The Effect Of Power Output And Cycling Cadence On Lower Extremity EMG Responses In Recreational Cyclists

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Introduction

Preferred cycling cadence (85-95 rpm) is substantially higher than the cadence that minimizes energy expenditure (50-60 rpm) (Coast and Welch, 1985; Marsh and Martin, 1993, 1997; Pugh, 1974; Seabury et al., 1977). This difference between preferred and most economical cadences suggests the selection of preferred cadence in cycling is dominated by factors others than energy cost or aerobic demand. The association between preferred cycling cadence and minimization of muscular effort (e.g., global expressions of lower extremity net joint moments, muscular stress, or muscle excitation) has been under investigation by several groups (Hull et al., 1988; MacIntosh et al., 2000; Marsh and Martin, 1995; Marsh et al., 2000; Redfield and Hull, 1986). Marsh and Martin (1995) quantified EMG patterns of five lower extremity muscles at a single power output (200 W) over a cadence range of 50-110 rpm. Using a global expression of EMG, the relationship between EMG and cadence was similar to that observed between aerobic demand and cadence. In other words, the global expression of muscle excitation was lowest at 50 and 65 rpm and, therefore, was not minimized at or near preferred cadence. In an expanded design, MacIntosh et al. (2000) quantified muscle excitation patterns of seven lower extremity muscles during ergometer cycling at power outputs ranging from 100 to 400 W and across a cadence range of 50-120 rpm. Based upon an average EMG measure across the seven muscles, MacIntosh et al. concluded lower extremity muscle excitation was affected by cadence for each power output tested. More importantly, the cadence at which average EMG was minimized over the tested cadence range increased as power output increased. To better understand the role of lower extremity musculature in generating power output and affecting preferred cadence during cycling, our purpose was to extend our previous assessments of lower extremity EMG response to cadence (Marsh and Martin, 1995) and contrast our new observations with recent findings by MacIntosh et al. (2000).

Methods

Ten recreational cyclists (age, 31.7±9.6 yrs; height, 179.1±7.8 cm; body mass, 78.3±7.8 kg) volunteered as subjects and provided informed consent. Each participated in a single test session. EMG electrodes were applied over six lower extremity muscles, gluteus maximus, rectus femoris, vastus lateralis, semimembranosus, gastrocnemius, and soleus, using standard surface EMG procedures. After a brief period of warm-up, voluntary maximal isometric muscle actions were recorded for each muscle under investigation. Following an adequate rest period, subjects then cycled on a Schwinn Velodyne ergometer under two power outputs (150 and 250 W) for several minutes at a self-selected cadence in the absence of cadence feedback. The average cadence over the last minute of each ride was recorded as the preferred cadence. Subjects then cycled using five cadences (50, 65, 80, 95, and 110 rpm) for each of the power output conditions. The order of power outputs was counterbalanced across subjects, and cadences were randomly ordered within each power output condition. EMG signals were preamplified at the recording site (gain = 35) with a selectable overall amplification of 1000 to 100,000 (Therapeutics Unlimited, bandwidth 20 to 4000 Hz, CMRR of 87 dB at 60 Hz, input impedance > 15 MΩ at 100 Hz). EMG for each muscle was sampled at 600 Hz for a minimum of five crank rotations, full-wave rectified, and low pass filtered (15 Hz). Average and peak excitation levels for each muscle and cycling condition were computed from the linear envelopes and normalized with respect to voluntary maximal isometric responses.
Results

Average preferred cadences were 88.2±3.1 and 85.7±5.6 rpm for 150 and 250 W, respectively. These values are comparable but slightly lower than previously reported values (91-97 rpm) for the same power output conditions from our lab (Marsh and Martin, 1997). As expected, both average and peak emg were systematically higher (approximately 55%) for 250 W than 150 W. The effect of cadence on emg was substantially less prominent than the power output effect. For all muscles but the gastrocnemius, average emg did not vary by more than 5% of isometric maxima across the 50-110 rpm cadence range. Emg levels for several muscles either did not change or declined slightly as cadence increased (Figures 1 and 2). In contrast, the gastrocnemius was more sensitive to cadence, reflecting variations of 17 and 11% across the cadence range for 150 and 250 W, respectively (Figure 3). Gastrocnemius emg showed a quadratic response with respect to cadence, was lowest at either 50 or 65 rpm, and highest at 110 rpm. A global emg expression was computed by averaging the normalized average emg values for the six muscles at each power output-cadence combination. At both 150 and 250 W, global emg displayed a shallow, U-shaped quadratic response with respect to cadence (Figure 4). At 150 W, the predicted cadence at which global emg was minimized was approximately 70 rpm. At 250 W, minimum global emg occurred at approximately 85 rpm.

Figures 1 (left) and 2 (right). Semimembranosus and soleus responses to cadence and power were typical of all muscles except the gastrocnemius; they showed a systematic power output effect but little difference in excitation across cadences.

Figure 3. Gastrocnemius showed the largest response to cadence of the six muscles tested.

Figure 4. The global emg responses to cadence for 150 and 250 W conditions were quadratic in nature with predicted minima at approximately 70 and 85 rpm, respectively.
Discussion

Although the global or overall lower extremity muscle excitation responses across cadence were shallow quadratic functions, these responses reflected minima at cadences that were unique for each power output. Consistent with results from MacIntosh et al. (2000), the cadence at which the global EMG response was minimized was higher for 250 W than 150 W. At 150 W, preferred cadence (88 rpm) was higher than the cadence at which global EMG was minimized (70 rpm); whereas at 250 W, preferred cadence (86 rpm) and the minimum global EMG cadence (85 rpm) were nearly identical. The higher sensitivity of the gastrocnemius to cadence is consistent with observations by Marsh and Martin (1995) but the reasons are not clear. Neptune et al. (1997) suggested the rate sensitivity of the gastrocnemius may be related to “coping with the increasing magnitude of velocity-dependent interaction forces arising either between individual limbs, or at the crank” (p.1057). In contrasting responses of the gastrocnemius and soleus to cadence, Marsh and Martin speculated that the gastrocnemius is more sensitive to cadence changes, whereas the soleus is more sensitive to power changes. Results from the current investigation support this speculation (see Figures 2 and 3). Average soleus excitation was nearly 50% higher for 250 W than 150 W cycling, whereas the gastrocnemius was only 15% higher for 250 W cycling. EMG variations across cadence for 150 and 250 W for the gastrocnemius were 17 and 11% of maximal levels, respectively. The same variations for the soleus were only 3 and 5% of isometric maxima. The difference in the shape of the global EMG-cadence responses between power output conditions (i.e., global EMG was minimized at a higher cadence for the higher power output condition) has been proposed to be a function of fundamental force-velocity and power-velocity properties of the muscles, and the need to recruit additional fast twitch motor units at higher cadences (MacIntosh et al., 2000). To gain further insight into lower extremity muscle function during cycling, current experimental research is considering musculotendon unit length and velocity profiles during cycling. Additionally, computer simulation is being used to assess the effect of motor unit properties on muscle energetics.

References


