



Original research

Oxygen uptake during repeated-sprint exercise

Kerry McGawley^{a,b,*}, David J. Bishop^{b,c}^a Institution of Health Sciences, Mid Sweden University, Sweden^b School of Sport Science, Exercise and Health, The University of Western Australia, Australia^c Institute of Sport, Exercise and Active Living (ISEAL), College of Sport and Exercise Science, Victoria University, Australia

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ABSTRACT

Objectives: Repeated-sprint ability appears to be influenced by oxidative metabolism, with reductions in fatigue and improved sprint times related to markers of aerobic fitness. The aim of the current study was to measure the oxygen uptake ($\dot{V}O_2$) during the first and last sprints during two, 5 × 6-s repeated-sprint bouts.

Design: Cross-sectional study.

Methods: Eight female soccer players performed two, consecutive, 5 × 6-s maximal sprint bouts (B1 and B2) on five separate occasions, in order to identify the minimum time (t_{rec}) required to recover total work done (W_{tot}) in B1. On a sixth occasion, expired air was collected during the first and last sprint of B1 and B2, which were separated by t_{rec} .

Results: The t_{rec} was 10.9 ± 1.1 min. The $\dot{V}O_2$ during the first sprint was significantly less than the last sprint in each bout ($p < 0.001$), and the estimated aerobic contribution to the final sprint (measured in kJ) was significantly related to $\dot{V}O_2$ max in both B1 ($r = 0.81$, $p = 0.015$) and B2 ($r = 0.93$, $p = 0.001$). In addition, the $\dot{V}O_2$ attained in the final sprint was not significantly different from $\dot{V}O_2$ max in B1 ($p = 0.284$) or B2 ($p = 0.448$).

Conclusions: The current study shows that the $\dot{V}O_2$ increases from the first to the last of 5 × 6-s sprints and that $\dot{V}O_2$ max may be a limiting factor to performance in latter sprints. Increasing $\dot{V}O_2$ max in team-sport athletes may enable increased aerobic energy delivery, and consequently work done, during a bout of repeated sprints.

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1. Introduction

Intense physical efforts performed at maximal or near-maximal speeds are important determinants of successful team-sport performance, with more fast-paced running and sprinting completed by top-level soccer players (both male and female) compared with their lower-level counterparts.^{1,2} However, the volume of high-intensity running (measured by distance covered) has been shown to decline over the course of a soccer match, irrespective of playing standard.¹ These findings reflect fatigue development and suggest that the ability to recover from high-intensity running and sprinting may be an important marker of successful physical performance within team sports. It has also been suggested that fatigue development following high-intensity bursts has a detrimental effect on technical performance, and that technical success may be related to the ability to recover.³

Various markers of aerobic fitness, including maximal oxygen uptake ($\dot{V}O_2$ max), velocity at $\dot{V}O_2$ max ($v\text{-}\dot{V}O_2$ max), velocity at the onset of blood lactate accumulation ($v\text{-}OBLA$) and $\dot{V}O_2$ kinetics, have been related to a reduction in fatigue (i.e., a smaller decrement in performance) over the course of a repeated-sprint bout.^{4–6} As well as performance decrement, other parameters associated with repeated-sprint ability (RSA) have been related to markers of aerobic fitness. For example, da Silva et al.⁶ found both $v\text{-}OBLA$ and $v\text{-}\dot{V}O_2$ max to be negatively correlated with the mean time to complete 7 × 34.2-m sprints. In addition, Dupont et al.⁵ reported a positive correlation between the time constant for the fast component of $\dot{V}O_2$ kinetics and the total time to complete 15 × 40-m sprints. Therefore, it appears that RSA is at least partially influenced by oxidative metabolism, perhaps via improved PCr resynthesis between sprints and greater aerobic contributions to latter sprints.^{7,8} Despite these relationships, the $\dot{V}O_2$ during isolated maximal sprints has not been investigated during repeated-sprint exercise.

The majority of studies reporting aerobic contributions to maximal exercise have used single sprints lasting more than 10 s, with reported estimates for 90-, 60-, 45- and 30-s sprints of 61–64%, 49%,

* Corresponding author.

E-mail address: kerry.mcawley@miun.se (K. McGawley).

31% and 23–28%, respectively.^{9,10} These data demonstrate a linear decrease in aerobic contribution as sprint time decreases and, using these values, the predicted aerobic contribution to a 6-s sprint would be ~9%. Péronnet and Thibault¹¹ calculated a value slightly lower than this estimate, suggesting a 5% aerobic contribution to a single 6-s sprint. However, this 5% value was derived from a mathematical model of metabolic energy production for the 1987 men's 60-m world record, rather than measured directly. Relatively few studies have attempted to unravel the complex energy contributions to repeated sprints lasting <10 s. Gaitanos et al.¹² showed a 65% decrease in anaerobic ATP production from the first to the last of 10 × 6-s sprints separated by 30 s. Since the associated performance decline was much smaller (27%), the authors hypothesised an increased aerobic energy contribution to the latter sprints. However, this was not measured directly and the hypothesis does not appear to have been tested to date.

The aim of the current study was to measure the $\dot{V}O_2$ and estimate the aerobic contribution during the first and last sprints of two, 5 × 6-s repeated-sprint bouts. It was hypothesised that (i) the $\dot{V}O_2$ and estimated aerobic contribution would be greater during the final sprint versus the first sprint of each respective bout and (ii) the estimated aerobic contribution to the final sprint of each bout would be related to $\dot{V}O_{2\text{ max}}$.

2. Methods

Eight female soccer players (mean ± SD: age, 26.7 ± 7.4 y; body mass, 60.9 ± 6.0 kg) volunteered to participate in this study. All participants were competing in the women's national soccer league and were training regularly throughout the testing period, which coincided with the competitive season. Participants were informed of all procedures, requirements, benefits and risks relating to the study before providing written informed consent and commencing any experimental tests. Ethical clearance for testing procedures was received from the University of Western Australia ethics committee.

Participants were familiarised with the testing equipment and protocols before completing seven experimental testing sessions. The first session involved a graded-exercise test to exhaustion (GXT) to determine the lactate threshold (LT) and $\dot{V}O_{2\text{ max}}$. In the subsequent five sessions participants completed two, consecutive, 5 × 6-s maximal sprint bouts (B1 and B2) separated by a range of passive recovery periods lasting between 5 and 14 min to identify the shortest time (t_{rec}) required for each individual to recover RSA, measured as total work done (W_{tot}) in B1. In the final testing session expired air was collected during the first and fifth sprints of both B1 and B2, which were separated by a passive recovery period equal in duration to t_{rec} . The second repeated-sprint bout was performed after t_{rec} to ensure that residual fatigue did not influence the $\dot{V}O_2$ measures.

The GXT was completed on an air-braked, track-cycle ergometer (Evolution Pty. Ltd., Australia) and commenced at a power output of 50–100 W, based on estimates during the familiarisation sessions. Each stage involved a 4-min work period followed by a 1-min rest period and power output increased by 25 W per stage. Verbal feedback was provided throughout the test with strong verbal encouragement provided during the latter stages. The test was terminated at volitional exhaustion or when the required power output could no longer be sustained. Expired air was collected using a turbine ventilometer (Morgan, 225A, England) and was continuously analysed for O_2 and CO_2 using Ametek gas analysers (Applied Electrochemistry, SOV S-3A11 and COV CD-3A, USA). Ventilatory parameters were displayed on an IBM computer system allowing $\dot{V}O_2$ to be monitored at 15-s intervals for the duration of the test. The sum of the four highest consecutive 15-s $\dot{V}O_2$ values gave the

$\dot{V}O_{2\text{ max}}$. Blood samples were collected from the earlobe during the rest period between each incremental stage and blood lactate concentration ($[La^-]_{\text{bl}}$) was analysed immediately (ABL™ 625, Radiometer, Denmark). The LT was identified by the point on the polynomial regression curve (power output versus $[La^-]_{\text{bl}}$) yielding the maximal perpendicular distance to the straight line connecting the first increase in lactate above resting level and the final lactate point.¹³

Sprints were performed on a modified, wind-braked, front-access, cycle ergometer (Model Ex-10, Repco, Australia) from a stationary, standing position and participants remained out of the seat throughout each maximal effort. Pedals were fitted with standard toe clips and a strong nylon heel strap. Two repeated-sprint familiarisation trials were prescribed prior to the main trials in accordance with previous research.¹⁴ All trials were performed at the same time of day (±2 h) to overcome any influence of circadian variance¹⁵ and no intense training was performed in the 24 h that preceded testing. The main trials were completed within six weeks for all participants.

Each main trial commenced with a warm-up of 5 min cycling at 80 W, followed by three practice sprint starts. Following the practice starts, and 90 s of passive rest, participants produced one, maximal, 6-s benchmark sprint. The benchmark sprint was followed by 5 min of passive recovery before participants completed B1. To prevent pacing effects, the work produced during sprint 1 of B1 was required to equal or exceed 95% of the work done during the benchmark sprint. If this criterion was not achieved, participants were required to rest for a further 5 min and restart B1 (this occurred on only two occasions out of 40 trials). During all maximal sprints, participants received strong verbal encouragement and clear instructions of when to stop sprinting, as well as continuous feedback during the active recovery periods to ensure that they recovered at the correct intensity and were in the stationary, ready position 3 s prior to the start of each sprint. The five sprints within each repeated-sprint bout were separated by 24 s of low-intensity cycling at 75% LT.

For the first five main trials, B1 and B2 were separated by passive recovery periods that were selected to determine the minimum time required to recover RSA. Performance was deemed to have recovered during B2 if W_{tot} exceeded 98% of the value measured during B1. The first trial used a recovery period lasting 5 min, after which the duration was modified gradually up or down over the next four trials to identify the shortest possible individual estimates of t_{rec} . In a sixth main trial, B1 and B2 were separated by t_{rec} and expired air was collected during the first and last sprints of each bout (i.e., S1, S5, S6 and S10) for the 6-s sprint periods using Douglas bags. The Douglas bags were 20 L in volume and were connected directly to the Hans Rudolph mouthpiece, which removed the issue of dead space resulting from connective tubing. The same set up was used for the first and last sprints of each bout so that any dead space from the mouthpiece itself (albeit small) would be constant. Mean power output (MP) and peak power output (PP) were recorded during each of the sprints. The decrement in PP (PP_{dec}) and work done (W_{dec}) over the six sprints within each bout were calculated using the formula for sprint decrement reported previously.¹⁶

The total energy requirements for S1, S5, S6 and S10 were estimated from the MP achieved during each of the sprints using the linear relationship between power output (W) and energy expenditure (kJ min^{-1}) obtained from the sub-LT portion of the GXT (Fig. 1). Total aerobic energy expenditure for each of the sub-LT stages of the GXT was calculated by multiplying $\dot{V}O_2$ by the energy equivalent per litre of oxygen at the given steady-rate respiratory quotient (RQ),¹⁷ then converting kcal min^{-1} to kJ min^{-1} :

$$\text{energy expenditure (kJ min}^{-1}\text{)} = (\dot{V}O_2 \times \text{kcal L}^{-1} \text{ for RQ}) \times 4.186$$

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