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Scalar-linear increases in perceived exertion are dissociated from residual physiological responses during sprint-distance triathlon

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HIGHLIGHTS

- Residual fatigue impairs performance throughout a triathlon run.
- Scalar-linear RPE development remains in the presence of residual fatigue.
- Despite subtle differences between triathlon disciplines, RPE resetting is absent.
- RPE and physiological responses are only indirectly related during triathlon.
- RPE remains a key pace regulator during multi-sport endurance performance.

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ABSTRACT

Objective: This study examined how residual fatigue affects the relationship between ratings of perceived exertion (RPE), physiological responses, and pacing during triathlon performance.
Methods: Eight male triathletes completed a sprint-distance triathlon (750 m swim, 20 km cycle and 5 km run) and isolated 5 km run on separate days. RPE, core temperature (T_{core}), heart rate and blood lactate concentration $[BLa^-]$ were recorded during both, in addition to performance time and speed.
Results: Triathlon run time (1248 ± 121 s) was significantly slower than the isolated run (1167 ± 90 s) ($p < 0.01$). Significant differences were observed at the start of the two conditions for all physiological measures (Heart rate 162 ± 4 vs 154 ± 5 beats min^{-1}; T_{core} 38.3 ± 0.8 vs 36.7 ± 0.6 C; $[BLa^-]$ 9.1 ± 2.8 vs 2.1 ± 0.4 mmol L^{-1}, for triathlon and isolated run, respectively, $p < 0.05$). No significant differences were observed for initial RPE ($p = 0.083$), rate of RPE increase ($p = 0.412$), or final RPE ($p = 0.329$) between run trials.
Conclusions: The maintenance of a scalar-linear increase in RPE by the brain remains the primary mechanism for pace regulation during both single and multi-modal endurance performance, with physiological responses being only indirectly related to this process. The apparent absence of any RPE 'resetting' between disciplines suggests that during shorter distance multi-sport performances (60–90 min) a cognitive pacing strategy for the entire event is employed. However, as subtle alterations in RPE development between disciplines were observed the existence of discipline-specific RPE 'templates' should not be discounted.

1. Introduction

Triathlon has long been considered as a unique case to examine pace regulation, due to the residual effects that consecutive swimming, cycling and running bouts impose on athletes compared to isolated performance in each discipline [1,2]. More specifically, the examination of pace regulation during triathlon running is considered particularly important as this discipline suffers the greatest levels of residual fatigue whilst having the greatest influence on overall success in the event [3–5].

It is currently proposed that pacing during endurance tasks is regulated in an anticipatory manner via a complex and continuous 'internal negotiation' process which depends heavily on perceived exertion (RPE) [6,7]. In order to optimise performance, it is thought a predetermined RPE 'template' allows exercise intensity to be selected, interpreted and adjusted continuously, based on previous experience, expected exercise duration, certainty of the endpoint, current progress, environmental conditions, level of competition and current physiological and psychological status [6,8–11].

The continued demonstration of a scalar-linear relationship between RPE and remaining exercise duration has provided evidence of this regulatory process during open and closed-loop exercise tasks, in differing exercise modalities, and across a range of exercise distances, intensities and environmental conditions [12–15]. However, it has recently been shown that RPE during triathlon performance may not develop in this manner, exhibiting instead a unique 'resetting' at the beginning of each discipline which is disassociated from physiological status [16]. This

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suggests that discreet RPE 'templates' may be utilised within individual modes of triathlon performance and that the proposed 'anticipatory-feedback RPE' model of pace regulation [8] may need revising to explain such findings.

It remains to be seen whether the findings of Parry and colleagues [16] during long-distance triathlon are applicable to shorter event formats (i.e. Sprint or Olympic-distance), which may impose higher levels of physiological strain and shorter periods of recovery in the transition between disciplines [17–20]. Furthermore, it is yet to be established whether the scalar-linear relationship between RPE and remaining exercise is affected by antecedent fatigue during self-paced performance. Imposing such residual fatigue has been shown to increase the rate of RPE development and consequently decrease performance during fixed-intensity time to exhaustion trials [21]. Expressed relative to total performance time though, no differences in RPE development were seen, suggesting an adjustment to how the RPE 'template' is utilised in the presence of residual fatigue. However, whilst these conclusions appear valid in relation to exhaustive constant-load (open-loop) exercise, further consideration is needed as to how perceived exertion and physiological parameters interact during performance within and between successive modes of self-paced (closed-loop) exercise when the pre-fatiguing exercise is not exhaustive (i.e. during triathlon).

Considering these observations, the aims of the present study were i) to determine whether antecedent fatiguing activity affects the scaling of RPE during a self-paced (closed-loop) triathlon run; ii) to examine the relationships between RPE, pacing and physiological status during triathlon running compared to running in a non-fatigued state; and iii) to explore whether RPE exhibits a unique 'resetting' during the transition between triathlon disciplines.

2. Methods

2.1. Participants

Eight male triathletes volunteered to participate in this study with a mean age, body mass and stature of 36.0 ± 5.7 yrs, 75.7 ± 5.3 kg and 1.77 ± 0.07 m, respectively. Participants had competed in triathlons for at least 12 months and during the study their average weekly training included 1.7 ± 1.1 h swimming, 4.3 ± 2.4 h cycling and 2.1 ± 1.7 h running (3.9 ± 2.7 km, 129.4 ± 89.0 km and 25.8 ± 27.5 km, respectively). Data collection was completed at the start of the close-season, whereby participants were not competing in formal competition. A medical history questionnaire and written, informed consent were obtained from all participants. Study procedures were approved by the institutional research ethics committee.

2.2. Design

A repeated-measures experimental design was employed, with participants completing two separate field-based performance trials. The first was a sprint-distance triathlon consisting of a 750 m pool-based swim, a 20 km single-loop cycle on a flat open-road course (elevation change ~9 m) and a 5 km run following a flat out-and-back route on tarmac footpaths (elevation change ~6 m). Between 7 and 18 days after completion of the triathlon trial participants completed an isolated 5 km running time-trial on the same course as the triathlon run. During the study period participants were allowed to maintain their usual training regime but were instructed to refrain from training in the 24 h prior to each trial. Furthermore, participants replicated dietary and fluid intake in the 24 h period preceding each trial, using a standardised recording sheet and serving as their own control.

2.3. Performance measures

During both trials each participant wore a wrist-mounted global positioning system (GPS) (Garmin 310XT, Garmin Europe, UK) which enabled performance time and speed ($km\ h^{-1}$) to be recorded throughout each run. GPS data was verified using split time recordings from a number of synchronised stopwatches.

2.4. Perceived exertion

At least 10 days prior to the triathlon trial, participants were instructed on the use of the Borg 6-20 RPE scale [22] and were provided with a copy of the scale to be memorised. Participants were asked to memorise their RPE score during the swim at 375 m and in the final length before getting out of the pool (i.e. 725–750 m). After negotiating the first transition and the start of the cycle, each participant recorded these memorised swim RPE scores using a waterproof recording sheet (and pen) secured to their handlebars. This sheet was then used to record RPE scores at each 2.5 km interval of the cycle course. In second transition, participants attached the RPE recording sheet and marker pen to the wrist of their non-dominant hand and recorded RPE scores for each completed kilometre of the run. Participants replicated this method and frequency of RPE recording during their isolated running trial.

2.5. Physiological responses

In the 10 days prior to each trial participants were given a core temperature pill (CorTemp; HQInc, USA) and were instructed to swallow this pill immediately after waking on the morning of the race (minimum 3 h before the race start). Before the start of both trials participants changed into their triathlon suits and fitted a chest-mounted transmitter belt to allow heart rate to be recorded via the wrist-mounted GPS system. Baseline measurements were then obtained for core temperature (T_{core}; CorTemp Ambulatory Data Recorder, HQ Inc., USA), blood lactate concentration ($[BLa^{-}]$; Lactate Pro, Kodak, Japan) and body mass (without shoes) (to 0.1 kg; Seca 875, Seca, UK). During the triathlon measures of T_{core} and $[BLa^{-}]$ were obtained in both transition periods. Immediately upon completion of both trials (i.e. at the run finish) final measures of T_{core}, $[BLa^{-}]$ and body mass (again without shoes) were taken.

2.6. Statistical analysis

All data were analysed using SPSS for Windows (Version 19, SPSS Inc., Chicago, USA). Means and standard deviations (±) were calculated for all variables. Normal distribution was confirmed by the Shapiro-Wilk test, whilst the assumption of sphericity was examined using the Mauchly statistic. A series of two-way within-subjects (run type × run distance) ANOVAs were conducted to analyse the effects of run condition and distance completed during the run using RPE, running speed, heart rate, T_{core} and $[BLa^{-}]$ as dependent variables. Repeated-measures ANOVAs were also used to identify changes in these variables within each trial. If the Mauchly test indicated a violation of sphericity then analysis of variance was corrected using the Greenhouse–Geisser correction factor to minimise the chance of type I error. Where appropriate, post-hoc dependent t-tests were used to determine differences within and between run condition and distance completed during running trials. Pearson's product moment correlation was used to determine the strength of relationships between RPE, physiological measures and distance completed during each run condition and also for overall triathlon performance. Individual b coefficient slopes for each participant were calculated from regression analysis of RPE and physiological measures against completed distance for each run condition, and also for RPE versus completed distance for the swim and cycle sections of triathlon performance. Dependent t-tests identified whether individual r or b coefficients differed between the two run conditions, whilst repeated-measures ANOVA examined differences in r or b coefficients between triathlon disciplines. For all statistical procedures the level of significance was set at $p < 0.05$ and adjusted accordingly.