Leg muscle recruitment in highly trained cyclists. (study of Electromyography methodology)

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In this study, we examined patterns of leg muscle recruitment and co-activation, and the relationship between muscle recruitment and cadence, in highly trained cyclists. Electromyographic (EMG) activity of the tibialis anterior, tibialis posterior, peroneus longus, gastrocnemius lateralis and soleus was recorded using intramuscular electrodes, at individual preferred cadence, 57.5, 77.5 and 92.5 rev x [min.sup.-1]. The influence of electrode type and location on recorded EMG was also investigated using surface and dual intramuscular recordings. Muscle recruitment patterns varied from those previously reported, but there was little variation in muscle recruitment between these highly trained cyclists. The tibialis posterior, peroneus longus and soleus were recruited in a single, short burst of activity during the downstroke. The tibialis anterior and gastrocnemius lateralis were recruited in a biphasic and alternating manner. Contrary to existing hypotheses, our results indicate little co-activation between the tibialis posterior and peroneus longus. Peak EMG amplitude increased linearly with cadence and did not decrease at individual preferred cadence. There was little variation in patterns of muscle recruitment or co-activation with changes in cadence. Intramuscular electrode location had little influence on recorded EMG. There were significant differences between surface and intramuscular recordings from the tibialis anterior and gastrocnemius lateralis, which may explain differences between our findings and those of previous studies.

Keywords: Electromyography, motor control, cadence, co-activation, cycling

Introduction

Previous descriptions of leg muscle recruitment during cycling are inaccurate and incomplete. The gastrocnemius, soleus and tibialis anterior muscles have been investigated but with highly inconsistent findings. For example, most studies have suggested that the activity of the tibialis anterior occurs in a monophasic burst pattern commencing
just before top centre (0[degrees] and 360[degrees] of the pedal stroke) and ending shortly after top centre (Gregor, Broker, & Ryan, 1991; Jorge & Hull, 1986). Other studies have indicated that recruitment of the tibialis anterior occurs between 180[degrees] and 270[degrees] crank inclination (Neptune, Kautz, & Hull, 1997; Raasch, Zajac, Ma, & Levine, 1997), with secondary periods of activation between 90[degrees] and 200[degrees] (Gregor, Komi, Jarvinen, 1987; Ryan & Gregor, 1992). Variability between individual cyclists is also large, with standard deviations of up to 90% being reported (Ericson, Nisell, Arborelius, & Ekholm, 1985). For the less superficial muscles, such as the tibialis posterior and peroneus longus, there are no in vivo data. The tibialis posterior and peroneus longus both contribute to plantar flexion and stabilization of the subtalar and midtarsal joints, enabling efficient energy transfer from the leg to the crank, and to control of rotation of the lower leg (O'Connor & Hamill, 2004; Rattanaprasert, Smith, Sullivan, & Gillearde, 1999), which is hypothesized to be an important factor in many cycling overuse injuries.

Inconsistencies between previous studies of the tibialis anterior, gastrocnemius lateralis and soleus may relate to methodology. First, surface electromyography (sEMG) techniques with poor selectivity, such as the use of one recording for both medial and lateral portions of the gastrocnemius, are common (Gregor et al., 1991; Jorge & Hull, 1986; Li & Caldwell, 1998; Ryan & Gregor, 1992). These nonselective recordings are likely to be inaccurate due to crosstalk from adjacent muscles (De Luca & Merletti, 1988; Solomonow et al., 1994), and may include artifactual changes due to movement of the muscle relative to the recording electrode (Rainoldi, Melchiorri, & Caruso, 2004; Rainoldi et al., 2000; Roy, De Luca, & Schneider, 1986). Secondly, patterns of muscle recruitment have been described in limited detail, such as the percentage of activity duration in each quadrant of the pedal stroke in the absence of more specific temporal and spatial detail (e.g. Eisner, Bode, Nyland, & Caborn, 1999), and often without adequate definition of data analysis techniques such as the criteria for EMG onset and offset detection. Thirdly, previous studies have included cyclists with varying amounts of experience (e.g. Mohr, Allison, & Patterson, 1981) or training histories (e.g. triathletes; Cruz & Bankoff, 2001), or have not detailed inclusion criteria (Gregor et al., 1987, 1991; Neptune & Herzog, 2000), despite data that demonstrate variations in patterns and consistency of muscle recruitment between more and less experienced cyclists (Ericson et al., 1985; McLean, 1987; Ryan & Gregor, 1992). We hypothesized that fine-wire EMG (fEMG) recordings, which avoid the problems of crosstalk from adjacent
muscles and electrode movement (Hodges & Gandevia, 2000a; Solomonow et al., 1994), from a homogeneous sample of highly trained cyclists, would provide a more accurate description of leg muscle recruitment and demonstrate that elite cyclists use similar patterns of leg muscle recruitment.

Knowledge of coordination, or co-activation, of leg muscles will provide further information about their functional significance. Previously, authors have discussed muscle co-activation using EMG waveforms generated by averaging (a) several pedal strokes from each cyclist and (b) the mean waveforms from each of the cyclists in the sample. This averaging process can lead to errors in interpretation (especially in co-activation), due to smoothing or demodulation of the EMG waveform; demodulation increases with the variability of the data, and is likely to have been significant when variability between individual cyclists was up to 90%. A demodulated signal leads to overestimation of EMG duration and therefore muscle co-activation. Furthermore, averaged data provide no information about the consistency of co-activation between pedal strokes--that is, the extent to which changes to one muscle's activity between pedal strokes are matched by changes to activity of another muscle. The consistency of muscle coactivation aids in understanding the strength and functional significance of a muscle pairing. Muscle co-activity calculated for each individual pedal stroke of each cyclist is required to accurately evaluate muscle coordination.

There is debate regarding the relationship between muscle recruitment and cadence and little is known of the relationship for the leg in highly trained cyclists. Macintosh, Neptune and Horton (2000) reported that EMG activity varied with cadence in a quadratic manner, with a minimal level...