Relationship Between Oxygen Uptake Kinetics and the Running Strategy on a 10 Km Race

EXERCISE AND SPORTS SCIENCES

ORIGINAL ARTICLE

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ABSTRACT

This study examined the influence of the $\dot{V}O_2$ kinetics on the running strategy adopted during a 10km running race in runners with different performance levels. Twenty-one runners (28.5 ± 5.3 years; 17.6 ± 7.3 cm; 66.3 ± 9.3 kg) performed 1) a test with increments of 1.2 km.h^{-1} every 3 min until exhaustion; 2) one 6-min test of constant velocity at 9 km.h^{-1} for determination of $\dot{V}O_2$ kinetics and; 3) a 10 km time trial simulation. The subjects were divided into two groups, Moderated Performance (MP) and Low Perfomance (LP), based on the 10-km running performance. Mean velocity (MP= 16.9 ± 0.8 vs BP= 14.9 ± 1 km.h^{-1}) on the 10km race was significantly different ($p<0.05$) between groups. There were no differences ($p>0.05$) between groups in any kinetics parameters analyzed. However, the $\dot{V}O_2$ increase amplitude (A1 parameter) was inversely correlated with mean velocity ($r= -0.48$, $p < 0.05$) and with the partial velocities on time trial (r between -0.44 and -0.48, $p < 0.05$), except for the last session ($r=-0.19$, $p > 0.05$). In conclusion, the correlation of A1 parameter with the partial velocities suggests an influence of running economy on the strategy adopted during the 10 km time trial.

Keywords: athletic performance, pulmonary gas exchange, physical exertion.

INTRODUCTION

In events of medium and long duration(1-5), the strategy applied usually applied by the athletes is based on a faster exit, followed by gradual decrease in the mean distance of the event, and final acceleration. It is believed that this fast exit may favor aerobic performance during the event due to acceleration in the kinetics of the oxygen consumption ($\dot{V}O_2$). Draper *et al.*(6) showed that in different running strategy situations, the one which reached higher percentages of $\dot{V}O_2$max was the strategy which had faster exit in the first 200m. Kilding *et al.*(7) showed that lower values of the time constant (τ), which is a parameter which describes the $\dot{V}O_2$ response time when in a given exercise, were negatively correlated with the initial velocities of 800, 1,500 and 3,000m events. In fact, Bishop *et al.*(8) demonstrated that making an athlete perform a fast exit produces higher $\dot{V}O_2$ values in the initial moments of a two-minute test in a kayak ergometer, when compared to a strategy where velocity is kept constant from the beginning of the event (*even pacing*). These researchers(7,8) suggested that this higher consumption after a fast exit would be related to higher rates of phosphoocreatine breaks in the beginning of the event.

Similarly, other studies(1,9,10) observed that the $\dot{V}O_2$ increases more rapidly in the beginning of the test at the fast exit condition when compared to the *even pacing*. When comparing the $\dot{V}O_2$ response in running events with different durations, Duffield *et al.*(10) observed that the faster exit velocity would be related to lower τ values. These findings confimr the hypothesis that a faster exit would be directly related to the $\dot{V}O_2$ temporal response. Additionally, some authors(9,10) suggest that this fast exit may favor performance both in high-intensity and short duration activities(9) and in middle-distance events(10).

Among the main factors which affect the $\dot{V}O_2$ kinetics, we highlight the training status(7,11,12). In a study, Phillips et al.(11) demonstrated that immediately after 30 days of aerobic training, the individuals presented decrease in τ, lower blood lactate concentrations, higher mitochondrial potential and higher $\dot{V}O_2$peak. Thus, it can be speculated that athletes with higher performance level for having lower $\dot{V}O_2$ response time, would be Abel to impose a faster rhythm in the beginning of the event, when compared to the less trained ones.

In fact, Lima-Silva *et al.*(3) demonstrated that athletes with higher performance level adopted running strategy with faster exit in a 10km event, reaching the highest velocities right in the beginning of the race (*fast-start*), while runners with lower level adopted a more conservative strategy, with discreet initial increase and not different from the subsequent velocities of the event. Thus, considering the previously highlighted relationship between the $\dot{V}O_2$ kinetics and running strategy, it seems reasonable to suppose that the most trained group had been able to reach higher velocities at the beginning of the event due to lower τ. However, until the present moment, no study has analyzed the correlation between the $\dot{V}O_2$ temporal response and the faster exit during a 10km event.

Thus, the aim of this study was to examine the relationship between the $\dot{V}O_2$ kinetic response and the running strategy adopted in a 10km event by runners with different performance levels. The hypothesis of the present study is that, in more trained runners, the τ would be lower, which could be directly related to higher exit velocity in a 10km event.

MATERIALS AND METHODS

Subjects

Twenty-one long-distance runners (28.5 ± 5.3 years; 172.6 ± 7.3cm; 66.3 ± 9.3kg; 62.1 ± 6.4ml/kg/min), of regional and national level, participated in this study. The subjects were divided in two groups: moderate performance (MP, n = 11) and low performance (LP, n = 10). The athletes who presented event time lower than the group mean (37.8 minutes) were considered MP, while the athletes with higher time, LP. All volunteers signed the Free and Clarified Consent Form containing the description of all risks and benefits of the experimental procedures. The study was approved by the Ethics Committee of the Physical Education and Sports School of the University of São Paulo (USP).

Experimental outlining

The participants were at the laboratory in three different occasions, being each one separated by a minimum of 48 hours. Each participant completed: 1) one maximum incremental test for determination of the $\dot{V}O_2$max and peak velocity; 2) one submaximal constant test on a tracking field in $9km.h^{-1}$ velocity for determination of the $\dot{V}O_2$ kinetics and 3) one simulation of a 10km event on tracking field for analysis of the running strategy. The tests performed on the track were conducted at the same day period, with similar wind and temperature conditions (19 to 22ºC).

Incremental test

After three-minute warm-up at $6km.h^{-1}$, the velocity was increased in $1.2km.h^{-1}$ at every three minutes, until voluntary exhaustion[13]. The treadmill was kept with 1% of inclination to simulate the running on track[14]. The $\dot{V}O_2$ was measured breath after breath during the entire test ($K4b^2$, Cosmed, Roma, Italy). The gas analyzer was calibrated before each test according to the manufacturer's specifications (instructions manual of the $K4b^2$). Heart rate (HR) was continuously measured using a cardiofrequencimeter (Polar Vantage NV, Kempele, Finland).

The $\dot{V}O_2$max was identified as the highest value reached during the last stage of the incremental test[3]. The highest velocity reached during a complete stage in the test was recorded as the velocity peak (VP)[15]. The HR_{max} was determined as the highest value recorded at the end of the last stage of the incremental test. The lactate threshold (LT) was determined for each subject as the running velocity associated with the first increase sign in the blood lactate above $1mmol.L^{-1}$[16].

Constant velocity test

The constant velocity test comprehended a six-minute running period at $9km{\cdot}h^{-1}$. This velocity was chosen for representing the moderate domain for all subjects, since it is below the lactate threshold[17].

In order to keep velocity constant, the subjects received sound signs through an amplified sound system. These signs determined the necessary rhythm to complete 20-meter distances. The gas exchanges were measured breath after breath in the entire test (Cosmed $K4b^2$, Roma, Italy).

10km running test

During the 10km event simulation, water was offered *ad libitum*. The subjects were told to complete the event as fast as possible, as if they were in a competition event. Verbal stimuli were given during the entire event. The times were recorded at every 400 meters and the velocity mean of each one these distances was calculated.

Data analysis

The event was divided in three phases: 1) initial (0-1.200m); 2) intermediate (1,200-9,200m); and 3) final (9,200-10.000m). The velocity mean of these distances was calculated and compared between groups, as well as within the same group.

To analyze the $\dot{V}O_2$ kinetics, the $\dot{V}O_2$ values of the constant load test were interpolated at every 5s, according to Slawinski *et al.*[18], and the curve monoexponentially adjusted by the equation below:

$$\dot{V}O_{2(t)} = A_0 + A1 + (1 - e^{-(t-\delta)/\tau})$$

Where $\dot{V}O_2$ (t) is the oxygen consumption in a given time (t); A_0 is the oxygen consumption of the baseline (rest); A1 is the $\dot{V}O_2$; increase amplitude, δ is the delay time; and τ is the time constant.

The monoexponential adjustment was chosen due to the constant load test has been performed below the lactate threshold ($9km.h^{-1}$) for all subjects in both groups, according to suggestion by Özyener *et al.*[19].

STATISTICAL ANALYSIS

The data distribution was verified by the Shapiro-Wilk test. The Student's *t* test for independent measurements was used to compare the descriptive, physiological and performance variables between the two groups. Factorial ANOVA (group x distance), with repeated measurements in the second factor was used for analysis of the running strategy. Subsequently, the isolate effect of the distance was separately investigated within each group using ANOVA with repeated measurements, followed by the Bonferroni *post-hoc* test. The Pearson correlation coefficient was calculated to determine the possible associations between the velocity partials and the kinetic parameters. The data were presented as mean and standard deviation and the significance level adopted was 5% ($p < 0.05$).

RESULTS

The groups' characteristics are presented in table 1. There were not significant differences between groups for the age, stature and weight variables, nor for the HRmax, $\dot{V}O_{2max}$, relative $\dot{V}O_{2max}$ and VP ($P > 0.05$).However, the LT was significantly higher in the MPgroup than in the LPgroup ($P < 0.05$).

Mean velocity and time in the 10km event were significantly

Table 1. Descriptive and physiological characteristics of the high and low performance groups.

	MP (n = 11)	LP (n = 10)	P
Age (years)	27.6 ± 5.0	29.5 ± 5.6	0.43
Stature (cm)	170.0 ± 6.0	175.6 ± 7.9	0.80
Weight (kg)	63.4 ± 5.1	69.5 ± 11.9	0.16
HRmax (bpm)	192 ± 5	189 ± 6	0.17
VO_2max ($L.min^{-1}$)	4.0 ± 0.6	4.2 ± 0.6	0.30
VO_2max ($ml.kg^{-1}.min^{-1}$)	62.9 ± 7.5	61.3 ± 5.2	0.60
VP ($km.h^{-1}$)	17.3 ± 1.3	16.8 ± 1.0	0.30
LT ($km.h^{-1}$)	12.3 ± 1.2	10.5 ± 1.4	0.01

MP: moderate performance; LP: low performance; HRmax: maximum heart rate; VO_2max: oxygen maximum consumption; VP: highest velocity reached during the incremental test; LT: lactate threshold

Table 2. Kinetic parameters of the oxygen parameters identified during the constant velocity test.

	MP (n = 11)	LP (n = 10)	P
A_0 ($ml.min^{-1}$)	498.2 ± 196.5	544.4 ± 94.5	0.50
™ (s)	2.5 ± 7.7	4.6 ± 5.5	0.50
I (s)	24.7 ± 6.4	26.9 ± 7.8	0.40
A1 ($ml.min^{-1}$)	1386.4 ± 148.6	1682.1 ± 491.3	0.07

MP: moderate performance; LP: low performance; A_0: O_2 baseline; ™: delay time; I: time constant A1: O_2 increase amplitude

different between groups ($p < 0.001$). Mean velocity in the MP group was 16.9 ± $0.8km.h^{-1}$, while in the LPgroup it was 14.9 ± $1.0km.h^{-1}$. Consequently, the time spent to complete the 10 km event in the MPgroup was 35.5 ± 1.6 min, while in the LP group it was 40.4 ± 2.8 min.

A significant effect of the distance over the running velocity was observed ($P < 0.05$), but with no interaction effects with the groups ($P > 0.05$). Separately assessing the groups, it can be observed that the MP group started the event with higher velocity than the mean velocity in the race (first 400m: 18.7 ± 1.3 and 800m: 18.4 ± $1km.h^{-1}$), gradually decreasing it in the intermediate distance of the event (1,600-9,200m: 16.7 ± $0.8km.h^{-1}$ and 9,600m: 16.5 ± $1km.h^{-1}$) (Figure 1). In the last 400m, there was again acceleration (17.8 ± $0.8km.h^{-1}$), but which was not significantly different from the previous velocities ($p > 0.05$).

Nevertheless, the mean velocity of LP in the initial phase was not significantly different from the mean running velocity (first 400m: 15.8 ± 1.9 and 800m: 15.5 ± $1.2km.h^{-1}$) ($p > 0.05$), showing a different strategy when compared to the HPgroup. Mean velocity of the intermediate distance of the event was very close to the mean velocity of the event (1,600-9,200m: 14.8 ± $1km.h^{-1}$). In the final distance, although it was possible to visually observe increase (Figure 1) in velocity in the last 400m (16.3 ± $1.2km.h^{-1}$), there were no differences when compared to the mean velocity ($p > 0.05$).

Concerning the $\dot{V}O_2$ temporal response in the constant load test, the values are displayed in table 2. Significant differences have not been found between groups in any of the kinetic variables (A_0, δ, τ and A1; $p > 0.05$).

Concerning the correlations between variables, neither the $\dot{V}O_2$ of the baseline (A_0) nor the delay time (δ) or the time constant (τ) were correlated with the total mean velocity or the velocity of the parts of the 10km race. However, the $\dot{V}O_2$ increase amplitude (A1) was directly correlated with the total time to complete the 10km and inversely correlated with the total mean velocity of the event. Likewise, A1 was also associated with the mean velocity in each part in the 10km race, except for the final 400m distance (between 9,600m and 1,000m) (table 3).

Table 3. Correlation coefficient between the running velocity sections and the kinetic parameters during the 10km event.

	A_0	™	I	A1
Mean Vel.10km	-0.30	-0.08	-0.26	-0.48*
Vel. 400m	-0.27	-0.03	-0.18	-0.46*
Vel. 800m	-0.22	-0.02	-0.12	-0.44*
Vel. 1,200m	-0.23	-0.07	-0.18	-0.47*
Vel. 1,200-9,200m	-0.32	-0.09	-0.28	-0.48*
Vel. 9,200m	-0.45*	-0.09	-0.25	-0.46*
Vel. 9,600m	-0.08	0.04	-0.11	-0.19

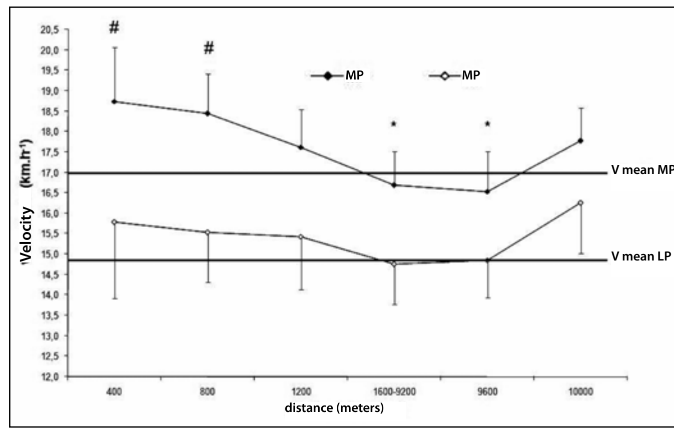

Figure 1. Running strategy adopted by the groups.
*Significant difference of the 400 and 800m ($p < 0.05$); # significant difference of the mean running velocity ($p < 0.05$).

DISCUSSION

The aim of the study was to assess the correlation between the adopted strategy during a simulated 10km event and the *on* kinetics of the $\dot{V}O_2$. One of the main findings of this study was that the group of MP runners started with velocity higher than the mean running velocity. The LP adopted a more conservative strategy, keeping constant velocity during the entire race. However, the kinetic parameters analyzed were not different between groups, despite the differences of the A1 between groups be close to the statistical significance ($p = 0.07$). Finally, the A1 values were significantly correlated with the total and partial mean velocities, except for the last event distance.

The two groups MP and LP adopted different strategy profiles and different times to complete the race. Despite of that, there were not significant differences between groups in the physiological variables measured in the maximal incremental test, as the $\dot{V}O_{2max}$ and the VP. In a study by Morgan *et al.*[20] with the subjects trained in 10km race and with similar $\dot{V}O_{2max}$ values, significant correlation was found only between the running time and the running velocity in which the $\dot{V}O_{2max}$ is reached. This correlation was mainly explained by the running economy, which can be defined as the $\dot{V}O_2$ for a given running velocity[21], showing that the most economical subjects, even with similar $\dot{V}O_{2max}$, could present better performance compared to the less economical ones. Thus, the fact that significant differences have not been found between groups in the $\dot{V}O_{2max}$ or VP probably suggests that other physiological variables besides these would be more sensitive to discriminate performance between groups.

The only kinetic parameter which presented correlation with the running velocity partials during the 10km event was the $\dot{V}O_2$ increase amplitude. Such fact shows that individuals who present lower amplitude reach higher velocities during all the sessions of the event, when compared to those with higher amplitude. Lower amplitude for the same running steady velocity ($9km.h^{-1}$) suggests that the MP subjects were economical, that is to say, performed the same task consuming less oxygen amount. In fact, from the mean A1 values (Table 2), it can be supposed that the MP group consumed approximately $300ml.min^{-1}$ less oxygen than the LP group to perform the same task. However, this statement should be carefully seen, since despite the correlations between $\dot{V}O_2$ increase amplitude and the velocity partials were significant, this methodology has not been considered standard for this measurement.

Despite this limitation, lower A1 in the MP group could be directly related to the strategy choice, which corroborates other findings in the literature[3]. Lima-Silva *et al.*[3], when assessing 10km runners, found negative correlations between running economy measured in 9 and $12km \cdot h^{-1}$ and all the velocity partials of a 10km event, showing hence that the more economical the athletes, the higher the reached velocity during the event will be. It could also explain why the MP group adopted a faster exit, while the LP group, a more conservative strategy. The logic for the more economical subjects start faster is not very clear, but when consuming more oxygen, the individuals of the MP group could save more energy avoiding the early installation of fatigue processes and therefore, increasing initial running velocity.

Many studies[11,21,22] showed improvement in $\dot{V}O_2$ kinetics with training. Hagberg *et al.*[21] demonstrated that in aerobically trained subjects the $\dot{V}O_2$ response time may be reduced. Similarly, Phillips *et al.*[11] observed decrease in response time of the $\dot{V}O_2$ after four training days, when compared to the pre-training initial values. However, although in the present study the groups have presented different performance levels, the $\dot{V}O_2$ response time did not present differences. The explanation for these results is not simple, since both groups had the same training time, the same quantity of performed events and similar $\dot{V}O_2max$. Although some studies[7,8] showed that a fast exit is associated with kinetics acceleration in the beginning of the event and that this fact would be benefic for increasing the aerobic participation, these differences may have not been found here for two reasons. Studies[1,10] which related the kinetic relation of the $\dot{V}O_2$ with the exit velocity analyzed events with shorter distance than the measured in the present study (<5km) or also, differently from it, measured τ during the event[1,17] and not in a constant load test. These methodological differences could explain the discrepancy between our results and the ones obtained in the literature.

Concluding, in groups of runners with different performance levels in a 10km event, different running strategies are adopted. The group with better performance seems to choose a faster exit, followed by velocity reduction in the intermediate distance of the event, with acceleration in the end, characterizing a rhythm in "U" shape. On the other hand, the group with lower level adopts a different strategy, with more constant velocities which do not differ from the mean running velocity, despite being possible to observe acceleration in the last part of the event. These different strategies may be attributed to the running economy, since in all measured kinetic parameters, the $\dot{V}O_2$ increase amplitude has been correlated with performance in the 10km event. Concerning the time constant, our results do no corroborate the suggestion that a faster $\dot{V}O_2$ kinetics could be related to the running strategy in the 10km or, specifically to a faster exit.

All authors have declared there is not any potential conflict of interests concerning this article.

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