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Rating of perceived exertion during cycling is associated with subsequent running economy in triathletes

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ABSTRACT

Objectives: To determine which commonly measured variables of cycling intensity are related to subsequent running economy in triathletes.
Design: Cross-sectional laboratory study.
Methods: Running economy was compared between a control run (no preceding cycle) and a run performed after a 45 min high-intensity cycle in eighteen triathletes. Power output, heart rate, rating of perceived exertion (RPE) and blood lactate concentration were monitored throughout the cycle. The relationship between measures of cycle intensity and the change in running economy was evaluated using Pearson's product moment correlation. Changes in running economy were also interpreted using the smallest worthwhile change (>2.4%) and grouped accordingly (i.e. impaired, no change, or improved running economy).
Results: Triathletes' RPE at the end of the cycling bout was significantly associated with the change in running economy after cycling ($r = 0.57$, $p = 0.01$). Average RPE of the cycle bout and RPE at the end of the cycling bout were significantly different between groups, with higher RPE scores being related to impairments in running economy ($p = 0.04$ and $p = 0.02$ respectively).
Conclusions: RPE during cycling is associated with subsequent running economy in triathletes. RPE is a simple, cost-effective measure that triathletes and their coaches can use in competition and training to control cycling intensity without the need for specialist equipment such as crank systems or blood analysers.

1. Introduction

Triathlon is a multi-disciplinary sport involving consecutive swim, cycle and run phases. The Olympic distance event comprises a 1.5 km swim, 40 km cycle and 10 km run, and takes athletes approximately two hours to complete in a draft legal format. It is widely recognised that the run component has the greatest relative bearing on success in Olympic distance triathlon.[1,2] This may be related to its position as the final stage of the race,[1] and so, triathletes are constantly striving to improve their run performance "off the bike". Running economy (RE), an established index of run performance, is often impaired during a triathlon run in comparison to an isolated run done at the same speed in both well-trained senior and junior triathletes and recreational triathletes.[3–5] Some evidence suggests physiological changes,[6] biomechanical[7,8] and neuromuscular factors[6] are related to the impairment in RE. However, variable results are reported within and between studies as to the cause and degree of such impairment.[4,8]

An improvement in RE when a lower power output was adopted within the final stages of the cycle leg was reported by Suriano et al.[9] However the workload in that study was artificially induced and triathletes often increase their power toward the end of the cycle leg so as to ensure a good position for the cycle-run transition.[1] Several studies have investigated the effect of preceding cycling on running physiological and biomechanical variables, but no studies to our knowledge have made comparisons between different measures of cycle intensity and subsequent RE. Power output, blood lactate, heart rate (HR) and rating of perceived exertion (RPE) are all measures that are commonly used to guide triathlete training and race day performance. However little information exists as to which of these measures may be differentially related to RE following cycling. RE has been shown to be a good

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predictor of running performance in triathlon,[8,10] and thus a goal for triathletes is to maximise RE following cycling. Therefore, knowledge of the variables that can guide such performance is vital. The purpose of this study was to determine what measures of cycle intensity are related to RE following a variable high-intensity cycle protocol.

2. Methods

Eighteen (13 male, five female) moderately trained triathletes gave their written informed consent to participate in the study. They were on average (SD) 21.6 (5.2) years of age, 175.5 (7.8) cm tall and weighed 65.3 (9.7) kg with a run $\dot{V}O_2$ max of 62.7 (6.7) ml min^{-1} kg^{-1}. The triathletes had competed in triathlon for 4.2 (1.0) years and had covered 8.4 (5.7) km swimming, 138 (66) km cycling and 30 (18) km running per week in the previous three months. Triathletes were excluded from the study if they had any musculoskeletal or neurological disorders affecting the spine or lower limb, or had competed in other sports on two or more occasions per week in the previous three months. The experimental procedures were approved by the University of Queensland and Australian Institute of Sport Human Research Ethics Committee.

We replicated the experimental procedures of our previous study.[7] The triathletes attended two testing sessions. On day one triathletes completed a submaximal run to determine RE, followed by an incremental running test to exhaustion to characterise each triathletes' maximal aerobic capacity ($\dot{V}O_2$ max). RE was determined by measuring sub-maximal $\dot{V}O_2$ for 4 min at 12 km h^{-1} as described in detail previously.[11] A standardised warm-up, 5 min in duration, preceded the RE measure on day one. RE was defined as the total $\dot{V}O_2$ collected from the sum of two consecutive 30 s samples during the final minute. Four minutes was deemed an adequate time to reach steady state based on previous research.[11] $\dot{V}O_2$ max was determined during an incremental test performed two minutes after the completion of the RE test. The treadmill speed was increased by 1 km h^{-1} (zero grade) every minute from the starting speed (12 km h^{-1} for females, 14 km h^{-1} for males) until volitional exhaustion.[11] $\dot{V}O_2$ max was taken when there was no further increase in $\dot{V}O_2$ despite continued effort; and the respiratory exchange ratio was greater than 1.10. Heart rate was monitored (Polar, Kempele, Finland) throughout the incremental test. Blood lactate concentration was measured (Lactate Pro, Arkray, Kyoto, Japan) on immediate conclusion of the test. In our laboratory, the typical error of measurement associated with sub-maximal $\dot{V}O_2$ is 2.4%; while it is 2.2% for $\dot{V}O_2$ max, 2.2% for heart rate, 27% for blood lactate and 6.7% for RPE.[11]

The second day of testing consisted of a 4 min RE test (identical to that carried out on day one), that was preceded by a 45 min high-intensity cycling bout designed to replicate the cycling portion of a draft legal elite triathlon.[7] To standardise the transition period between cycle and run, yet replicate the demands of competition, a controlled period of 60 s was allowed to enable triathletes to dismount the ergometer and change footwear. All running trials were performed on a custom-built motorised treadmill (Australian Institute of Sport, Belconnen, Australia). The cycling bout consisted of three 5 min stages at 100 W, 150 W and 200 W (Lode Excalibur, Groningen, The Netherlands) followed immediately by 30 min of cycling that involved five high-intensity intervals of 2, 2, 4, 10 and 4 min duration interspersed with four active recovery periods of 2 min duration.[7] Interval and recovery period intensity was customised for each triathlete based upon training history and performance level. Triathletes were instructed to maintain a constant power output at a freely chosen cadence (which was between 90 and 100 rpm) for each interval and recovery period. Average (SD) power for each interval was 300 (79), 300 (79), 250 (57), 225 (58) and 234 (50) W respectively, similar to the average power measured in an elite-level Olympic distance triathlon[12] and other experimental studies.[13]

Several studies have investigated cycling cadence and subsequent run performance with conflicting results.[14,15] Although some findings indicate that adopting a lower cadence in the final minutes of the cycle may enhance a triathlete's run performance,[15] anecdotal evidence suggests that triathletes tend to prefer to select higher cadences in the final minutes preceding the cycle-run transition.[12] Further, as there is no clear link between cycle cadence and run performance in triathletes, cycling cadence was set within 10 rpm of freely chosen cadence (90–100 rpm).

Power output was monitored throughout the cycle (Lode Excalibur, Groningen, The Netherlands). Blood lactate, HR and RPE were recorded during the final minute of each high-intensity interval. RPE data was obtained using a Borg 15-point (6–20) RPE scale. Data from the last minute of the final interval of the cycling bout, and the average for the high-intensity bouts were used for analysis. Power output, heart rate and blood lactate values obtained during the cycling bout were entered into data analysis both as the raw absolute values and also as relative values (e.g. as a percent of maximum) in order to account for physiological differences between triathletes. Blood lactate and HR were expressed relative to the maximum values obtained in the $\dot{V}O_2$ max test. Peak cycling power was derived from the $\dot{V}O_2$ max test results as a strong linear relationship has been determined between maximal oxygen consumption and peak power output ($r = 0.97$, $p < 0.0001$).[16] This relationship is expressed in the following equation: Peak power (W) = $\dot{V}O_2$ max (l min^{-1}) − 0.435/0.01141.[16] Cycling power output was also normalised to body weight (W kg^{-1}) to take into account differences in body mass of the athletes.

The relationship between the measures of cycle intensity and RE were examined using Pearson's product moment correlations. Changes in RE were also interpreted using the smallest worthwhile change (>2.4%), as recommended by Saunders et al.[11] The triathletes were grouped (three groups: impaired, no change and improved RE) according to this criteria. The differences in cycle intensity between groups were evaluated using a Kruskal Wallis test. When indicated post hoc testing was conducted with the Mann–Whitney *U* test. The standardised mean difference (SMD) and 95% confidence intervals (95% CI) were calculated for significant post hoc findings to express the magnitude of differences between groups. The SMD was calculated as a ratio of the mean change score divided by the pooled standard deviation. Significance level was set at ≤0.05.

3. Results

Heart rate, blood lactate and RPE reported during the cycle (Table 1) indicate that the cycle was performed at an intensity that normally corresponds to above lactate threshold intensity in triathletes.[5,9,13] The extent to which changes in RE following the cycling bout, were observed over the control run-only condition, was highly individual specific. Some triathletes demonstrated an impaired RE whilst others had an improved RE (impaired = five triathletes, no change = eight triathletes, improved = five triathletes, Fig. 1). Triathletes' RPE at the end of the cycling bout was significantly associated with the change in RE over the control run-only condition ($r = 0.57$, 95% CI = 0.14–0.82, Table 2 and Fig. 1). Average RPE for the entire cycle and RPE at the end of the cycling bout were significantly different between groups (0.048 and 0.02 respectively). Post hoc tests revealed RPE at the end of the