Running economy in elite soccer and futsal players: differences among positions on the field

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OBJECTIVE: To determine running economy in a large sample of elite soccer and futsal players to obtain benchmarks in different positions.

METHODS: Running Economy is the energy demand at a submaximal running velocity. Players were divided into 6 subgroups. Soccer: defenders, midfielders, and strikers; futsal: defenders, wingers, and pivots. Elite soccer players (n=129) and elite futsal players n=72 performed an incremental running test starting at 8.4 km.h^{-1} with increments of 1.2 km.h^{-1} every two minutes on a treadmill until exhaustion. Running Economy was determined by interpolation between ventilatory thresholds 1 and 2 (VT_1 and VT_2).

RESULTS: Running Economy (measured as mL.kg^{-1}.km^{-1}) was compared between the playing positions in the two team sports. In soccer, running economy was 222.7 (defenders), 227.0 (midfielders), and 219.8 (strikers) mL.kg^{-1}.km^{-1}, respectively. In futsal, the corresponding values were 198.5 (defenders), 196.9 (wingers), and 190.5 (pivots) mL.kg^{-1}.km^{-1}, respectively. We no found significantly differences between the three positions in both sports. The Running Economy of futsal players was 12.5% better than that of soccer players. Running Economy correlated positively with oxygen uptake at VT_2 in both sports and in all positions.

CONCLUSION: Futsal players exhibited better Running Economy than soccer players; this should be considered as a factor in the athlete's training plan.

KEYWORDS: maximal oxygen uptake, ventilatory threshold, oxygen cost, aerobic performance, intermittent exercise.

INTRODUCTION

Various physiological parameters have been shown to have strong correlations with soccer performance. The monitoring of aerobic function parameters on a regular basis is an important tool to evaluate the effectiveness of physical training and the preparedness of soccer players to compete. Soccer is a sport that in addition to speed, agility, and skill requires well-developed cardiopulmonary functional capacity for prolonged energy production. It is a sport of long duration and intermittent low and high intensity and is influenced by the efficiency of performed effort, which is reflected in the Running Economy (RE) of players.

In contrast, futsal is a medium-length sport, practiced in a smaller pitch and with different rules. Interestingly, soccer and futsal are sister sports with high physiological demands, with variations in running patterns and physical activities. It has been suggested that futsal players cover more high-intensity running distance than soccer players during a match (22.6% vs. 10% of total covered distance executed at high-intensity running).

Running Economy is the amount of energy required to maintain submaximal running speed and is measured by the oxygen cost per unit of body mass.

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per unit distance run (mL·kg⁻¹·km⁻¹). The importance of RE in both sports is the high submaximal rate of oxygen consumption (soccer, 70-80% and futsal, >75%) which occurs during matches. A better RE reduces energy expenditure and accelerates the athletes’ recovery process in terms of ATP production. In short, to improve economy, a reduction of the energy cost is of paramount importance. However, there is no real agreement amongst coaches and scientists on the best way to achieve this result. Although many studies have examined RE in long and middle-distance runners, the number of studies evaluating RE in soccer and futsal players according to their position is rather limited. In relation to the higher aerobic contribution in soccer, we hypothesized that the Running Economy of different field positions would be more expressive in soccer than futsal.

**METHODS**

**Participants and Study design**

The study design was cross-sectional. Professional male soccer players numbered 129, including 44 defenders, 49 midfielders and 36 strikers; Professional male futsal players numbered 72, including 20 defenders, 36 wingers and 16 pivots. The players belonged to several teams and were tested at the Laboratory of Movement Studies of the Institute of Orthopedics and Traumatology, Center of Sports Medicine of the Faculty of Medicine of the University of São Paulo. The soccer players had 6±2 years of experience, whereas the futsal players had 10±2 years. Routine training consumed an average of 8±2 hours a week for both sports. All athletes were in a preseason training period. All the players were in good health (defined as being free of diabetes, heart disease, musculoskeletal dysfunction, cancer, and smoking) and were regularly participating in training sessions and competitions with their respective clubs.

**Ethical considerations**

Prior to their participation in the study, all the participants were given a verbal explanation of the aim of the research, and the procedures to be carried out, and all signed an informed consent form. The study was carried out in strict accordance with the ethical guidelines of the Declaration of Helsinki and was approved by the Ethics Committee (CAPPESQ case # 1251/07) of the Hospital das Clínicas of the School of Medicine of Universidade de São Paulo, Sao Paulo, Brazil.

**Experimental Procedures**

All measurements took place under laboratory conditions. Participants wore appropriate racing flat shoes, and laboratory conditions were similar throughout all the running assessments (temperature: 20±3°C, relative humidity: 45 ± 15%). For the testing sessions, participants came to our laboratory after a period of at least 24h without training.

Under medical supervision, athletes underwent standard incremental cardiopulmonary exercise tests on a motor-driven treadmill (h/p/cosmos™, pulsar; Nussdorf-Traunstein, Germany) up to a symptom-limited maximum. The treadmill slope was kept constant at 1% (futsal, hard surface) and 2% (soccer, soft surface). In this protocol, the players remained at rest for two minutes, and then warmed up for three minutes at velocities of 4.8, 6 and 7.2 km h⁻¹ (one minute each). The test proper began at 8.4 km h⁻¹ and speed was increased by 1.2 km h⁻¹ every two minutes. During the test, breath-by-breath pulmonary ventilation, oxygen consumption, carbon dioxide production, and respiratory exchange ratio (RER) data were determined via an open air gas collection system (CPX/Ultima, MedGraphics™, St. Paul, MN, USA). Prior to testing, the pneumotach was calibrated for flow rate using a 3-L calibration syringe (Hans Rudolph Inc™, Shawnee, Kansas, USA). The gas analyzers were calibrated before each test to room air and medically certified calibration gases (12.1 and 20.9% O₂, and 4.96% CO₂ respectively). Heart rate (HR) was continuously recorded during exercise by electrocardiography (ECG V6 HeartWare™, Belo Horizonte, Minas Gerais, Brasil). The usual ECG parameters (heart rate, PR interval, QRS duration, QT and QTc intervals, and P, QRS and T axes) were continuously recorded. Arterial blood pressure was checked by auscultation using a sphygmomanometer (Tycos™, USA) at rest, at every two minutes of exercise, and at the first, second, fourth, and sixth minutes of the recovery period.

Maximal oxygen uptake (VO₂ max), was reckoned to be present if any three of the following criteria occurred: (i) a plateau, when the difference in the VO₂ in the last two stages of incremental test was ≤ 2.1 mL·kg⁻¹·min⁻¹; (ii) the respiratory exchange ratio (VCO₂/VO₂) ≤ 1.10; (iii) maximal HR within 10 beats·min⁻¹ of the age-predicted maximum (208 – [0.7* age]); (iv) volitional fatigue; (v) more than 18 on the subjective Borg scale; (vi) clinical indications such as sweating, hyperpnoea and facial flushing. In addition, data from the VO₂ max tests were time-averaged using 30-s intervals.

Ventilatory threshold 2, VT₂, (i.e., respiratory compensation point), was determined as the point where minute ventilation (Vₑ), ventilatory equivalent of oxygen (VE/VO₂), ventilatory equivalent of carbon dioxide (VE/ VCO₂) and end-tidal oxygen pressure (PETO₂) concomitantly increased and end-tidal carbon dioxide pressure (PETCO₂) decreased (second inflection point of curves in progressive exercise). This is the transition between “steady” and “heavy” paces.

Ventilatory threshold 1, VT₁, was determined by the lower value of VE/VO₂ and PETO₂ before its continuous increase associated with the beginning of abrupt and continuous increase of respiratory quotient (RQ=VCO₂/VO₂) (first inflection point of the curve in progressive exercise). VT₁ pace is termed as “steady”.
Running Economy determination

For the determination of running economy, VO₂ and running speed were expressed as functions of ventilatory thresholds 1 and 2 (VT₁ and VT₂). The VO₂ and running speed at VT₁ and VT₂ were determined by interpolation. Based on these running speeds, VO₂ at VT₁ and VT₂ was calculated in mL kg⁻¹ km⁻¹ and averaged over these two intensities. RE was defined as oxygen uptake was ≤ 85% of VO₂max for all athletes, which is required to assess RE. Additionally, we monitored the respiratory quotient (VCO₂/VO₂ = RQ) between VT₁ and VT₂ to ensure that it remained below 1.0, indicating that oxidative metabolism was the main metabolic pathway.

Statistical analysis

The Gaussian distribution (normality) for the data was verified by the Kolmogorov–Smirnov goodness-of-fit test (Z value < 1.0). Data are presented as mean ± standard deviation (SD). The univariate general linear model (ANOVA) was applied to detect significant differences between groups. If a significant F ratio was obtained, Bonferroni's post hoc test was used to locate differences between means. The relationships were assessed by Pearson's coefficient correlation (r). The level of significance was set at p < 0.05. Statistical analyses were performed using Sigma Stat (version 3.5, Systat Software, Inc, Point Richmond, CA).

RESULTS

Table 1 presents the characteristics of futsal players according to their field positions. Age and height did not differ between the different positions, but pivots and defenders were significantly heavier vs. wingers. Running economy did not differ between the three different positions. Defenders had significantly higher VO₂max compared to wingers. The %VO₂max at the VT2 did not differ among positions.

Table 1. Age, anthropometric characteristics and physiological profile for the different positions in male futsal players.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pivot (n=16)</th>
<th>Winger (n=36)</th>
<th>Defender (n=20)</th>
<th>All players (n=72)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.7 ± 6.1</td>
<td>26.2 ± 5.5</td>
<td>26.8 ± 7.2</td>
<td>26.2 ± 6.1</td>
<td>ns</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.7 ± 5.0*</td>
<td>74.2 ± 6.4</td>
<td>79.3 ± 8.2*</td>
<td>76.8 ± 7.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.8 ± 4.0</td>
<td>177.4 ± 5.4</td>
<td>180.8 ± 4.5</td>
<td>178.5 ± 5.3</td>
<td>ns</td>
</tr>
<tr>
<td>RE (mLkg⁻¹ km⁻¹)</td>
<td>190.5 ± 11.8</td>
<td>196.9 ± 16.2</td>
<td>198.5 ± 10.8</td>
<td>195.3 ± 4.2</td>
<td>ns</td>
</tr>
<tr>
<td>VO₂max (mLkg⁻¹ min⁻¹)</td>
<td>48.6 ± 3.2</td>
<td>47.4 ± 2.4</td>
<td>49.4 ± 3.0*</td>
<td>48.4 ± 1.0</td>
<td>0.05</td>
</tr>
<tr>
<td>%VO₂max (VT₂)</td>
<td>83.8 ± 4.7</td>
<td>81.8 ± 6.6</td>
<td>85.0 ± 4.6</td>
<td>83.5 ± 1.6</td>
<td>ns</td>
</tr>
<tr>
<td>VO₂VT₂ (mLkg⁻¹ min⁻¹)</td>
<td>41.1 ± 4.0</td>
<td>38.7 ± 3.4</td>
<td>42.1 ± 2.7*</td>
<td>40.6 ± 1.7</td>
<td>0.05</td>
</tr>
<tr>
<td>vVT₂ (km.h⁻¹)</td>
<td>12.4 ± 0.7</td>
<td>12.9 ± 0.9*</td>
<td>12.3 ± 0.8</td>
<td>12.7 ± 0.9</td>
<td>0.05</td>
</tr>
</tbody>
</table>

RE, running economy; VO₂max, maximal oxygen uptake; %VO₂max, percentage of maximal oxygen uptake at the ventilatory threshold 2; VO₂VT₂, oxygen uptake at the ventilatory threshold 2; vVT₂, running speed at the ventilatory threshold 2. Weight: Pivot > Defender (P<0.05; Defender > Winger (P<0.05). VO₂max: Defender > Winger (P<0.05); VO₂VT₂: Defender > Winger (P<0.05); vVT₂: Winger > Defender (P<0.05).

Figure 1. Futsal players: correlations between running economy (RE, mL.kg⁻¹.km⁻¹) and oxygen uptake at the ventilatory threshold 2 (VO₂VT₂, mL.kg⁻¹.min⁻¹) in pivots, wingers, and defenders.
vVT₂ was significantly (p<0.05) better in wingers than in defenders.

Figure 1 shows that Running Economy was significantly correlated to VO₂VT₂ for all positions.

Table 2 presents the characteristics of soccer players according to their field positions. There were no significant differences (p>0.05) for any of the variables between the three positions in soccer players. However, as was found for futsal players, RE was significantly correlated to VO₂VT₂ in all positions, as shown in Figure 2.

**DISCUSSION**

The major finding of this study is that the Running Economy of futsal players was better than that observed in soccer players. Within each sport, no significant differences occurred for this parameter between player positions. To our knowledge, this is the first study in which RE was compared between positions on the field in soccer and futsal players. Because the RE of the futsal players was better than that of soccer players for all field positions, it follows that futsal players were more economical than soccer players in all positions.

Aerobic fitness has been normally based on three indicators (VO₂ max, ventilatory threshold, and RE). Improvement in RE at race pace means less energy used while running the same pace. Therefore, economical athletes can continue at a given speed longer than inefficient striders, outdistancing them. Among endurance runners a high percentage of slow twitch fibers is associated with superior RE. In contrast, the intrinsic demands required for soccer and futsal probably complicate this optimization due to the need for explosive movements and sprints in combination with aerobic fitness. The VO₂ max values were different between the positions when the two sports were compared. Because athletes were starting the season, the aerobic level of the soccer players was higher than that of the futsal players. Research has shown that there is a large variation between individuals in their RE, which can vary among athletes with similar levels of VO₂ max by as much as 30%. In the current study, the RE in futsal players was

Table 2. Age, anthropometric characteristics and physiological profile are presented for the different positions in male soccer players.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Midfielders (n=49)</th>
<th>Defenders (n=44)</th>
<th>Strikers (n=36)</th>
<th>All players (n=129)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.9 ± 3.8</td>
<td>20.1 ± 2.4</td>
<td>18.6 ± 1.8</td>
<td>19.5 ± 0.8</td>
<td>ns</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.9 ± 5.5</td>
<td>69.9 ± 4.6</td>
<td>69.8 ± 4.3</td>
<td>70.2 ± 0.6</td>
<td>ns</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.2 ± 4.9</td>
<td>174 ± 5</td>
<td>176.2 ± 4.5</td>
<td>175.1 ± 1.1</td>
<td>ns</td>
</tr>
<tr>
<td>RE (mL.kg⁻¹.km⁻¹)</td>
<td>227.0 ± 19.9</td>
<td>222.7 ± 16.7</td>
<td>219.8 ± 17.2</td>
<td>223.1 ± 3.6</td>
<td>ns</td>
</tr>
<tr>
<td>VO₂ max (mL.kg⁻¹.min⁻¹)</td>
<td>58.3 ± 2.8</td>
<td>57.8 ± 3.3</td>
<td>58.4 ± 2.7</td>
<td>58.1 ± 0.3</td>
<td>ns</td>
</tr>
<tr>
<td>%VO₂ max (VT2)</td>
<td>82.3 ± 6.2</td>
<td>81.8 ± 5.7</td>
<td>79.9 ± 5.0</td>
<td>81.0 ± 1.7</td>
<td>ns</td>
</tr>
<tr>
<td>VO2VT2 (mL.kg⁻¹.min⁻¹)</td>
<td>47.9 ± 4.1</td>
<td>47.7 ± 5.2</td>
<td>46.1 ±3.4</td>
<td>47.2 ± 0.9</td>
<td>ns</td>
</tr>
<tr>
<td>vVT2 (km.h⁻¹)</td>
<td>13.0 ± 1.0</td>
<td>12.6 ± 1.0</td>
<td>12.8 ± 0.9</td>
<td>12.8 ± 1.0</td>
<td>ns</td>
</tr>
</tbody>
</table>

RE, running economy; VO₂ max, maximal oxygen uptake; %VO₂ max, percentage of maximal oxygen uptake at the ventilatory threshold 2; VO₂ VT₂, oxygen uptake at the ventilatory threshold 2; vVT₂, running speed at the ventilatory threshold 2.

**Figure 2.** Soccer players: correlations between running economy (RE, mL.kg⁻¹.km⁻¹) and oxygen uptake at the ventilatory threshold 2 (VO₂VT₂, mL.kg⁻¹.min⁻¹) in midfielders, defenders, and strikers.
12.5% better (i.e. RE reflected a lower oxygen cost) than soccer players. This means that the VO\textsubscript{2}max high does not guarantee a better RE. The present study showed that oxygen consumption at VT\textsubscript{1} was more important, because it showed correlation with RE in all positions. In contrast, Boone et al.\textsuperscript{21} showed that differences in running speed at anaerobic threshold in soccer could be attributed both to differences in VO\textsubscript{2} peak and in RE. There are several factors that affect RE and they can be categorized as internal and external factors (differences in fiber composition, training characteristics, genetic endowment, age, and others). In terms of RE, even though it is a complex parameter, research has shown that the economy of simple movements can be improved by improving the storage and release of elastic energy. This ability can be enhanced with specific training (e.g. sprint-training, interval-training, strength training, and plyometric exercises).

Paavolainen et al.\textsuperscript{22} have shown that nine weeks of explosive resistance training resulted in an 8.1% improvement in RE. This in turn led to a 3.1% improvement in the 5-km run time, with no changes in VO\textsubscript{2} max or lactate threshold. Similarly, Spurrs et al.\textsuperscript{23} found that male runners who performed six weeks of plyometric training in conjunction with their normal running training improved their RE by 4-6% across the different test speeds, and as a result, their 3-km run time improved by 2.7%, whilst VO\textsubscript{2} max and lactate threshold remained unchanged. Millet et al.\textsuperscript{24} showed that performing heavy weight training twice a week in addition to normal training in triathletes led to improved maximal strength, economy and velocity at VO\textsubscript{2} max, with no effects on VO\textsubscript{2} kinetics; consequently, they recommend strength training to be part of the athletes’ training program. More specifically, studies on intermittent sports have shown that aerobic high-intensity running training leads to VO\textsubscript{2} max enhancement and increased RE (3% to 7%).\textsuperscript{8,25} Therefore, an improvement in RE is highly desirable for both soccer and futsal players.

Soccer and futsal are long and medium duration sports, respectively. A good RE allows players to run at a faster rate without increasing energy expenditure; above all, a good RE is associated with a quicker recovery from intermittent high-intensity efforts.\textsuperscript{8,19} For both sports, aerobic efficiency is key. Therefore, strength, sprint, and aerobic interval training may improve RE by a number of different mechanisms. An increase in explosive strength could improve mechanical efficiency, muscle coordination and neuromotor recruitment patterns for both sports. The key component of RE is the ability to store and use elastic energy produced during eccentric contractions. It is likely that the explosive movements performed more often by futsal than by soccer players results in alterations of neural control during the stretch-shortening cycle, allowing greater storage and use of the elastic energy, thereby decreasing ground contact time and improving RE. In this sense, researchers observed that the ability to perform high-intensity intermittent exercises associated with strength and plyometric exercises are a decisive factor of performance for increased RE, VO\textsubscript{2} max and VT\textsubscript{2} in soccer and futsal.\textsuperscript{1-3,6,8-9}

\section*{CONCLUSION}

Futsal players have a better Running Economy than soccer players. Results observed in the present study may influence current physical trainers to realize that RE is a real phenomenon, and that coaches can use this information to obtain improvement in the submaximal aerobic profile of players in both sports.

\section*{CONFLICT OF INTEREST}

Authors report no conflict of interest regarding this paper.

\section*{AUTHOR PARTICIPATION}

PRSS: Lead author, wrote the manuscript, analyzed the data, corrected the manuscript, corrected the data. JMDAG and AP supervised the project.

\section*{ECONOMIA DE CORRIDA EM JOGADORES DE FUTEBOL E FUTSAL DE ELITE: DIFERENÇAS ENTRE AS POSIÇÕES EM CAMPO}

\textbf{OBJETIVO:} Determinar a Economia de Corrida numa grande amostra de jogadores de futebol e futsal de elite em diferentes posições do campo.

\textbf{MÉTODOS:} Os jogadores foram subdivididos em três subgrupos: futebol (jogadores de defesa, meio-campistas e atacantes) e futsal (jogadores de defesa, alas e pivôs). Foram 129 jogadores de futebol e 72 jogadores de futsal, que competem nas respectivas primeiras divisões do Brasil. Os jogadores foram submetidos a teste de esforço em esteira (8,4 km h\textsuperscript{−1}+1,2km h\textsuperscript{−1} a cada dois minutos) até a exaustão. Consumo máximo de oxigênio, limiares ventilatórios e Economia de Corrida foram registrados por análise de troca gasosa respiratória. A Economia de Corrida foi determinada por interpolação utilizando as velocidades dos limiares ventilatórios 1 e 2 e o consumo de oxigênio nas duas velocidades.

\textbf{RESULTADOS:} Os valores de Economia de Corrida entre as posições nos dois esportes foram os seguintes: Futebol, jogadores de defesa (222,7±16,7mL kg\textsuperscript{−1} km\textsuperscript{−1}), meio-campistas (227±19,9mL kg\textsuperscript{−1} km\textsuperscript{−1}), e atacantes (219,8±17,2mL kg\textsuperscript{−1} km\textsuperscript{−1}). Futsal, jogadores de defesa (198,5±10,8mL kg\textsuperscript{−1} km\textsuperscript{−1}), alas (196,9±16,2mL kg\textsuperscript{−1} km\textsuperscript{−1}),...
Running economy in futsal and soccer players

CONCLUSÃO: Futsal tem melhor Economia de Consumo do que futebol. O presente estudo aponta a importância dos índices Economia de Consumo no plano de treinamento físico dos atletas.

PALAVRAS-CHAVE: consumo máximo de oxigênio, limiar ventilatório, custo de oxigênio, desempenho aeróbico, exercício intermitente

REFERENCES


