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The peak velocity of Carminatti's Test for aerobic-fitness training in male soccer players

O pico de velocidade do Teste de Carminatti para treinamento aeróbio em jogadores de futebol

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Abstract – Aerobic energy transference is highly required and accounts for more than 90% of total energy consumption during a soccer match. In addition high aerobic fitness contributes to recovery from high-intensity intermittent exercise, specific to performance in soccer. The aim of the present study was to examine whether the peak velocity in the Carminatti's test (PV_{T-CAR}) for prescribing interval-training drills is effective in eliciting aerobic-fitness development intensities in male soccer-players. Fifteen Brazilian male elite soccer-players (U20) were tested for T-CAR and monitored for heart rate (HR) during PV_{T-CAR} prescribed interval-training drills (i.e., 4x4min with 3min passive recovery). Drills were performed with a 1:1 work-to-rest ratio with either straight-line (6/6s) or 180° shuttle running (12/12s). The interval training performed at PV_{T-CAR} elicited HR above 90% of HRmax and lactate above 4m.mol.l^{-1}. In the shuttle-running drills, HR and lactate (93.3±2.1% HR_{max}; 7.7±1.4 m.mol.l^{-1}) were significantly higher than in the straight line drills (vs 90.3±2.6 %$HR_{max;}$ 4.5±0.9 m.mol.l^{-1}). The coefficient of variations showed low inter-subject variability in HR (CV 2.3 and 3.0% for 12/12 and 6/6 respectively). The results of this study demonstrated that PV_{T-CAR} can be successfully used to individualize high-intensity interval running training in players with different aerobic profiles, while shuttle-running drills presented higher values at intern load than straight line. The physiological and time-motion profiles resemble the most demanding phases of the match, especially for the fittest players.

Key words: Aerobic fitness; Field test; Intermittent exercise; Training.

Resumo – *A transferência de energia aeróbia é altamente necessária e representa mais de 90% do consumo total de energia durante um jogo no futebol. Ademais, a alta aptidão aeróbia contribui para a recuperação durante exercício intermitente de alta intensidade, específico do desempenho do futebol. O objetivo deste estudo foi examinar se o pico de velocidade no teste de Carminatti (PVT-CAR) para a prescrição de treino intervalado é funcional na obtenção de desenvolvimento de aptidão aeróbia em jogadores de futebol. Quinze jogadores de futebol brasileiros (Sub-20) foram testados no T-CAR e monitorados por freqüência cardíaca (FC) durante o treinamento intervalado prescrito por* PV_{T-CAR} *(ou seja, 4x4min com recuperação passiva de 3min). Os treinos foram realizados com uma relação de trabalho e repouso de 1:1 com corrida em linha reta (6/6s) e corrida de 180° com mudança de direção em vai-e-vem (12/12s). O treinamento intervalado prescrito com PVT-CAR induziu respostas de FC acima de 90% de FCmax, lactato superior a 4m.mol.*l^{-1}. *uOs resultados de FC e lactato no treinamento de corrida com mudança de direção (93,3±2,1%* FC_{max}*; 7,7±1,4 m.mol.*l^{-1}*) foram significativamente maiores que no treino de corrida em linha (vs 90,3±2,6 %*$FC_{max;}$ *4,5±0,9 m.mol.*l^{-1}*). O coeficiente de variação mostrou baixa variabilidade inter-sujeitos na frequência cardíaca (CV 2,3 e 3,0% para 12/12 e 6/6, respectivamente). Os resultados do estudo mostraram que o PVT-CAR pode ser utilizado com sucesso para individualizar o treinamento de corrida intervalado de alta intensidade em jogadores com diferentes perfis aeróbicos. Os perfis fisiológicos e momentos de demandas se assemelham às fases mais exigentes da partida, especialmente para os jogadores melhor condicionados.*

Palavras-chave: *Aptidão aeróbia; Exercício intermitente; Teste de campo; Treinamento.*

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INTRODUCTION

Soccer players are often required to perform repeated high-intensity exercises with short recovery intervals[1,2]. Due to these specific demands, studies have been searching for training methods that adequately develop cardiorespiratory and musculoskeletal fitness[3–5]maximal aerobic speed (MAS. Aerobic high-intensity training in soccer is usually based on continuous test outcomes and has been widely used by physical trainers to prescribe and control training. However, in soccer, specific on-field physical training approaches should involve shuttle runs to introduce accelerations, decelerations, and changes of direction[1]. In order to enable coaches and fitness trainers to prescribe individualized training load on an individual basis, using either straight-line or shuttle running as an exercise mode, there is a need for field tests that set a reference velocity for training prescription, taking into consideration the impact of directional changes[6].

Carminatti et al.[7] proposed a new field-based test to be used with soccer players (Carminatti's test - T-CAR). This test, which involves shuttle running at progressive speeds over an increasing distance until exhaustion (using audio cues - beeps - with constant timing), has demonstrated very large associations with a number of aerobic fitness variables usually considered for training prescription and relevant to match performance in soccer[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s. Indeed, the T-CAR peak velocity ($PV_{T\text{-}CAR}$) has been associated with VO_2max (r=0.54, p=0.004), vVO_2max (r=0.74, p=0.0008), and lactate thresholds (r=0.63, p=0.0003) measured in the laboratory[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s. Furthermore, $PV_{T\text{-}CAR}$ was significantly correlated with repeated-sprint ability in soccer players (r= - 0.71, p=0.0002)[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s and positively associated (r= 0.78, p<0.01) with the amount of high-intensity activity in match performance[9].

Given the above, it seems possible to prescribe exercise-mode specific (i.e., intermittent high-intensity shuttle or straight-line running) training to soccer players using $PV_{T\text{-}CAR}$. An additional practical value of using T-CAR may be the individualization of training intensity, simply by modifying the running distance according to the individual's fitness using the same audio cues (6 s). Moreover, the reported high T-CAR reliability makes it suitable for monitoring training-induced fitness changes in soccer players[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s. Silva et al.[10] used $PV_{T\text{-}CAR}$ to prescribe soccer-specific training sessions (intensity used was 100% of PV with a work to rest ratio of the 1:1 during the 2 training programs).The authors[10] found that both training modes (straight line and shuttle run) similarly improved the LT, vVO_2max, PVtreadmill and the performance in T-CAR in soccer athletes. However, they did not describe acute responses of the different training models (shuttle-running versus straight-line drills) in the same group of subjects. This is critical for coaches and fitness trainers that need to select the running intensities according to their objectives.

An advantage of the training prescription from T-CAR in relation to the other aerobic interval training models published previously [11,12]is the fact of using exercises with and without change of direction, short distances for stimuli (up to 34 m), intermittent running (stimulus-pause), characteristics that present greater ecological validity in concerning to demands of the game. The fact of prescribing based on value of the $PV_{T\text{-}CAR}$ without use of heart rate monitor, since it is difficult to think in practical ways how a player can control or adjust the intensity of the exercise during interval training, especially when exercising at high speed, locking in the watch [13].

To plan an appropriate training program, the energy requirements of the game need to be understood[14]. Studies indicate that aerobic energy transference is highly required and accounts for more than 90% of total energy expenditure during a match[14,15], and also emphasize that soccer requires players to repeatedly produce maximal or near maximal actions with short recovery periods[16–18]4 \u00d7 4 min running at 90\u201395% of HRmax; n = 21. Thus, high aerobic fitness contributes to recovery from intermittent high-intensity exercise, being relevant to soccer performance[18,19]completed twice a week. The following outcomes were measured at baseline (Pre. The development of different methods that can support in prescription of training with the objectives of quick responses of physiological adaptations using structures and scores of field tests, would contribute to the planning and training of the demands of the game, preparing the athletes and optimizing the time to reach optimal levels of conditioning.

Therefore, the aim of this study was to examine the applicability of T-CAR for high-intensity interval-training prescription for aerobic fitness development in soccer players. It was hypothesized that $PV_{T\text{-}CAR}$ may induce cardiovascular and metabolic responses in the range of those proven useful to promote aerobic fitness development in soccer players, with low inter-individual variability.

METHODOLOGICAL PROCEDURES

Fifteen Brazilian male elite-soccer players (U-20) from a professional club volunteered for this study (18.1±1.4 years, 177.5.0±5.1 cm, 74.2±5.2 kg). Prior to the study commencement, written informed consent was obtained from all participants and guardians. All procedures were approved by the ethics committee of the Federal University of Santa Catarina, Brazil (711.384).

In this study a between group cross-sectional design was used. Each soccer player was tested for T-CAR (first visit) and monitored for acute training (straight-line or shuttle run interval training drills) responses (at least 48 hours apart). During T-CAR, players were assessed for $PV_{T\text{-}CAR}$ and peak HR (HR_{max}). The T-CAR requires participants to perform repeated bouts of 5x12 s shuttle running at progressively faster speeds until volitional exhaustion[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s. The 12 s bouts were separated by 6 s recovery periods, so each stage had a duration of 90 s. The initial running distance was set at 15 m (9 $km \cdot h^{-1}$) and increased by 1 m (0.6 $kmSymbolh^{-1}$) at each stage (90 s)[8]28 players performed Carminatti's test, a repeated sprint ability test, and an intermittent treadmill test. In Study 2, 24 players performed Carminatti's test twice within 72 h to determine test-retest reliability. Carminatti's test required the participants to complete repeated bouts of 5 \u00d7 12 s shuttle running at progressively faster speeds until volitional exhaustion. The 12 s bouts were separated by 6 s recovery periods, making each stage 90 s in duration. The initial running distance was set at 15 m and was increased by 1 m at each stage (90 s.

In the second testing session, players performed $PV_{T\text{-}CAR}$ interval training using a 1:1 work-to-rest ratio but different time intervals (12/12s or 6/6s). Interval training drills were organized in 4 sets of 4-min with 3-min passive recovery between sets[11]. Differently from the 6/6, the 12/12 drill included a 180° change of direction at 6-s[10]. On all occasions HR was monitored at 5-s intervals using a short-range telemetry system (PolarS610; Polar Electro Oy, Kempele, Finland).

A rest interval of 30 s was given between stages, during which a 25 μL capillary blood sample was taken from an earlobe for analysis of blood lactate concentration. The blood lactate was measured using an electrochemical analyzer (YSI 2700 STAT, Yellow Springs, OH, USA). v-OBLA was considered the velocity corresponding to a blood lactate concentration of 3.5 $mmol^{-1}$ [20]. The subjects provided the rating of perceived exertion (RPE) based on the Borg scale (20-point scale) after the end of each set during the two protocols[21].

Data are presented as mean ± standard deviation. Variability of measures is presented as coefficient of variation (CV). Normality was assessed with the Shapiro-Wilk test in each variable. Association between variables was assessed using Pearson's correlation coefficients. Differences in HR, %HR, lactate and RPE within each set were assessed by repeated measures ANOVA, followed by Bonferroni post hoc tests. The Student's *t*-test for paired samples was used to compare the mean values of variables at 6/6 and 12/12. The software G*Power version 3.1.9.2 was used to determine the power of analysis. The statistical power of total sample size calculated in this study was 0.71–1.00 in Student's *t*-test. Effect size (ES) was calculated using Cohen *d*.[22]. Values were considered trivial (<0.2), small (0.2-0.5), moderate (0.5-0.8), and large (>0.8). The level of statistical significance was set at $p<0.05$.

RESULTS

The $PV_{T\text{-}CAR}$ and HR_{max} were 17.5±0.7 $km{\cdot}h^{-1}$ and 198.1±8.4 $b{\cdot}m^{-1}$ respectively. The %HR and lactate in the shuttle-run drills (93.3±2.1 $\%HR_{max}$; 7.7±1.4 $m.mol.l^{-1}$) were significantly higher than those recorded in the straight-line drills (90.3±2.6 $\%HR_{max;}$ 4.5±0.9 $m.mol.l^{-1}$). Additionally, the ES showed a large values for %HR (ES = 1.3) and lactate (ES = 2.8) when comparing 12/12 and 6/6. Coefficient of variations for HR demonstrated low inter-subject variability (CV 2.3 and 3.0% for 12/12 and 6/6 respectively). In the 6/6 group, the HR response across the sets resulted in significantly different values ($p<0.01$). In the 12/12 condition, the HR of the first set was significantly different from the second, third, and fourth sets ($p<0.05$) (Figure 1).

In the 6/6 the $\%HR_{max}$ in all sets differed among them. In the 12/12 the first set (CV = 2.6%) was significantly different from the second (CV = 2.7%) third (CV = 2.3%), and fourth (CV = 2.4%) sets ($p<0.01$), and the second set differed from the fourth set ($p<0.01$) (Figure 2).

Lactate and RPE increased progressively across sets in the two training modes. The mean of the two variables differed significantly in the 6/6 and 12/12 ($p<0.05$). The ES presented moderate value (0.8) for comparison of models for RPE. Other results are presented in figures 3 and 4.

In the 6/6 condition, the lactate in the first set was significantly different from the second, third, and fourth sets ($p<0.05$), while in the 12/12 all sets differed among them ($p<0.05$).

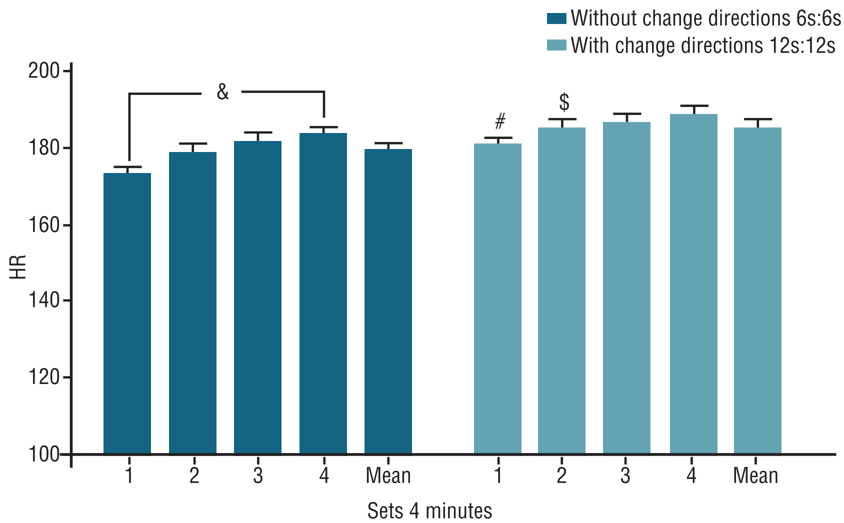

Figure 1. Heart rate responses during the training sets.
& = significantly different at $p<0.05$ in relation to all sets among sets;
# = significantly different at $p<0.05$ in relation to sets 2, 3 and 4;
$ = significantly different at $p<0.05$ in relation to set 4;
* = significantly different at $p<0.05$ from mean of training 6s:6s.

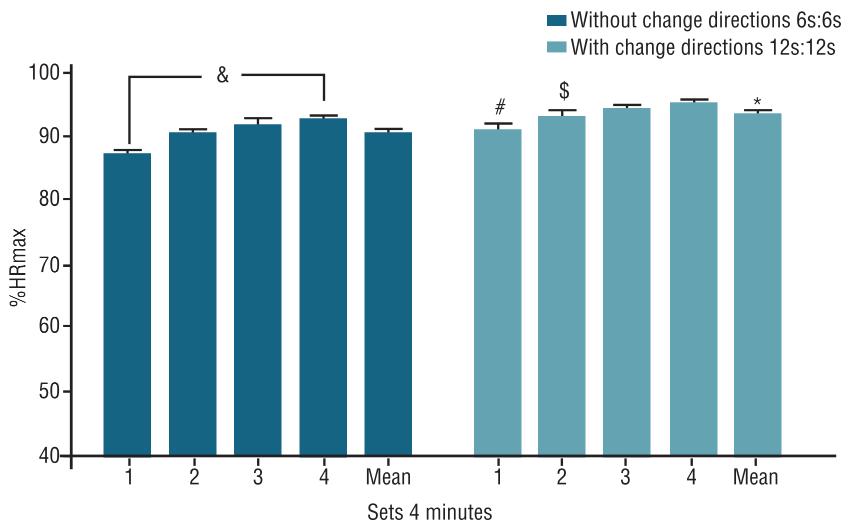

Figure 2. Percentage of heart rate during the training sets.
& = significantly different at $p<0.05$ in relation to all sets among sets;
# = significantly different at $p<0.05$ in relation to sets 2, 3 and 4;
$ = significantly different at $p<0.05$ in relation to set 4.
* = significantly different at $p<0.05$ from mean of training 6s:6s.

In the 6/6 condition, the RPE of the first set was significantly different from the second, third, and fourth sets ($p<0.05$), and the second set differed from the fourth set ($p<0.05$). In the 12/12 the RPE of the first set was significantly different from the second, third, and fourth sets ($p<0.05$), the second set was significantly different from the third and fourth sets ($p<0.05$), and the third set differed from the fourth set.

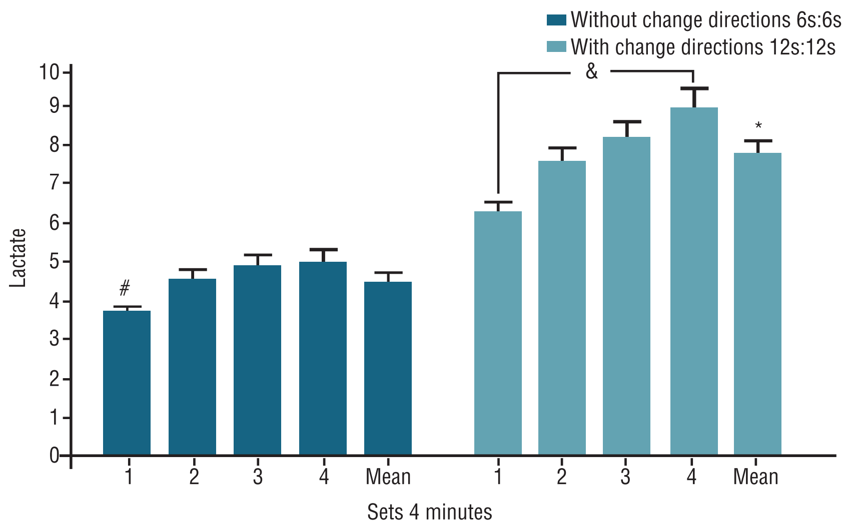

Figure 3. Blood lactate concentration during the training sets.
& = significantly different at p<0.05 in relation to all sets among them;
# = significantly different at p<0.05 in relation to sets 2, 3 and 4;
* = significantly different at p<0.05 from mean of training 6s:6s.

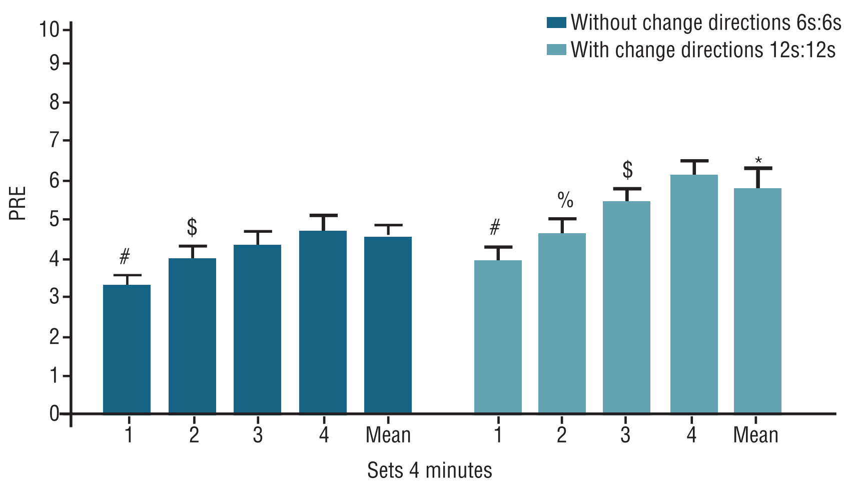

Figure 4. Rating of perceived exertion during the training sets.
= significantly different at p<0.05 in relation to sets 2, 3 and 4;
$ = significantly different at p<0.05 in relation to set 4;
% = significantly different at p<0.05 in relation sets 3 and 4;
* = significantly different at p<0.05 from mean of training 6s:6s.

DISCUSSION

This is the first study to examine the applicability of an intermittent field test (T-CAR) to prescribe training intensity in elite soccer players. The results showed that $PV_{T\text{-}CAR}$ can be used as a reference for short-interval running training to impose high cardiovascular stress (>90% HRmax) with low inter-individual differences in the HR response (i.e., low %CV). The %HRmax, lactate and RPE in 12/12 was significantly higher than (p<0.05) 6/6 condition. This results enable the coaches and physical trainers choose the players of team according to different aerobic profiles and perform the training with the groups simultaneously, using 12/12 for the players who need to increase their condition in short periods. The coefficients of variation were smaller than those found by Buchheit[23], who performed training with The University of Montreal Track Test (9.3% CV) and The 20-Meter Shuttle Run Test (10.6% CV) with young athletes, confirming the reliability of 12/12 and 6/6 training (CV 2.3 and 3.0%, respectively). When compared to training velocities based on the 30-15 Intermittent Fitness Test, the coefficients of variation were similar (3.1% CV).

Interestingly, the present study showed that the exercise intensity was significantly higher when intermittent exercise at the same relative intensity was performed with shuttle-runs compared with straight-line running. The main finding of the present study was in line with that of Dellal et al.[6] using different bout-intervals (10/10, 15/15, and 30/30s). However, in that study exercise intensity was determined with a continuous test not involving directional changes (i.e., shuttle-running). The discrepancies in energetic cost of different running modes (i.e., straight-line vs shuttle-running) was reported to be particularly higher at speeds faster than 4 $m \cdot s^{-1}$ (i.e.,13.6 $km \cdot h^{-1}$), when using short distances (<20 m)[24]. Therefore, the applicability of a shuttle-running field-test for aerobic fitness over a set distance (i.e., 20 m) to prescribe exercise using different running modes (i.e., straight-line running) over longer distances is questionable due to inherent limitations of such approach.

This study showed that by using T-CAR, the known practical limitations of fixed distance field tests can be easily avoided simply by providing individual distances to players according to their respective $PV_{T\text{-}CAR}$. The use of the same sound beeps (i.e., 6 s sound intervals) with individually based running velocities set by the distances to be covered in the same period illustrates the practical applicability of Carminatti's test for simultaneous administration to many players.

Peak velocities obtained in continuous progressive tests have been used by fitness coaches to individualize generic aerobic training[25]. However, the logic validity of this method can be questioned, as soccer involves shuttle-runs with accelerations, decelerations, changes of direction, and recovery periods[6]. Attempts to use continuous tests[26] using straight-line running to implement shuttle-runs proved to be impractical and did not provide a suitable speed to elicit aerobic-fitness enhancing training intensities[6]. On the other hand, the shuttle-run test over short distances may fail to determine suitable exercise intensities when applied to straight-line drills for aerobic fitness. Given this, adjustments in peak test speed (i.e., 15-20% higher than peak speed) were proposed in order to elicit the target exercise intensities for aerobic fitness development[27]. However, this may require a trial-and-error procedure, thus resulting in a training set-up of limited practical interest due to the laborious work required. When considering exercise intervals of 10 s (i.e., 10/10), Dellal et al.[6] showed that to elicit HR in the aerobic fitness development zone speed, using the Léger and Boucher test[26], peak speed should be increased by 20% when using shuttle-running as the exercise mode, with running distances ranging from 21 to 41 m.

Indeed, with the 4x4 min paradigm considered herein, $PV_{T\text{-}CAR}$ was shown to provide training intensities in the 90–95% of HR_{max} range, reported to induce enhancements in the aerobic fitness domain. Several studies[11,28] have suggested that interval runs at 90–95% of HR_{max} of 2-min duration or longer are effective for improving soccer players' aerobic fitness over a short period of time (4–8 weeks). The minimum of 2-min duration is thought to be necessary to overcome the metabolic and circulatory inertia at the start of the exercise[28].

In the present study, the blood lactate concentration and RPE responses were higher in the 12/12 training protocol compared to the 6/6 with ES large (2.8) and moderate (0.8), respectively. This can be explained by the characteristics of the 12/12 training that include decelerations followed by changes of direction; these physiological demand characteristics require greater participation of the different muscle groups of the lower limbs that need to perform actions in a short time, executing movements with greater contribution of the anaerobic energy system, with higher recruitment of type II fibers, typical of eccentric actions. Similar findings were found in the literature, where the actions with accelerations, decelerations, and changes of direction require more effort from the muscle groups that perform the action[29,30]HIT group (n = 8. The RPE was also greater for the 12/12 training, which was expected, since activities that require greater displacement with deceleration actions require more effort which can be perceived by the individuals[29]. Further, it is important to emphasize that the higher absolute duration of each bout of exercise in this regimen can also explain the higher demand when compared to the 6/6.

Interestingly the $PV_{T\text{-}CAR}$ interval-training drills considered in the present study were able to produce a training work-rate that was similar to that reported in the most demanding 5-min phases of a competitive match. Indeed, with this training paradigm players were able to accumulate an average distance of approximately 2200 m, corresponding to a work-rate of 137.5 $m \cdot min^{-1}$. This would lead to 688 m for a 5 min interval, a distance quite similar to the 650 m reported for the most intense phases of a competitive match in male professional soccer players during competitive matches[12]. This consideration provides further practical evidence to support $PV_{T\text{-}CAR}$ training in elite-level soccer.

The two types of training presented distinct responses with regard to physiological evaluations, biomarkers, and psychobiological responses. In order to compare the effects of the two training models used in the present study, Silva et al.[10] distributed 17 athletes into two groups and applied 6/6 training with a group of 8 athletes and 12/12 training with 9 U-20 soccer athletes and did not find statistical differences in the comparisons between the two types of training. Nevetheless, the 6/6 training, because of its straight-line characteristics, can be used in an introductory way in the training routine, given that it presents physiological responses which can induce aerobic adaptations. The 12/12 training (180° shuttle running) has the characteristics of intermittent activities with changes of direction that are movements closer to those that occur in the modality[30]HIT group (n = 8. This type of training seems to be a useful tool to elicit adaptations in anaerobic glycolysis, while implying eccentric muscular efforts, and increasing the cost of energy[29]. In this way, the use of 12/12 training presents suitable physiological responses to induce the adaptations necessary to cope with the efforts during the game. The training model is presented as a reliable tool to be used in the short periods (i.e., pre-season) and this one provide adaptations quickly, since the needs for athletes to increase their condition immediately is common, besides which, the training proposal is monitored, enabling adjusments to the necessary adaptive responses.

CONCLUSION

In conclusion, $PV_{T\text{-}CAR}$ can be considered as a viable method to prescribe high-intensity (>90%HRmax) interval training with and without changes of direction. The 6/6 can be used as an introduction to the training method and also for the maintenance of the physical condition and the 12.12 by the characteristic of changes of direction provide more stress and possibly greater adaptations in soccer players of different categories, with good accuracy and low inter-individual differences (low %CV in HR response). Therefore, these results should be of interest to coaches and sport scientists, since it is possible to individualize the high-intensity intermittent training models in players with different aerobic profiles, using the same audio cue simultaneously. The physiological and time-motion profiles resemble the most demanding phases of the match, especially for the fittest players.

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