# Oxygen uptake in the 1500 metres 

Christine Hanon, Jean-Michel Lévêque, L. Vivier, Claire Thomas

## To cite this version:

Christine Hanon, Jean-Michel Lévêque, L. Vivier, Claire Thomas. Oxygen uptake in the 1500 metres. New Studies in Athletics, 2007, 22 (1), pp.15-22. hal-01753885

HAL Id: hal-01753885
https://insep.hal.science//hal-01753885
Submitted on 29 Mar 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Oxygen uptake in the 1500 metres 

By Christine Hanon, J. M. Levêque, L. Vivier, C. Thomas


#### Abstract

The main aim of this two-part study was to evaluate the time course of oxygen uptake in the 1500 m . In part one, races of 49 world-class and national-class


 runners were analysed to identify the pacing model used by elite performers. In part two, eleven trained middle distance runners performed a progressive increment test to determine $\mathrm{VO}_{2} \max$ and a full effort time trial (the mean running velocity corresponding to $107.6+2 \%$ of maximum aerobic speed) using the identified pacing model. In both tests, performed on the track, $\mathrm{VO}_{2}$ response was measured with a portable telemetric gas exchange system. It was found that the mean value of $\mathrm{VO}_{2}$ max recorded during the progressive test $(66.1+7.0$ $\mathrm{ml} / \mathrm{mn}^{-1} / \mathrm{kg}^{-1}$ ) was reached $459+$ 59.6 metres ( $55.9+7.5$ seconds) after the start. It was also found that $\mathrm{VO}_{2}$ decreased (8\%) at the end of the run for 8 of 10 of the subjects.
## Introduction

Recent studies on the evolution of oxygen uptake over the 800 m distance have demonstrated that results obtained in treadmill tests (SPENCER ET AL 1996; DRAPER ET AL 2005) are not the same as those obtained on the track (HANON ET AL 2002, THOM AS ET AL 2005). It should

be noted that the design for the treadmill tests mentioned called for the subjects to run at a constant pace while the track test called for a careful start and a fast finish of the race. Contrary to constant pace treadmill running, it seems that starting faster than the average running speed for the distance, as is common in 800 m races, leads to the athlete reaching his/her $\mathrm{VO}_{2}$ max (maximum oxygen
uptake) during the race (THOMAS ET AL 2005). However, for the 1500 m distance, also run at above the speed associated with $\mathrm{VO}_{2}$ max, neither treadmill nor track tests show the achievement of $\mathrm{VO}_{2}$ max (SPENCER ET AL 1996; SPENCER, GASTIN, 2001).

The aim of the present study was to evaluate the time course of oxygen uptake during a 1500 m run at full effort based on the strategy most commonly used in competition. To do so, it was necessary to examine the pacing strategies of national and international level 1500 m runners and then to test the kinetics of $\mathrm{VO}_{2}$ during a time trial based on the model identified. Therefore, the study consisted of two parts. The first, named "Pacing Strategy Analysis" aimed to propose a model of pacing used during national and international 1500 m races. The second, called " 1500 m Study" consisted of two different tests: a test to determine $\mathrm{VO}_{2}$ max on the track and a test to determine the maximal $\mathrm{VO}_{2}$ value obtained during a 1500 m time trial $\left(\mathrm{VO}_{2} 1500\right)$.

## Pacing strategy analysis

## Method

In order to describe the strategy of elite 1500 m runners, races of 49 different athletes in 13 different competitions (performances between $3: 28$ and $3: 45$ ) were analysed. The data were collected from images of television or from personal films. The split times for each 100 m were determined by means of a time code or a stopwatch. The races of athletes who performed 3 seconds or more over their best performance were not analysed.

Results
According to our analyses (Figure 1), worldclass (<3:35) and national-class (3:35-3:45) performances share some common characteristics:

1) The first 100 m is always significantly the fastest part of the race.
2) A deceleration is observed in the second 100 m .
3) Except for the segment from 500 m to 600 m , the athletes run relatively regularly between 200 m and 1200 m .


Figure 1: Time course of running velodity during world-dass and national-dass 1500 m races
4) Acceleration is noted from 1200 to 1300 m . At the world-class level, this acceleration was highly significant ( $\mathrm{p}<$ .0001).
5) During the last 300 m , the higher velocity (relative to the middle of the race) is maintained.
6) Finally, there is no acceleration in the final straight, at either level of performance.

## Discussion

It is notable that 1500 m races with the aim of maximising time performance at both the world-class and national-class levels are run according to a relatively common pace model. This model shows that the pacing is not based on the regularity of speed but on a fast departure from the start to 100 or 150 m , followed by a velocity plateau of 1100 m in length and then an acceleration between the 1200 m and 1300 m marks. Contrary to the visual impression given by the athletes, there is no significant acceleration in the final straight at either level of performance. A specific speed for the 1500 m does not exist. There are, instead, three distinct specific speed phases.

Our 1500 m study used this chronometric model to calibrate the pacing of the athletes studied (Figure 2).


Figure 2: Pace profile model for the 1500 m

## 1500 m study

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

A progressive test was used to determine $\mathrm{VO}_{2}$ max and a controlled1500m time trial was used to determine $\mathrm{VO}_{2} 1500$. In both tests, each athlete's $\mathrm{VO}_{2}$ was recorded continuously by means of a gas exchange telemetric system (Cosmed K4, Roma, Italy). HR (heart rate) was measured and recorded continuously with a heart rate monitor (Sport Tester PE 3000, Polar, Kempele, Finland). Blood lactate was collected from the ear lobe and measured with the Lactate Pro analyser (Arkray, Japan).

## Progressive test

The test used is called TUB II (Test of the University of Bordeaux II) and was developed by CAZORLA and LÉGER (1993). It consists of running on a track, with markers every 25 m , for a succession of stages each of 3 minutes duration. The athlete begins at a pace of $14 \mathrm{~km} / \mathrm{h}^{-1}$ and increases his/her speed in each stage by $2 \mathrm{~km} / \mathrm{h}^{-1}$ up to $18 \mathrm{~km} / \mathrm{h}^{-1}$, then by $1 \mathrm{~km} / \mathrm{h}^{-1}$ to the superior speeds. The stages are separated by one minute of recovery to allow a sample of blood to be taken. In each stage, the athlete must follow the speed imposed by broadcast sound signals. The test is stopped when the athlete is no longer capable of maintaining the rhythm imposed by the signals and is unable to reach the required mark by the time of the signal.

During the test, the MAS (maximal aerobic speed) corresponds to the first stage where $\mathrm{VO}_{2}$ max is attained (mean of the three consecutive highest values) and where the subsequent increase in $\mathrm{VO}_{2}$ is less than 2.1 $\mathrm{mmol} / \mathrm{kg}^{-1}$ for an increase in speed of $1 \mathrm{~km} / \mathrm{h}^{-1}$. Moreover $\mathrm{VO}_{2}$ max must be associated with a blood lactate value, a respiratory exchange ratio and a heart rate equal to 8 to $12 \mathrm{mmol} / \mathrm{I}^{-1}, 1.1$ and minimum $90 \%$ of the the-
oretical maximal HR (220-age in years) respectively.

## 1500m time trial

The athletes were asked to perform a set warm-up (jogging, stretches, mobility exercises, strides) plus $3 \times 150 \mathrm{~m}$ at 1500 m start pace. This was followed by a break of four minutes. During the warm-up, the runners were gradually equipped (heart-rate monitor, K4). The athletes then performed a 1500 m time trial on the track. For each runner, the speed was pre- determined for the first 1200 m according to the pacing model described previously. The last 300 m was to completed as quickly as possible. Whistle signals every 50 m on the basis of established times allowed to the athletes to adjust their pace accordingly. An experimenter on bicycle accompanied and encouraged each athlete.

A blood sample was taken from the earlobe at the end of the warm-up, at the end of the 1500 m and $3,5,7$, and 10 minutes after the run. All the tests were filmed to make it possible to determine a posteriori the exact speed.

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

Results - progressive test
The mean values of the different variables obtained in the progressive test are presented in Table 1. During this test, $\mathrm{VO}_{2} \mathrm{max}$ and v $\mathrm{VO}_{2} \mathrm{max}$ were equal to $64.2 \pm 6.5 \mathrm{ml} / \mathrm{min}^{-1} / \mathrm{kg}^{-1}$ and $20.3 \pm 1.1 \mathrm{~km} / \mathrm{h}^{-1}$

Table 1: Mean and standard deviations of the parameters observed during the progressive incremental test

| $\begin{gathered} \mathrm{VO}_{2} \max \\ \left(\mathrm{mlO}_{2} / \mathrm{min}^{-1} / \mathrm{kg}^{-1}\right) \end{gathered}$ | HRmax (batt/ $/ \mathrm{min}^{-1}$ ) | $\begin{gathered} \mathrm{MAS} \\ \left(\mathrm{~km} / \mathrm{h}^{-1}\right) \end{gathered}$ | M aximal lactatémia ( $\mathrm{mmol} / \mathrm{l}^{-1}$ ) |
| :---: | :---: | :---: | :---: |
| $64.2 \pm 7.5$ | $195.3 \pm 6.5$ | $20.3 \pm 0.6$ | $12.4 \pm 1.6$ |

$\mathrm{VO}_{2}$ max: maximum oxygen uptake
HRmax: maximum heart rate
MAS: maximum aerobic velocity
Maximal lactatémia:

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

| $\mathrm{VT}(\mathrm{I})$ | HR <br> $\left(\mathrm{batt} / \mathrm{min}^{-1}\right)$ | VE <br> $\left(\mathrm{I} / \mathrm{min}^{-1}\right)$ | FR <br> $\left(\mathrm{cycle} / \mathrm{min}^{-1}\right)$ | Blood Lactate <br> $\left(\mathrm{mmol} / /^{-1}\right)$ |
| :--- | :---: | :---: | :---: | :--- |
| $2.6 \pm 0.3$ | $192.2 \pm 7.4$ | $155.1 \pm 19.8$ | $63.8 \pm 6.9$ | $15.0 \pm 0.9$ |

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

Results - 1500 m time trial
The mean performance in the 1500 m time trial ( $3: 56+9.9 \mathrm{sec}$ ) can be considered as a supra-maximal exercise with regard to the average velocity achieved ( $21.8 \mathrm{~km} / \mathrm{h}^{-1}$ ), which is $107.6 \%$ of MAS.

As expected from the preliminary study, running velocity presented some large variations. Until 1100 m , the athletes in the test respected the designed pacing strategy. In the last 300 m , the speed increased ( $102.2 \%$ of the average 1500 m speed) as observed in the preliminary study, but the actual acceleration varied among the subjects between 95 and $107 \%$ of the average 1500 m speed. Because of the experimental conditions, some subjects did not achieve 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 Figure 3, $\mathrm{VO}_{2}$ attained during the $1500 \mathrm{~m}\left(\mathrm{VO}_{2} 1500\right)$ reached $\mathrm{VO}_{2} \max$ (determined in the incremental test) (459.1 $\pm$ 59.6 metres or $56.0 \pm 7.5$ seconds) after the start of the 1500 m . These $\mathrm{VO}_{2} 1500$ values ( $69.5+6.5 \mathrm{mlO}_{2} / \mathrm{min}^{-1} / \mathrm{kg}^{-1}$ ) although slightly higher were not significantly different from $\mathrm{VO}_{2} \max \left(66.08+7 \mathrm{mlO}_{2} / \mathrm{min}^{-1} / \mathrm{kg}^{-1}\right)$. The time constant $(\tau)$ with which $\mathrm{VO}_{2} 1500$ was reached was $30.1+4.4 \mathrm{sec}$. At the end of the time trial, the $\mathrm{VO}_{2} 1500$ decreased significantly ( $7.9+7.6 \%$ ) between 1300 and 1500 m . This fall was observed in 8 of 10 subjects.

Relationships between velocity, time course of oxygen uptake and performance
It is noteworthy that the performances realised during the 1500 m time trial are strongly correlated to $\mathrm{v}-\mathrm{VO}_{2} \max (\mathrm{r}=0.73, \mathrm{P}<$ 0.001 ).

*: the increase or decrease of $\mathrm{VO}_{2}$ is significant between two consecutive values, $\mathrm{p}<0.05$
-: $\quad \mathrm{VO}_{2} \max$ obtained during incremental test
I: $\quad \mathrm{S}-\mathrm{D}$ for $\mathrm{VO}_{2}$ max incremental test
$\Gamma$ : the increase or the decrease is significantly different between two non-consecutive values, $\mathrm{p}<0.05$.


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

The slow down period of $\mathrm{VO}_{2}$ is correlated with the difference between peak speed and speed at 1300 m . The final value of $\mathrm{VO}_{2}$ and the 1500 m performance are significantly and negatively correlated ( $\mathrm{r}=-0.65, \mathrm{p}=$ 0.02 )

## Discussion

The results of the present study demonstrate that $\mathrm{VO}_{2}$ max was attained during an exercise protocol that reproduced the pacing conditions of a 1500 m competition: a fast start followed by an even velocity.

These results confirm those that our team has obtained with a similar methodology for the 800 m but are in contradiction to those reported on treadmill running for 800 m by DRAPER and WOOD (2005), treadmill running for 800 and 1500 m by SPENCER ET AL (1996), SPENCER and GASTIN (2001) and treadmill running for a five minute duration by DRAPER ET AL (2003). In these studies, subjects reached from 85 to $98.5 \%$ of $\mathrm{VO}_{2}$ max. M oreover, with special regard to the 1500 m , it is noted that these studies, carried out using constant pace, or with a careful start and a fast finish (SPENCER, GASTIN 2001), were realised at only $103 \%$ of MAS while in serious competition, the 1500 m is performed between 107 and 109\% of MAS (LACOUR ET AL 1990 and personal data). In the present study, the subjects performed the 1500 m time trial at $107.6+2 \%$ of MAS.

Furthermore, it is notable that the best performances over $400 \mathrm{~m}, 800 \mathrm{~m}$ and 1500 m are realised with a fast start followed by a short transition to even-pacing strategy as observed for the 400 m and 800 m by GAJ ER ET AL (2000) and for the 1500 m by the present study (Pacing Strategy Analysis). 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 $\mathrm{VO}_{2}$ response. ÅSTRAND and SALTIN (1961) and MARGARIA ET AL (1965), among others, have suggested that the kinetic of $\mathrm{VO}_{2}$ adaptation speeds up when the intensity of the supra-maximal exercise was greater. The $\mathrm{VO}_{2}$ 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 result in an increased rate of glycolysis (CHIATOSIS ET AL 1987). Therefore, a fast start pace leads to greater rates of PCr breakdown and consequently to stimulate the system of resynthesis of the ATP by the oxidative processes (MEDBÖ, TABATA 1989).

However, whereas a fast start may lead to the athlete reaching $\mathrm{VO}_{2}$ max earlier, it can also cause premature fatigue. Because the final performance is inversely related to the start-velocity ( 200 to 400 m after the start of the 1500 m ) expressed in \% of v - $\mathrm{VO}_{2}$ max, our study shows that, indeed, a fast start can impair the overall performance.

Furthermore, as observed previously for 800 m , it emerged during the present study that there is a significant decrease of $\mathrm{VO}_{2}$ at the end of a 1500 m race. This phase appears for 8 athletes and is characterised by a decrease of $5.3+8 \%$ and $7.9+7.6 \%$ detected respectively in the last 300 m and 200 m . Some authors, among whom are NUM MELA and RUSKO (1995) for the 400 m , GASTIN and LAWSON (1994) and PERREY ET AL (2002) have reported the same phenomenon. Although the exercise intensity and therefore the duration of the exercises were not similar, they were all performed to voluntary exhaustion.

This $\mathrm{VO}_{2}$ decrease has been shown to be correlated with the difference between the peak speed and the speed at 1300 m . Never-
theless, in spite of this decline, the speed remains superior to the MAS of the subjects (on average $110.9 \pm 2.1 \%$ of MAS in the last $50 \mathrm{~m})$.

Numerous physiological hypothesis are suggested to explain this $\mathrm{VO}_{2}$ decrease: respiratory fatigue (PERREY ET AL 2002), a decrease of cardiac output and or an alteration of the arterio-venous difference (GON-ZALES-ALONSO ET AL 2003) or a decrease in arterial haemoglobin saturation (HARMS ET AL 2000). Indeed, further research is needed to elucidate the mechanism(s) underpinning this phenomenon.

## Practical conclusion

Firstly, it is important to note that at the studied levels of performance, a 1500 m race is not realised at a steady pace but is run between 103 and 114\% of MAS and between 21 to $23 \mathrm{~km} / \mathrm{h}^{-1}$. Tactical considerations are assumed to explain fast starts but a fast start can allow $\mathrm{VO}_{2}$ max to be reached during mid-dle-distance races and more particularly, to be reached faster. This would seem to explain the fact that $100 \%$ of the records for these
distances have been achieved according to this pacing strategy. However, success seems to be a matter of starting fast and being able to accelerate again after 1200 m . Therefore, a over-fast start could be as harmful as one that is too slow. According to our data, the start velocity must be inferior to $115 \%$ of v $\mathrm{VO}_{2} \max$ and the duration of this velocity should not exceed 25-30 seconds.

We can therefore conclude that the 1500 m runner should perfectly regulate his pacing strategy: start fast enough to enhance $\mathrm{VO}_{2}$ kinetics and quickly regulate his pacing to minimise energetic cost in the middle part of the 1500 m in order to be able to accelerate 300 m before the finish line.

## Acknowledgements

The authors would like to thank the following for their active collaboration or support: the subjects who participated in the study, the Fédération Française d'Athlétisme and the French Ministry of Youth and Sport.

## Pleasesendall carespandanceto:

christine.hanon@ insep.fr

## REFERENCES

ÅSTRAND, P.O.; RODAHL, K. (1994): Précis de physiologie de l'exercice musculaire. 3rd edition, MASSON

BISHOP, D.; BONETTI, D.; DAWSON, B. (2002): The influence of pacing strategy on VO2 and supramaximal kayak performance. M ed Sci Sports Exerc 34: 10411047

CAZORLA, C.; LÉGER, L.: Comment évaluer et développer vos capacités aérobies? Epreuve de course navette et épreuve vameval? Edition Association Recherche et evaluation en activité physique et en sport (1993)

CHASIOTIS, D.; BERGSTRÖM , M.; HULTM AN, E. (1987): ATP utilization and force during intermittent and continuous muscle contractions. J Appl Physiol 63: 167-174

DRAPER, S.B,; WOOD, D.M. (2005): The $\mathrm{VO}_{2}$ response for an exhaustive treadmill run at 800 m pace: a breath-by breath anaIysis. Eur J Appl Physiol 93: 381-389

DRAPER, S.B.; WOOD, D.M .; FALLOWFIELD, J.L. (2003): The $\mathrm{VO}_{2}$ response to exhaustive square wave exercise: influence of exercise intensity and mode. Eur J Appl Physiol 90: 92-99

FOSTER, C.; SNYDER, A.C.; THOM PSON, N.N.; GREEN, M .A.; FOLEY, M.; SCHRAGER, M. (1993); Effect of pacing strategy on cycle time trial performance. M ed Sci Sports Exerc. 25(3):383-8

GAJER, B.; HANON, C.; MARAJ O, J.; VOLLM ER, J.C. (2000): Le 800 mètres: analyse descriptive et entraînement. Collection entraînement INSEP

GASTIN, P.B.; LAWSON, D.L. (1994): Influence of training status on maximal accumulated oxygen deficit during supramaximal all-out and constant intensity exercise. M ed Sci Sports Exerc 27: 255263

GONZALES-ALONSO, J.; JOSÉ, A.L.; CALBET, M.D. (2003): Reductions in systemic and skeletal muscle blood flow and oxygen delivery limit maximal aerobis capacity in Humans. Circulation 107:824-830

HANON, C.; THOM AS, C.; LE CHEVALIER, J.M.; GAJER, B.; VANDEWALLE, H. (2002): How does VO2 evolve during the 800m? New studies in Athl 17:2; 61-68

HARM S, C.A.; M CCLARAN, S.R.; NICKELE, G.A.; PEGELOW, D.F.; NICKELE, G.A.; NELSON, W.B.; DEM PSEY, J.A. (2000): Effect of exercise-induced arterial 02 desaturation on V02max in women. Med Sci Sport Exerc 32:1101-1108

LACOUR, J.R.; BOUVAT, E.; BARTHELEM Y, J.C. (1990): Post competition blood lactate concentrations as indicators of anaerobic energy expenditure during 400 m and 800 m races. Eur J Appl Physiol 61:172-176

NUM MELA, A.; RUSKO, H. (1995): Time course of anaerobic and aerobic energy
expenditure during short-therm exhaustive running in athletes. Int J Sports Med 16:522-527

M ARGARIA, R.; M ANGILI, F.; CUTTICA, F.; CERRETELLI, P. (1965): The kinetics of the oxygen consumption at the onset of muscular exercise in man. Ergonomics 8: 49-54

M EDBÖ, J.I.; TABATA, I. (1989): Relative importance of aerobic energy release during short-lasting exhausting bicycle exercise. J Appl Physiol 67: 1881-1886

PERREY, S.; CANDEAU, R.; MILLET, G.Y.; BORRANI, F.; ROUILLON, J.D. (2002): Decrease in oxygen uptake at the end of a high-intensity submaximal running in humans. Int J Sports M ed 23:298-304

ROSSITER, H.B.; WARD, S.A.; KOWALCHUK, J.M.; HOWE, F.A.; GRIFFITHS, J.R.; WHIPP, B.J. (2002): Dynamic asymetry of phosphocreatine concentration and oxygen uptake between the on- and offtransients of moderate- and high-intensity exercise in humans. J Physiol 541: 991-1002

SPENCER, M .R.; GASTIN, P.B.; PAYNE, W.R. (1996): Energy system contribution during 400 to 1500 meters running. New studies in Athl 11: 59-65

SPENCER, M.R.; GASTIN, P.B. (2001): Energy contribution during 200 - to 1500 m running in highly trained athetes. Med Sci Sports Exerc 33: 157-162

THOM AS, C.; HANON, C.; PERREY, S.; LE CHEVALIER, J.; COUTURIER, A. VANDEWALLE, H. (2005): Oxygen uptake response to an 800 m running race. Int J Sports Med 26: 268-273

