Time course of velocity and oxygen uptake during 1500 meters realised with a strategy of best chronometric performance

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Abstract

The propose of this research was to examine the time course of oxygen uptake during 1500-m realised according to the competition model. So the following study is made of two parts: 1) analyse of the pacing strategy during national and international competitive 1500-m 2) experimental protocol worked out to study time course for oxygen uptake ($\dot{V}O_2$) during the 1500-m races.

1) In an attempt to reproduce subsequently and experimentally the strategy of the athletes during competition event, the runs of national and international athletes were observed and analysed. Our observations allow to determine the following model: fast departure during 100 to 200-m (105 % of mean speed), steady pace up to 1200-m (98 % of the mean speed) and acceleration from 1200 to 1300-m (105%), so that the last lap is realised 102% of the mean speed. We fall to observe a final acceleration in the last 100-m. 2). On an outdoor track, 11 middle-distance runners performed an incremental test to determine $\dot{V}O_{2\,max}$ and a supramaximal 1500-m at least 2 days apart. The 1500-m pace was based on the model beforehand established. The $\dot{V}O_2$ response was measured from the start to the end of exercise with the use of a portable telemetric gas exchange system (Cosmed K4).
The races were performed at a mean running speed corresponding to 107,6 $\pm$ 2% de MAS (maximal aerobic speed). The mean value of $\dot{V}O_{2\,max}$ recorded during the incremental test (66,1 $\pm$ 7,0 $ml.mn^{-1}.kg^{-1}$) is reached 459 $\pm$ 59,6 m (55,9 $\pm$ 7,5 s) after the onset of the 1500-m running. At the end of the 1500-m, $\dot{V}O_2$ decreases (8 %) for 8 subjects on 10.
In conclusion, our results suggested that $\dot{V}O_{2\,max}$ can be reached during a 1500-m running performed on a track according to the competition pacing strategy.

Biography
C. Hanon, PhD, who was an international 800 meters runner, is member of INSEP, the french olympic campus. She is director and researcher in the Biomechanics and physiology laboratory in INSEP. INSEP has dedicated its life to Elite sport performance since its creation in 1945. It offers optimal education opportunities to elite athletes, who can study (high school and university) and prepare their professional career while training for international events. The 850 athletes who live there are recruited by their respective national sport federations and benefit from all available equipment and infrastructure, including a Sport Sciences Department whose priority is to favour the scientific environment of sport and high level performance.

1- Introduction

Recent studies carried out about the evolution of $\dot{V}O_{2\,max}$ during 800-m demonstrated that results obtained on treadmill running (Spencer et al 1996; Draper 2005) do not end in the same results as those obtained on the track (Hanon et al 2002, Thomas et al 2005). Contrary to the results obtained on treadmill running, it seems that starting faster than the average speed of running, as in 800-m competition, leads to reach $\dot{V}O_{2\,max}$ during the race (Thomas et al 2005).

While 1500-m is ran above the speed associated with $\dot{V}O_{2\,max}$, previous studies falls to show the achievement of $\dot{V}O_{2\,max}$ (Spencer et al 1996; Spencer et Gastin, 2001). It is to note that all these experimental designs were realised on treadmill running at a constant pace (Spencer et al 1996) or with a careful start and a fast finish of the race (Spencer et Gastin, 2001).
Based on the real strategy used in competition, the present study aimed to evaluate the time course of oxygen uptake during a 1500-m running.

In order to answer this question, it was necessary to examine the pacing strategy of the national and international 1500-m runners and then to test the kinetic of $\dot{V}O_{2\,max}$ during a race based on this model.

2 - Protocol

This study consisted of two parts. The first one named "pacing strategy analysis"(A) aimed to propose a model of pacing during national and internationals 1500-m in the only case of races realised in a project of performance.

The second one, called "1500-m study"(B) was established by two different tests: a test to determine $\dot{V}O_{2\,max}$ on the track and a test to determine the maximal $\dot{V}O_2$ value obtained during the 1500-m ($\dot{V}O_{2\,1500}$).

A – Pacing strategy analysis

A1- Method

In order to describe the strategy of the best 1500-m runners, the races of 49 different athletes (races times within 3 min 28 s and 3 min 45 s) were analysed during 13 different events.

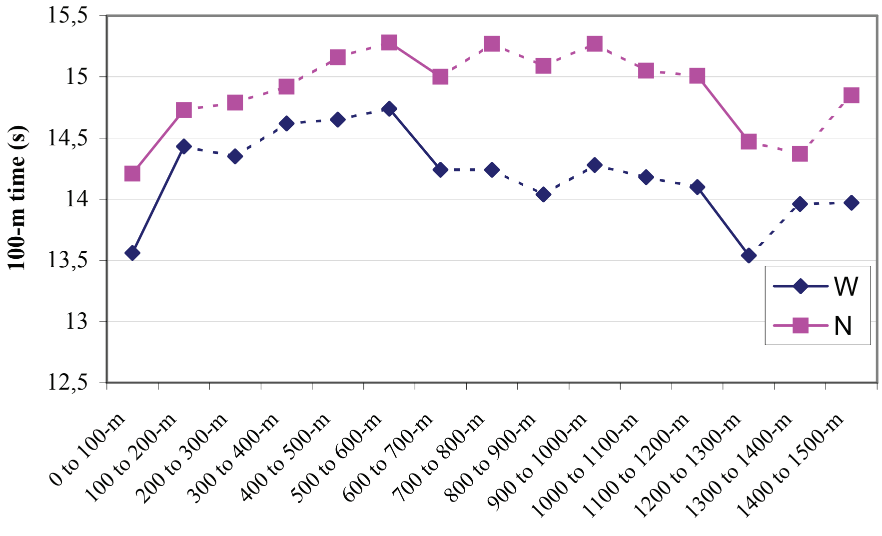
The data were collected from images of television or from personal films. The times of passage were determined for all the 100-m by means of a time code or of a stopwatch. The athletes who performed at 3 sec and more of their best performance were not retained for the analyse.

A2-Results

According to our analyses (table 1), the world (performance<3 min35 s) and national (3 min 35 sec< performance<3 min 45sec) levels are characterised by some common characteristics:

1) The first 100-m is always significantly the fastest part of the 1500-m.
2) A deceleration is observed in the second 100-m.
3) Excepted from 500 to 600-m, the athletes run relatively regularly between 200-m and 1200-m after the onset of the 1500-m.
4) Acceleration is noted from the 1200 to 1300-m that is in the opposite straight line. At the world level, this acceleration was highly significant ($p < .0001$).
5) During the last 300-m, the speed remains.
6) Finally, there is globally no acceleration in the final straight, whatever is the level.

Figure 1 – Time-course of running velocity during world and national competitive 1500-m running



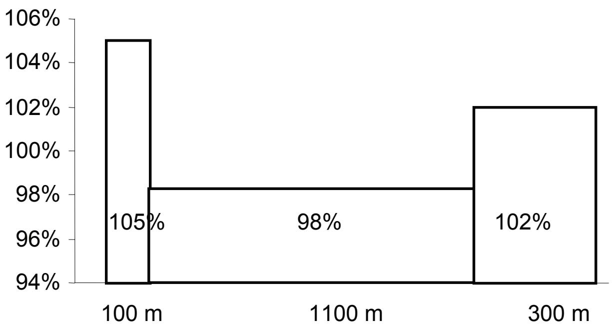
----- : the difference between the two 100-m is non significant, ___ : the difference between the two 100-m is significant. W = World level, N= National level

A3- Discussion

It is to note that the entire 1500-m running achieved with the intention of a chronometric performance, are realised according to a relatively common model. This model advances the fact that the running is not based on the regularity of speed, but on the contrary on a fast departure from start to 100 or 150 m, followed by a plateau of 1100m and by acceleration from 1200m to 1300m. Contrary to the visual impression left by the athletes, there is no significant acceleration in the final straight, whatever is the level. The specific speed of the 1500-m distance does not exist, but consists of 3 distinct specific speeds.

Our following study thus based itself on this chronometric model to calibrate the running of the participating athletes (figure 2).

Figure 2: Race profile proposed to the athletes



The velocities are expressed in % of the mean velocity

B – 1500m study

The protocol is established by two different tests: a test to determine $\dot{V}O_{2\,max}$ on the track and a test to determine $\dot{V}O_{2\,1500}$.

B1- Experimental design

Ten middle-distance runners (age 22.6 ± 4.7 years, height 174.9 ± 4.4 cm, and body mass (65.4 ± 3.9 kg) volunteered for the study. They trained 5-10 times per week for 1500-m and were successful in regional or national running races (average performance of ~3 m 56 s, range of 3 m 43 s to 4 m 05 s).

For both tests, the oxygen uptake ($\dot{V}O_2$), was recorded continuously by means of a gas exchange telemetric system (Cosmed K4, Roma, Italy). Heart rate (HR) was measured and recorded continuously with a heart rate monitor (Sport Tester PE 3000, Polar, Kempele, Finland) for each athlete. Blood lactate was collected from the ear lobe and measured with the Lactate Pro analyser (Arkray, Japan).

B2- Incremental test

This test is called Test of the University of Bordeaux II (TUB II) according to Cazorla and Léger (1993). The test consists of running on a track, with markers every 25m, for a succession of stages each of 3 minutes duration, beginning at 14 km h^{-1} and increasing by 2 kmh^{-1} up to 18 km h^{-1}, then by 1 km h^{-1} to the superior speeds. These stages are separated by one minute of recovery to allow a sample of blood to be taken. At each stage, the athletes should follow the speed imposed by a broadcasting device of sound signals. The test is stopped when the athletes are not capable any more of following the rhythm imposed by the signals and are unable to make the mark by the signal.

During the progressive test of TUB_2, the maximal aerobic speed (MAS) corresponds to the first stage where $\dot{V}O_{2\,max}$ attained (mean of the 3 consecutive and highest values) and where the subsequent increase in VO_2 is less than 2.1 $mmol.kg^{-1}$ for an increase in speed of 1 $km.h^{-1}$. Moreover $\dot{V}O_{2\,max}$ must be associated with a blood lactate, a respiratory exchange ratio and a heart rate equals respectively, to 8 to 12 $mmol.l^{-1}$, 1.1 and minimum 90% of the theoretical maximal HR (220-âge).

B3- The 1500-m

The athlete was asked to perform a regular warm-up (jogging, stretches, mobility exercises, straight lines), and each athlete performs exactly the same warm-up, including 3 * 150-m at 1500-m beginning pacing. This is followed for all the athletes by a break of 4 minutes. During the warm-up, the runners were gradually equipped (heart-rate monitor, K4). For each runner, the speed is pre-determined for the first 1200-m according to the model of running described previously. The last 300-m are realised as quickly as possible. Blows of whistle each 50-m on the basis of established times allow to the athlete to adjust accordingly. An experimenter on bicycle accompanies and encourages the athlete.

A blood sample is taken from the earlobe at the end of the warm-up, at the end of the 1500-m test and 3, 5, 7, and 10 minutes after the 1500-m. All the tests of 1500-m are filmed so as to determine a posteriori the exact speed.

Since 1500-m performance were different between athletes, cardio-respiratory and kinematics data obtained as a function of time every five seconds during the 1500-m race were averaged over 50-m intervals in order to normalise data for all subjects.

B4- Results

Incremental test

The mean values of different variables obtained in the incremental test are presented in Table1. During this test, $\dot{V}O_{2\,max}$ and v-$\dot{V}O_{2\,max}$ were equal to 64.2 ± 6.5 ml. min^{-1}. kg^{-1} and 20.3 ± 1.1 km. h^{-1}

Table1 - Mean and standard deviations of the parameters determined during the incremental test

$\dot{V}O_{2\,max}$ ($mlO2.min^{-1}.kg^{-1}$)	HRmax ($batt.min^{-1}$)	MAS ($km.h^{-1}$)	Maximal lactatémia ($mmol.l^{-1}$)
64.2 ± 7.5	195.3 ± 6.5	20.3 ± 0.6	12.4 ± 1.6

1500-m running test

The mean performance during the 1500-m race (3 min 56 s ± 9.9s) can be considered as a supramaximal exercise with regard to the average velocity achieved (21.8 $km.h^{-1}$) that is 107.6% of MAS.

Table 2 : Peak values (Mean +SD) of blood lactate and cardio-respiratory parameters observed during the 1500-m

VT (l)	HR (batt. min^{-1})	VE (l. min^{-1})	FR (cycle.min^{-1})	Blood Lactate ($mmol.l^{-1}$)
2.6 ± 0.3	192.2 ± 7.4	155.1 ± 19.8	63.8 ± 6.9	15. 0 ± 0.9

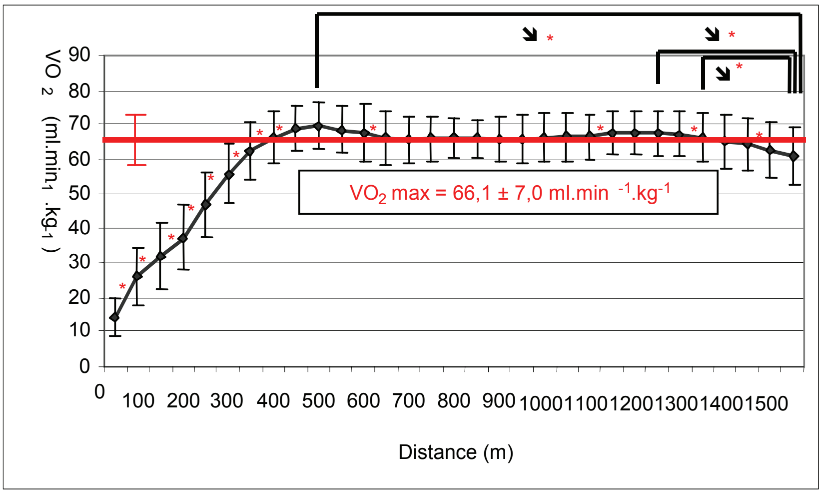
VT: tidal volume, HR: heart rate, VE: minute ventilation, FR: frequency respiratory

As expected, according to the preliminary study, running velocity presented some large variations.. Until 1100-m, the athletes have respected the designed pacing strategy. In the last 300-m, the speed increased (102, 2% of the 1500-m average speed) as observed in the preliminary study, but it varied among the subjects between 95 and 107% average speed. Because of the experimental conditions, some subjects did not succeed in respecting the final expected time. Nevertheless, at all moments of the race and for all the subjects the speed stayed greater than the maximal aerobic speed.

As shown in Fig.3, $\dot{V}O_2$ attained during the 1500-m ($\dot{V}O_{2\,1500}$) reached $\dot{V}O_{2\,max}$ (incremental test) (459.1 ± 59. 6 m or 56.0 ± 7.5 s) after the onset of the 1500-m. These $\dot{V}O_{2\,1500}$ values (69.5 ± 6.5 $mlO_2.min^{-1}.kg^{-1}$) although slightly higher were not significantly different from $\dot{V}O_2$ max (66.08 ± 7

$mlO_2.min^{-1}.kg^{-1}$). The time constant (τ) with witch $\dot{V}O_{2\ 1500}$ was 30. 1 $\pm$ 4.4 sec. At the end of the race, $\dot{V}O_{2\ 1500}$ decrease significantly (7.9 $\pm$ 7.6%) between 1300 and 1500-m. This fall is observed in 8 of the 10 subjects.

Figure 3 : Average time course of oxygen uptake (in $ml.min^{-1}.kg^{-1}$) during the 1500-m.



* : the increase or decrease of $\dot{V}O_2$ is significant between two consecutive values, $p < 0,05$

: $\dot{V}O_2$ max obtained during incremental test

: S-D for $\dot{V}O_2$ max incremental test

: the increase or the decrease is significantly different between two non-consecutive values, $p<0.05$.

Relationships between velocity, time course of oxygen uptake and performance

It is noteworthy that the performances realized during 1500-m are strongly correlated to v-$\dot{V}O_{2\,max}$ ($r = 0.73$, $P < 0.001$).

The start velocities (200 to 400-m after the onset of the 1500-m test) expressed in % of v-$\dot{V}O_{2\,max}$ are significantly correlated with the time at which $\dot{V}O_{2\,1500}$ is reached ($p<0.05$). Nevertheless, these velocities are negatively correlated with final performance ($p<0.05$).

The slow down period of $\dot{V}O_2$ is correlated with the difference between peak of speed and speed at 1300-m. At last, the final value of $\dot{V}O_2$ and the 1500-m performance are significantly and negatively correlated ($r= - 0,65$, $p = 0.02$)

B5- Discussion

The results of the present study demonstrate that $\dot{V}O_{2\,max}$ was attained during an exercise protocol which reproduced the conditions of a 1500-m running competition: a fast start strategy followed by an even pacing velocity. These results confirm those that our team obtained with a similar methodology for the 800-m but are in contradiction with those reported on treadmill running on 800-m by Draper and Wood (2005), on 800 and 1500-m by Spencer et al. (1996), Spencer and Gastin (2001) and on 5 min duration by Draper et al (2003). In these studies performed on treadmill running, subjects reached from 85 to 98.5 of $\dot{V}O_{2\,max}$. Moreover, with special regard to the 1500-m, it is noted that these studies carried out at constant power, or with a careful start and a fast finish (Spencer et Gastin, 2001), were realized at only 103 % of MAS (Maximal Aerobic Speed) while a 1500-m is performed, according to the sportive level, between 107 and 109% of MAS (Lacour et al 1990 and personal data). In the present study, runners performed the 1500-m race at 107,6 $\pm$ 2% of MAS.

Furthermore, it is to note that the best performances on 400, 800 and 1500-m are realized with a fast start followed by a short transition to even-pacing strategy as observed on 400-m and 800-m by Gajer et al.(2000) and on 1500-m (present preliminary study). The efficiency of this pacing strategy has already been experimented by Foster et al (1993) for cycling, and by Bishop et al (2002) for kayak.
This fast start associated with a high relative intensity could explain the differences in $\dot{V}O_2$ response. Astrand and Saltin (1961) and Margaria et al (1965) among others, have suggested that the kinetics of VO2's adaptation was speed up when the intensity of the supramaximal exercise was greater. The $\dot{V}O_2$ response at the onset of an intense exercise increased in connection with decreasing phosphocreatine concentration [PCr] and decreasing ATP/ADP ratio (Rossiter et al 2002) which results in an increased rate of glycolysis (Chiatosis et al 1987). Therefore, a fast start pace is supposed to led to greater rates of PCr breakdown and consequently to stimulate the system of resynthesis of the ATP by the oxidative processes (Medbö et Tabata, 1989).

However, whereas a fast start may induce a shorter delay to reach $\dot{V}O_{2\max}$, it can also cause a premature fatigue. Because the final performance is inversely related to the start-velocity (200 to 400-m after the onset of the 1500-m) expressed in % of v-$\dot{V}O_{2\max}$, our study indeed shows that a fast departure can impair the global performance.

Furthermore, as observed previously on 800-m, it emerges during the present study a significant decrease of $\dot{V}O_2$ at the end of the 1500-m race. This phase appears for 8 athletes and is characterised by a decrease of 5.3 $\pm$ 8% and 7.9 $\pm$ 7.6% detected respectively in the last 300-m and 200-m.
Some authors among whom Nummela and Rusko (1995) for the 400m, Gastin and Lawson (1994) and Perrey et al (2002) have reported the same phenomenon. Although the exercise intensity and therefore the duration of the exercise were not similar, these exercises were all performed to voluntary exhaustion.
This $\dot{V}O_2$ decrease has been shown to be correlated with the difference between the peak of the speed and the speed at 1300-m. Nevertheless, in spite of this decline, the speed remains superior to the MAS of the subjects (on average 110,9 ± 2,1 % of MAS in the last 50-m).
Numerous physiological hypothesis are suggested to explain this $\dot{V}O_2$ decrease: respiratory fatigue (Perrey et al, 2002), a decrease of cardiac output and /or an alteration of the arterio-venous difference (Gonzales-Alonso et al 2003) or a decrease in arterial haemoglobin saturation (Harms et al, 2000). Indeed, further researches are needed to elucidate the mechanism(s) underpinning this phenomenon.

Practical conclusion

First of all, it is important to note that even for this level of performance, a 1500-m is not realized at a steady pace but is ran between 103 and 114% of MAS and from 21 to 23 km.h-1 for the present level of performance.
So, only strategic aspects have been taken in consideration to explain the fast departures, up to this point,: the fast departure can allow $\dot{V}O_{2\max}$ to be reached during the middle- distances and more particularly, to be reached faster. This would seem to explain the fact that 100 % of the records on these distances are realised according to this pacing strategy.
Obviously, it is a question of starting fast while being able to accelerate again 1200-m after the onset of the race. So, a too fast departure could be also harmful as a too slow start. According to our data, the start velocity must be inferior to 115 % of v-$\dot{V}O_{2\max}$ and should not exceed 25-30 s.
We can then conclude that the 1500-m runner should perfectly regulate his pacing strategy: start fast enough to enhance $\dot{V}O_2$ kinetics and quickly regulate his pacing to minimize energetic cost in the middle part of the 1500-m in order to be able to accelerate 300-m before the finish line.

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