Peak running velocity predicts 5-km running performance in untrained men and women

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Received: 12.07.2018
Accepted: 02.01.2019

Summary

Objective: The aim of the present study was to examine the relationship between 5-km running performance and peak running velocity (V_{peak}) in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}.
Methods: Fifty young and untrained participants (20 female and 30 male) aged between 20 and 35 years participated in this study. Firstly, they performed a continuous incremental test on treadmill to determine V_{peak}; the second test was a 5-km running performance performed in 400 m outdoor track. V_{peak} test started with a velocity of 8 km•h^{-1} and increased by 1 km•h^{-1} between each successive 3-minute stage until participants reached volitional exhaustion. The 5-km time trial running performance for each participant were recorded and registered by the evaluator to determine the test duration (t_{5km}). The comparisons between female and male were performed using Student´s *t* test for independent samples; the relationship between V_{peak} and 5km running performance was examined using Pearson correlation coefficient (r), adjusted coefficient of determination (R^2) and standard error of estimate (SEE). Simple linear regression analyses were used to generate predictive equations for t_{5km} from V_{peak}.
Results: The V_{peak} and 5-km performance (t_{5km} and M_{V5km}) were significant higher for the male group compared to the female group ($P < 0.001$). In addition, both female and male presented high correlations values for the association between V_{peak} and t_{5km}.
Conclusion: V_{peak} is a good predictor of 5-km endurance running performance in untrained men and women. In practical application, V_{peak} could be used to prescribe and control running training in beginners in running practice.

Key words:
Exercise test. Peak treadmill velocity. Performance prediction. Time trial. Untrained runners. Sex difference.

La velocidad máxima predice el rendimiento en la prueba de 5 km en hombres y mujeres no entrenados

Resumen

Objetivo: El objetivo del presente estudio fue examinar la relación entre el rendimiento en la carrera de 5 km y la velocidad máxima (V_{peak}) en hombres y mujeres no entrenados y proponer ecuaciones específicas de acuerdo con el sexo para la predicción del rendimiento basada en la V_{peak}.
Métodos: Cincuenta participantes jóvenes y no entrenados (20 mujeres y 30 hombres) con edades comprendidas entre 20 y 35 años participaron en este estudio. Primero, realizaron una prueba incremental continua en la cinta rodante para determinar la V_{peak}; la segunda prueba fue una prueba de 5 km realizada en una pista de 400 m al aire libre. La prueba para determinar la V_{peak} comenzó con una velocidad de 8 km·h^{-1} y aumentó en 1 km·h^{-1} entre cada etapa sucesiva de 3 minutos hasta que los participantes alcanzaron el agotamiento volitivo. El rendimiento de cada participante fue registrado por el evaluador para determinar la duración de la prueba (t_{5km}). Las comparaciones entre mujeres y hombres se realizaron utilizando el Student's *t* test para muestras independientes; la relación entre V_{peak} y el rendimiento en la prueba de 5 km se examinó utilizando el coeficiente de correlación de Pearson (r), el coeficiente de determinación ajustado (R^2) y el error estándar de estimación (SEE). Se utiliza el análisis de regresión lineal simple para generar ecuaciones predictivas para t_{5km} desde la V_{peak}.
Resultados: V_{peak} y 5-km (t_{5km} y M_{V5km}) fueron significativamente mayores para el grupo masculino en comparación con el grupo femenino (P <0.001). Además, tanto hombres como mujeres presentaron altos valores de correlaciones para la asociación entre V_{peak} y t_{5km}.
Conclusión: V_{peak} es una buena predictora del rendimiento em la prueba de 5-km en hombres y mujeres no entrenados. En la aplicación práctica, V_{peak} puede utilizarse para prescribir y controlar el entrenamiento de carrera en principiantes en la práctica de correr.

Palabras clave:
Prueba de ejercicio. Velocidad máxima en la cinta rodante. Predicción del rendimiento. Prueba de 5.000 m. Principiantes en la práctica de correr. Diferencias entre sexos.

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Introduction

Peak running velocity (V_{peak}) is the highest velocity attained during a maximal incremental test that reflects the maximal aerobic speed and an important advantage in using this variable is that its determination does not depend on highly expensive equipment, such as gas analyzers[1-3]. V_{peak} is related to the speed associated with VO_{2max} (vVO_{2max})[3] and has been considered one of the most useful aerobic indices for running training prescription, with various application in different models of aerobic training sessions[4,5].

Previous studies demonstrated that V_{peak} is a good predictor of endurance running performance, in which high correlation values were found between V_{peak} and 5-km, 10-km, and 1-h time trials[1-3,6]. It is important to emphasize that V_{peak} is also a great tool for practical application[4,5], and its use ranges from submaximal continuous training (*e.g.,* light-intensity continuous training, moderate-intensity continuous training)[7], high-intensity interval training at V_{peak} (also known as long high-intensity interval trainings)[5] to supramaximal (*i.e.,* above V_{peak}) interval training (also known as short high-intensity interval training)[8].

However, these previous studies evaluated a specific sample of recreational[1-3,6] or trained runners[4], and the relationship between V_{peak} and endurance running performance in untrained individuals was unknown. More participants (including subjects not engaged in systematic running training programs) have been investigated for endurance running races[9], and as these numbers increase, the need for tools with great practical application also increases. Given its extremely low cost of determination[1-3] and high correlation with performance[1], V_{peak} has gained attention of being this potential tool. It may become a better option to individualize and optimize training outcomes and race performance, as results related to training application were highly positive[3,4,7]. Furthermore, in the majority of studies, only male runners were evaluated, and data on female participants are scarce. Sex-related differences in physical performance should be taken into account, given that men consistently present greater endurance performance than women of the same training level[10,11].

Given this, both performance level and differences between sexes may influence the prediction equation of running performance based on V_{peak}, which reinforces the need for reporting sex-specific equations in the same study with similar sample training level and procedures to determine exercise tests. Thus, we aimed to examine the relationship between 5-km running performance and V_{peak} in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}. Our hypothesis is that 5-km running performance is highly associated with V_{peak} in untrained men and women.

Material and method

Participants

Fifty young and untrained participants (20 female and 30 male) aged between 20 and 35 years participated in this study. We considered untrained runners as those who had never engaged in a systematic running training program (*i.e.,* with a coach, specific tests and individualized running training prescription). Volunteers were excluded if they use regular pharmacological agents or nutritional supplements; were smoking or have diabetes, hypertension, asthma, and/or present any cardiovascular disorder; have a body mass index ≥ 30 $kg \cdot m^{-2}$; and were engaged in systematic running training. Prior to testing, written informed consent was obtained from all participants and all procedures and test protocols were explained individually for each participant. The protocol was approved by the Local Human Research Ethics Committee (#623.581/2014; #409.162/2013) and appropriate standards for human experimentation have been followed.

Experimental overview

The participants performed two running tests after familiarization with the protocols to improve prediction power. Initially, in the first visit, the anthropometric measures were obtained in the laboratory. Subsequently, they performed a continuous incremental test under laboratory conditions (temperature = 20–22 °C and relative humidity = 50–60%) on a motorized treadmill (Super ATL; INBRAMED®, Porto Alegre, Brazil) to determine V_{peak}. The second was a 5-km running performance test performed in an outdoor track (temperature = 18–26 °C; relative humidity = 60–80%; air speed = 7-11 $km \cdot h^{-1}$).

To minimize circadian variations in performance, all evaluations were performed at the same period of the day, between 06:00 and 8:00 h p.m., due to availability of participants and the fact that the performance is better during the night[12]. These evaluations were performed in a maximum period of 7 days and had an interval of 48 h to ensure the recovery of the participants[13]. Participants were instructed to attend the testing sessions well rested, nourished, hydrated, and wearing comfortable clothing. Furthermore, were also instructed to avoid eating 2 h before the tests, to abstain from caffeine and alcohol, and to refrain from strenuous exercise for 24 h before testing.

Anthropometric measurements

All the anthropometric measures were obtained in the laboratory before the incremental test and were made by a single researcher to minimize possible inter-tester errors. Body mass (BM) and height were measured using standardized procedures. Body mass was measured to the nearest 0.05 kg using a Filizola® scale with a capacity of measuring 150 kg. Subjects were wearing light clothes and no shoes. Height was measured with a Seca® stadiometer to the nearest 0.05 cm and capacity of measuring 2 m. Participants were positioned in anatomic position and the reference being the distance between vertex and the plantar aspect of the foot. Skinfold measures were used to calculate body fat percentage using a Harpenden® skinfold caliper at seven sites: pectoral, triceps, abdominal, thigh, subscapular, suprailiac and midaxillary. Measures were taken at each site three times, adopting the average of these values as final value. Body density (BD) was determined using the seven skinfolds protocol of Jackson and Pollock[14]. Subsequently, body fat percentage (%BF) was calculated from BD using Siri's equation[15].

Incremental exercise test to determine peak velocity (V_{peak})

After a warm-up, comprised walking at 6 km•h^{-1} for three minutes, the continuous protocol started with a velocity of 8 km•h^{-1} and increased by 1 km•h^{-1} between each successive 3-minute stage until participants reached volitional exhaustion, with the gradient set at 1%[1,2]. This protocol was chosen because we previously demonstrated that this incremental rate and stage duration presented the highest correlations with endurance running performance and has been suggested as a tool for endurance running training prescription[4,5]. The V_{peak} of the incremental test was calculated as the velocity of the last complete stage added to the completed fraction of the incomplete stage[16], calculated according to the equation $V_{peak} = V_{complete}+t/T$, in which $V_{complete}$ is the running velocity of the last complete stage, t the time in seconds sustained during the incomplete stage, and T the time in seconds required to complete a stage. During the test (*i.e.*, 15 seconds before the end of each stage) the HR (Polar RS800sd; Polar®, Finland) and rating of perceived exertion (RPE)[17] were monitored and the maximal HR (HR_{max}) and maximal RPE (RPE_{max}) were defined as the highest (*i.e.*, 100%) HR and RPE values, respectively, obtained during the test. The percentage of age-predicted maximum heart rate (%APMHR) was calculated using the HR_{max} obtained during the incremental test and the age-based equation proposed by Tanaka *et al.*[18] ($HR_{max} = 208 - 0.7 \times$ age).

5-km running performance

The 5-km time trial running performance was performed on a 400 m outdoor track and preceded by a self-determined warm-up of 10 min. Participants freely choose their pacing strategy during the performance. Based on the incremental test result, experienced running coaches provided suggestion of pace to avoid participants to start the race too fast or too slow. All of the participants were encouraged to give their best performance. Participants performed the tests with more runners on the track; however, they started the race at different times.

The 5-km time for each participant were recorded and registered by the evaluator to determine the test duration (t_{5km}) and to calculate the mean velocity (MV_{5km}). This result was considered the running performance of the participant.

Statistical analysis

The Shapiro-Wilk test was used and confirmed the normality of the data distribution. Data are presented as means ± standard deviations (SD) and were analyzed using the Statistical Package for the Social Sciences 17.0 software (SPSS® Inc., USA). The comparisons between female and male were performed using Student´s *t* test for independent samples. The relationship between V_{peak} and 5km running performance was examined using Pearson correlation coefficient (r), adjusted coefficient of determination (R^2) and standard error of estimate (SEE). Simple linear regression analyses were used to generate predictive equations for t_{5km} from V_{peak}. Statistical significance was set at $P < 0.05$.

Results

A total of 50 participants (20 female and 30 male) completed the study. There was no age difference between groups (Female = 25.9 ± 3.8 years, Male = 27.4 ± 4.5 years; $P = 0.247$). However, the anthropometric measures were different: height (m): Female = 1.7 ± 0.1, Male = 1.8 ± 1.0, $P < 0.001$; body mass (kg): Female = 61.8 ± 10.8, Male = 79.7 ± 8.7, $P < 0.001$; body mass index (kg•m^{-2}): Female = 22.7 ± 4.1, Male = 25.4 ± 2.7, $P = 0.014$; body fat (%): Female = 26.1 ± 3.5, Male = 17.4 ± 5.4, $P < 0.001$. The results obtained during the incremental test and 5-km running performance are presented in Table 1. The V_{peak} and 5-km running performance (t_{5km} and MV_{5km}) were significantly higher in the male group compared to that in the female group ($P < 0.001$). In addition, % V_{peak} referring to the mean 5-km running velocity, was different between groups ($P < 0.001$).

Table 2 presents the relationship between V_{peak} and 5-km running performance and the prediction equations for the indirect determina-

Table 1. Comparison between groups for variables obtained during the performance tests.

Variables	Female (n = 20)	Male (n = 30)	Total (n = 50)
V_{peak} (km·h^{-1})	10.5 ± 1.1	13.4 ± 1.1*	12.2 ± 1.8
HR_{max} from V_{peak} test (bpm)	195 ± 8.8	194 ± 9.9	195 ± 9.4
RPE_{max} from V_{peak} test (6-20)	19.8 ± 0.4	19.7 ± 0.7	19.7 ± 0.6
%APMHR	102.7 ± 4.5	102.9 ± 5.1	102.8 ± 4.8
t_{5km} (min)	38.7 ± 4.2	27.3 ± 3.1*	31.9 ± 6.6
MV_{5km} (km·h^{-1})	7.8 ±0.8	11.1 ± 1.3*	9.8 ± 2.0
% V_{peak} of MV_{5km}	75.1 ± 3.9	82.9 ± 4.2*	79.8 ± 5.6

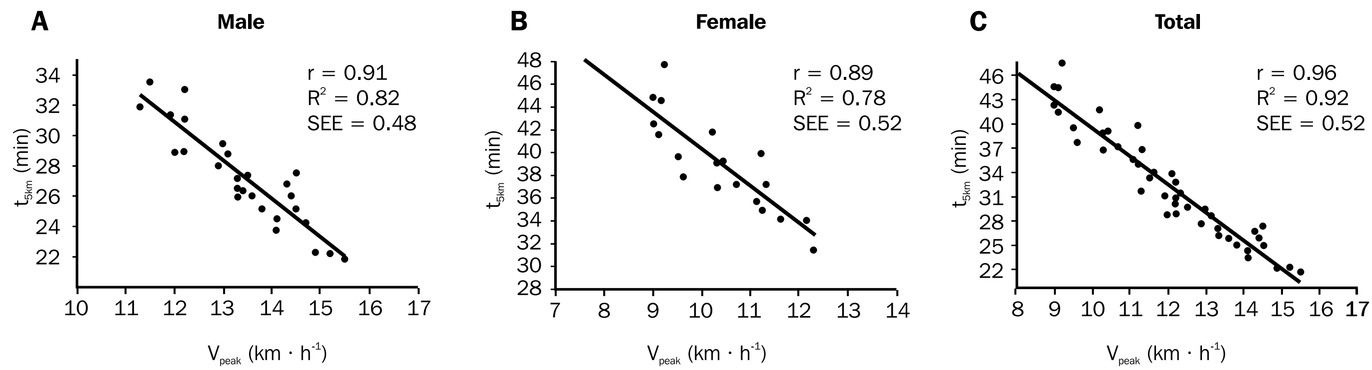
Note: V_{peak}: peak velocity; HR_{max}: maximal heart rate; RPE_{max}: maximal rating of perceived exertion; %APMHR: percentage of age-predicted maximum heart rate; t_{5km}: 5-km time; MV_{5km}: mean 5 km running velocity; % V_{peak}: referring to the mean 5-km running velocity. *$P < 0.05$ compared to female group.

Table 2. Relationship between peak velocity (V_{peak}) and 5-km time (t_{5km}) for different gender.

Protocols	r (95% CI)	Adjusted R^2	SEE (km•h^{-1})	Regression equation
Female (n=20)	0.89* (0.74–0.96)	0.78	0.52	$t_{5km} = 73.04 - 3.28 * V_{peak}$
Male (n=30)	0.91* (0.82–0.96)	0.82	0.48	$t_{5km} = 60.80 – 2.50 * V_{peak}$
Total (n=50)	0.96* (0.93–0.98)	0.92	0.52	$t_{5km} = 74.32 – 3.47 * V_{peak}$

CI: confidence interval; r: Pearson product-moment correlation coefficient; R^2: coefficient of determination; SEE: standard error of estimate in km•h^{-1}; V_{peak}: peak velocity; t_{5km}: 5-km time. *$P < 0.05$.

Figure 1. Correlation between peak velocity (V_{peak}) and 5-km time (t_{5km}).



A: for male; B: for female; C: for all participants (total).

tion of 5-km time. Figure 1 illustrates these relationships. Both the female and male groups presented high correlation values for the association between V_{peak} and t_{5km}.

Discussion

The present study aimed to examine the relationship between 5-km running performance and V_{peak} in untrained men and women and propose sex-specific equations for performance prediction based on V_{peak}. The main finding was that V_{peak} is a good predictor of 5-km running performance for both untrained men and women.

It is important to highlight that V_{peak} is a performance variable with high reliability[19] that should be determined during an incremental running test with initial speed of 8 km•h^{-1}, with 3 min stage duration and 1 km•h^{-1} speed increment[1,2,6]. We used this design because previous studies[1,2,6] found that the V_{peak} values obtained were better correlated with endurance running performance than other protocols tested.

The correlation values in our results for the association between V_{peak} and 5-km were 0.89 and 0.91 for female and male participants, respectively. Our results are similar to others studies that investigated the relationship between V_{peak} and endurance running performance with different distances in male[1,2,6,20] and female[21-23] runners and demonstrated high association. However, it is important to mention that Machado *et al.*[1] (r = 0.95 with 5-km), Alves *et al.*[6] (r = 0.92 with 10-km) and Noakes *et al.*[20] (r = 0.94 with 10-km) demonstrated higher correlation values with runners compared to our data. In contrast, other studies reported the same correlation values[22,24] or lower correlation values[21] (r = 0.83 for male and 0.80 for female). Thus, based on these results, it appears that performance level does not largely influence the relationship between V_{peak} and endurance running performance.

It is important to note that, specifically with 5-km running performance, few studies determined this association[1,21,24]. Machado *et al.*[1] in a sample of 27 male recreational runners determined V_{peak} using the same protocol as that in the present study and found a high association between V_{peak} and 5-km running performance with a correlation value of 0.95, SEE of 0.57 and R^2 of 0.91, which was similar to our findings.

The other two studies also demonstrated this association in those defining V_{peak} during an incremental test for VO_{2max} determination[21,25]. Stratton *et al.*[25] demonstrated similar results with those in our study, in which they found that final treadmill velocity was the best predictor (among other physiological variables) of 5-km performance in untrained (r = 0.89) and trained states (r = 0.83) (*i.e.*, pre and post six weeks of running training); in addition, a stepwise multiple regression analysis of the full pretesting data set revealed that, in the untrained state, 77.8% of the variance in 5-km performance could be explained by V_{peak} alone. Scott and Houmard[21] investigated a group of highly trained male and female distance runners and found that V_{peak} was related to 5-km time trial performed on treadmill in both men (r = 0.83) and women (r = 0.80) and when the data of both groups were combined (r = 0.94). It is important to mention that the correlation values determined by Scott and Houmard[21] were lower compared to those in our study; however, it is important to emphasize that the differences between protocols to determine V_{peak} influence these results[1,2,3], mainly because in the study of Scott and Houmard[21] both maximal oxygen consumption (VO_{2max}) and V_{peak} were determined using the same incremental protocol. Moreover, it is expected that trained subjects present lower coefficient of variation in the sample than untrained subjects, which was observed in our study compared to Scott and Houmard[21]. This higher homogeneity could play a role in reducing the correlation values.

To our knowledge, this is the first study to associate V_{peak} determined in a protocol without use of a gas analyzer and 5-km running performance in untrained participants. Moreover, only study of Machado *et al.*[1] on recreational runners proposed a prediction equation of running performance based on V_{peak}. These equations have high practical application and can help coaches to combine V_{peak} assessment with training prescription and performance prediction[4,5].

In addition, women are poorly investigated in this context compared to men[26], although there are evidences that women are adhering more to endurance running races[9] and consequently to running training programs in previously untrained subjects.

The reasons in separating women and men are related to different factors, including social, psychological, and physiological. However, due to the association between V_{peak} significance and physiological factors, they play an important role in defining equations specifically for men and women[12]. Joyner[26] recently suggested that from the key factors related to endurance performance (*i.e.*, VO_{2max}, lactate threshold, and running economy), it seems that VO_{2max} is the main differential variable between sexes. Men present larger muscle cross-sectional area[27] and lower percentage body fat and higher red cell mass for a given body weight[26,27]. Additionally, there are some evidences that women have smaller lungs relative to their body size and are more prone to arterial desaturation during intense exercise[26,28,29].

The $\%V_{peak}$ referring to the mean 5-km running velocity were 75.1 ± 3.9% and 82.9 ± 4.2% in women and men, respectively. These values were significantly different between groups and may be explained by the physiological differences between men and women discussed previously, such as larger muscle cross-sectional area[27], lower percentage body fat, and higher red cell mass for a given body weight[26,27]. These physiological advantages should contribute to the higher percentages of V_{peak} observed in male participants[26].

It is important to emphasize that, although incremental test led participants to exhaustion (based on RPE_{max}, HR_{max} and the %APMHR), this information was not obtained in the track test. However, both men and women performed 5-km running in similar percentages of V_{peak} with that in the study of Scott and Houmard[21]. It is also important to point out that participants were encouraged to give their best in the track test.

The Vpeak test (*i.e.*, incremental test) is highly applicable than 5-km running performance in training routines of different level runners, including untrained ones[1,2,4,5]. In our perspective, it is very useful to provide prediction equations to obtain 5-km running performance with V_{peak} as it will add one more practical benefit for this variable besides all the possibilities related to a more individualized training prescription. V_{peak} can be applied to a variety of training sessions (*e.g.*, long high-intensity interval training, short high-intensity interval training, moderate-intensity continuous training, light intensity continuous training, and race pace[4,5,7,8] and presents very high correlation values with different running performance distances (*e.g.,* from 1.5 to 90 km)[1,20].

Therefore, we concluded that V_{peak} is a good predictor of 5-km running running performance in untrained men and women. In practical application, in agreement with previous studies that demonstrated the importance of this variable[4,5], V_{peak} could be used to prescribe and control training in beginners in running practice since its determination is simple and does not require expensive equipment or invasive techniques.

Conflicts of interest

The authors declare no conflict of interests.

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