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ORIGINAL RESEARCH

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.

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INTRODUCTION

Various physiological parameters have been shown to have strong correlations with soccer performance.[1] 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.[2] 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.[3] 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).[3]

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 ($mL \cdot kg^{-1} \cdot km^{-1}$).[5] 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.[6-7] A better RE reduces energy expenditure and accelerates the athletes' recovery process in terms of ATP production.[8] 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.[9] 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 $km \cdot h^{-1}$ (one minute each). The test proper began at 8.4 $km \cdot h^{-1}$ and speed was increased by 1.2 $km \cdot h^{-1}$ 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% O_2 and 4.96% CO_2, 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 (VO_2max), was reckoned to be present if any three of the following criteria occurred: (i) a plateau, when the difference in the VO_2 in the last two stages of incremental test was ≤ 2.1 $mL \cdot kg^{-1} \cdot min^{-1}$;[10] (ii) the respiratory exchange ratio (VCO_2/VO_2) ≤1.10;[11] (iii) maximal HR within 10 $beats \cdot min^{-1}$ of the age-predicted maximum (208 – [0.7* age]);[12] (iv) volitional fatigue; (v) more than 18 on the subjective Borg scale;[13] (vi) clinical indications such as sweating, hyperpnoea and facial flushing.[14] In addition, data from the VO_2max tests were time-averaged using 30-s intervals.

Ventilatory threshold 2, VT_2, (i.e., respiratory compensation point), was determined as the point where minute ventilation (V_E), ventilatory equivalent of oxygen (VE/VO_2), ventilatory equivalent of carbon dioxide (VE/VCO_2) and end-tidal oxygen pressure ($PETO_2$) concomitantly increased and end-tidal carbon dioxide pressure ($PETCO_2$) decreased (second inflection point of curves in progressive exercise).This is the transition between "steady" and "heavy" paces. [15-16]

Ventilatory threshold 1, VT_1, was determined by the lower value of VE/VO_2 and $PETO_2$ before its continuous increase associated with the beginning of abrupt and continuous increase of respiratory quotient ($RQ=VCO_2/VO_2$) (first inflection point of the curve in progressive exercise). VT_1 pace is termed as "steady" [15-16]

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Running Economy determination

For the determination of running economy, VO_2 and running speed were expressed as functions of ventilatory thresholds 1 and 2 (VT_1 and VT_2). The VO_2 and running speed at VT_1 and VT_2 were determined by interpolation. Based on these running speeds, VO_2 at VT_1 and VT_2 was calculated in $mL·kg^{-1}·km^{-1}$ and averaged over these two intensities. RE was defined as oxygen uptake was ≤ 85% of VO_2max for all athletes, which is required to assess RE.[17] Additionally, we monitored the respiratory quotient (VCO_2/VO_2=RQ) between VT_1 and VT_2 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 VO_2max compared to wingers. The $\%VO_2$max at the VT2 did not differ among positions.

Table 1 also shows that VO_2VT_2 was significantly ($p<0.05$) better in defenders than in wingers. In contrast,

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

Variables	Pivot (n=16)	Winger (n=36)	Defender (n=20)	All players (n=72)	ANOVA
Age (years)	27.7 ± 6.1	26.2±5.5	26.8 ± 7.2	26.2±6.1	ns
Weight (kg)	84.7± 5.0*	74.2±6.4	79.3 ± 8.2*	76.8±7.1	0.05
Height (cm)	180.8 ± 4.0	177.4±5.4	180.8 ± 4.5	178.5±5.3	ns
RE ($mL.kg^{-1}.km^{-1}$)	190.5±11.8	196.9±16.2	198.5±10.8	195.3±4.2	ns
VO_2max ($mL.kg^{-1}.min^{-1}$)	48.6 ± 3.2	47.4 ± 2.4	49.4 ± 3.0*	48.4 ± 1.0	0.05
$\%VO_2$max (VT_2)	83.8 ± 4.7	81.8 ± 6.6	85.0 ± 4.6	83.5 ± 1.6	ns
VO_2VT_2 ($mL.kg^{-1}.min^{-1}$)	41.1 ± 4.0	38.7 ± 3.4	42.1 ± 2.7*	40.6 ± 1.7	0.05
vVT_2 ($km.h^{-1}$)	12.4 ± 0.7	12.9 ± 0.9*	12.3 ± 0.8	12.7 ± 0.9	0.05

RE, running economy; VO_2max, maximal oxygen uptake; $\%VO_2$max, 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).VO_2max: Defender> Winger (P<0.05); VO_2VT_2: Defender>Winger (P<0.05); vVT_2: Winger > Defender (P<0.05).

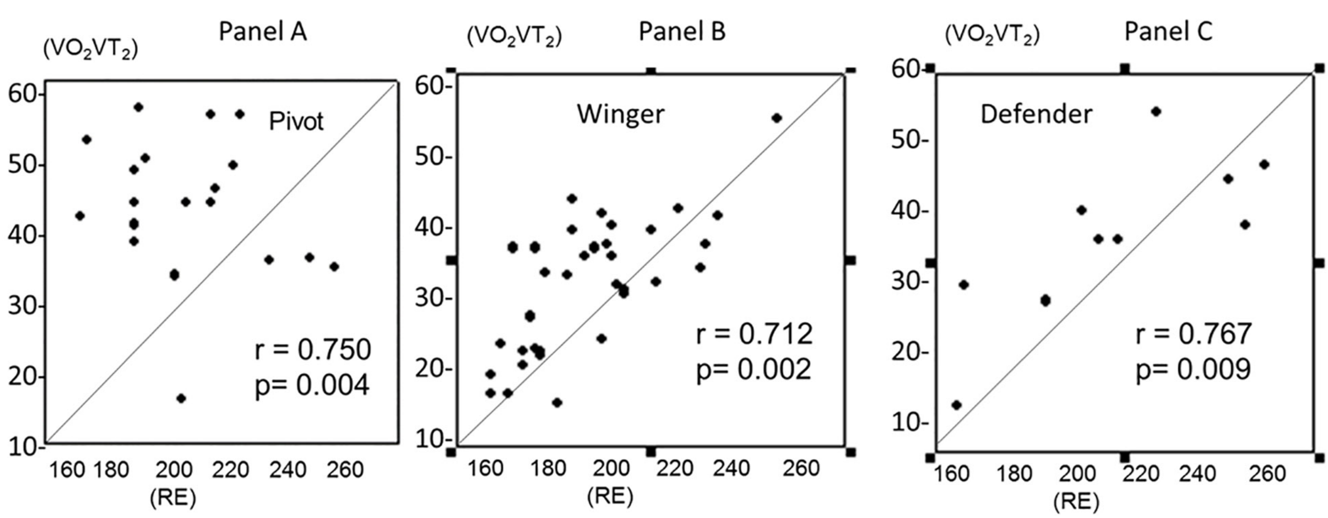

Figure 1. Futsal players: correlations between running economy (RE, $mL.kg^{-1}.KM^{-1}$) and oxygen uptake at the ventilatory threshold 2 (VO_2VT_2, $mL.kg^{-1}.min^{-1}$) in pivots, wingers, and defenders.

vVT_2 was significantly ($p<0.05$) better in wingers than in defenders.

Figure 1 shows that Running Economy was significantly correlated to VO_2VT_2 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 VO_2VT_2 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 (VO_2max, 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.[18] 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 VO_2 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.[19] Research has shown that there is a large variation between individuals in their RE, which can vary among athletes with similar levels of VO_2max by as much as 30%.[20] 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.

Variables	Midfielders (n=49)	Defenders (n=44)	Strikers (n=36)	All players (n=129)	ANOVA
Age (years)	19.9 ± 3.8	20.1 ± 2.4	18.6 ± 1.8	19.5 ± 0.8	ns
Weight (kg)	70.9 ± 5.5	69.9 ± 4.6	69.8 ± 4.3	70.2 ± 0.6	ns
Height (cm)	175.2 ± 4.9	174 ± 5	176.2 ± 4.5	175.1 ± 1.1	ns
RE ($mL.kg-1.km^{-1}$)	227.0 ± 19.9	222.7 ± 16.7	219.8 ± 17.2	223.1 ± 3.6	ns
VO_2max ($mL.kg^{-1}.min^{-1}$)	58.3 ± 2.8	57.8 ± 3.3	58.4 ± 2.7	58.1 ± 0.3	ns
$\%VO_2max$ (VT2)	82.3 ± 6.2	81.8 ± 5.7	79.9 ± 5.0	81.0 ± 1.7	ns
VO2VT2 ($mL.kg-1.min^{-1}$)	47.9 ± 4.1	47.7 ± 5.2	46.1 ±3.4	47.2 ± 0.9	ns
vVT2 ($km.h^{-1}$)	13.0 ± 1.0	12.6 ± 1.0	12.8 ± 0.9	12.8 ± 1.0	ns

RE, running economy; VO_2max, maximal oxygen uptake; $\%VO_2max$, percentage of maximal oxygen uptake at the ventilatory threshold 2; VO_2VT_2, oxygen uptake at the ventilatory threshold 2; vVT_2, running speed at the ventilatory threshold 2.

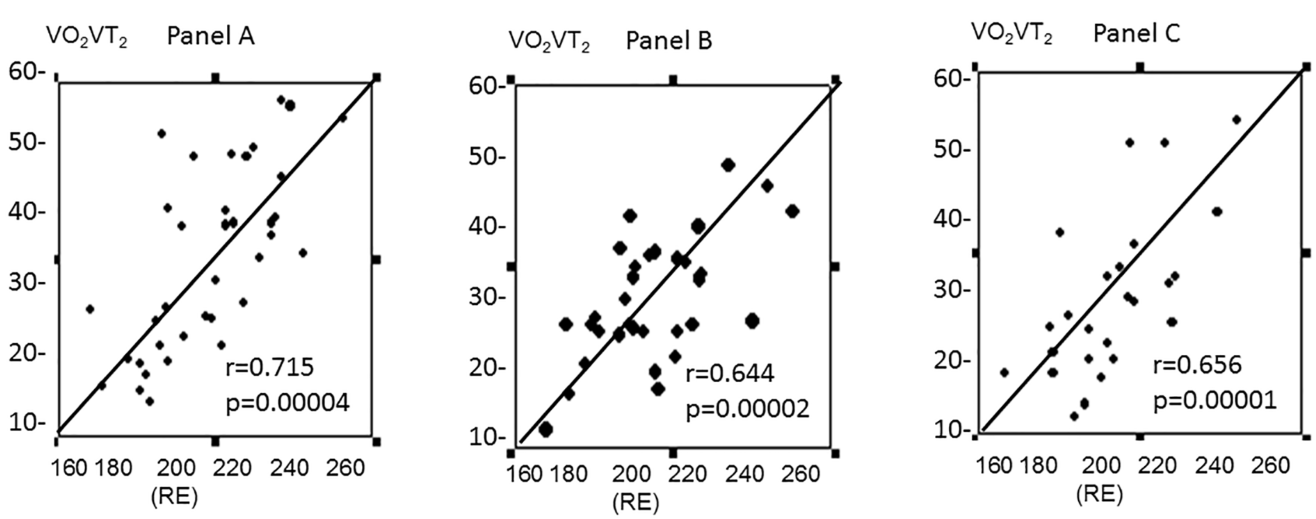

Figure 2. Soccer players: correlations between running economy (RE, mL.kg-1.KM-1) and oxygen uptake at the ventilatory threshold 2 (VO2VT2, mL.kg-1.min-1) in midfielders, defenders, and strikers.

12.5% better (i.e. RE reflected a lower oxygen cost) than soccer players. This means that the VO_2max high does not guarantee a better RE. The present study showed that oxygen consumption at VT_2 was more important, because it showed correlation with RE in all positions. In contrast, Boone et al.[21] showed that differences in running speed at anaerobic threshold in soccer could be attributed both to differences in VO_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.[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_2max or lactate threshold. Similarly, Spurrs et al.[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_2max and lactate threshold remained unchanged. Millet et al.[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_2max, with no effects on VO_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_2max enhancement and increased RE (3% to 7%).[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.[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_2max and VT_2 in soccer and futsal.[1-3,6,8-9]

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.

CONFLICT OF INTEREST

Authors report no conflict of interest regarding this paper

AUTHOR PARTICIPATION

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

ECONOMIA DE CORRIDA EM JOGADORES DE FUTEBOL E FUTSAL DE ELITE: DIFERENÇAS ENTRE AS POSIÇÕES EM CAMPO

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

METODOS: 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 ($8{,}4\ km^{-1}\cdot h+1{,}2km^{-1}\cdot h$ 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 consume de oxigênio nas duas velocidades.

RESULTADOS: Os valores de Economia de Corrida entre as posições nos dois esportes foram os seguintes: Futebol, jogadores de defesa ($222{,}7\pm16{,}7mL\cdot kg^{-1}\cdot km^{-1}$), meio-campistas ($227\pm19{,}9mL\cdot kg^{-1}\cdot km^{-1}$), e atacantes ($219{,}8\pm17{,}2mL\cdot kg^{-1}\cdot km^{-1}$). Futsal, jogadores de defesa ($198{,}5\pm10{,}8mL\cdot kg^{-1}\cdot km^{-1}$), alas ($196{,}9\pm16{,}2mL\cdot kg^{-1}\cdot km^{-1}$),

e pivôs (190,5±11,8mL.kg^{-1}.km^{-1}). Não foram encontradas diferenças significativas entre as três posições em ambos os esportes. A Economia de Corrida dos jogadores de futsal foi 12,5% melhor do que dos jogadores de futebol. Neste estudo, os jogadores da posição pivô no futsal tiveram os melhores valores de Economia de Corrida (custo de oxigênio mais baixo). Embora o consumo máximo de oxigênio (VO_2max) e o limiar ventilatório 2 (LV2) fosse maior nos jogadores de futebol, a Economia de Consumo foi pior. Esta correlacionou-se positivamente com o VO_2 no LV_2 em ambos os esportes e em todas as posições

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 aeróbio, exercício intermitente

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