Journal of Electromyography and Kinesiology 23 (2013) 223–229

Contents lists available at SciVerse ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

The impact of altered task mechanics on timing and duration of eccentric bi-articular muscle contractions during cycling

Mark J. Connick [a,*], François-Xavier Li [b]

[a] School of Human Movement Studies, University of Queensland, Brisbane, Australia
[b] School of Sport and Exercise Sciences, University of Birmingham, United Kingdom

ARTICLE INFO

Article history:
Received 10 May 2012
Received in revised form 10 August 2012
Accepted 21 August 2012

Keywords:
Pedalling
Cadence
Seat height
Concentric
EMG
Coordination
Kinematics

ABSTRACT

In order to understand muscle adaptations to altered task mechanics during cycling, this study investigated the impact of altered seat height and cadence on timing and duration of gastrocnemius (GAST), biceps femoris (BF) and vastus lateralis (VL) eccentric contractions and muscle activation patterns, and cycling economy. Ten male cyclists completed 9×5 min of cycling at 3 seat heights and 3 cadences. Three-dimensional leg kinematics and muscle activation patterns were recorded to estimate timing of eccentric muscle contractions. Onset, offset and duration of eccentric contractions and, onset, offset and duration of muscle activation were calculated, along with cycling economy. Duration of GAST and VL eccentric contractions decreased with increasing seat height due to earlier offset of eccentric muscle contractions. Duration of BF eccentric contractions significantly increased with seat height due to a later eccentric contraction offset. Offset of GAST and BF muscle activation occurred earlier with increasing cadence. Cycling economy was significantly affected by cadence but not seat height. The results suggest that as a consequence of altered seat height, proprioceptive feedback is used to fine-tune the timing of bi-articular eccentric muscle contractions. These results may have implications for seat height self-selection.

1. Introduction

The uni-articular thigh muscles, such as vastus lateralis (VL), contribute between 34% and 39% of the mechanical energy required to propel the rotating crank during cycling (Raasch et al., 1997), which is more than any other muscle group. To perform this function, these muscles contract concentrically to overcome the resistive torque (Ericson et al., 1986; Raasch et al., 1997). However, the contraction modality of the bi-articular leg muscles such as gastrocnemius (GAST) and biceps femoris (BF) are not as well understood during cycling because GAST and BF work across two joints with sometimes opposing actions. The first study to quantify eccentric work done by the leg muscles during cycling found that the ankle plantarflexors (including GAST) and hip extensors (including BF) are responsible for 57% and 32% respectively of the total eccentric work done (Ericson et al., 1986). Eccentric contraction of GAST and BF help smooth the transition from leg extension to leg flexion close to bottom dead centre (BDC) by transferring power between joints and to the pedal, and controlling the rate of knee and ankle angular velocity (Ryan and Gregor, 1992; Raasch et al., 1997; Sanderson and Amoroso, 2009). Some authors have suggested that GAST undergoes a stretch–shortening cycle (SSC) during early propulsion (0–25% of the crank cycle) in order to deliver a constant net torque in the second half of propulsion (25–50% of the crank cycle) (Gregor et al., 1991; Sanderson et al., 2006).

A common biomechanical problem is to understand how muscle activation and movement patterns relate to the performance of a task, and what muscle coordination pattern changes occur in response to altered task mechanics (Neptune and Herzog, 2000). Studies suggest that the human nervous system adapts very quickly to altered task mechanics during cycling by using proprioceptive feedback to change the muscle activation and movement patterns to the demands of the on-going movement (Mileva and Turner, 2003); GAST and BF muscle activation patterns adapt to altered seat height (Diefenthaeler et al., 2008), cadence (McGhie and Ettema, 2011), body orientation (Brown et al., 1996), crank length (Mileva and Turner, 2003) and chainring shape (Neptune and Herzog, 2000). Although cycling requires a complex pattern of muscle coordination, task mechanics can be easily and strictly controlled with alterations to seat height and cadence. Muscle activation and joint kinematics are modulated as a function of seat height without associated changes to cycling economy; a small change in seat position of 1 cm from the self-selected position affects muscle activation and technique, whilst seat heights between 96% and 100% of trochanter height (TH) do not affect cycling economy (Price and Donne, 1997; Diefenthaeler et al., 2008; Sanderson

---

* Corresponding author. Address: School of Human Movement Studies, University of Queensland, Brisbane, Queensland 4072, Australia. Tel.: +61 7 3365 6117; fax: +61 7 3365 6877.

E-mail address: m.connick@uq.edu.au (M.J. Connick).

1050-6411/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jelekin.2012.08.012

and Amoroso, 2009). In contrast, movement kinematics, muscle activation patterns and cycling economy are all affected by alterations to cadence (Foss and Hallen, 2004; Sanderson et al., 2006). Despite the importance of GAST and BF eccentric contractions, the impact of altered seat height and cadence on the timing and duration of GAST and BF eccentric contractions is not known. We posit that timing and duration of GAST and BF eccentric contractions and muscle activation patterns will change in response to altered seat height in order to maintain cycling economy, but will not change with altered cadence. Conversely, we posit that VL will not exhibit an eccentric contraction during propulsion. Seat height and cadence are commonly the focus of experimentation for recreational and experienced cyclists, so in addition to improved understanding of muscle adaptations to altered task mechanics, results may have implications for seat height and cadence self-selection. This study aimed to investigate if the timing and duration of GAST and BF eccentric contractions and muscle activation patterns adapt to altered seat height and cadence. It was hypothesised that the timing of eccentric contractions and muscle activation patterns of the bi-articular muscles would adapt to altered seat height but would not adapt to altered cadence.

2. Methods

2.1. Participants

Ten male cyclists who had a minimum of four years recreational cycling experience, were currently cycling a minimum of 3 days per week and were healthy as determined by a general health questionnaire signed an informed consent form to volunteer to take part in the study. Participants mean (± SD) age (years), height (cm), body mass (kg), VO_2 peak (L/min) and W_{max} (W) were 33.2 (± 9.1), 180 (± 6.4), 75.0 (± 4.9), 4.56 (± 0.47) and 368.1 (± 25.5) respectively. The study was approved by the University of Birmingham local ethics committee. All participants were fully informed of the purposes, protocols and procedures prior to taking part.

2.2. Procedures

Participants visited the laboratory on two occasions, separated by at least 48 h. All cycling tests were performed on an electromagnetic braked cycle ergometer (Lode Excalibur, Groningen, Netherlands).

2.3. Visit one (maximal incremental cycle exercise test)

All subjects completed an incremental cycle exercise test to volitional exhaustion to determine VO_2 peak and power output at VO_2 peak (W_{max}). Prior to starting the incremental test, height and body mass were recorded. Participants then started cycling at 95 W for 3 min followed by incremental steps of 35 W every 3 min until volitional exhaustion. W_{max} was determined by the formula: $W_{max} = W_{out} + [(t/180) \cdot 35]$, where W_{out} is the power output (W) during the last completed stage, and t is the time (s) in the final stage (Wallis et al., 2005). Expired gases were collected using Douglas bags for exactly the last minute at each workload. The Douglas bag yielding the highest VO_2 data was deemed as having the VO_2 peak values.

2.4. Visit two (experimental trial)

Participants warmed up for 5 min cycling at a constant power output of 200 W with a self-selected cadence and seat height set to 98% trochanter height (TH). This was followed by 2 min of cycling at a power output of 200 W, a cadence of 90 rpm and a seat height set to 98% trochanter height (TH). Amplitude of EMG can affect timing of the calculated muscle contraction so in order to dynamically normalise the EMG data (Albertus-Kajee et al., 2011) from the experimental trials, muscle activation was recorded for GAST, BF and VL for the last 30 s of this trial. Participants completed all experimental cycling trials at a constant power output of 200 W which corresponded to approximately 54% W_{max} (Sanderson et al., 2006). Participants were required to perform $3 \times 3 \times 5$ min bouts of cycling with cadences of 75, 90 and 100 rpm, at seat heights representing 96%, 98% and 100% TH (Nordeen-Snyder, 1977; Price and Donne, 1997). TH was measured from the superior border of the right greater trochanter to the floor when the participant was standing barefoot.

The order of seat heights and cadences were randomised for each participant, and a recovery of 4 min separated each cycling bout. An electronic inclinometer (LS160, Unilevel, Australia) was used to standardise trunk angle to 40° throughout testing to eliminate the influence of postural changes. Trunk angle was defined as the angle between the vector from the right shoulder to the right trochanter and the horizontal (Fig. 1).

Kinematic and muscle activity data were collected for 30 s during each 5-minute bout, starting at 90 s into the bout. Three-dimensional data were captured using a Vicon MX motion analysis system (Oxford Metrics Ltd., Oxford, England) with 13 cameras operating at a sampling rate of 250 Hz and calibrated with residual error less than 1 mm. Kinematic data were collected as previously described (Schache et al., 2002). Retro-reflective markers were attached with double-sided adhesive tape by the same tester to limit inter-tester variability and were placed over the greater trochanter, the lateral femoral condyle, the lateral malleolus, the base of the calcaneus, the head of the fifth metatarsal, the hallux of the right lower limb and foot, and bilaterally on both ASIS and PSIS. Additional reflective markers ($n = 4$) were placed superior to the heel counter of cycling shoes, tibial tuberosity and halfway along the lateral and frontal aspects of the thigh. A further reflective marker was placed on the pedal spindle of the bicycle ergometer to identify crank cycles during post-processing (Baum and Li, 2003). The foot was defined as the vector from the head of the fifth metatarsal to the heel. The shank was defined as the vector from the lateral malleolus and the lateral epicondyle, and the thigh was defined as the vector from the lateral epicondyle to the greater trochanter.

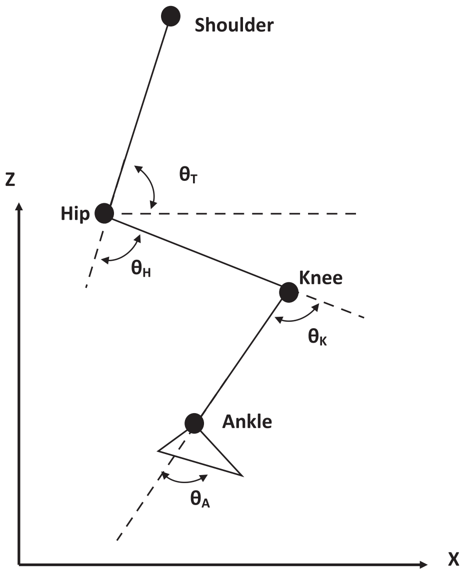

Fig. 1. Joint angle definitions. θ_T – trunk angle, θ_H – hip angle, θ_K – knee angle, θ_A – ankle angle.