

BENAJMIN LLOYD OWEN

ST05002650

SPORT AND EXERCISE
SCIENCE

UNIVERSITY OF WALES
INSTITUTE CARDIFF

**A COMPARISON OF THE VO₂
KINETIC RESPONSE BETWEEN
400- AND 1500-METRE TRACK
ATHLETES TO SUPRAMAXIMAL
TREADMILL RUNNING**

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Acknowledgement

I would like to thank a number of people, whom without their support and backing this dissertation would not have been possible. Firstly I would like to thank my dissertation supervisor Dr. Deborah Welford whose expertise in the field of oxygen uptake kinetics has both helped and inspired me.

I would also like to give thanks to both of the laboratory technicians Mr. Mike Stembridge & Mr. Daniel Newcombe whose support and advice helped greatly.

My good friends also deserve a great deal of thanks as they have helped me in hours of need.

Both thanks and congratulations are in order for all participants as their effort during the exercise tests was both excellent and extremely valuable.

I would finally like to thank my loving family. Without their support this dissertation would not have been possible.

ABSTRACT

Purpose: The aim of the present study was to investigate if a difference existed in the time course of 400- and 1500m track athletes, in response to supramaximal treadmill running. **Methods:** Twelve collegiate level male athletes consisting of seven 400-metre sprinters (mean \pm SD 400: age 20.7 ± 1.4 yr; $\dot{V}O_{2\max}$ 62.8 ± 6.7 mL \cdot kg $^{-1}\cdot$ min $^{-1}$; Personal best 50.08 ± 0.65 seconds) and five 1500-metre middle distance athletes (mean \pm SD 1500: age 21 ± 0.9 yr; $\dot{V}O_{2\max}$ 73.16 ± 4.6 mL \cdot kg $^{-1}\cdot$ min $^{-1}$; Personal best $4.06 \pm 0.2.5$ minute, seconds) were used as subjects in the investigation. Each subject completed an initial incremental steady state $\dot{V}O_{2\max}$ treadmill test to determine maximal treadmill velocity at $\dot{V}O_{2\max}$. Subsequent exercise transitions of 3 minutes at 110% of peak $\dot{V}O_{2\max}$ treadmill velocity. (km \cdot h $^{-1}$) to represent supramaximal intensity treadmill running were then used as a means of modelling the $\dot{V}O_2$ response to supramaximal intensity running. Pulmonary gas measurement was measured breath-by-breath and H.R was taken at 5-s intervals. **Results:** T-tests revealed that no significant difference ($P= 0.1993$) exists between the mean τ response exists between 400- and 1500-metre athletes in the

supramaximal intensity domain. The homogenous populations exhibited significantly different $\dot{V}O_{2\max}$ scores (P value =0.017) and final minute H.R (P-value 0.0075). **Conclusions:** From the responses exhibited by the two populations assumptions can be that the τ in response to supramaximal treadmill running is not a function of an athletes $\dot{V}O_{2\max}$. Any differences in $\dot{V}O_2$ kinetics observed between the two populations could be attributed to varying central and peripheral adaptations induced by the varying training methods for the two events although no significant difference existed.

CHAPTER I

INTRODUCTION

1.0 INTRODUCTION

The 400-m and the 1500-m track events require the unique ability to sustain high intensity work for prolonged periods of time. The body's ability to cope with the exercise challenges from these events involves significant energy contributions from both anaerobic and aerobic energy systems. The degree to which an athlete tolerates the demand of the exercise imposed will depend, in part, on the speed of their oxygen kinetics (Jones & Poole, 2005). Unresponsive VO_2 on-kinetics are believed to result in a greater depletion of intra-muscular high-energy phosphates, and greater accumulation of lactate and hydrogen ions (H^+) i.e. a greater anaerobic energy contribution (Jones & Koppo, 2005, in Jones & Poole 2005). An increase in $[\text{H}^+]$ (acidosis) and inorganic phosphate (Pi) during exercise will lead to muscular fatigue and performance decrements (Wilkie, 1986). Ideally, it would be advantageous for athletes to offset the depletion of the muscles finite phosphocreatine (PCr) stores, and the accumulation of fatiguing anaerobic by-products. Faster VO_2 on-kinetics will facilitate this process, as the oxygen deficit is subsequently reduced, thereby indicating a sparing of intra-muscular [PCr] and attenuating the production of lactic acid (Jones & Poole, 2005, p.379).

The process of exercise training has consistently been shown to accelerate phase II VO_2 on-kinetics (Berger *et al.*, 2006; Carter *et al.*, 2000; Koppo *et al.*, 2000). However, the optimal training strategy to accelerate VO_2 kinetics is, at present, unknown (Berger *et al.*, 2005). The contrasting training undertaken by 400-m and 1500-m runners make them interesting populations to compare. Differences in VO_2 kinetics of sprint versus endurance athletes have been investigated for moderate intensity exercise but relatively untouched in the field of severe intensity exercise (Draper *et al.*, 2005). Specifically, 400-m athletes typically engage in repeated-

sprint training, while the 1500-m athlete counterparts undertake predominantly extended endurance bouts of exercise. The dynamic VO_2 response exhibited by these athletes, during an abrupt transition to a supramaximal work rate, will provide insights into the most suitable training interventions to accelerate VO_2 kinetics.

Initial energy pathways such as the ATP, adenosine di-phosphate (ADP) and creatine phosphate (CP), which provide the immediate source of energy, are exhausted within 30 seconds (Linderman & Gosselink, 1994). Thereafter, energy from both the aerobic and anaerobic pathways fuels the working muscles during events lasting over 40 seconds to 5 minutes i.e. 400-m and 1500-m (depending on ability). To execute supramaximal or severe intensity work, both sprint and endurance trained athletes will require cardio-respiratory and metabolic responses to exercise which will enable them to sustain the energy production necessary to optimise running speed over their chosen distances, while minimising the accumulation of fatiguing bi-products. This has recently received a great deal of research attention; primarily the dramatic increase in blood flow (O_2 delivery) and O_2 uptake observed at exercise onset, in order to meet this increased metabolic demand (Caputo & Denadai., 2004).

The nature of the 400-m event is that it involves heavy reliance upon all 3 of the energy pathways (Duffield *et al.*, 2003), primarily being the ATP, ATP-PC and lactic acid systems. As the time to complete the 400-m exceeds 30s the predominating energy source for the event is anaerobic glycolysis (a non-oxidative metabolic process). At the onset of exercise the rapidity with which the rate of adenosine triphosphate (ATP) supply through oxidative phosphorylation can alter to meet the total ATP turnover rate in the transition to a higher metabolic rate is a

central determinant of exercise tolerance (Jones & Poole, 2005). Indeed, it has recently been found that the energy pathways supplying the ATP during the 400-m is more aerobic than previously assumed. Accordingly, 400m trials conducted by Spencer & Gastin (2000) found the event to have an aerobic contribution of 43% and as high as 59% (Duffield et al., 2003). Comparing this figure with that of the 1500-m discipline we see a substantial change in the contribution of aerobic metabolism, with studies (Hill, 1999; Spencer, et al., 1996; Duffield, et al., 2003) quantifying the aerobic contribution as high as 83%. Although the 400-m and 1500-m track events have significantly different energy system contributions, they both require a rapid response at the onset of exercise. With this in mind, it is in the interest of the researcher to investigate which of the two disciplines demonstrates a more immediate cardio-dynamic response to exercise.

The purpose of the current study is, therefore, to compare the $\dot{V}O_2$ kinetics of trained 400-m and 1500-m runners to supramaximal exercise. From this it is then possible to infer the optimal training necessary to accelerate $\dot{V}O_2$ kinetics. This would be of interest to both coaches and exercise physiologists and provides further information on the mechanisms behind the $\dot{V}O_2$ kinetic response.

CHAPTER III

METHODS

3.0 METHODS

3.1 Subjects and experimental design:

Twelve male subjects in total were selected from the track and field team at the University of Wales Institute Cardiff (UWIC) and agreed to participate. They comprised of seven 400-metre track athletes and five 1500-m/ cross country athletes. The study was granted ethical approval from the University of Wales Ethics board. The participants' anthropometric and physiological and performance characteristics are presented in Table 1.

Table 1, Descriptive statistics:

| SUBJECTS: | AGE: (YEARS) | HEIGHT: (CM) | WEIGHT: (KG) | PERSONAL BEST: 400- (SECS) 1500- (MINS. SECS) |
|----------------------|-------------------------|-------------------------|-------------------------|--|
| 400-metre athlete | 20.4±1.4 | 176.1±8.1 | 74.4±6.9 | 50.08±0.65 |
| 1500- metre athletes | 18.8±1.3 | 179.8±5.2 | 66.2±5.6 | 4.06±0.26 s |
| Complete sample | 19.8±1.5 | 177.7±7.0 | 71.0±7.5 | N/A |
| | | | | |

Prior to the measurements being taken, each subject was fully informed of the risks, commitment required and the testing procedures. After verbal and written consent to participate in the study, a physical activity readiness questionnaire (PARQ) was completed by each subject (Appendix B). Each subject's personal best time for their event was also noted. The personal best times are representative of well trained collegiate level athletes.

Each subject was then familiarised with the equipment being used during the test to allow the subjects to get used to the testing procedure e.g. allowing the athletes to

become accustomed to initiating running on the treadmill when it is already at high speeds, although many of the subjects were already highly accustomed to high intensity treadmill running. The habituation also allowed the participants to become accustomed to running with heart rate monitor and face mask on. The subjects were also instructed to arrive at the laboratory in as rested and fully hydrated state as possible. Subjects were requested to avoid drinking alcohol and caffeine for a minimum of 12 hours prior to participating in each test and all transitions were conducted at the same time of day (\pm two hours), to reduce the effects of biological variation on the $\dot{V}O_2$ kinetic response (Carter *et al.*, 2002).

3.2 Steady state $\dot{V}O_{2\max}$ test

Following their recruitment to the study the subjects performed a steady state incremental $\dot{V}O_{2\max}$ treadmill test to exhaustion in order to determine $\dot{V}O_{2\max}$ and peak treadmill velocity.

Heart rate was collected at 5-s intervals during all exercise sessions using non-invasive telemetry (Polar S610, Polar Electro, Oy, Kempele, Finland) and the tests were all performed on a motorised treadmill (Woodway Ergo Rona ES70, Germany). During the test the treadmill remained at a constant gradient of 1% in order to represent the energy cost experienced during outdoor running (Jones & Doust, 1996). Each subject started the test at a speed where projected volitional exhaustion would be elicited in approximately 15 minutes or at least 5 stages of incremental exercise had been undertaken. Starting speed was thus determined by training status and perceived velocity at exhaustion. The treadmill speed was increased by 1 km.h⁻¹

every 3 minutes, whilst pulmonary gas exchange and ventilation was determined using a breath-by-breath through low resistance mouth-piece and impeller turbine assembly attached to a face mask. Gas concentrations were determined through O₂ and CO₂ analyzers (Erich Jaeger, Oxycon Delta, LA Bunnick, The Netherlands) via a capillary line connected to the mouthpiece attached to a face mask. Gas exchange variables were calculated and displayed once volume and concentration signals had been accounted for. Calibration took place immediately before each test.

The treadmill used had two handrails, which were used by the participants to lower themselves onto the treadmill belt and gather the required leg speed upon starting the test (typically taking 2-4 seconds). Upon exhaustion the treadmill was stopped and the face mask immediately removed. Subjects were given the option of both fluid intake and a slow walk at approximately 2.5km.h⁻¹ to aid recovery.

The attainment of $\dot{V}O_{2\text{ max}}$ was confirmed by the incidence of a plateau phenomenon in $\dot{V}O_2$, RER values above 1.10, and heart rate within 5 b.min⁻¹ of age-predicted maximum heart rate (Carter *et al.*, 2002).

3.3 Determination of VO₂ kinetics

For the assessment of on-transient VO₂ kinetics, participants completed a 3 minute severe intensity exercise transition on the treadmill, thus the speed of the treadmill was equivalent to 110% of peak treadmill velocity attained during the $\dot{V}O_{2\text{ max}}$ test. Transitions were repeated on separate days until a 95% confidence limit of $\pm 5s$ was

achieved and it could be regarded as an accurate representation of the kinetic response.

Subjects were fitted with a heart rate monitor on arrival to the laboratory and given 10 minutes to perform any static stretching they believed necessary, while trying to keep their heart rate as close to resting as possible as any dynamic, pulse raising exercise could be regarded as prior exercise which has shown to promote a faster $\dot{V}O_2$ kinetic response to exercise (Burnley *et al.*, 2002).

The test began with 2 minutes of motionless standing (feet astride the treadmill belt) for the measurement of resting $\dot{V}O_2$. Subjects were warned of the proximity of the test 1 min, 30 sec and 10 sec before a final 5 second count where the subjects were allowed to use the handrails to support body weight whilst gathering the required leg speed that matched the treadmill belt velocity. A safety harness was fitted to any athlete who requested it. After the 3 minute bout of exercise, the treadmill was stopped and subjects were then also requested to remain as static as possible for recovery kinetics to be obtained over 5 minutes.

3.4 Pulmonary $\dot{V}O_2$ kinetic analysis

Due to its nature $\dot{V}O_2$ data emerges as ‘noisy’ when recorded as a low signal-to-noise ratio (S/N) exists which in turn has significant influence on the confidence of the kinetic parameters and their interpretation (Jones & Poole, 2005). So participants breath by breath responses were averaged every 5s, time aligned and then averaged

to enhance the signal to noise ratio (Lamarra *et al.*, 1987). A single exponential that included a time delay was used to analyse the averaged response using least squares non-linear regression analysis (Graph Pad Prism, Graph Pad Software, San Diego, CA). Also Here any errant breaths caused by coughing, swallowing, talking could be excluded. Doing this would also enhance the underlying response characteristics present in the data. The primary response known as the ‘Phase I response’ exists during the first 20s of $\dot{V}O_2$ data and characterisation of the phase II pulmonary $\dot{V}O_2$ exercise onset responses was achieved by fitting a single-exponential model including a delay term following the initial 20 s (to exclude phase I) of the exercise.

$$p \dot{V}O_2 (t) = p \dot{V}O_2_{ss} W (1 - e^{-(t-DE)/\tau})$$

where $p \dot{V}O_2 (t)$, $\dot{V}O_2_{ss}$, DE and τ represent the value of $p \dot{V}O_2$ at a given time (t) , the amplitude change in $p \dot{V}O_2$ from baseline to a new steady-state amplitude, time delay and the time constant of the response, respectively.

3.5 Statistical Analysis

The data was analysed using a T-Test in a statistical analysis software package to compare the two means of the time constant to obtain if any significance existed between the two populations.(Graph Pad Prism, Graph Pad Software, San Diego, CA). The level of significance was set at $P < 0.05$.

CHAPTER IV

RESULTS

4.0 RESULTS

4.1 $\dot{V}O_{2\max}$ & Heart rate

The parameters of the $\dot{V}O_2$ kinetic response in the transition to the same absolute severe work rate (110% of peak treadmill velocity corresponding to $\dot{V}O_{2\max}$) are displayed in tables 1 & 2. The trained subjects were all aerobically fit on recruitment to the study, as reflected within the $\dot{V}O_{2\max}$ 400-m $62.8 \pm 6.7 \text{ ml.kg}^{-1}.\text{min}^{-1}$ and 1500-metre $73.2 \pm 4.6 \text{ ml.kg}^{-1}.\text{min}^{-1}$. T-tests revealed significant difference (P value =0.017) in the $\dot{V}O_{2\max}$ of the populations, representing a significantly higher $\dot{V}O_{2\max}$ amongst the 1500-m athletes. Figures for amplitude of the $\dot{V}O_2$ response (A1) for the 400-m $3430 \pm 162.4 \text{ (mL.min}^{-1}\text{)}$ are considerably lower than that of the 1500-m athletes where $A1 = 3919 \pm 293.4$. Both delay time (s) and time constant (τ) were faster amongst the 1500-m athletes. Although as displayed in table 3 below no variable was significantly different between the two populations. Final minute HR was also recorded for 400-metre athletes at a mean value of $174.8 \pm 0.7 \text{ bpm}$ and 1500-metre mean HR of $170.4 \pm 5.4 \text{ bpm}$, which revealed significant difference (P-value 0.0075) between the populations. Although a significant difference existed between both heart rate and $\dot{V}O_{2\max}$, no difference (P value =0.3986 between heights, P value=0.0574 between weights) existed between the height and weight characteristics of the two populations competing in the different event categories.

Table 2, The Mean \pm SD for all responses to treadmill running

| Variable | 400m (mean \pm sd) | | 1500m | | P Value | Significant Difference |
|-------------------------|--------------------------|-------------|------------|----------------|---------|---------------------------|
| A1 | 3430 | ± 162.4 | Mean:3919 | SD ± 293.4 | 0.1474 | NO |
| DE | 6.041 | ± 1.0 | Mean:4.978 | SD ± 1.2 | 0.5165 | NO |
| TAU | 22.14 | ± 2.6 | Mean:17.67 | SD ± 1.3 | 0.1993 | NO |
| VO2 MAX | 62.8 | ± 6.7 | Mean:73.2 | SD ± 4.6 | 0.0174 | <u>YES</u> |
| HR (Final Minute) | 174.8 | ± 0.7 | Mean:170.4 | SD ± 5.4 | 0.0075 | <u>YES</u> |

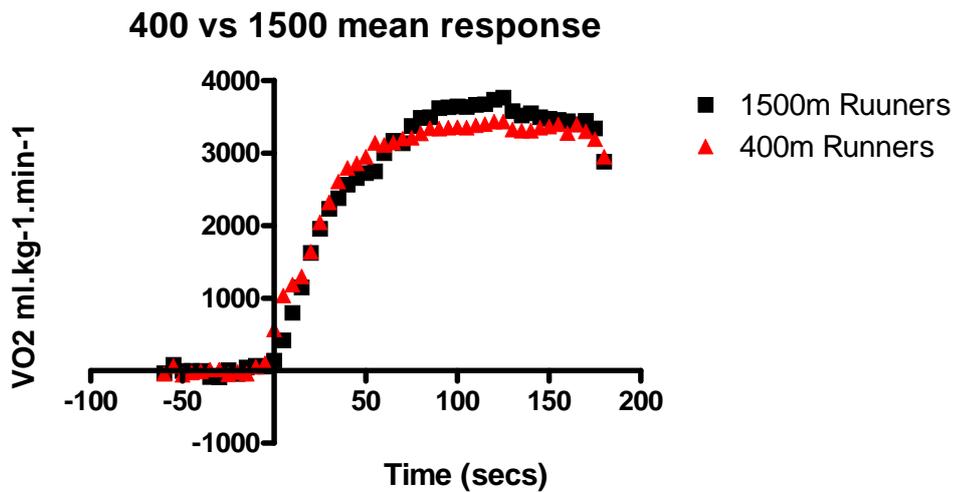


Figure 2. The two mean exponential for 400- and 1500-metre time constants in transition to obtain a steady state to the same absolute work rate (110% of VO_{2max}) during severe intensity running.

4.2 Comparison of the $\dot{V}O_2$ on-transient response between 400-m and 1500-m athletes

When 400- and 1500-metre track athletes were compared it was clear that the 1500-m endurance trained athletes' elicited the lower τ (1500-m: 17.7 ± 1.28 vs. 400-m: 22.1 ± 2.56) The parameters of the $\dot{V}O_2$ on-kinetics in 400- and 1500-m athletes in severe intensity running transitions are displayed in table 3 and figure 1.

Although it is clearly visible from the mean τ exponentials in figure 2 and the mean values shown in table 3 that a clear difference exist between the two populations, T-test indicates no significant differences in the oxygen uptake response to severe intensity treadmill running between 400- and 1500-m athletes ($P= 0.1993$).

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APPENDICIES

APPENDIX A

Table 4. All the mean kinetic responses to supramaximal intensity treadmill running.

| Subject 400 | Amplitude (mL.min¹) | Time Delay (s) | Time constant (s) | Subject 1500 | Amplitude (mL.min¹) | Time Delay (s) | Time constant (s) |
|--------------------|---------------------------------------|-----------------------|--------------------------|---------------------|---------------------------------------|-----------------------|--------------------------|
| Subject 1-(AST) | 3669.000 | 6.902 | 29.280 | Subject 1-(AF) | 4846.000 | 7.290 | 17.550 |
| Subject 2-(BO) | 3092.000 | 9.518 | 16.580 | Subject 2-(HJ) | 4094.000 | 1.679 | 22.300 |
| Subject 3-(DC) | 3504.000 | 8.447 | 20.400 | Subject 3-(PB) | 3574.000 | 7.364 | 15.860 |
| Subject 4-(GF) | 2763.000 | 3.934 | 28.170 | Subject 4-(TM) | 3079.000 | 6.151 | 17.800 |
| Subject 5-(JH) | 3796.000 | 3.403 | 29.280 | Subject 5-(TP) | 4004.000 | 2.408 | 14.860 |
| Subject 6-(JL) | 3980.000 | 2.712 | 18.570 | | | | |
| Subject 7-(JM) | 3208.000 | 7.369 | 12.670 | | | | |
| Average - 400m | 3430.3 | 6.0 | 22.1±2.56 | Average - 1500m | 3919.4 | 5.0 | 17.7±1.28 |

APPENDIX B

UWIC PARTICIPANT CONSENT FORM

UWIC Ethics Protocol Number:

Participant name or Study ID Number:

Title of Project:

Name of Researcher:

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet dated for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my relationship with UWIC, or my legal rights, being affected.

3. I understand that relevant sections of any of research notes and data collected during the study may be looked at by responsible individuals from UWIC for monitoring purposes, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.

4 I agree to take part in the above study.

Signature of Participant

Date

Name of person taking consent Date

Signature of person taking consent

APPENDIX D

