during competition match play (Edwards et al. 2003). During the 90-s recovery period, the subjects walked back to the starting line. The recording of running time was done using photocell gates (Newtest OY, Oulu, Finland) placed 0.4 m above the ground with an accuracy of 0.001 s. The subjects commenced the sprint when ready from standing start, 0.5 m behind the start. Stance for the start was consistent for each subject. The time was automatically activated as the subject passed the first gate at the 0 m mark and split times were recorded at 5 and 15 m. The run with the lowest time was selected for further analysis.

The endurance running test was performed 5 min after the end of the sprint running test. Each subject performed a four-stage submaximal discontinuous progressive running test around an artificial outdoor grass soccer court (100 m × 50 m) with a 3-min rest between each run. The running velocities for the four stages were 12, 13, 14 and 15 km h^{-1}. Time for each stage was 10 min except the last stage that lasted 5 min. The present protocol was chosen because it has been suggested that a series of discontinuous 10-min exercise bouts are long enough to accurately determine and estimate the $[La]_b$ for a given submaximal work output (Weltman 1995). To assure constant velocity for each running stage, subjects were instructed to even pace their running through an audio signal connected to a pre-programmed computer (Balise Temporelle, Bauman, Switzerland). During the test, heart rate was recorded every 15 s (Sportester Polar, Kempele, Finland) and averaged for the last 60 s of each stage. Immediately after each exercise stage, capillary blood samples for the determination of lactate concentrations were obtained from hyperaemic earlobe. Samples for whole blood lactate determination (100 μl) were deproteinized, stored at 4°C, and analyzed (YSL, 1500 Sport Lactate Analyzer, OH, USA). The blood lactate analyzer was calibrated after every fifth blood sample dose with three known controls (5, 15 and 30 mmol l^{-1}). Individual data points for the exercise blood lactate values were plotted as a continuous function against time. The exercise lactate curve was fitted with a second degree polynomic function. From the equation describing the exercise blood lactate curve, the velocity associated with a $[La]_b$ of 3 mmol l^{-1} (V_3) was intrapolated. The running velocity associated with a given submaximal $[La]_b$ has been shown to be an important determinant of endurance performance capacity (Weltman 1995).

Muscle power test

The power load of the leg extensor muscles was tested in half-squat exercise using the relative loads of 75, 100 and 125% of body mass. A detailed description of the muscle power testing procedure can be found elsewhere (Izquierdo et al. 2002). In half-squat position shoulders were in contact with a bar and the starting knee angle was 90° (Izquierdo et al. 2002). On command the subjects performed a concentric leg extension (as fast as possible) starting from the flexed position to reach the full extension of 180° against the resistance determined by the weight plates added to both ends of the bar. Two testing actions were recorded and the best reading (with the best velocity) was taken for further analysis. The time period of rest between each trial and set was always 1.5 min.

During the lower extremity test actions, bar displacement, average velocity (m s^{-1}) and mean power (W) were recorded by linking a rotary encoder to the end part of the bar. The rotary encoder recorded the position and direction of the bar within accuracy of 0.0002 m. Customized software (JLML I + D, Madrid, Spain) was used to calculate the power output for each repetition of the half-squat performed throughout the whole range motion. Average power output for each repetition of half-squat was determined. Strong verbal encouragement was given to each subject to motivate them to perform each test action as maximally and as rapidly as possible. The reproducibility of the measurements has been reported elsewhere (Izquierdo et al. 2002).

Statistical procedures

Standard statistical methods were used for the calculation of the mean and standard deviations. Pearson product-movement correlation coefficients (*r*) were used to determine the association between physical characteristics, jumping explosive strength, power–load relationship of the leg extensor muscles, 5 and 15-m sprint running time and running endurance. Statistical power calculations for *t*-test correlation ranged from 0.69 to 0.95 in this study. The differences between the two groups for the aforementioned variables were determined using one-way ANOVA, with Newman–Keuls post hoc comparisons. The $P \leq 0.05$ criterion was used for establishing statistical significance.

Results

Physical characteristics

The physical characteristics of the OS and IS players are presented in Table 1. IS players showed higher ($P < 0.05$) percent average body fat (9.7 ± 2%) values than OS players (6.9 ± 1%). There were no differences in average age, height, body mass and fat-free body mass between the teams.

Jumping and sprinting tests

The results of vertical jumping (CMJ) heights and maximal running sprint time are presented in Table 2. The CMJ height in IS players (38.1 ± 4.1 cm) was 15% lower ($P < 0.01$) than in OS players (44.9 ± 4.1 cm).

During the sprint running tests IS players exhibited 2% higher ($P < 0.05$) maximal sprint running time for 5 m than OS players (1.01 ± 0.02 and 0.99 ± 0.03 s for IS and OS, respectively). Similarly, during the sprint running test IS players exhibited 4% higher ($P < 0.01$) time for 15 m than

Table 2 Average (±SD) vertical jumping height and 5 and 15 m sprint running times in the elite outdoor and indoor soccer teams

	Height in CMJ (cm)	Time 5 m (s)	Time 15 m (s)
Outdoor soccer team ($n = 25$)	44.9 (4.1)***	0.99 (0.03)*	2.32 (0.06)***
Indoor soccer team ($n = 15$)	38.1 (4.1)	1.01 (0.02)	2.41 (0.08)

Significant difference (*$P < 0.05$, ***$P < 0.001$) compared to indoor soccer team

OS players (2.41 ± 0.08 and 2.32 ± 0.06 s for IS and OS, respectively).

Endurance running

Eight subjects in the OS team and nine subjects in the IS team did not complete the endurance running test due to exhaustion. During the endurance running test, no differences in mean $[La]_b$ were observed in both groups at running velocities of 12, 13, and 15 km h^{-1} (Fig. 1). The average running velocity associated with a $[La]_b$ of 3 mmol l^{-1} (V_3) was similar between IS (12.5 ± 0.6 km h^{-1}) and OS (12.8 ± 0.7 km h^{-1}) players.

No differences in mean heart rate values were observed in both groups at running velocities of 12, 13 and 15 km h^{-1} (Fig. 1). At running velocities of 14 km h^{-1}, higher ($P < 0.05$) average heart rate was observed in IS players (180 ± 5 beats·per minute) than in OS players (171 ± 10 beats per·minute).

Muscle power output

The average concentric half-squat power load in absolute values differed between groups (Fig. 2). At all absolute loads examined (from 75 to 125% of body mass) average power output of the lower extremities was lower in IS players ($P < 0.001$) than in OS players. Average power output index at all loads examined in IS players (625 ± 112 W) was 20% lower ($P < 0.001$) than in OS players (781.69 ± 84.6 W).

When muscle power output of the concentric half-squat actions was expressed relative to body mass (W kg^{-1}), the differences between IS and OS players were maintained. Thus, average power output index at all loads examined expressed relative to body mass in IS (8.13 ± 1.23 W kg^{-1}) was 21% lower ($P < 0.001$) than in OS (10.3 ± 1.03 W kg^{-1}). Similarly, when muscle power output of the concentric half-squat actions was expressed relative to fat-free body mass, the differences between IS and OS were maintained. Thus, average power output index at all loads examined expressed relative to fat-free body mass was 20% lower ($P < 0.001$) in IS (8.86 ± 1.2 W kg^{-1}) than in OS (11.03 ± 1.16 W kg^{-1}) players.

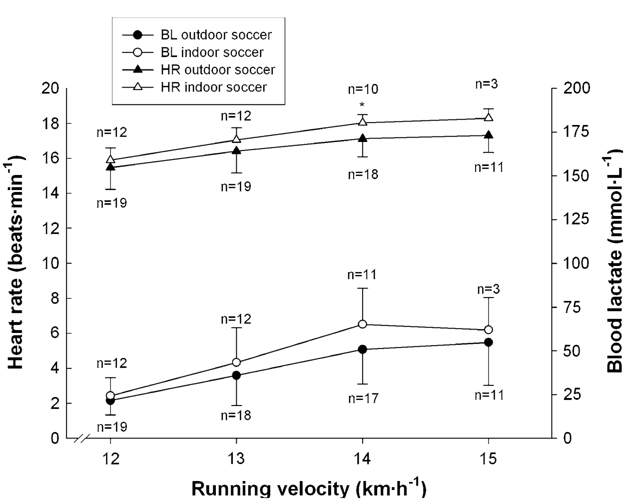

Fig. 1 Mean (±SD) heart rate (*HR*) and blood lactate (*BL*) concentrations at running velocities of 12, 13, 14 and 15 km h^{-1} (*$P < 0.05$)

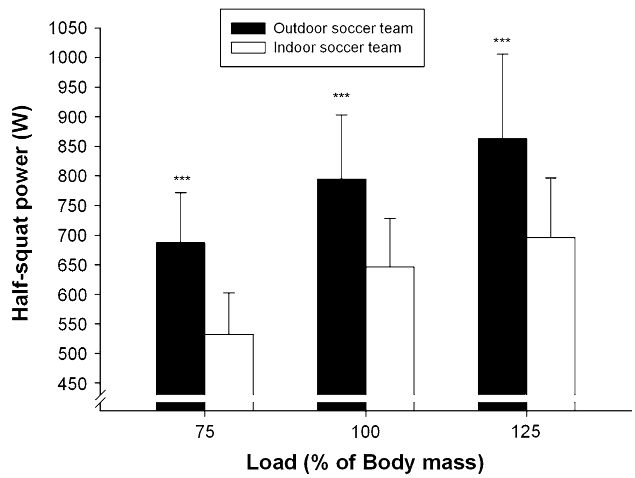

Fig. 2 Mean (±SD) muscle power output, in absolute values, of the lower extremity muscles in the concentric half-squat action at 75, 100 and 125% of individual body mass (***$P < 0.001$)

Relationships between sprint and endurance running

In each group, the individual values of 5 m maximal sprint running times correlated negatively with the individual values of $[La]_b$ at running velocities of 12 km h^{-1} ($r = -0.73$ and -0.49, $P < 0.05$, $n = 19$ and 12 for IS and OS, respectively). Similarly, when the groups (IS and OS) were taken as a whole, the individual values of 5-m maximal sprint running times correlated negatively with the individual values of $[La]_b$ at running velocities of 12 km h^{-1} ($r = -0.45$, $P < 0.05$, $n = 31$) and 13 km h^{-1} ($r = -0.40$, $P < 0.05$, $n = 30$) (Fig. 3).

Relationships between leg power production and sprint running

In the whole group of soccer players, significant negative correlations were found between the individual values of maximal sprint running time (5 and 15 m) and the individual values of concentric power production during the half-squat actions at the load of 125% of body mass expressed relative to body mass ($r = -0.36$ and -0.70, $P < 0.05$–0.001) (Fig. 4), as well as with the individual values of concentric power production at the load of 75 and 100% of body mass expressed relative to body mass ($r = -0.68$ and

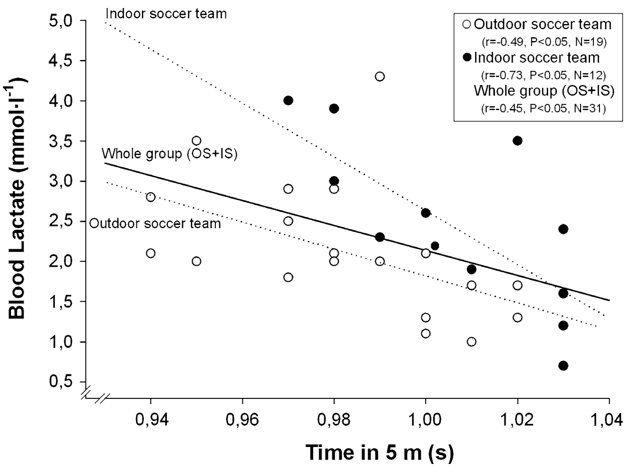

Fig. 3 The relationship between the individual values of maximal 5-m sprint running time and the individual values of blood lactate concentration at running velocities of 12 km h^{-1}, for the soccer players as a whole

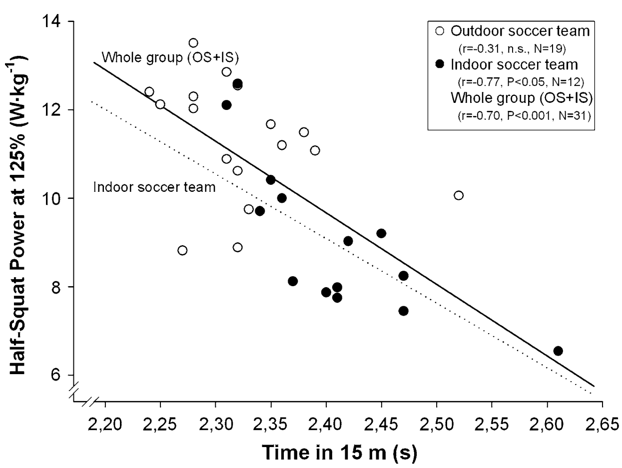

Fig. 4 The relationship between the individual values of maximal 15-m sprint running time and the individual values of concentric power production during the half-squat actions at the load of 125% of body mass expressed relative to kilogram of body mass, for the soccer players as a whole

−0.70, $P < 0.001$). These relationships were particularly relevant in IS players ($r = -0.81$, $P < 0.05$, $n = 13$), whereas in OS players the highest negative relationship between muscle power of the lower extremities and sprint running variables was observed between the individual values of maximal 15-m sprint running time and the individual values of CMJ height ($r = -0.81$, $P < 0.001$, $n = 22$).

Relationships between percent body fat, leg power production, endurance and sprint running

In the whole group the individual values of percent body fat correlated positively with the individual values of maximal sprint 15-m running time ($r = 0.60$, $P < 0.001$, $n = 35$). Furthermore, these individual values of percent body fat correlated negatively with the individual values of CMJ height ($r = -0.50$, $P < 0.01$, $n = 36$), and positively with the individual values of $[La]_b$ at running velocities of 13 km h^{-1} ($r = 0.38$, $P < 0.05$, $n = 30$). All these correlations were particularly relevant in OS players.

Discussion

To our knowledge, this is the first study that simultaneously analyzes anthropometric, muscle power output of the lower extremities, running speed and endurance characteristics of an elite male IS team compared to an OS team. In the present study, higher values of average percent body fat (28%) and lower values of vertical jumping height (15%), sprint running performance (2%) and average concentric half-squat power load (20%) were observed in IS compared with OS players, whereas there were no differences between both groups in body height, body mass and endurance running characteristics.

To our knowledge, only two studies have measured some anthropometrical and/or physical fitness (maximal oxygen uptake) characteristics of elite IS players (Barbero-Alvarez et al. 2008; Castagna et al. 2008). The average body weight and body mass values observed in these few studies are similar to those observed in the present study in IS players. On the contrary, descriptive normative anthropometrical and physical fitness data for elite OS players have been sparsely presented. It is difficult to compare the results of the large number of studies that have measured anthropometric and physical fitness characteristics in international OS players because they differ markedly in the testing procedures and technologies used. In any case, the OS players in the present study showed similar average body mass (Stolen et al. 2005), body height (Stolen et al. 2005), vertical jumping height (Arnason et al. 2004; Bosco et al. 1996; Casajus 2001), percent body fat (Rienzi et al. 2000; Strudwick et al. 2002), 5 and 15-m sprint (Zerguini et al. 2007) and endurance running (Casajus 2001) performance values compared to those reported in professional elite OS playing in the 21st century using similar methodologies to the present study (Barbero-Alvarez et al. 2008; Stolen et al. 2005). In addition, it seems that actual average percent body fat values of elite OS players (between 7 and 9%) (Rienzi et al. 2000; Strudwick et al. 2002) are lower than those (around 12–13%) reported in international elite national teams competing in the 1970s and 1980s (White et al. 1988). Taken together, the present results indicate that our players can be considered as representatives of present elite IS and OS.

One of the major findings in the present study was that absolute maximal power of the lower extremity muscles during half-squat and vertical jump actions were 20 and

15% lower, respectively, in IS than in OS players. When muscle power output during half-squat at submaximal loads was expressed relative to body mass or relative to fat-free body mass, the differences observed between both groups in the ability to rapidly move different relative loads were maintained. This suggests that: (1) neural activation patterns and/or twitch tension per muscle mass under submaximal concentric knee extension actions are lower in IS than in OS players, and (2) the differences observed between groups in absolute maximal muscle power could not account for differences in fat-free body mass. The lower absolute and relative levels of muscle power compared with OS will give IS players a clear disadvantage to sustain the forceful muscle contraction required during some soccer game actions such as kicking, tackling, turning, blocking, changing pace and sustaining forceful contractions to maintain balance and control of the ball against defensive pressure (Wisloff et al. 1998).

Lower values in sprint running performance were observed in IS when compared to OS players. These lower values in sprint performance compared with OS give IS players a clear disadvantage to sustain the frequent running sprinting actions occurring at maximal or near maximal velocities for very short periods in soccer games. It was also interesting to observe that significant negative correlations were found in the whole group of soccer players between the individual values of maximal 5 or 15-m sprint running times and the individual values of concentric power production during the half-squat actions at the load of 75–125% of body mass expressed in relation to body mass. In addition, significant correlations have been observed after several weeks of training in handball (Gorostiaga et al. 2006; Granados et al. 2008) and young soccer players (Gorostiaga et al. 2004) between the individual changes of concentric power production during knee extension actions and the individual changes in sprint running velocity over 5 and 15 m. Taken together these relationships suggest a possible transfer from the gain in leg muscle power into enhanced sprint performance. Furthermore, it agrees with studies performed on soccer players (Gorostiaga et al. 2004), emphasizing the importance of combining adapted leg muscular power training with sprint running training programs for improving short-distance sprint performance.

It has been shown that the running velocity associated with a given submaximal blood lactate concentration is an accurate predictor of aerobic capacity (Costill et al. 1973) and of the individual values of distance covered during official match competitions in elite OS (Bangsbo and Lindquist 1992). There is a paucity of information in IS about the blood lactate accumulation during a progressive running exercise. In the present study, average running velocity associated with a $[La]_b$ of 3 mmol l^{-1} (V_3) was similar between IS and OS players. This is an unexpected finding because, at first, lower aerobic capacity should be expected in IS than in OS players, bearing in mind that: (1) during an official game, compared to top-class OS players, IS players play on average less time (70 min vs. 80 min) (Bangsbo et al. 1991; Barbero-Alvarez et al. 2008), and cover less total distance (4–6 km vs. 10–13 km) (Barbero-Alvarez et al. 2008; Mohr et al. 2003) on a lower surface area (800 m^2 vs. 8,000 m^2) with lower absolute energy expenditure, and (2) basketball and handball players, who compete in relatively similar playing areas, with similar total times, distances covered (McInnes et al. 1995; Pers et al. 2002) and free changes to IS players, have lower aerobic capacity than OS soccer players (Gorostiaga et al. 2005). However, it has been shown that the percentage of the total distance covered at high and maximum speed (Alexander and Boreskie 1989; Bangsbo 1994; McInnes et al. 1995) as well as the mean heart rates and percentages of maximum heart rate values (Alexander and Boreskie 1989; McInnes et al. 1995) recorded in IS players during plays and games (Castagna et al. 2008) are greater than in basketball, handball and OS. These higher physical and cardiorespiratory demands made by training and competition could explain the higher endurance capacity values observed in IS players compared to elite basketball or handball players. It is suggested that IS and OS players have similar running endurance capacities because the low playing time and distance covered during IS compared to OS is counterbalanced by more vigorous activity during games and training sessions.

The results of the present study show that, compared to elite OS, elite IS players clearly present lower physical fitness characteristics because absolute and relative power production of the lower extremity muscles as well as sprint running performance were 4–20% lower, whereas percent body fat was 28% higher in IS than in OS players. Although the reasons for these differences are unknown, they may have several origins, as follows: (1) differences in physical demands between IS and OS plays and games. This seems unlikely because muscle strength, power and speed are important physiological characteristics of both IS and OS soccer players in order to perform sprinting, jumping, tackling and kicking in their soccer games (Reilly et al. 2000), (2) the differences may also be related to differences between the amount and type of training that IS and OS players underwent aside from actual game time, as well as overall neuromuscular proficiency on the tests performed, (3) finally, the more likely explanation could be attributed to the fact that IS, due to lower financial incentives and number of players, has more difficulty in recruiting physically gifted talented players compared to OS. In fact, elite IS players seem to have similar physical and anthropometric characteristics to low level OS players. Indeed, a number of studies have previously reported that, compared to

OS players at a higher level, OS players playing at a lower level have a significantly lower sprint running performance (10–15 m) (Arnason et al. 2004; Davis et al. 1992; Ekblom 1986; Reilly et al. 2000) and knee extension strength or power (Faina et al. 1988; Wisloff et al. 1998), whereas they present higher percent body fat (Arnason et al. 2004). Although endurance capacity is important in OS because soccer relies predominantly on aerobic energy pathways and a positive relationship between endurance capacity and performance has been observed in professional OS players (Bangsbo and Lindquist 1992), aerobic fitness does not differentiate between elite and lower level OS players (Arnason et al. 2004; Faina et al. 1988; Reilly et al. 2000; Wisloff et al. 1998). It is, therefore, suggested that the decreased physical fitness and increased percent body fat observed in IS compared to OS players are probably related to number of factors including lower globalization and international player recruitment, lower financial and social incentives, and fewer advances in nutrition, ergogenic aids, training methods or medical and kinesiological development techniques due to lower financial and social incentives.

Elite OS players are characterized by a relative heterogeneity in physical fitness characteristics (Costill et al. 1973; Davis et al. 1992; Reilly and Thomas 1977). In the present study, significant negative correlations were observed in IS and OS players between the individual values of 5-m maximal sprint running time and the individual values of $[La]_b$ at running velocities of 12 and 13 km h^{-1}. Negative correlations between leg anaerobic power characteristics and running endurance have already been found in professional OS players (Bosco et al. 1996) indicating that those OS players with higher sprint running or vertical jump height performances tend to have lower endurance running capacities versus OS players with lower leg anaerobic characteristics. These differences in physical fitness between elite OS players have been related to differences in muscle fiber type characteristics (Bosco et al. 1996). Taking into consideration the different physical profiles observed in OS and IS players, it is suggested that careful attention should be given to the full soccer training program to avoid the negative interference effects observed when carrying out similar concurrent aerobic and resistance training programs for the whole group in players with a wide and even opposite range of strength and endurance characteristics (Gorostiaga et al. 2006).

During the season, but particularly during the first preparatory period, soccer coaches urged the majority of players to decrease their percent body fat. This is based on the belief that superfluous body fat in soccer is disadvantageous because it acts as dead weight, thereby increasing the physiological strain associated with the exercise (Rienzi et al. 2000; Strudwick et al. 2002). This excess in body fat seems to be particularly relevant in elite OS players approaching their early thirties (Wittich et al. 2001). The results of the present study agree with this belief because in the whole group, and especially in OS players, the individual values of percent body fat correlated negatively with maximal sprint and endurance running performance as well as with vertical jumping capacities. It indicates that elite IS and OS players with lower values of percent body fat may be able to reach higher strength, sprint and endurance running performances versus those with higher percent body fat values. Although the correlations were modest, it is reasonable to suppose that soccer players with low percent body fat values around 6–8% using the Jackson and Pollock (1978) equation, or 11–12% using the Durnin and Wommersley equation (Carey 2000) are at an advantage in male soccer. In this hypothesis, gradual and reasonable individual programs of body fat reduction with professional guidance should be recommended in some soccer players to improve their physical fitness. However, it may be necessary to pay special attention to individual programs of loss of body fat to avoid the concomitant decrease in muscle power that has been observed in elite male and female team sports (Gorostiaga et al. 2006; Granados et al. 2008) when these programs are performed without professional guidance.

Conclusion and practical application

In conclusion, elite male IS players present similar values in body height, body mass, fat-free body mass and endurance running when compared to OS players, but present higher values in percent body fat and lower values in vertical jump height, sprint running performance and power during half-squat actions. Lower absolute levels of muscle power compared with OS give IS players a clear disadvantage when it comes to sustaining the forceful muscle contraction required during certain soccer game actions. The relationships observed in the present study between certain anthropometric and physical fitness characteristics in the whole group of soccer players suggest that those with higher sprint running or vertical jump height performances tend to have lower endurance running capacities. These relationships also suggest that soccer players with higher values of percent body fat may achieve lower strength, sprint and endurance running performances versus those with lower percent body fat values.

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