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Neuromuscular and physiological variables evolve independently when running immediately after cycling

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ABSTRACT

During the early period of running after cycling, EMG patterns of the leg are modified in only some highly trained triathletes. The majority of studies have analysed muscle EMG patterns at arbitrary, predetermined time points. The purpose of this study was to examine changes to EMG patterns of the lower limb at physiologically determined times during the cycle-run transition period to better investigate neuromuscular adaptations. Six highly trained triathletes completed a 10 min isolated run (IR), 30 min of rest, then a 20 min cycling procedure, before a 10 min transition run (C-R). Surface EMG activity of eight lower limb muscles was recorded, normalised and quantified at four time points. Oxygen uptake and heart rate values were also collected. Across all muscles, mean (±SD) EMG patterns, demonstrated significant levels of reproducibility for each participant at all four time points ($\alpha < 0.05$; $r = 0.52–0.97$). Mean EMG patterns during C-R correlated highly with the IR patterns ($\alpha < 0.05$). These results show that EMG patterns during subsequent running are not significantly affected by prior cycling. However, variability of muscle recruitment activity does appear to increase during C-R transition when compared to IR.

1. Introduction

Successful performance in triathlon is largely dependent on the ability of an athlete to overcome the complications of transitioning between disciplines, the most crucial of which is the cycle-run transition (C-R) (Millet and Vleck, 2000). The C-R transition is defined as the period from the last kilometre of the cycle leg to the end of the first kilometre of the run (Millet and Vleck, 2000), and is considered an overall performance determinant (Bonacci et al., 2010b). Therefore, understanding and limiting cycling-induced changes to an athlete's running ability both biomechanically and physiologically is of significant importance (Millet and Vleck, 2000). Previous research has established the impaired effects of prior cycling on subsequent running economy performance among a variety of triathlete populations (Hue et al., 1998; Millet and Bentley, 2004). In particular, within the first minutes of running after cycling oxygen uptake ($\dot{V}O_2$), breathing frequency, minute ventilation and heart rate (HR) are all elevated compared to during isolated running (IR) (Guezennec et al., 1996; Hausswirth et al., 1996; Millet and Vleck, 2000). Furthermore, alterations to muscle recruitment activity may influence running economy (Bonacci et al., 2009) and indirectly $\dot{V}O_2$ when running after cycling (Bonacci et al., 2010b). In their study, muscle recruitment activity was altered in seven of 15 moderately trained triathletes, accompanied with clinically significant alterations to $\dot{V}O_2$ during C-R exercise. They concluded that cycling related muscle recruitment changes are linked with alterations to running economy during subsequent running. However, this group (Bonacci et al., 2011) later suggested that prior low or high intensity cycling did not influence neuromuscular control or running economy in seven elite international triathletes. A relationship between muscle recruitment activity and $\dot{V}O_2$ when running after cycling is far from conclusive, and likely dependent upon an athlete's experience and training history (Hausswirth et al., 1997). However, past studies have established a reasonable link between muscle recruitment activity and metabolic cost during constant load exercise (Moore et al., 2014; Saunders et al., 2000). Therefore, understanding changes in muscle recruitment activity, resulting from prior cycling exercise, may potentially assist in identifying changes and adaptations of early phase changes in $\dot{V}O_2$ during the subsequent C-R phase within triathlete populations. Previous studies looking at changes to muscle recruitment activity during the C-R phase have used arbitrary time points (i.e. 1 min, 2 min and 3 min), rather than times based upon individual physiological variables. The challenge is to recognise where within the transition

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period muscle recruitment activity and $\dot{V}O_2$ changes occur and if they are the result of prior cycling in the absence of fatigue. Therefore, the purpose of this study was to analyse muscle recruitment patterns during the C-R phase, compared to IR, at specific time points based upon individually calculated physiological variables representing physiological adaptation. We were also interested in understanding if and how EMG patterns quantified at those specific time points reflected changes in those physiological variables.

2. Methods

2.1. Subjects

Six trained, competitive triathletes were selected to participate in this study. All had experienced Australian National level and/or International Triathlon Union (ITU) level competition and had gained this experience in at least the year preceding testing. Age, physical characteristics, competitive experience, training distances and sessions and personal records are given in Table 1.

2.2. Protocol

A controlled single-group laboratory-based investigation was conducted to compare muscle recruitment activity, $\dot{V}O_2$ and HR values during submaximal intensity IR and C-R exercise. The protocol used has been specifically developed, using moderate intensity cycling and running in order to analyse neuromuscular changes when running after cycling and has been shown to be highly repeatable providing a robust baseline measure of neuromuscular control during running without causing undue fatigue (Chapman et al., 2009).

All subjects completed a 10 min IR, followed by 30 min of rest before completing a 20 min variable cadence cycle bout and a 30 min transition run. Participants had to transition between cycling and running in less than 60 s. All running tests were conducted on a treadmill (grade = 0%, Landice, Randolph, USA) to allow comparison with past research of a similar nature (Bonacci et al., 2010a, 2011). Treadmill speed was reached within the first 20 s of commencing running and remained constant for the entirety of IR and C-R conditions. Prior to experimental testing a standardised five minute warm-up run was completed. During this period participants were asked to self-select a running speed that would be manageable and non-fatiguing for 30 min of running. This self-selected speed was used as the treadmill speed for both the IR and C-R for that individual. Following the warm-up exercise, participants were required to rest in a seated position to allow their HR to recover to baseline values. The resting period between warm-up and testing exercise was 10 ± 0.6 min. Participants performed the variable cadence cycling protocol using their personal road bikes mounted on a stationary magnetic cycle ergometer (Tacx Satori Trainer, Tacx, Netherlands). Cadence was controlled using an ANT+ bike computer compatible with the speed/cadence monitors on the participant's bicycles. During the first five-minutes and final three-minutes the participants cycled at an individually preferred cadence. Four cadence blocks of three-minute duration – (1) individually preferred cadence, 55–60 rpm, 75–80 rpm and 95–100 rpm – were randomly ordered between the 6th to 17th min. During the variable cadence cycling protocol the participants were required to sustain a level of intensity consistent with an RPE of 14.

2.3. Data acquisition

2.3.1. EMG

Electromyographic activity of the gluteus medius (GM), biceps femoris (BF), vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), gastrocnemius medialis (MG), gastrocnemius lateralis (LG) and tibialis anterior (TA) was recorded from the left leg in all participants. This current study focused on muscles of the thigh and leg due to their functional importance to both cycling and running performance during triathlon (Chapman et al., 2008b; Manninen and Kallinen, 1996). Further, evidence suggests that atypical muscle recruitment patterns and musculoskeletal injury of the lower limb are potentially related (Chapman et al., 2008b; Cowan et al., 2002). Preparation of each EMG skin site included shaving, mildly abrading and cleansing with isopropyl alcohol swabs according to the "Standards of Reporting EMG Data" (Electromyography and Kinesiology, 1997). Additionally, pre-gelled bipolar Ag/AgCl 1 mm parallel-bar surface EMG electrodes (fixed inter-electrode distance of 10 mm) (Delsys®, USA) were anatomically positioned on the mid-belly of each muscle, with the electrode bars situated perpendicular to the direction of muscle fibres of each muscle in accordance with procedures outlined by the European Surface EMG for the Non-Invasive Assessment of Muscles (SENIAM) to minimise crosstalk. A ground reference Dermatrode® (American Imex, Irvine, USA) electrode was positioned on the left lateral malleolus. EMG signals were recorded using an eight channel Delsys® Bagnoli™ EMG System (Delsys®, USA). EMG measurements were recorded at a sampling frequency of 1000 Hz and digitised by a 16-bit Analog-to-digital converter. The bipolar signal was amplified (input impedance >1 MΩ) and band-pass filtered between 10 and 500 Hz with a mode rejection ratio of 110 dB, gain of 305 and maximum noise of 1.6 μV and a second order Butterworth filter was applied to the data to remove contamination from movement artefacts before being full-wave rectified, DC offset. EMG data were integrated into subject specific time bins. Rectified EMG data were exported in an embedded VICON c3d file and stored for computer processing.

2.3.2. $\dot{V}O_2$ and HR

Ventilatory data, including total $\dot{V}O_2$, were measured continuously and recorded at breath-by-breath rate using a metabolic gas analysis cart (Parvo TrueMax 2400, Parvomedics, USA). Prior to testing standing-resting $\dot{V}O_2$ was measured over a five-minute period to provide a comparative level of baseline $\dot{V}O_2$ values. Participants wore a nose clip and breathed through a low-dead space, minimal resistant mouthpiece that was secured via a capillary line attached to the mouthpiece, to the volume transducer. Starting $\dot{V}O_2$ was recorded as the first breath after the onset of exercise. Beat-by-beat HR was measured using a short-distance telemetry Polar Interface module synchronised to a Polar heart rate monitor chest unit (Polar Electro, Port Washington, N.Y., USA) during both running conditions.

Table 1
Age, physical characteristics, competitive experience, training distances/sessions[a] and personal records (PR).

	Age (yrs)	Mass (kg)	Height (cm)	Experience (yrs)	Cycle (km/wk)	Run (km/wk)	Sessions (km/wk)	10 km PR (min)	OT PR (h)
Triathletes	24.8	69.1	178.4	4.4	296.7	55.4	10.2	32.3	1 h 53
$n = 6$	(±7.6)	(±6.3)	(±7.2)	(±1.1)	(±72.3)	(±11.4)	(±1.2)	(±1.3)	(±2.2)

[a] Training distances/sessions recorded during the three months prior to testing.