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review article

Physiological characteristics, evaluation and prescription of aerobic training in Futsal

Características fisiológicas, avaliação e prescrição do treinamento aeróbio no Futsal

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Abstract – Futsal has intermittent characteristics with different requirements of displacements and changes of direction, requiring simultaneously aerobic and anaerobic capacities of athletes. So, during counter-attacks and returns to defense or fast movements to get rid or perform marking, there is maximum mobilization of specific capabilities of the sport and the ability to perform high-intensity intermittent exercise is a key factor of performance. The aim of this study was to perform an expositive review on the physiological characteristics, high-intensity interval training and aerobic evaluation methods that have been used and suggested in scientific literature in original studies. A search in scientific portals Google Scholar, Scopus®, SciELO®, ScienceDirect® (Elsevier) and PubMed® was conducted to find articles with publication date since 2000 using the following terms in different combinations: "Futsal", "performance", "aerobic evaluation", "high-intensity interval training", "field tests" and their variations in English. Analysis of physiological indexes related to game performance can help in the knowledge about the aerobic fitness of Futsal players and improve training assessment, prescription and monitoring, also serving as a reference to assist professionals of this sport in the preparation of high intensity interval training programs to meet the particular needs of the sport. Field tests with specific features of the sport were created as a means of assessment and also training prescription and are recommended due to their specificity and ecological validity.

Key words: Aerobic performance; Field tests; High-intensity interval training; Review.

Resumo – *O futsal apresenta características intermitentes com diferentes exigências de deslocamentos e mudanças de direção, exigindo simultaneamente as capacidades aeróbias e anaeróbias dos atletas. Assim, durante os contra-ataques e retornos à defesa, ou movimentações rápidas para se desmarcar ou realizar marcação, há uma mobilização máxima das capacidades específicas da modalidade, sendo que a habilidade de realizar exercícios intermitentes de alta intensidade é um fator decisivo da performance. O objetivo do presente trabalho foi realizar uma revisão de literatura expositiva sobre as características fisiológicas, treinamento intervalado de alta intensidade e métodos de avaliação aeróbia que vêm sendo utilizados e sugeridos na literatura científica em estudos originais. Realizou-se uma pesquisa nos portais científicos da Google Scholar, Scopus®, SciELO®, ScienceDirect® (Elsevier) e PubMed® buscando artigos com data de publicação a partir do ano 2000 pelos seguintes termos em diferentes combinações: "futsal", "performance", "avaliação aeróbia", "treinamento intervalado de alta intensidade", "testes de campo" e suas variações em inglês. A análise dos índices fisiológicos relacionados à performance de jogo podem auxiliar no conhecimento a respeito da aptidão aeróbia de jogadores de futsal e aprimorar a avaliação, prescrição e acompanhamento do treinamento. Adicionalmente, servem de referência para auxiliar os profissionais da modalidade na elaboração de programas de treinamento intervalado de alta intensidade que atendam às necessidades específicas do esporte. Os testes de campo com características próprias da modalidade foram criados como forma de avaliação e também prescrição de treinamento e são recomendados pela especificidade e validade ecológica que possuem.*

Palavras-chave: *Performance aeróbia; Revisão; Testes de campo; Treinamento intervalado de alta intensidade.*

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INTRODUCTION

Despite its worldwide popularity, there are few studies investigating Futsal; therefore, the physiological and neuromuscular demands required from athletes of this modality are not fully known[1-5]. Furthermore, Martin-Silva et al.[6] have reported that there are only few studies aimed at investigating women's futsal.

Since it is a team sport characterized by intermittent efforts of high intensity, interspersed with variable recovery periods during matches, futsal under the physiological point of view, is a balanced modality, in which the level of performance of athletes depends on variables related to both aerobic and anaerobic metabolism[2-4,7,8], and the effort: pause ratio during matches is approximately 1: 1[9].

By means of analysis of movement, studies has shown that deciding periods on a fustal match are preceded by rapid and high-intensity runs (10 - 30 m or 2 - 4 seconds), and professional players spend approximately 5 - 12 % of the match time performing high-intensity races (> 15 $km.h^{-1}$), highlighting the importance of high-intensity interval training for futsal players[1]. In this sense, Castagna and Barbero Álvarez[8] observed that the ability to perform high-intensity intermittent exercises is a decisive factor of performance in futsal. However, studies have shown that the performance achieved during this training model depends on the duration of recovery periods and the activity performed[10].

The identification of physiological requirements required from futsal players during matches is crucial for prescribing training, as they decisively contribute to the technical staff to propose a training program appropriate for the specific needs of the sport in order to improve the metabolic ATP production so that athletes can achieve maximum performance[2]. Thus, Tomlin and Wenger[11] reported that high levels of maximal oxygen uptake (VO_2max) can be decisive in the ability to restore phosphagenic between high-intensity intermittent exercises. In addition, studies have shown that players with higher aerobic power values are more economical to perform the requested actions, resulting in higher performance maintenance throughout the match[2,7]. According to Midgley et al.[12], maximum-intensity interval training (MIIT) contributes to the development of capacity and aerobic power in relatively short periods of time, as it provides gains related to central adaptations (increased systolic volume that generates an increase in cardiac output and consequently VO_2max values) and peripheral adaptations (improvement of the working capacity to produce and use ATP). Dellal et al.[13] also reported that MIIT requests the use of aerobic and anaerobic metabolism of energy supply and also stimulates neuromuscular adaptations.

The aim of this study was to perform a literature review on the physiological characteristics, high-intensity interval training and aerobic evaluation methods that have been discussed in scientific literature in original studies, serving as a reference to assist sport professionals in the elaboration of training programs that meet the particular needs of futsal athletes.

For the development of this study, original and review articles that were related to the aims of this research were analyzed. This review included articles indexed from 2000 to 2015 using five electronic databases: Google Scholar, Scopus®, SciELO®, ScienceDirect® (Elsevier) and PubMed®. The keywords used to search for articles, according to descriptors in health sciences (MeSH) were: futsal, performance, aerobic evaluation, high-intensity interval training, field trials and their variations in English. Operator "AND" was used for the combination of descriptors and terms used for tracking publications.

The search on electronic databases was conducted in January 2015. After the first analysis and evaluation of titles, 55 articles were eligible for the second phase of this review, which consisted of reading the abstracts. After evaluating the abstracts for relevance to the study purpose, the references that met the inclusion criteria were read in full. To define which of these would be part of the review, some inclusion criteria were adopted: a) original or review study; b) to present data on futsal; c) published since 2000, except for articles relevant to the development of the study commonly cited in literature; d) title, abstract or keywords with at least two of the descriptors (keywords); e) meet the study objectives. Exclusion criteria were: a) dissertations or theses; b) articles that were not performed in the period of time adopted. After analyses, 33 studies met all the inclusion criteria.

DEVELOPMENT

Movement Pattern

Futsal is a sport in which the number of substitutions is unlimited; the game intensity maintained by the player remains high throughout the entire match due to moments of recovery during rest, which becomes essential for maintaining high performance[1,3].

To occupy the court spaces in the various match circumstances, players constantly change the distance, speed and the running direction in every action performed[4,14]. Barbero Álvarez and Andrín[7] reported that the effort-rest ratio in futsal is 1: 1.4, and effort means the distance traveled at intermediate (10.9 km.h^{-1} to 18.0 km. h^{-1}), high (18.1 km.h^{-1} - 25.0 km.h^{-1}) or maximum running intensity (> 25.1 km.h^{-1}) and resting denotes that the player is almost stopped (0 km.h^{-1} to 0.36 km.h^{-1}), walking (0.37 km.h^{-1} - 3.6 km.h^{-1}) or running at low intensity (3.7 km.h $^{-1}$ - 10.8 km.h^{-1}), and of the 121 m.min^{-1} (105 - 137 m min^{-1}) which players run during a match, 5% (1 - 11%) are sprints (> 18.3 km.h^{-1}) and 12% (3.8 - 9.5%) are races at high intensity (> 15.5 km.h^{-1}) [2]. In addition, the same authors stated that in each period of the match, athletes perform 26.4 (13-39) races with change of direction at high intensity (> 15.5 km.h^{-1}), of which 7.2 (1.5 - 12.9) are sprints (> 18.3 km.h^{-1}), which are repeated every 79 seconds.

Castagna et al.[2] showed that during Futsal matches, there are sequences of short runs at full speed with change of direction (3-4), interspersed with very short recovery periods (20-30 seconds) performed at a lower intensity

(<12 km.h^{-1}). Thus, the constant demand for maximum intermittent efforts and with active and passive breaks of varying duration does not allow the athlete's complete recovery, requiring the constant involvement of aerobic and anaerobic processes throughout the match[9].

Dogramaci and Watsford[15] observed that for 26% of the total length of a Futsal match, players perform high-intensity movements, in which the movement pattern changes every 3.28 seconds. In turn, Barbero Álvarez et al.[16] demonstrated that 8.6 actions are performed per minute, and every 23 seconds, one high-intensity effort is performed. Soares et al.[17] found that the average distance traveled by Brazilian players during matches was 3,554 m, who remained 60% of the time at low-intensity effort, 30.13% at intermediate intensity and 9.95% at high intensity[17].

Dogramaci et al.[3] found that world-class players performed displacements 42% higher during matches compared to their national-level peers (4.277 ± 1.030 vs. 3.011 ± 999 m, respectively). The average total distance traveled by professional athletes during a match of the Spanish League was 4313 ± 2139 meters, and the relative distance consisted of 117.3 ± 11.6 m.min^{-1} (102.7 - 145.4 m.min^{-1})[1]. It is noteworthy that in sports with unlimited substitutions, such as futsal, the distance covered per minute, i.e., the relative distance indicates more efficiently the effort intensity and can be used as a more precise variable to represent the demands of competition[1].

Importantly, the displacement of Futsal athletes during matches is determined mainly by the tactical role played, suggesting that each athlete has specific metabolic requirements, which results in different physiological demands, determining the length of stay on the court[2,17].

Physiological characteristics

Due to its high-intensity intermittent characteristic, under the physiological point of view, futsal is a balanced modality that depends on aerobic and anaerobic metabolism[1,2,7]. The ATP-CP system is the main source of energy for the achievement of maximum and short-duration efforts, whereas lactic anaerobic metabolism is the main route in high-intensity displacement sequences and successive sprints and, in turn, aerobic metabolism has a significant participation during the course of matches by around 90%[1,12].

Castagna et al.[2] also found that it is essential that professional athletes have VO_2max values close to 55 mL.kg^{-1}.min^{-1} so they can meet their physiological demands, highlighting the importance of maximal aerobic power for performance in futsal. Additionally, Castagna et al.[18] also observed an inverse and significant relationship between VO_2max level and time spent above 90% of maximum heart rate (HRmax: $r = - 0.79$, $p \leq 0.01$), suggesting that Futsal players with greater aerobic power are more economical to perform movements required during the match[7].

According to Castagna et al.[2], athletes remain much of the playing time performing high-intensity activities, and in 46% of them, the values are above 80% of VO_2max, while this percentage increases to 52% above 90% HRmax. During a professional match, the average oxygen uptake (VO_2) and

heart rate (HR) values are, respectively, 75% (59-92%) and 90% (84-96%) of maximum values obtained by players in the incremental test. Peak VO2 and HR values consisted of 99% (88 - 109%) and 98% (90 - 106%) of their highest values, respectively, while the average blood lactate concentration value was 5.3 mmol. L^{-1} (1.1 - 10.4 mmol.L^{-1}), representing intensity close to 80 - 85% of maximum values[2].

Through the analysis of movement in professional matches, Barbero Álvarez et al.[1] observed that the mean heart rate was 173 ± 7 bpm (164-181 bpm), which represented 90 ± 2% (86-93%) of HRmax values, suggesting that athletes remained 73% of the playing time performing vigorous movements. Additionally, Futsal requires high cardiovascular demand, ranging from 85 to 90% of HRmax[1] and the modality requires a high anaerobic component from players, as they exhibited mean blood lactate concentration value of 8.5 ± 2.6 mmol.L^{-1} (4.1 - 12.6 mmol.L^{-1})[9]. Similarly, Castagna et al.[2] observed that professional players achieved high blood lactate concentration levels, suggesting that anaerobic metabolism significantly contributes to the power supply during matches.

Based on the analysis of collective training of a professional team, it was found that the average HRmax values ranged from 71 to 90%[14]. In turn, Rodrigues et al.[4] observed that during national-level matches, players kept average HR values close to 86.4 ± 3.8% of HRmax, corresponding to 79.2 ± 9.0% of VO_2max values.

Additionally, it was observed that there is a few number of studies evaluating the intensity of women's futsal matches[1,4,6,9,16]. Miles et al.[19] found that in women's futsal matches, the average HR was 171 ± 17 bpm (85.7% of HRmax). Martin-Silva et al.[6] indicated that the average HR observed in two professional matches consisted of 178 ± 9 bpm and 170 ± 30 bpm (89 ± 3% and 86 ± 13% HRmax), representing an intensity of 82% and 78% of VO_2max, respectively. In turn, the effort intensity in national-level matches was 90.6% ± 3.6 HRmax obtained in Futsal Intermittent Endurance Test (FIET) (unpublished data).

In addition to physiological aspects, athletes must have high levels of muscle power to perform the required movements, such as the numerous changes of direction with constant acceleration and deceleration[20,21], which is indispensable for futsal performance. In addition, athletes must present ability to withstand fatigue and to be able to maintain maximum performance during their stay on the court[20]. Thus, due to the high demands of the ATP-CP system as a result of the lack of full recovery that enables the full restoration of energy reserves, fatigue becomes a decisive factor in the performance of maximum and intermittent efforts. Fitz Simons et al.[22] reported that athletes able to maintain high levels of maximum speed tend to have better performance in matches due to lower fatigue index.

Identifying the physiological demands of futsal athletes is extremely important for coaches and physical trainers to prepare strategies and training sessions increasingly appropriate to the sport's specific needs[2].

Maximum-intensity interval training (MIIT)

Barbero Álvarez et al.[9] observed that the ability to perform high-intensity intermittent exercise is a key factor of performance in futsal. However, studies have shown that the performance achieved depends on the duration of recovery and activity periods performed during the match[23]. Thus, Tomlin and Wenger[11] concluded that high VO_2max values can be decisive in the ability to recover energy among high-intensity intermittent exercises, being able to discriminate different competitive levels[2], highlighting the importance of maximal aerobic power for performance in this modality. In this context, MIIT has as main aim to improve VO_2max of players[24], allowing them to perform efforts for longer periods compared to continuous training performed at the same intensity due to increased resynthesis of phosphocreatine and lower lactate accumulation, which are partially metabolized during recovery periods[5].

Thus, it could be inferred that MIIT conducted with stimulus lasting from one to four minutes at intensity of 85-100% VO_2max[25], which has recovery period similar to the effort time, appears to be a valid model to be adopted by coaches of intermittent modalities such as futsal. This model contributes to aerobic development in relatively short periods of time, as it provides gains related to central (increased systolic volume that generates an increase in cardiac output and consequently VO2max values) and peripheral adaptations (improved work capacity to produce and use ATP)[12]. The same authors suggested that training conducted at or near the VO_2max intensity can cause maximum stress on physiological processes that limit this value, providing the ideal stimulus for the subject's adaptation. Thus, it was observed that in trained subjects, overload reaches the maximum exercise intensity values associated with the VO_2max range [26]. This mechanical overload is the main stimulus for myocardial adaptation associated with increased systolic volume, which supports the use of MIIT to improve the performance of futsal players. Dellal et al.[13] reported that intermittent training requests the use of aerobic and anaerobic metabolism of energy supply, enabling improving the oxidative capacity of enzymes, reaction time and stimulate neuromuscular adaptations.

Edge et al.[27] observed that while MIIT held above the first physiological transition threshold (LTF1: 120-140%) resulted in a 25% increase in muscle buffering capacity of women engaged in team sports (soccer, basketball, hockey), continuous training performed below LTF2 (80-95%) promoted an increase of only 2%, suggesting that training intensity can be considered an important stimulus for improving the muscle buffering capacity. Therefore, one should recall that improving this mechanism causes the delay in the accumulation of hydrogen ions (H^+), which can reduce performance, since it affects effort perception, ionic regulation, enzyme activity and the functioning of contractile proteins during muscle actions [27].

Helgerud et al.[28] found that MIIT (four replicates of four minutes at 90 - 95% HRmax for three recovery minutes at 50 - 60% HRmax) carried out for eight weeks (two times per week), provided significant increase in

VO_2max (10.8%) at LTF2 (16%) and running economy (6.7%) in soccer players of international teams, resulting in improving both capacity and aerobic power. The same study also found, by means of movement analysis, that the average distance traveled during the match increased by 20%, while the number of sprints performed doubled, and also that the amount of plays with the ball had a 24.1% increase. Corroborating these findings, Impellizzeri et al.[29] demonstrated that, after applying the same MIIT in running held before the competitive season with world-class players, the average VO_2max value increased by 7%, the LTF2 speed by 10 % and the running economy by 2%.

Importantly, the physiological responses of MIIT held straight are already known[25], but the possible differences caused due to changes of direction, which are fundamental to the movement pattern in futsal, remain unclear[13]. When compared to straight racing, changes of direction can influence the muscles involved, thus affecting power consumption, which results in more significant physiological responses[13]. Dellal et al.[13] demonstrated that the blood lactate concentration and PSE values in soccer players were significantly higher during the performance of high-intensity interval training with changing direction of 180º compared to straight racing. Despite the importance of MIIT for the performance of futsal players, there are no studies analyzing its effects on this modality; in addition, to our knowledge, no study has investigated the possible differences that can be observed in physiological adaptations related to races performed with changing direction of 180 º in these athletes.

Field tests for aerobic evaluation in futsal

There has been a great interest among researchers about the use of physiological indexes for prescribing intensity and controlling the effects of training aimed at improving the performance of high-level athletes, highlighting the considerable increase in the use of laboratory and field tests in recent decades for this purpose[30].

However, although assessments carried out in laboratory provide valuable data on the performance and physiological characteristics of athletes[25], they usually do not have ecological validity, being unable to reproduce the specific movement patterns associated with intermittent modalities[30]. Thus, to overcome some deficiencies of laboratory tests, more specific field protocols have been developed in order to more appropriately reflect the intermittent nature of these modalities[10,31]. According to Fernandes da Silva et al.[32], multi-stage tests have been widely used to study the physiological responses of intermittent exercise involving changes of direction, such as futsal. Such protocols aim to reproduce the movement pattern performed in team sports, allowing the simultaneous evaluation of a large number of athletes at minimum cost[32].

The 20-m shuttle run test (SHT20) of Leger et al.[33], is a maximum incremental test composed of multi-stages of 60 seconds of duration in shuttle running protocol consisting of a number of varied running repetitions. The

SHT20 provides power data (VO_2max; PV estimates) and aerobic capacity (HR deflection point (HRDP)).

In turn, Fernandes da Silva et al.[30] developed the incremental intermittent running test (T-CAR), which is an intermittent-type maximum test with multi-stages of 90 seconds of duration in shuttle running protocol consisting of five repetitions of 12 second run (variable distance), interspersed by six seconds of walking (5 meters). The test has increments of 0.6 $km.h^{-1}$ at every stage by successive increases of one meter from the initial distance of 15 m. The T-CAR allowed identifying variables related to power (PV_{TCAR}) and aerobic capacity (HRDP).

Buchheit[31] proposed the Intermittent Fitness Test (30-15 $_{IFT}$), which consists of 30 seconds of running in the shuttle running protocol interspersed with 15 second of passive recovery with initial speed of 8 $km.h^{-1}$ in the first 30 seconds of running and increases of 0.5 $km.h^{-1}$ every 45 seconds. The 30-15 $_{IFT}$ provides the maximum running speed (MRS) performed intermittently, which may be considered a precise variable to discriminate the athlete's physiological profile, serving as a reference for standardization of individualized MIIT sessions (85% -100% PV).

Recently, Castagna and Barbero Álvarez[8] proposed a specific test, called Futsal Intermittent Endurance Test (FIET), which is a field intermittent high-intensity test based on the analysis of movements on futsal matches. The FIET consists of shuttle running races of 45 m (3 x 15 meters), which are interspersed with 10 second of active recovery, and there is a longer period of 30 seconds of pause after each block of eight replicates (8 x 45 meters). Castagna and Barbero Álvarez[8] stressed the importance of the aerobic and anaerobic systems of power supply of athletes during the test, as occurs in futsal matches.

Importantly, several physiological mechanisms may contribute to performance in FIET such as the ability to perform the requested changes of directions and the ability to withstand high running intensities, reflected by the athlete's anaerobic capacity[10]. It may also be suggested that the performance in FIET requires the participation of the neuromuscular system, since the protocol involves racing with changes of direction at high intensity held in a short distance, indicating that it can also be influenced by peripheral fatigue, and the physiological mechanisms (temporary and / or accumulated fatigue) that contribute to the FIET interruption are similar to those that interrupt the test of repeated sprints[8]. Additionally, Castagna, and Barbero Álvarez[8] demonstrated that even with 47% of the test time being used for recovery periods, FIET can be considered a field protocol that emphasizes the use of the anaerobic pathway, showing that this metabolism plays an important role in the onset of fatigue.

Based on the aforementioned information, it could be concluded that FIET is a peculiar field test used to evaluate the performance of Futsal players, since it provides relevant information about the physiological characteristics necessary for performing high-intensity intermittent exercises according to the modality needs [8,9].

FINAL COMMENTS

Futsal is a sport of intermittent nature, in which athletes perform maximum efforts with short active recovery periods during the match, as most of the time they reach HR and VO_2 values close to their upper limits. Therefore, the analysis of physiological indexes can provide important information that serve as a reference to assist in the development of appropriate training programs. Compared with continuous training, MIIT is the most suitable model for aerobic developing in short periods of time mainly due to improvements observed in VO_2max values in futsal players. Finally, field tests with specific characteristics of the sport modality were created as a means of training assessment and prescription, highlighting FIET, for being specifically developed for futsal.

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