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Assessment of critical velocity in track and treadmill: physiological profiles and relationship with 3000-meter performance

Avaliação da velocidade crítica de corrida em pista e esteira: perfis fisiológicos e relações com o desempenho em 3000 metros

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Abstract – The present study aiming to verify the interference of different conditions (treadmill vs. track) on critical velocity (CV) values, as well as on the correlation to the 3000-meter performance (v3000m), and thus infer about the specificity of each values as training parameter for this distance. Seven runners (15.3±1.4 years) were submitted to a maximal progressive test (1.0 km×h^{-1} increments per minute until exhaustion) to assess V̇O$_2$max and maximal aerobic velocity (vV̇O$_2$max). Subsequently, CV was estimated from three running performances at each test condition, with exercise intensities adjusted for different time limits (t_{Lim}) at 900, 2100 and 3300 meters in track or at 90, 95 and 115% of vV̇O$_2$max in treadmill. From linear adjustments, using stepwise method, CV was assessed on treadmill ($CV_{TREADMILL}$) and track (CV_{TRACK}), and both compared by the Mann-Whitney test. The sample-adjusted dispersion coefficient (R^2_{adj}) analyzed the variance of v3000m with CV_{TRACK}, $CV_{TREADMILL}$ and vV̇O$_2$max. In all analyses, significance was set at P≤0.05. In progressive test, V̇O$_2$max reached 54.2±5.2 mLO$_2$×kg^{-1}×min^{-1} and vV̇O$_2$max reached 16.8±1.9 km×h^{-1}. No differences were observed between $CV_{TREADMILL}$ and CV_{TRACK} (14.0±1.8 vs. 12.3±3.2 km×h^{-1}, P=0.46). Correlations were observed for v3000m with $CV_{TREADMILL}$ (R^2_{adj} ~0.94), CV_{TRACK} (R^2_{adj} ~0.99) and vV̇O$_2$max (R^2_{adj} ~0.90), all showing P=0.001. It could be concluded that no influence was observe on the ability to achieve identical CV values from different assessment conditions. The correlation to the v3000 meters suggested better specificity of CV_{TRACK} than $CV_{TREADMILL}$ for training prescription and performance control.

Key words: Athletic performance; Exercise test; Exercise tolerance; Oxygen uptake; Track and field.

Resumo – *O presente estudo averiguou se as diferenças nas circunstâncias (esteira vs. pista) de avaliação da velocidade crítica (VC) interferem no valor e na relação com a desempenho em 3000 metros (v3000m) e, assim, indicar a especificidade de cada valor como parâmetro de treinamento para esta distância. Sete corredores (15,3±1,4 anos) submeteram-se a um teste progressivo máximo (incrementos de 1,0 km×h^{-1}×min^{-1}, até a exaustão) para avaliação do VO$_2$max e velocidade aeróbia máxima (vVO$_2$max). A seguir, a VC foi estimada a partir do desempenho de corrida em três diferentes intensidades do exercício, em cada ambiente de avaliação, registrando-se o tempo-limite (t_{Lim}) nas distâncias de 900, 2100 e 3300 metros na pista, e à 90, 95 e 115% vVO$_2$max em esteira. Ajustes lineares, pelo método "stepwise", forneceram os parâmetros VC em esteira ($VC_{ESTEIRA}$) e pista (VC_{PISTA}), que foram comparados pelo teste de Mann-Whitney. O coeficiente de dispersão ajustado à amostra (R^2_{aj}) averiguou a variância de v3000m com VC_{PISTA}, $VC_{ESTEIRA}$ e vVO$_2$max. Em todas as análises adotou-se P≤0,05. No teste progressivo, o VO$_2$max atingiu 54,2±5,2 mLO$_2$·kg^{-1}·min^{-1} e a vVO$_2$max foi 16,8±1,9 km×h^{-1}. Não se observaram diferenças entre $VC_{ESTEIRA}$ e VC_{PISTA} (14,0±1,8 vs. 12,3±3,2 km·h^{-1}, P=0,46). Houveram correlações entre v3000m com $VC_{ESTEIRA}$ (R^2_{aj}~0,94), VC_{PISTA} (R^2_{aj}~0,99) e vVO$_2$max (R^2_{aj}~0,90), todas com P=0,001. Conclui-se que o contexto de avaliação não interfere na consistência do valor de VC. Porém, quanto à relação com v3000 metros, a VC_{PISTA} apresenta melhor especificidade, tornando-a mais autêntica que $VC_{ESTEIRA}$ para a prescrição do treino e monitoramento do desempenho.*

Palavras-chave: *Atletismo; Consumo de oxigênio; Desempenho atlético; Teste de esforço; Tolerância ao exercício.*

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INTRODUCTION

During efforts at distances with time limit (t_{Lim}) between 10 and 15 minutes, such as 3000 meters, the performance-determining physiological scenario is characterized by higher metabolic rate, which can be sustained without the early disturbance of muscular and blood homeostasis in relation to the high blood lactate levels ([La^-]) and the continuous increase in the $\dot{V}O_2$ response[1,2,3]. This metabolic profile typifies the border between the heavy and severe exercise domain, which has been parameterized in running by critical velocity (CV)[3]; above which the exercise is (in) tolerable for a period of time dependent on the demand intensification on non-O_2-dependent metabolic pathways (e.g., on *D'*)[1,3].

However, CV and *D'* evaluation involves a mathematical description by linear or hyperbolic adjustments between exercise intensity and time limit[3,4]; and dependent on variability associated with the protocol (e.g., at least 3 efforts, with time limit of 2-15 minutes, and 5 viable adjustment equations)[2,4]. Another relevant aspect is the specificity of the test condition, which, despite representing the everyday life of athletes (e.g., track in which training is developed), implies the adequacy of the time limit model standardized treadmill, mainly regarding the adjustment and control of exercise intensity. Thus, if on the one hand, CV evaluation in controlled environments (laboratory) allows questioning about the transfer of this training parameter to ("in loco") daily practice conditions[5-8]; on the other hand, the possibility of interferences in the reproduction of the CV protocol in track, such as speed oscillation and running economy[9], compromise t_{Lim} and, thus, the CV evaluation authenticity.

In spite of these particularities, metabolic similarities has been observed between track and treadmill running for the running intensity between 10.5 and 18.0 km·h^{-1}, as described by Jones and Doust[6]. This similarities allowed the reproduction of the speed-time model (v-1/t_{Lim}, which is analogous to the time limit model) in track, whose estimated CV value (292.9 ± 20.8 m·min^{-1}) (299.5 ± 19.8 m·min^{-1}) allowed authors such as Kranemburg and Smith[8] to conclude that, among trained runners, track and treadmill performance conditions provide reciprocal exhaustion times and, therefore, the CV diagnosis in track maintains the authenticity of the original treadmill estimation. Additionally, Simões et al.[10] analyzed the consistency of CV determination in track and observing the absence of difference when estimating it by different linear models (d-t_{Lim} and v-1/t_{Lim}) and different t_{Lim} combinations in the predictive efforts. Their results also showed that the CV values in track correlated with velocity corresponding to the minimum lactate threshold (vlm) (r = 0.96) and to velocity at 3000 meters (v3000m) (r = 0.995), although v3000m characterized running intensity significantly higher than both, also because vlm and CV stood at ~92% and ~96% respectively of v3000m. However, CV evaluated on treadmill has also shown the propensity to index running performance, given the correlations evidenced both with short-distance performance capacity indexes, as the maximum oxygen uptake ($\dot{V}O_2max$, r = 0.51 – 0.70) and its occurrence rate ($v\dot{V}O_2max$, r = 0.64 – 0.86), as well as with long-term performance indexes, such as velocity corresponding to the lactate threshold by fixed concentration of 4.0 $mmol·L^{-1}$ (OBLA, r = 0.66 – 0.73)[11,12,13]. These correlations reveal an ambiguity in the representation and application of CV, but also reveal that CV evaluation is not affected by the difference running conditions (treadmill *vs*. track) and has validity when representing physiological indexes of medium- and long-duration exercises, as those described above.

However, the theoretical information is still inconclusive about the influence of the running condition (treadmill *vs*. track) on the potential of correlation between CV and medium-distance performance (as v3000m) and the applicability of each value obtained as training parameter. This is because studies carried out on treadmill and track have sometimes been concerned with the physiological significance of CV evaluations, presenting their correlations with aerobic fitness parameters[8], sometimes describe the relationships between CV and running performance at medium[10] or long distances[11], using CV evaluations obtained in single contexts, such as track[10] and treadmill[11]. Therefore, the question whether CV evaluation context is influenced by the specificity of the environment (track) or the evaluation accuracy (treadmill), regarding the propensity of this parameter in indexing the running performance, it stills remains without a definitive answer. In addressing this issue, there is a need to gather methodological (compatibility between assessment procedures), conceptual (to contextualize its physiological meaning by similarity with other demand parameters and metabolic nature in exercise) and application information (relationships with running performance in a specific domain of exercise intensity).

Thus, the aim was to analyze the adequacy of the CV evaluation protocol in track against the gold standard of treadmill determination, considering the possibility of clarifying if there are differences in the exhaustion time and blood lactate response, when comparing the CV predictive running performances, as well as, if differences, once verified, alter the mathematical adjustment of the CV evaluation model to the point of interfering in the specificity of its theoretical application: to index performance of middle and long distances. The thematic focus on the 3000-meter performance is related, in the present study, to the population analyzed, since this distance is the maximum allowed in national competitions for the age group investigated.

METHODOLOGICAL PROCEDURES

Seven athletes (15.3 ± 1.4 years, 1.7 ± 0.1 m, and 59.2 ± 13.2 kg), who returned the consent form aware of the procedures signed by parents/guardians, participated in the present study. This is an occasionally sample, given the lack of running training circumstances involving adolescents that met the training specificity (middle distance), training time (minimum one year with daily routine), sex and age group. All participants performed (1) progressive test (ramp type) for $\dot{V}O_2max$ and $v\dot{V}O_2max$[14] evaluation; (2) performance tests on track delimited by medium distances for CV track evaluation (CV_{TRACK})[12]; and (3) constant tests up to the limit of tolerance at running intensity around $v\dot{V}O_2max$ for CV treadmill evaluation ($CV_{TREADMILL}$)[4]. A minimum interval of 24h and a maximum of 48h were established between progressive test and CV determination tests, as well as between each predictive effort on track and treadmill. Track tests were carried out on a 300-meter open track (pressed charcoal floor), always at the same time of day and prior to the training session. Subjects were instructed to avoid exhaustive workouts, alcoholic and caffeinated beverages the day before the evaluation, as well as attending fed and hydrated. The present study was approved by the Local Ethics Committee (FC - UNESP / Bauru) and registered under CAAE protocol 02589012.3.0000.5398.

Maximum Progressive Test

During the progressive test, the slope was maintained at 1.0%[6] and the speed progressed 1.0 $km \cdot h^{-1} \cdot min^{-1}$ from 7.0 $km \cdot h^{-1}$ until exhaustion on treadmill model HP/Cosmos Pulsar (Nussdorf-Traunstein, Germany). $\dot{V}O_2$ was measured breath-to-breath throughout the test by an automated unit (QuarkPFTergo, Cosmed, Rome, Italy). System calibration was performed prior to each test as instructed by the manufacturer. $\dot{V}O_2$ values were smoothed by three-second filter and averaged at each six-second interval. $[La^-]$ was analyzed at rest and in the first minute after the end of the test. Lactate concentration analysis was performed using the enzymatic method (YSL 2500STAT, Yellow Spring, Colorado) using arterial blood samplings.

$\dot{V}O_2max$ was considered the highest 30s average value. The $v\dot{V}O_2max$ was considered the slowest velocity that projected $\dot{V}O_2$ to the maximum. The gas exchange threshold (GET) was determined according to recommendations of Whipp[14], by the $\dot{V}_E \cdot \dot{V}CO_2^{-1}$, $\dot{V}_E \cdot \dot{V}O_2^{-1}$, $P_{ET}CO_2$ and $P_{ET}O_2$ responses, observing the increase in $\dot{V}_E \cdot \dot{V}O_2^{-1}$ and $P_{ET}O_2$ curves without alteration in $\dot{V}_E \cdot \dot{V}CO_2^{-1}$ and $P_{ET}CO_2$ response. GET and $\dot{V}O_2max$ evaluations were performed by two or three experienced researchers, independently. In determining the velocity corresponding to GET (vGET) and $\dot{V}O_2max$ ($v\dot{V}O_2max$), mean response time (MRT) of 40 seconds was considered[15]. The calculation of v50%Δ was performed based on the difference between vGET and $v\dot{V}O_2max$[9,15]. This parameter is also considered a reference of the threshold exercise intensity between the heavy/severe domains[1,15].

Critical velocity (CV) assessment on track and treadmill

Predictive CV efforts in track (900, 2100, 3300 meters) and treadmill (90%, 95% and 115% $v\dot{V}O_2max$) were performed in a random manner, with minimum intervals of 24h, whose track distances and treadmill running intensity were adopted according to recommendations of Kranenburg; Smith[8] and Bull et al.[4], respectively. The time limit (t_{Lim}) was recorded in seconds and the velocity and t_{Lim} values were adjusted by v-t_{Lim}^{-1} and d-t_{Lim} models, according to Equations 1 and 2, using standard error of estimate (SEE) as a criterion for choosing the CV value for each participant[4,13].

$$v = D' \times \frac{1}{(t)} + VC \quad [1]$$

$$d = D' \times t + VC \quad [2]$$

where: "v" = running speed; "D" = amount of work with anaerobic resources; "t" = is the t_{Lim} of predictive efforts and "CV" = is the critical velocity in track (CV_{TRACK}) or treadmill ($CV_{TREADMILL}$). [La^-] was also analyzed at rest and at the first minute after the end of each track and treadmill running performance.

3000-meter test

The 3000-meter performance was carried out on a 300-meter track where athletes routinely trained. The time to complete the 3000 meters was determined by the sum of the 300-meter partials and used to calculate the average speed (v3000m).

Exercise intensity

Relative oxidative demand (%$\dot{V}O_2$max) and relative effort intensity (%v$\dot{V}O_2$max) were determined for CV_{TRACK}, $CV_{TREADMILL}$, v300m and v50%Δ. The proportional relationship between velocities of these parameters and the maximum aerobic velocity (% v$\dot{V}O_2$max) were determined by the percentage variation. Oxidative demand ($\dot{V}O_2$) at each velocity was determined by linear trend analysis of the individual velocity and $\dot{V}O_2$ responses during the incremental test and by the percentage variation of values obtained with $\dot{V}O_2$max[16].

Statistical analysis

Data were expressed as mean ± SD. Differences between CV and D' on treadmill and track were verified by the Mann-Whitney Test (U) and time-limit differences (t_{Lim}) between track and treadmill predictive efforts were analyzed by the Wilcoxon Test. Analysis of variance and concordance between track and treadmill CV were performed by the dispersion coefficient (R^2), standard error of estimation (SEE) and by Bland-Altman[17]. The sample power regarding the linear correlation coefficient was determined by Equation 3.

$$Z_{1-\beta} = \sqrt{n-3}\,\frac{1}{2}Ln\left(\frac{1+r}{1-r}\right) - Z_{1-\alpha/2} \quad [3]$$

where $Z_{1-\beta}$ provides the coefficient for the determination of the sample power by the normal two-tailed distribution of its value and "r" is the Pearson linear coefficient among variables[18]. The correlations of v3000m with CV (treadmill and track), v$\dot{V}O_2$max and $\dot{V}O_2$max were determined by the adjusted dispersion coefficient (R^2_{adj}) for participant sampling (N) and dependent variables (k). The "least squares" method was used in all simple linear adjustment procedures. In all analyses, P≤0.05 was used. Statistical procedures were performed in SPSS 24⁰ software (IBM, Chigado, IL, USA).

RESULTS

The maximum values obtained in the progressive test were: 54.2 ± 5.2 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ and 16.8 ± 1.9 $km \cdot h^{-1}$, corresponding to $\dot{V}O_2$max and v$\dot{V}O_2$max, respectively. CV evaluation presented SEE <5%, regardless of evaluation environment (treadmill vs. track) and adjustment model (Figure 1). The mean SEE associated with $CV_{TREADMILL}$ assessment was 0.30 ± 0.14 m^{-1} (2.1 ± 1.0%), while CV_{TRACK} reached 0.58 ± 0.33 m^{-1} (4.9 ± 2.9%). For the D' parameter, SEE on treadmill was 14.8 ± 5.9 m (11.9 ± 5.1%) and in track, value was equivalent to 66.6 ± 58.3 m (30.4 ± 23.6%). No differences were observed when comparing $CV_{TREADMILL}$ and CV_{TRACK}: 14.0 ± 1.8 vs. 12.3 ± 3.2 $km{\cdot}h^{-1}$ (P = 0.46). No differences were observed when comparing the anaerobic reserve parameter (D') in treadmill and track: 137.1 ± 22.5 m vs. 267.9 ±115.4 m (P = 0.07). When analyzing the distance-limit model (d_{Lim}) on the track and comparing it to the time-limit model (t_{Lim}) applied on treadmill, Table 1 highlights differences only in terms of the t_{Lim} of the highest intensity predictor (115% $vV{\cdot}O_2max$ vs. 900 m), but in the other predictors, t_{Lim} did not present differences between protocol application environments.

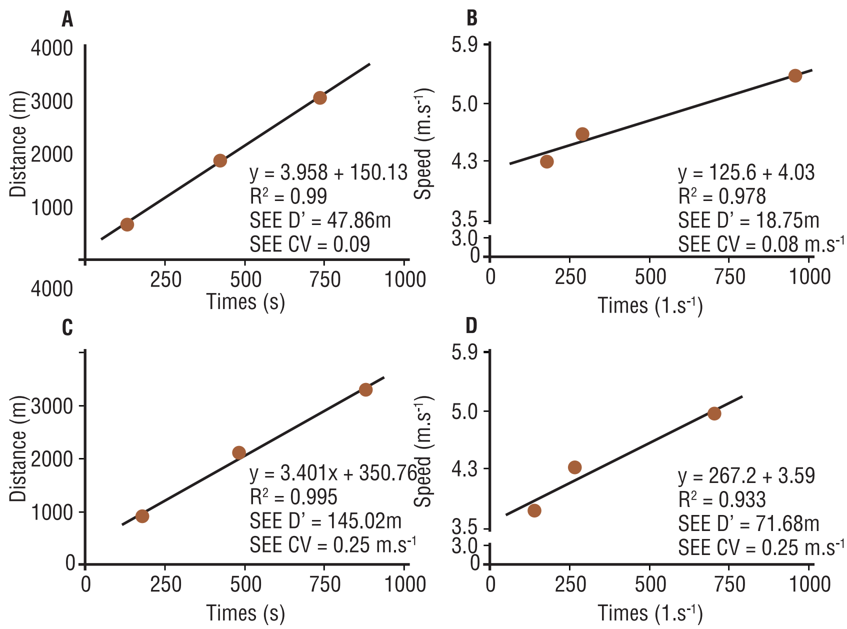

Figure 1. CV determination by the d-tLim and v^{-1}/tLim models, presenting SEE of the adjustment on treadmill (Panels A and B) and track (Panels C and D) as a criterion for selecting values for a runner (subject 7: $V{\cdot}O_2max$ = 60.25 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$).

Table 1. Mean tLim values of and physiological response during CV prediction efforts in treadmill and track.

	t_{Lim} (s)	Final HR (bpm)	Final [La] ($mmol{\cdot}L^{-1}$)
		Treadmill (%$vV{\cdot}O_2max$)	
90%	817.9 ± 170.3	192.3 ± 7.8	9.5 ± 2.5
95%	469.0 ± 45.0	201.6 ± 8.7	12.8 ± 4.6
115%	119.7 ± 36.8*	204.3 ± 10.6	10.9 ± 3.7
		Track (meters)	
3300	943.6 ± 218.1	206.6 ± 10.4	13.4 ± 5.6
2100	555.0 ± 123.5	206.9 ± 13.8	11.7 ± 4.1
900	189.0 ± 19.7*	197.7 ± 10.9	12.7 ± 1.5

Note. *Significant difference at P ≤ 0.05 between predictions in 900-m track and treadmill at 115% $vV{\cdot}O_2max$.

The exercise intensity contextualized by the oxidative demand in $\%\dot{V}O_2max$ and effort in $\%v\dot{V}O_2max$ differs between $CV_{TREADMILL}$ and CV_{TRACK} (P = 0.03 and P = 0.02) and between CV_{TRACK} and v50%Δ (13.7 ± 1.6 $km{\cdot}h^{-1}$) (P = 0.04 and P = 0.01) when comparing them respectively by both parameters (Figure 2). It was also verified by Figure 2 that v3000m does not characterize exercise different from $CV_{TREADMILL}$ and CV_{TRACK} and v50%Δ, either when comparing them respectively by $\%\dot{V}O_2max$ (P = 0.23, P = 0.29, P = 0.15), or by $\%v\dot{V}O_2max$ (P = 0.18, P = 0.27, P = 0.47).

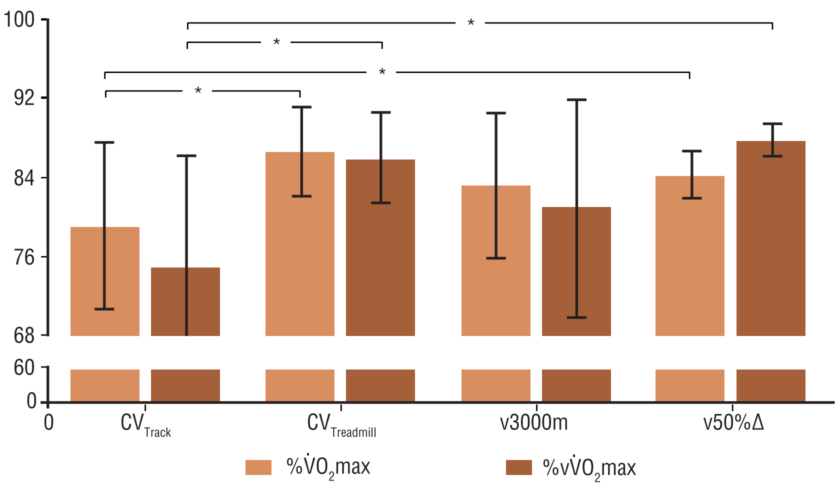

Figure 2. Comparison between oxidative demands (%V̇O2max) and running intensity (%vV̇O2max) corresponding to CV (track and treadmill), to v3000m (performance velocity at middle distances) and v50%Δ (corresponding to 14.2 ± 1.6 km×h-1). * Significant difference at P ≤ 0.05.

There was concordance between $CV_{TREADMILL}$ and CV_{TRACK} values (Figure 3A and 3B), with 87% of variance in the treadmill evaluation associated to values determined in track and constant error of ~1.6 $km{\cdot}h^{-1}$. The sampling power (n = 7) for the association between $CV_{TREADMILL}$ and CV_{TRACK} values was calculated in 94.3%, for safety level of 80% (Z_1-α/$_2$ =1.282) and Pearson's coefficient r = 0.943.

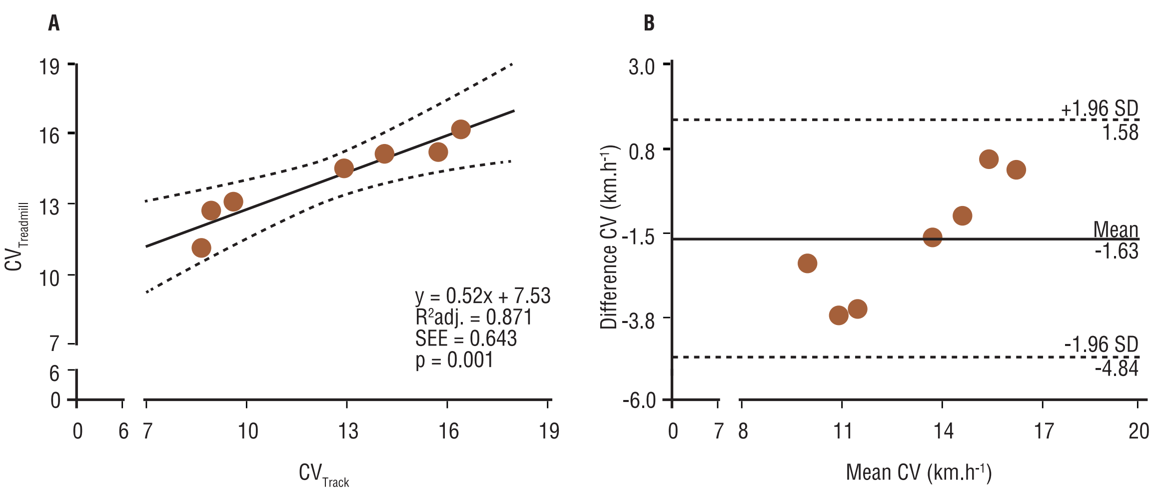

Figure 3. Dispersion analysis (Panel A) and Bland-Altman agreement (Panel B) between CV values (km·h-1) determined in track and treadmill.

High association between v3000m with $CV_{TREADMILL}$, CV_{TRACK} and $v\dot{V}O_2max$ was observed, but the association between v3000m and $\dot{V}O_2max$ was not significant (Figure 4). The sample power (n = 7) for statistically significant associations was calculated as 99.9% (Z_{1-b}=4.03), 99.3% (Z_{1-b}=2.48) and 96.7% (Z_{1-b}=1.84), respectively to ensure confidentiality of relationships between v3000m vs. CV_{TRACK}, v3000m vs. $CV_{TREADMILL}$ and v3000m vs. $v\dot{V}O_2max$. In these calculations, safety level of 80% (Z_1-$\alpha/_2$ = 1.282) was adopted, with Pearson coefficients r = 0.99, r = 0.98 and r = 0.96, respectively.

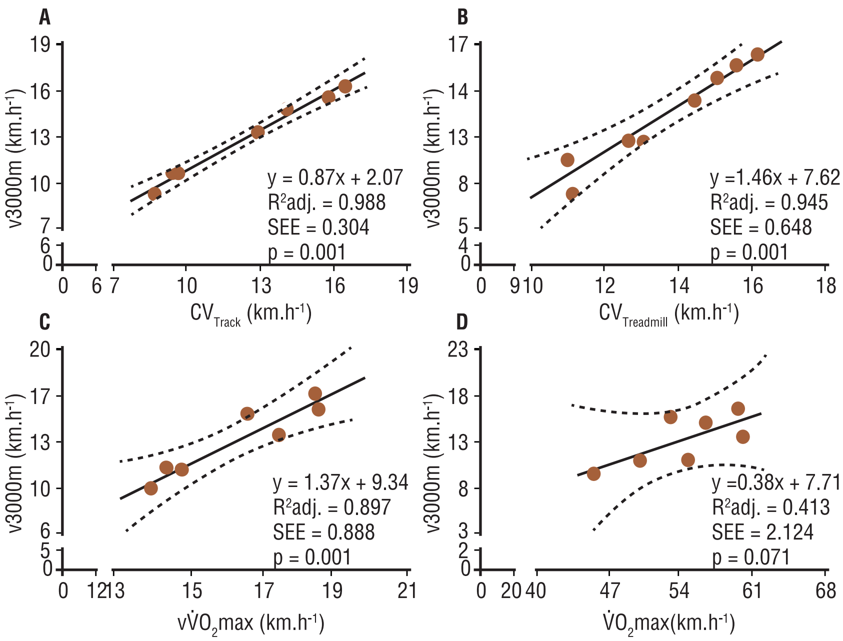

Figure 4. Dispersion analysis between v3000m and CV_{TRACK} values (Panel A), $CV_{TREADMILL}$ (Panel B), $v\dot{V}O_2max$ (Panel C) and $\dot{V}O_2max$ (Panel D)

DISCUSSION

When estimating CV in different environments, no differences were found between absolute velocity values on track and treadmill, but the exercise conditions differed when characterized by aerobic demand (%$\dot{V}O_2max$) or running intensity (%$v\dot{V}O_2max$). Thus, it was not possible to accept the hypothesis that the evaluation environment would provide indiscriminately reciprocal CV values. In addition, CV values are mutually consistent, corroborating the results observed by Kranemburg and Smith[8], who did not find differences between CV values among young runners. The results also corroborated those obtained by Galbraith et al.[19], whose laboratory CV value (4.05 ± 0.22 $m{\cdot}s^{-1}$) did not differ from that obtained in track (4.07 ± 0.28 $m{\cdot}s^{-1}$) with fixed d_{Lim} predictions (3600, 2400 and 1200 meters). Therefore, it was concluded that the environment does not interfere with the CV value or in the protocol, since predictions in treadmill based on %$\dot{V}O_2max$ are compatible with predictions in track based on the t_{Lim} by fixed distances.

In cycling, a sporting modality in which contextual interferences were verified during the application of the time-limit model, there are indications that the laboratory performance does not ecologically reproduce some elements present in track, such as familiarity with the competition environment and equipment, providing critical power evaluations (CP, analogous to CV), with low transfer to the training and competition context. In fact, when comparing the oxidative demand ($\dot{V}O_2$) in the cycle ergometer (laboratory) and track cycling in similar power (78% $\dot{V}O_2$max), efficiency and economy were higher on track (~ 12% and 11%, respectively), regardless of terrain slope or pedal cadence[20]. This difference supported the conclusion that tolerance is lower during exercise in the severe field in cycle ergometer (laboratory), influencing changes in the result of the mathematical model and, therefore, in the CP values (adjustment slope) and W '(adjustment intercept). However, Karsten et al.[21] and Triska et al.[22] could not confirm the existence of differences between CP values assessed in different contexts. For Karsten et al.[21], even differences observed for t_{Lim}, final [La-] and pedal power during velodrome (3, 7 and 12 min) and laboratory (80, 100 and 105% i$\dot{V}O_2$max) were determinant to change the CP value, even analyzing it by different linear adjustments (W-t_{Lim} and W-1/t_{Lim}) in velodrome (234.0±24.4 vs. 235.0±24.1 W) and laboratory (234.0 ± 25.5 vs. 236.0 ± 29.1 W). In the study by Triska et al.[22], the evaluation of CP in laboratory and field conditions provided similar values (280W vs. 281W, respectively); however, the authors warned against reciprocal use due to the high variability of ~7% (95% CI: -55 to 50W) in the CP evaluation between contexts. In the present study, it was observed that many of the information described for cycling apply to track and treadmill running conditions.

Regarding the reproduction of the CV evaluation protocol on track, young runners presented exhaustion times of approximately 3, 9 and 15 minutes for the 900, 2100 and 3300 meter distances, similar to exhaustion times of 3, 7 and 12 minutes observed by Triska et al.[13], as well as by Galbraith et al.[19] for distances of 1200, 2400 and 3600 meters. Although a clear difference in running velocity (by associating distance and time among studies), which may have occurred due to differences in age, experience and training status in the population analyzed by Galbraith et al.[19], the quality of reproduction of the CV protocol on track is verified, regardless of age, and also, as already noted by Nimmerichter et al.[23], regardless of training status.

Regarding the comparison between CV evaluation protocols performed in track and treadmill, highly correlated exhaustion time values have been reported ($r = 0.89$ to 0.94, $P < 0.01$)[19]. However, as in the cycling evaluation, the present study found the occurrence of a trend of reduction in treadmill exhaustion time when compared to track, which could not be statistically demonstrated by comparing duration or by heart rate and blood lactate responses at each protocol performance. This trend, confirmed only for higher intensity performances between track and treadmill protocols, can be explained by the difficulty in elaborating paired protocols regarding the distance and exhaustion time between track and treadmill contexts[19]. Another possible explanation would be the running cost (C) which, since it is inversely related to running speed, provides higher demand on the $\dot{V}O_2$ fraction used with the increase in velocity achieved[24,25]. However, since "C" is relatively constant (= 3.8 to 3.9 $J \times m^{-1} \times kg^{-1}$) for distances between 800 and 5000 meters, the aerobic contribution would also be constant (27.1 $W \times kg^{-1}$ or ~2.87 $mLO_2 \times kg^{-1} \times min^{-1}$)[25], which could explain differences between track and treadmill protocols in case of time and duration discrepancies, such as higher speed performance. In addition, for being aerobic demand able to project $\dot{V}O_2$ to maximum and provide exhaustion as the anaerobic reserve is exhausted, which is the fundamental principle of the CV evaluation protocol[1,9], it could be assumed that the mechanical adjustments, which contextualize running on an accelerated carpet as a task distinct from that of accelerating the body itself on the track[26], interfere with the efficiency of converting metabolic energy into kinetic energy and thus change "C"[25], precipitating treadmill exhaustion by increasing anaerobic resources depletion rate.

However, it is emphasized that this difference in treadmill exhaustion time is not able to change the mathematical adjustment between distance vs. time or velocity vs. distance to the point where the CV value differs from that evaluated on the track, but justifies the prediction of relative $\dot{V}O_2$ demand greater for CV performance on treadmill. Therefore, it is possible to question the environmental ecology of the CV evaluation on treadmill, but in doing so, its application as a reference of running intensity transferable to the control of high-intensity aerobic training on track is also questioned. On the other hand, it could be assumed that the CV evaluation on track underestimates the maximum intensity reference, above which tolerance during exercise is compromised by metabolic acidosis, since the reference standard is designed for treadmill[1,4,9]. In the present study, the relationship with 3000-meter performance was elevated for CV in both protocols (treadmill and track), as well as with $v\dot{V}O_2max$. However, CV_{TRACK} was strongly associated (~99%) to the v3000m variation, and also $CV_{TREADMILL}$ and $v\dot{V}O_2max$, but with lower explanatory potentials (~94% and ~89%, respectively). This result can be explained by the environmental specificity, which tends to provide aerobic evaluation parameters with greater associative potential with time, or performance velocity, as the highest $v\dot{V}O_2max$ associations in track (78% and 66%, respectively), compared to $v\dot{V}O_2max$ associations in treadmill (62% and 35%, respectively) with performance at 1500 m (t_{Lim}: 4.8 ± 0.2 min) and 5000 m (t_{Lim}: 18.2 ± 0.8 min)[27]. However, for Busso and Chatagnon[28], an aerobic capacity indicator becomes relevant to estimate the performance in medium distances as the performance time is close to 10 minutes.

Thus, the association between CV and 3000-meter performance seems to be dependent on both the specificity of the assessment context and the running time for this distance. In the study by Grant et al.[29], adult runners with $\dot{V}O_2max$ ~73 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ and 3000-meter performance of ~584 s presented velocities corresponding to lactate thresholds (above rest and set at 4 mmol×L^{-1}), more associated with v3000m in greater magnitude (r = 0.93 for both) than to $v\dot{V}O_2max$ (r = 0.86). Another study addressing 5000- meter performance determinants found that time (~19 min and 36 s) and velocity (4.29 m×s^{-1} or ~15.4 km×h^{-1}) were more strongly associated to CV (v-1×t_{Lim}^{-1}: r = -0.77 and 0.78, respectively), than to $v\dot{V}O_2max$ (r = -0.71 and 0.74, respectively) among adult runners with moderately high fitness level ($\dot{V}O_2max$ = 63.6 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$)[30]. In the present study, involving young runners still in the formation process ($\dot{V}O_2max$ = 54.2 ± 5.2 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ and with t_{Lim} in 3000 meters of ~14 min and 31s), it is evident the potential of an aerobic capacity parameter (in this case CV) to index the medium-duration performance.

The limitation of the present study refers to the reduced number of efforts to predict CV that generated high SEE for the D' on track. Above all, the implications of the present study are restricted to the age group and training status of participating runners. However, future studies should verify the similarity between laboratory vs. field environments in runners of different age groups and training status.

CONCLUSION

The results indicated that CV determined on track is a reliable parameter of exercise in the heavy domain (e.g., exercise reference with high oxidative activation rate, without requiring continuous loss of metabolic homeostasis), easy to apply and reduced cost, which can be used by coaches and athletes for evaluation, prescription and monitoring of training, as well as for the prediction of middle-distance performance in young runners, thus demonstrating the ecological validity of this evaluation.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee –FC – UNESP/Bauru, and the protocol was written in accordance with standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

DAM, BSD and DMPF conceived and designed the experiments. DAM, RAC, LOCS and ARS performed the experiments. DAM RAC, LOCS, ARS and DMPF analyzed data. BSD and DMPF contributed with reagents/materials/analysis tools. DAM, RAC, BSD and DMPF wrote the paper.

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