Metabolic and lactate responses to supramaximal exercise in elite junior soccer players and distance runners

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Abstract

Aim: *Elite soccer players are considered not as excellent but as good endurance athletes. Because of the characteristics of the game which is faster and is played at higher intensity, a high anaerobic power is also required characteristic of elite soccer players. Hence, the purpose of the present study was to compare the metabolic and lactate responses to 30 s maximal cycle ergometer tests in high school soccer players and distance runners.*

Methods:*Ten elite high school male soccer players (SP) and ten elite high school male distance runners (DR) volunteered as subjects in this study. Anaerobic power measures were obtained using Wingate anaerobic test including peak power (PP) and mean power (MP). The oxygen uptake (VO_2) was recorded breath-by-breath during the test (30 s) and during the first 30 s of recovery. Blood samples for lactate concentrations were drawn at rest before the test and during the 30-min recovery period.*

Results: *Values(±SEM) of PP were 647 (±27) and 568 (±24) W in the SP and DR, respectively being significant ($P<0.05$). During the test, the DR had a significantly greater VO_2 than the SP ($P<0.01$). Blood lactate concentrations, on the other hand in recovery after the test were higher in the SP than DR.*

Conclusion: Those results would indicate that the energy supply for the 30 s supramaximal exercise depended on the competitive specialty. The energy supply *of the SP was more provided by the anaerobic metabolism and in the DR by the aerobic system.*

Introduction

Soccer is universally popular and most widespread sport in the world. Soccer is considered a physically demanding sport, which requires strength, speed and agility. Today's soccer game has become faster and is played at higher intensity. A study[1] has revealed that players in competitive soccer engage in high intensity running (including sprinting) for over 8% of the total game time. In fact, during the most decisive actions of the game, intense anaerobic exercise is performed. Because the game involves high intensity intermittent exercise, it has been suggested that a high anaerobic power is a required characteristic of elite soccer players.[2]

Most sports science studies have concerned conventional aerobic activities such as running, swimming, cycling and cross country skiing. However, it has been found that male elite soccer players cover 8-12 km during a game, depending on team role.[3] Aerobic power has been well recognized as an important physiological factor to soccer performance.[2] In deed, a significant correlation between maximal oxygen uptake (VO_2max) and distance covered during a match was found.[1] The average VO_2max for international level male soccer players ranges from 55-68ml.kg^{-1}.min^{-1}.[4] Thus, soccer players can be considered as not excellent endurance athletes, but good endurance athletes.

The purpose of the present study was to compare physiological responses to a 30 s Wingate test in elite junior soccer players and distance runners.

Materials and Methods

Subjects

A total of ten male high school soccer players (SP) and ten male high school distance runners (DR) were volunteered to participate in this study. They were competing at national level and trained for at least three years. They were thoroughly familiarized with all testing equipment and procedures before the study.

Procedures

The subjects reported to the laboratory . First, the subject's height, body mass, body fat percent and pulmonary functions were assessed. A week later the subjects returned to the laboratory for anaerobic power assessments. Body fat percent was estimated from body impedance (Weight Manager 2.05, RJL Systems, Clinton, MI). The Autospiro AS-302 (Minato Medical Science CO., LTD., Tokyo) was used to evaluate pulmonary functions by calculating the forced vital capacity (FVC) and forced expired volume at one second ($FEV_{1.0}$).

Anaerobic power test and blood samples

The second part of the study took place in the absence of any competition or exhaustive training. On arrival in the laboratory with post-prandial state (about 0900 hr), each subject sat down on a chair. Following a 30 min sitting rest period, the baseline venous blood samples were taken. A small needle was used to take a few microliters of capillary blood from a fingertip. Then the subject sat on the cycle ergometer.

An anaerobic performance was measured using the Wingate anaerobic test, with a friction-loaded cycle ergometer (Lode Excalibur) interfaced with a microcomputer. The braking load was calculated according to Bar-Or[5], i.e., 0.075 kg • kg body mass^{-1}. A warm-up was allowed for 4 min at a submaximal load of 50 w and a velocity of 60 rpm. During this exercise, the subjects were required to pedal for 30 s as fast as possible. Verbal encouragement was given to get subjects to reach their peak power and maintain it as long as possible. Then, after a 5-min recovery, a few microliters of capillary blood was taken from a finger tip for lactate analysis since a delay is necessary for the transport of the lactate from the muscle to the vascular bed. The blood samplings were conducted during 30 min of recovery (at 10, 15 and 30 min after).

The gas exchanges during the Wingate test and the recovery of the exercise were measured using a breath-by-breath auto gas analyzer (MetaMax system (Cortex Biophysik GmbH, Leipzig, Germany). The data was subsequently processed with a running average of 0.5 s. The highest value (Watts) during the 30s was defined as peak power (PP), and the mean power (MP) was calculated as the average W value during the 30s. The difference between the peak power value and the lowest value occurring at the end of the 30s, divided by the peak value and multiplied by 100 was taken as a fatigue index (%), (FI).

Whole blood lactate concentration was measured immediately after sampling (1500 Sport, Yellow Springs Instrument CO, OH.). Lactate was immediately determined

Data analyses

The level of significance of the differences between group means was assessed using one way ANOVA, and correlation coefficients were obtained with linear regression, using SPSS soft ware pack. The level of significance for statistics was set at $P < 0.05$.

RESULTS

Physical characteristics of the subjects are presented in Table 1. There was no significant difference in body mass between the

Table 1. Physical characteristics of soccer players and distance runners.

	SP	DR
Age (yr)	17.8 ± 0.4	17.7 ± 0.5
Height (cm)	170.6 ± 7.7	170.9 ± 3.8
Body mass (kg)	61.8 ± 7.6	56.5 ± 5.6
BMI	21.3 ± 2.5	19.3 ± 1.3*
Body fat (%)	12.3 ± 2.1	10.4 ± 2.0*

SP: soccer players; DR: distance runners
Values ± SEM
* $P<0.05$

Table 2. Selected pulmonary function measurements of SP and DR groups.

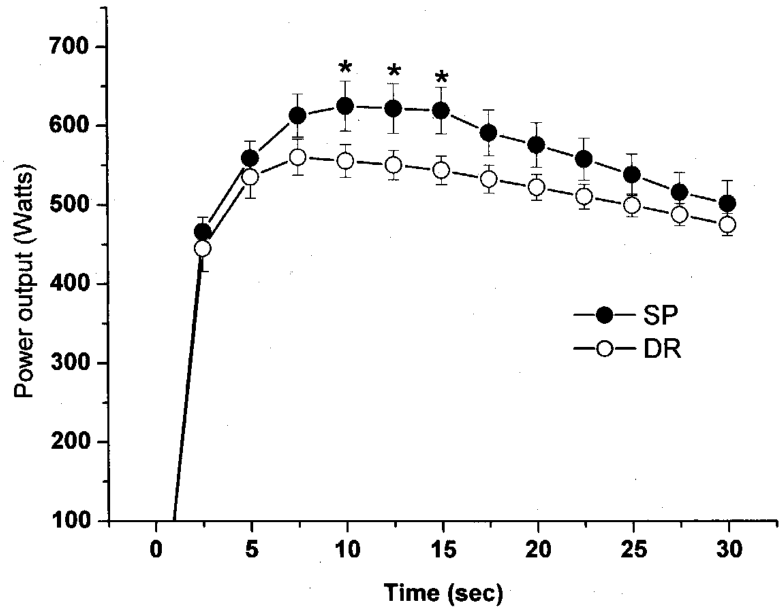
	SP	DR
FVC (L)	4.42 ± 0.48	4.53 ± 0.48
$FEV_{1.0}$ (L)	3.97 ± 0.58	3.97 ± 0.50
$FEV_{1.0}$ (%)	89.9 ± 5.4	87.8 ± 6.2

SP: soccer players; DR: distance runners
Values ± SEM
FVC = forced vital capacity
$FEV_{1.0}$ = forced expiratory volume at 1.0 s

SP and DR although the SP group tended to be heavier than the DR group. Both body fat percentage and BMI were significantly ($P<0.05$) lower in the DR than in the SP. However, estimated lean body mass (fat mass was subtracted from body mass) in the SP was greater than in the DR.

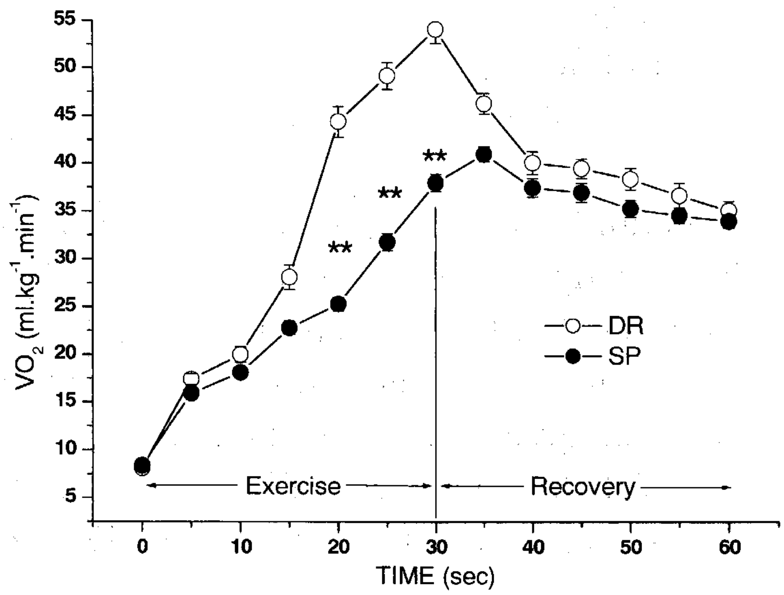
Table 2 indicates FVC, $FEV_{1.0}$ and %$FEV_{1.0}$ in both SP and DR. All values for the measurements were very similar between the two groups.

Figure 1 illustrates the power out put in the two groups at every 2.5 seconds during the Wingate test. Mean peak power (PP, anaerobic power) for the SP and DR was 647.0 w and 568.2 w, respectively and the PP was significantly ($P<0.05$) higher in the SP than in the DR. Mean power (MP, anaerobic capacity)



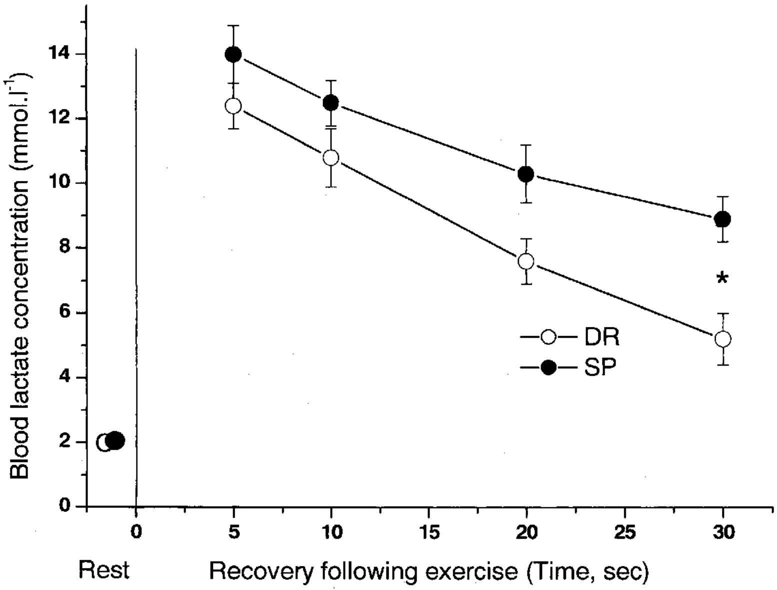
*: Significant difference (P< 0.05) between the groups.

Figure 1. Power output during a 30-sec supramaximal exercise in distance runners and soccer players. Values are mean±SEM.



**: Significant difference (P<0.001) between the groups.

Figure 2. Time course of oxygen uptake (VO_2) over the 30 s of the Wingate test and during the first 30 s of recovery in distance runners (DR) and soccer players (SP). Values are mean±SEM.



*: Significant difference (P<0.05) between the groups.

**Figure 3. Changes in blood lactate concentrations at rest and during the 30 min of recovery from the Wingate test in distance runners (DR) and soccer players (SP).
Values are mean±SEM.**

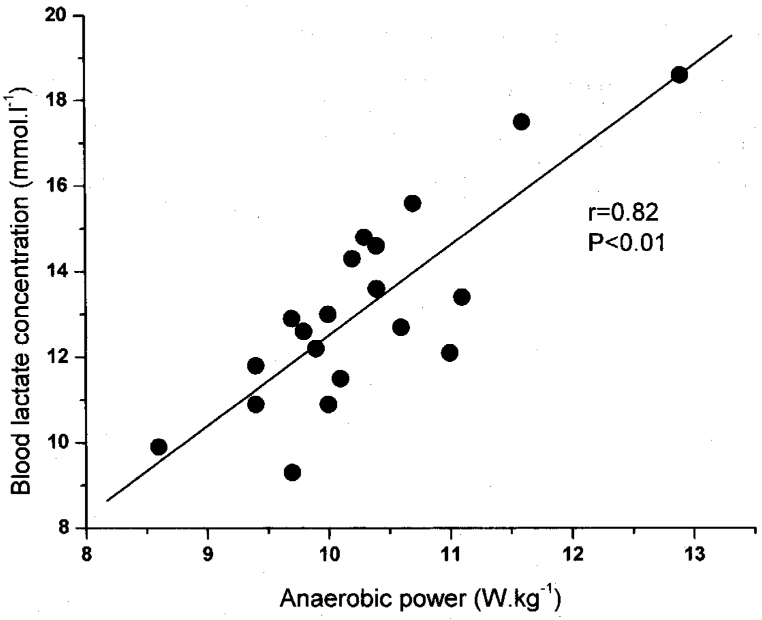


Figure 4. Relationship between lactate concentrations measured 5 min after the Wingate test and anaerobic power (W).

for the SP and DR was 566.6 and 519.8 w, respectively and the difference was significant ($P < 0.0001$). However, the power discrepancy in both peak and mean powers was reduced with non-significance when the values were expressed relative to body mass ($w.kg^{-1}$). Fatigue index for the SP and DR was 21.7 and 16.3%, respectively, and the index was significantly ($P < 0.05$) lower in the DR than SP.

Figure 2 shows the mean values for VO_2 average every 5 seconds at rest, over the 30 seconds of Wingate test, and the first 30 seconds of recovery. Oxygen uptake kinetics were different between the two groups. The mean values of VO_2 were steeper and higher for the DR than for the SP.

The time course of the mean blood lactate concentrations at rest and 30 min of recovery for the two groups were shown in Figure 3. Blood lactate concentrations at rest were almost the same in the SP and DR. As expected, the supramaximal exercise produced great changes on blood lactate response. The peak values were 6- and 7-fold respectively higher in the DR and SP than baseline concentrations. However, the peak concentrations were not significant between the DR and SP ($P = 0.058$). The patterns of changes of blood lactate concentration during recovery were similar but the slope for removal of lactate was steeper in the DR than the SP. Consequently the lactate concentration in the SP was significantly ($P < 0.05$) higher at the 30 min point. A significant ($r = 0.82$, $P < 0.01$) correlation was observed between anaerobic power ($W.kg^{-1}$) and blood lactate concentrations (Figure 4).

DISCUSSION

Soccer players (SP) were heavier than distance runners (DR) in the present study (Table 1). Lean body mass in the SP was also greater than that in the DR. Body mass composition is an important aspect of fitness for soccer as the game now demands more physical contact. Soccer players with high lean muscle mass will generate higher forces for jumping, kicking and tracking.

The FVC of 4.42 L in the SP in the present study appears to be comparable to the Chinese elite junior soccer team (4.43 L)[6] and a national junior team of Hong Kong Chinese (4.60 L)[7], but lower than that of elite junior Hungarian soccer players (5.1 L)[8]. The mean $FEV_{1.0}$ (3.97 L; $\%FEV_{1.0}=89.9$) in the SP group observed in the present study demonstrated a high efficiency of respiratory muscles. This may be likely to the fact that soccer requires intermittent bursts of intense action in which players frequently rely on anaerobic mechanisms. These values in this study, however, lower than those in elite junior swimmers ($FEV_{1.0}$: 5.62 L; %FEV: 93.4)[9]. The similar results in the pulmonary function tests were obtained for the DR group as well. FVC relative to body mass was, therefore higher in the DR than the SP. Explanation for this result remains unknown.

The present study shows that during the Wingate test the distance runners had a greater VO_2 than the soccer players and that the soccer players had a tendency demonstrating greater blood lactate concentrations ($P=0.089$).The aerobic contribution was higher in the distance runners, whereas the anaerobic contribution was higher in the soccer players.

While the figure of VO_2max, even though determined by different methods, is universally used as an indicator of aerobic capability, comparisons between studies of figures on anaerobic capability are made difficult by the large number of different tests used. Vertical jumps, stair climbs, sprints, maximal cycle ergometer efforts, most with a variety of protocols have also been used. A 30-second Wingate cycle ergometer test was used in the present study for assessing anaerobic power. The anaerobic power as indicated by the PP was significantly ($P<0.001$) greater in the SP than the DR (Figure 1). This higher anaerobic power value may has resulted from years of strenuous sprint training. However, the difference was not significant when the values were expressed relative to body mass. Short-term maximal power output is closely associated with body mass and lean body mass.[10]

Since peak power, normally attained during the first few seconds of the Wingate test, probably relies predominantly on the phosphagen energy stores while the mean power would be more dependent on the glycolytic power. However, the DR is better to sustain a high power development through the 30 s test than the SP as expressed by the lower fatigue index (FI) of the SP, and this could be due to an anaerobic endurance obtained through speed-running training and interval-run training.

The results of the VO_2 and blood lactate kinetics showed differences between the two groups. The increase in VO_2 during the Wingate test apparently became more rapid in the DR as opposed to the SP after only the first 15 s of exercise. A higher percentage of total energy output was generated from the aerobic system in the DR and, in contrast, from the anaerobic system in the SP.

To determine the peak lactate concentrations, blood samples were collected 5 min after the end of the exercise since a delay is necessary for the transport of the lactate values are found to be higher within 3 to 7 min after the exercise rather than just after the end.[11, 12] The maximal concentration of lactate measured after the end of the exercise in the SP was greater than in the DR. Although a statistical significance between the two groups was not obtained, a tendency in the greater concentration for the SP was seen ($P=0.058$). Such trend could be explained by the soccer players' higher portion of anaerobic training as well as soccer game. That is, the higher concentration of blood lactate in the SP seems to have resulted from an enhanced potential to derive energy via the glycolytic pathway. In deed, sprint training is known to enhance muscle glycogen contents and glycolytic enzyme concentrations which may enhance brief and intense exercise performances. Balsom[13] reported that the higher the playing level of the players the greater is their anaerobic capacity and ability to tolerate lactic acid. In summary, we found that during the Wingate test the energy supply depended on the competitive specialty. That is, the energy supply of the soccer players was predominantly provided by the anaerobic metabolism and in the distance runners by the aerobic system.

Acknowledgements

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REFERENCES

1 Bangsbo J, Norregaard L, Thorso F. Activity profile of competition soccer. Can J Sport Sci. 16:110-6, 1991.

2 Wisloff U, Helgerud J, Hoff J. Strength and endurance of elite soccer players. Med Sci Sports Exerc. 30: 462-7, 1998.

3 Railly T. Motion analysis and physiological demands. In: Science and Soccer, London: RTE & FN Spoon, 65-79, 1996.

4 Bar-Or O. Anaerobic performance. In: Docherty D, ed. Measurement in Pediatric Exercise Science. Champaign, IL: Human Kinetics, 1996; 161-182.

5 Liu H. A longitudinal study of growth and maximal aerobic power in young footballers. J Nat Res Inst Sport Sci, 2: 28-31, 1989.

6 Chin M, So RCH, Yuan YWT, Li RCT, Alison S, Wong K. Cardiorespiratory fitness and isokinetic muscle strength of elite Asian junior soccer players. J Sport Med Phys Fitness, 34: 250-7, 1994.

7 Apor P. Successful formulae for fitness training. In: Reilly T, Lees A, Davids K, Murphy WJ, eds. Science and Football. London: E & FN Spon, 95-107, 1988.

8 McKay EE, Braund RW, Chalmers RJ, Williams CS. Physical work

capacity and lung function in competitive swimmers. Br J Sport Med, 17: 27-33, 1983.

9 Mercier B, Mercier J, Granier P, Le Gallais D, Prefaut C. Maximal anaerobic power: relation to anthropometric characteristics during growth. Int J Sports Med, 13:21-26, 1992.

10 Weinstein Y, Bediz C, Dotan R, Falk B. Reliability of peak-lactate, heart rate, and plasma volume following the Wingate-test. Med Sci Sports Exerc 30: 1456-1460, 1998.

11 Kobayashi Y. High doses of vitamin E to aid aerobic work performance at altitude. Research J Phys Educ, 48: 31-44, 1975.

12 Esbjorsson-Liljedahl M, Sylven C, Holm I, Jansson E. Different responses of skeletal musle following sprint training in men and women. Eur J Appl Physiol, 74: 375-85, 1996.

13 Balsom PD, Seger JY, Ekblom B. A physiological evaluationof high intensity intermittent exercise. Abstract, Second World Congresson Science and Football, Evaluation, The Netherlands, May, 1991.

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