

Running velocity at maximum oxygen uptake and at maximum effort: important variables for female military pentathlon

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Abstract - Aim: to correlate cardiopulmonary capacity widely used variables with athletic performance in 4 km cross country race, in elite female military pentathlon athletes. **Methods:** Five military pentathlon athletes from Brazilian team with 27.5 [25.0; 29.3] years old underwent an incremental ramp treadmill test to determine VO_2max , vVO_2max (velocity of initial VO_2 plateau), maximum velocity, and these same variables in anaerobic threshold. Furthermore, the performance obtained on the cross-country race of the last trial before the world military games was recorded. Spearman's correlations were used to investigate the association between cardiopulmonary variables and athletic performance ($p < 0.05$). **Results:** The athletes exhibited a median total body weight of 64.3 [60.9; 66.6] kg and height of 1.75 [1.66; 1.76] cm. Race performance was positively correlated with vVO_2max ($r = 0.98$, very strong correlation) and maximum velocity reached ($r = 0.95$, very strong correlation). The remaining cardiopulmonary variables did not show similar behavior, with r varying between -0.26 and 0.44. **Conclusion:** Maximum velocity and vVO_2max indicators are directly related to athletic performance in the 4 km cross country race of elite female military pentathlon athletes. Thus, the technical team must pay particular attention to athletic performance in these cardiopulmonary variables in both the selection of new athletes and the identification of the effectiveness of applied training strategies.

Keywords: physical education, exercise physiology, athletic performance, running, oxygen consumption.

Introduction

The military pentathlon was created in the 40's proposing the inclusion of typically military characteristics in a sports competition. It consists of five events: (i) shooting with a standard rifle (200 m); (ii) obstacle running (500 m); (iii) obstacle swimming (50 m); (iv) grenade throwing: one event for precision and one for distance; and (v) cross country running - 8 km for men and 4 km for women. Points are awarded according to performance in each event and the competitor with the highest total number of points at the end is the winner¹.

In recent years, the number of military pentathlon athletes taking part in competitions organized by the International Military Sports Council (CISM) has increased significantly, having the latest competition, in 2019, the participation of 26 teams from different countries around the world². Besides the increasing number of military pentathlon athletes worldwide², it has been continuously observed better technical and physical quality of the participants, making the competitions even harder. Thus, all

strategies that could be used to improve performance in each event favoring the final result should be considered. In this case, it includes the identification of physiological variables to be manipulated in training.

Regarding each military pentathlon event, cross-country running is the one in which the aerobic system is predominantly used and therefore, an optimal cardiopulmonary capacity is necessary to achieve good performance. The Cardiopulmonary Exercise Test (CPET) permits to direct assessment of the individual's cardiopulmonary capacity throughout the gas exchange and pulmonary ventilation analysis. The most CPET indices used to describe and improve aerobic performance are maximum oxygen consumption (VO_2max)³⁻⁵, the lowest velocity at which VO_2 plateau is observed (vVO_2max)^{6,7}, running economy^{8,9}, anaerobic threshold, and exhaustion time in vVO_2 (T_{lim})⁷.

Several literature studies use these physiological indices to predict the aerobic performance of endurance runners and other sport modalities⁷⁻¹¹, but none for military pentathlon. Furthermore, it is important to underscore

that to date the samples of scientific articles have been composed of male subjects. The knowledge of which CPET variables are associated with athletic performance could help the technical team in both selections of new athletes and monitoring athletes' evolution over a season.

Thus, the present study aimed to correlate, in elite female military pentathlon athletes, the performance in the 4 km cross country running with physiological variables widely used to describe aerobic performance, here considered: VO_2 , heart rate, and running velocity at maximum and anaerobic threshold points, and $\text{vVO}_{2\text{max}}$.

Methods

Study design and participants

The present study was approved by a local ethics committee (protocol number CAAE: 49600515.0.0000.5235) and all participants gave their written informed consent before the study entry. From the six military pentathlon athletes who composed the female Brazilian military team in 2015, five were included in this cross-sectional study. Only one athlete refused to give her consent and thus was not included. All participants were aged 18 years or more and had the index to participate in the 6th World Military Games, held in Korea, in 2015.

Cardiopulmonary exercise test

All participants were submitted to a maximal Cardiopulmonary Exercise Test (CPET) on a treadmill (Technogym Excite Run 700; Italy). The ramp protocol was applied as follows: (i) warm-up - three min at a velocity of 8.0 km/h; (ii) main part - successive increments of 0.4 km/h every 30 s from the initial velocity of 8 km/h. The ramp characteristics were selected to ensure a test duration of between 8 and 12 min, in line with American Heart Association guidelines¹²; and (iii) recovery - three min at 40% of maximum velocity.

It was verified whether the following pre-test instructions were adhered to: not engaging in exhausting physical activity on the same day of the test, not drinking alcoholic beverages or those containing caffeine since the previous night, and not smoking in the four hours preceding the CPET.

The expired gases were measured in the respiration-respiration mode, and stored as the average of three breaths, using the VO2000 metabolic gas analyzer (Medgraphics, USA) throughout the tests. The Aerograph 4.3 program (AeroSport Inc., USA), which displays and stores real-time ventilatory data, was applied.

The following cardiopulmonary variables were measured or calculated: oxygen consumption (VO_2 ; $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$); heart rate (HR; bpm); and running velocity (km/h). These variables were analyzed at two moments of effort: (i) ventilatory anaerobic threshold and (ii) peak. If

the athlete reached the VO_2 plateau, the lowest plateau velocity, named $\text{VO}_{2\text{max}}$ velocity ($\text{vVO}_{2\text{max}}$), was also analyzed (13). Heart rate was continuously monitored with a RCX3 heart rate monitor (Polar, Finland).

The $\text{VO}_{2\text{max}}$ was the highest mean of three VO_2 values in the last min of the test when the plateau was characterized^{3,14}. The velocity observed at the moment that the VO_2 increase was less than 0.5 $\text{mL}/\text{kg}/\text{min}$ over 30 s and/or less than 2 $\text{mL}/\text{kg}/\text{min}$ over 2 min was called $\text{vVO}_{2\text{max}}$ (adapted from Bragada et al.¹³). When the formation of the plateau could not be observed, the velocity at which peak VO_2 was recorded was used as $\text{vVO}_{2\text{max}}$ ¹⁴.

The participants of this study were verbally encouraged during the test. Blood pressure (BP) was also checked before and after the test in order to monitor the behavior of the cardiovascular system under stress and ensure the safety of the individual. Similarly, the modified Borg perceived exertion scale¹⁵ was used, ranging from 0 (absence of fatigue) to 10 (maximum fatigue), to assess the level of discomfort during the exercise.

The ventilatory threshold was identified using analysis of ventilatory equivalents for oxygen and carbon dioxide (VE/VO_2 and VE/VCO_2 , respectively). The moment of effort at which VE/VO_2 increased without a concomitant rise in VE/VCO_2 was considered the ventilatory threshold¹⁶. This identification was performed by two researchers.

Cross-country running athletic performance

Athletic performance in cross-country running was expressed in pentathlon points, according to the point conversion table, specific for this modality, and taking into account the time elapsed to complete 4 km, in minutes and seconds. The better the performance the higher the score. Data were obtained from the championship in which the athletes who composed the Brazilian team in the 6th World Military Games were selected.

Statistical analysis

Non-parametric strategies were elected due to the small sample size. Descriptive analyses were presented as median, 1st, and 3rd quartiles, and minimum and maximum values. Spearman's correlations were used to investigate the association between cardiopulmonary variables and athletic performance in cross-country running, considering $\text{VO}_{2\text{max}}$, VO_2 at the ventilatory threshold, maximum velocity, the velocity at the ventilatory threshold, and $\text{VO}_{2\text{max}}$ velocity ($\text{vVO}_{2\text{max}}$). Correlation coefficient (r) classification was: very strong for r values ≥ 0.90 ; strong for $0.6 \leq r < 0.9$; fair for $0.3 \leq r < 0.6$; and weak for r values < 0.3 ¹⁷.

All the analyses were carried out using the SPSS 13.0 (Chicago, IL, USA), and p-values < 0.05 were considered statistically significant.

Result

The athletes had a median age of 27.5 [25.0; 29.3] years, a total body mass of 64.3 [60.9; 66.6] kg, and a height of 1.75 [1.66; 1.76] m. Their routine consisted of six hours of training a day (including physical and technical training) and all the athletes were training the modality for more than two years. Descriptive analysis of cardiopulmonary variables during the CPET and athletic performance in the cross-country race are presented in Table 1. All of them achieved a score of 10 of perceived exertion (maximum fatigue) before interrupting the test.

The variables that were significantly correlated with athletic performance in the cross-country running were vVO_{2max} ($r = 0.98$; $p = 0.005$) and maximum velocity ($r = 0.95$; $p = 0.014$), as presented in Figures 1 and 2, showing a very strong correlation. The other variables

exhibited correlation coefficients between -0.36 and 0.60 (Table 2).

Discussion

The purpose of this study was to determine which cardiopulmonary exercise capacity variables are more correlated to the 4 km cross-country performance of elite military pentathlon women athletes. The results indicated two variables as possible determinants of performance: velocity at the start of the VO_{2} plateau (vVO_{2max}) and maximum velocity. This relationship has been widely investigated for other sports modalities^{7,18-21} with mainly aerobic characteristics, but never for military pentathlon athletes. With the increasing practice and number of athletes of this modality in military events, research should be

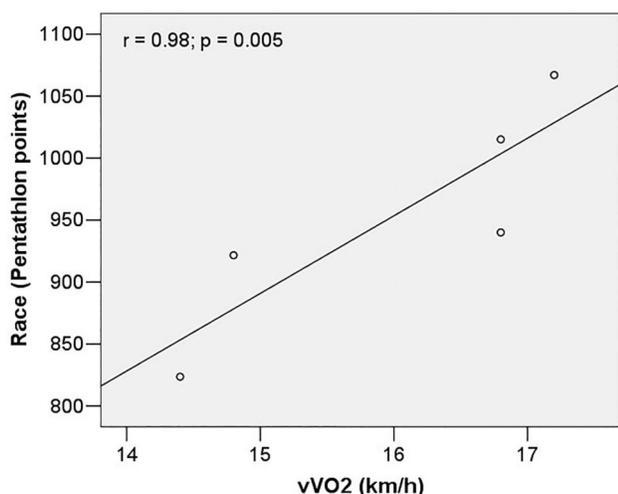


Figure 1 - Dispersion graph of vVO_{2} points (velocity at the start of the VO_{2} plateau) and performance in the race (n=5). The coefficient correlation (r) = 0.98 is classified as very strong, showing a significant relationship between race performance and vVO_{2max} .

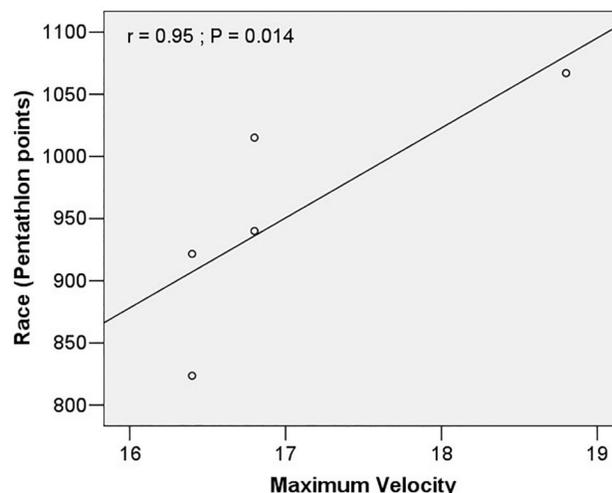


Figure 2 - Dispersion graph of maximum velocity and race performance points (n=5). The coefficient correlation (r) = 0.95 is classified as very strong, showing a significant relationship between 4 km cross country race performance and maximum velocity reached in the cardiopulmonary exercise test.

Table 1 - Cardiopulmonary behavior under exercise and athletic performance in military pentathlon athletes from the Brazilian Army (n=5).

Variable	Median [1 st quartile-3 rd quartile]	Minimum-Maximum
Pre exercise HR (bpm)	65.0 [55.5-75.0]	55-84
VT vel (km/h)	14.8 [14.6-16.0]	14.4-16.8
VT HR (bbm)	191.0 [165.5-194.5]	151.0-195.0
VT VO_{2} (mL.kg ⁻¹ .min ⁻¹)	40.2 [38.5-46.0]	37.2-47.9
Max vel (km/h)	17.0 [16.4-17.9]	16.4-18.8
Max HR (bpm)	196.0 [175.0-199.0]	170.0-202.0
VO_{2max} (mL.kg ⁻¹ .min ⁻¹)	44.8 [39.7-51.3]	39.1-54.7
vVO_{2max} (km/h)	15.6 [14.5-17.0]	14.4-17.2
*Race performance (points)	940.0 [872.6-1041.0]	823.6-1067.0

HR = heart rate; VT Vel: ventilatory anaerobic threshold velocity; VT HR = heart rate at the ventilatory anaerobic threshold; VT VO_{2} = oxygen consumption at the ventilatory anaerobic threshold; Max velocity = maximum velocity; Max HR = maximum heart rate; VO_{2max} = maximum oxygen consumption; vVO_{2max} = lowest velocity at which oxygen consumption plateau is observed. * Race performance is expressed in "pentathlon points". The better the performance the higher the score. The athlete's score in pentathlon points is found on the race time conversion table.

Table 2 - Correlations between cross country running points and CPET variables in military pentathlon athletes from the Brazilian Army (n=5).

Variable	Spearman coefficient	Coefficient classification
VT Vel (km/h)	0.56	fair
VT HR (bpm)	-0.10	weak
VT VO ₂ (mL.kg ⁻¹ .min ⁻¹)	0.60	strong
Max vel (km/h)	0.95	very strong
Max HR (bpm)	-0.36	fair
VO ₂ max (mL.kg ⁻¹ .min ⁻¹)	0.30	fair
vVO ₂ max (km/h)	0.98	very strong

HR = heart rate; VT Vel: ventilatory anaerobic threshold velocity; VT HR = heart rate at the ventilatory anaerobic threshold; VT VO₂ = oxygen consumption at the ventilatory anaerobic threshold; Max velocity = maximum velocity; Max HR = maximum heart rate; VO₂max = maximum oxygen consumption; vVO₂max = lowest velocity at which oxygen consumption plateau is observed.

applied focusing on the better selection and preparation of its practitioners.

Our results are close to those reported by Denadai et al.⁷, in terms of the relevance of the vVO₂max variable for athletic performance. The authors inferred that vVO₂max and the time in which they continued after reaching the VO₂ plateau (Tlim) explained 88% of the variation in endurance athlete performance in a 1500 m race. This variable was also studied by Guglielmo et al.¹⁸, who carried out several protocols in nine endurance athletes, in order to identify variables associated with performance in 1500 m, 3000 m, and 5000 m races. vVO₂max was the only variable that determined performance in 1500 m and 3000 m races, showing a negative correlation with time at the different distances ($r = -0.78$ and $r = -0.81$ respectively). In another study issuing this relationship, Souza et al.¹⁹ conducted track and laboratory tests to predict the performance of middle and long-distance runners. vVO₂max was the only variable selected to explain performance in 1500 m and 5000 m races (62% and 35% respectively). Even for amateur athletes, vVO₂max was found to correlate with running performance²⁰. The results of the study of Lourenço et al.²⁰ showed a significant and very large negative correlation ($r = -0.89$) between vVO₂max and the time spent for 3000 m running. The velocity at the ventilatory threshold and the respiratory compensation point also presented this behavior, with almost perfect correlation coefficients, $r = -0.92$ and $r = -0.96$, respectively.

The vVO₂max, the minimum speed at which the maximal VO₂ is achieved, is the intensity beyond which there is no additional contribution of the aerobic metabolic system for the additional energy required from the effort. The higher this velocity, the less the athlete will suffer from the acidosis from the anaerobic system utilization even at high absolute intensities. Consequently, she will be able to perform the running task more easily and achieve better results. Due to its remarkable relationship with athletic performance, this variable has been an excellent indicator for prescribing exercise intensity²¹ and has been successfully used for runners and cyclists²².

McLaughlin et al.²³ corroborate the previous explanation when stating that vVO₂max is a composition of VO₂max and running economy. So, our results are in accordance with the exercise physiology literature and also with studies with other sports modalities, previously described in this paper. It should be noted that those studies were conducted with male subjects, and because of that the comparison and the discussion should be done cautiously. However, due to the validity of the aforementioned studies, the scarcity of research with women, and the similar behavior exhibited by both sexes for O₂ kinetics²⁴, the results of these studies were considered while discussing our outcomes.

With respect to VO₂max, the present study found no significant relationship between this variable and performance in the 4 km cross country race, such that athletes with the highest VO₂max values were not necessarily the best runners at the distance analyzed. This corroborates the importance of the concept of running economy instead of maximal cardiopulmonary capacity, especially for elite athletes, which mostly already have very high VO₂max values. Other studies concerning running performance corroborate our results since they also failed to find VO₂max as an important predictive variable in significant regression models^{20,25}.

The present study has some limitations. First of all, the small sample size ($n = 05$), that prevented the use of more robust statistical analysis strategies. It is important to underscore, however, that this is a representative number of Brazilian female military pentathlon athletes, given that there are fewer than 30 women in this population (including Army, Navy, and Air Forces). Furthermore, the target population of the study (Brazilian military pentathlon team) involves six athletes with the best performance in the country, five of whom participated in our study. Another issue that should be better developed is to consider the other four events: shooting, grenade throwing, obstacle running, and obstacle swimming, since one athlete must have high performance in all of them, in addition to the cross country running.

The findings of the present study may be extremely valuable in the selection process of athletes for the military pentathlon team, given the association observed between performance and these indicators ($v\text{VO}_2\text{max}$ and maximum velocity). Moreover, they should also be used to monitor the development of athletes on the military pentathlon team in response to the elected training intervention.

Furthermore, we strongly suggest that future studies include longitudinal analysis, monitoring the evolution of race performance and the $v\text{VO}_2\text{max}$ and maximum velocity, to confirm the present cross-sectional results.

Conclusion

The results of the present study allow us to conclude that $v\text{VO}_2\text{max}$ and maximum velocity are correlated to the performance of military pentathlon athletes in the 4 km cross-country race. The athletes that achieved the highest values in these indicators covered the race distance in the shortest time, obtaining the highest score in this event.

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