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Patterns of leg muscle recruitment vary between novice and highly trained cyclists

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Abstract

This study compared patterns of leg muscle recruitment and coactivation, and the relationship between muscle recruitment, coactivation and cadence, in novice and highly trained cyclists. Electromyographic (EMG) activity of tibialis anterior (TA), tibialis posterior (TP), peroneus longus (PL), gastrocnemius lateralis (GL) and soleus (SOL) was recorded using intramuscular fine-wire electrodes. Four experimental conditions of varying cadence were investigated. Differences were evident between novice and highly trained cyclists in the recruitment of all muscles. Novice cyclists were characterized by greater individual variance, greater population variance, more extensive and more variable muscle coactivation, and greater EMG amplitude in periods between primary EMG bursts. Peak EMG amplitude increased linearly with cadence and was not different at individual preferred cadence in either novice or highly trained cyclists. However, EMG amplitude in periods between primary EMG bursts, as well as the duration of primary EMG bursts, increased with increasing cadence in novice cyclists but were not influenced by cadence in highly trained cyclists. Our findings suggest that muscle recruitment is highly skilled in highly trained cyclists and less refined in novice cyclists. More skilled muscle recruitment in highly trained cyclists is likely a result of neuromuscular adaptations due to repeated performance of the cycling movement in training and competition.

Keywords: Cycling; Motor control; Electromyography (EMG); Cadence

1. Introduction

Studies spanning nearly a century have focussed on motor learning and adaptations of control of movement that occur with task rehearsal. These studies provide evidence that repeated performance of a movement task facilitates neuromuscular adaptations, which result in more skilled movement and muscle recruitment patterns. This more skilled control of movement and muscle activation is characterized by decreased amplitude and duration of muscle activity (Bennett et al., 1992; Burdet et al., 2001; Gomi and Kawato, 1996; Osu et al., 2002; Osu et al., 2004; Schneider et al., 1989), greater control of variation of the amplitude of muscle activity during movement Schneider et al., 1989), decreased muscle coactivation (Milner, 2004; Osu et al., 2002; Osu et al., 2004; Thoroughman and Shadmehr, 1999) and less variability of movement and muscle activation patterns between repetitions (Broderick and Newell, 1999; Jaegers et al., 1989; Osu et al., 2002; Thoroughman and Shadmehr, 1999). However, these studies have examined changes in control of movement that occur over a small number of movement repetitions, e.g., 96–120 (Osu et al., 2002), and provide little insight into adaptations that may occur in response to years of continued training.

Highly trained cyclists can ride more than 1000 km and complete more than 100,000 pedal stroke repetitions per week, and may continue to train at this level for more than 10 years. Despite significant performance and training

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disparities, there is little evidence that highly trained cyclists use different patterns of muscle recruitment than novice cyclists. It has been proposed that greater cycling efficiency (Boning et al., 1984; Sidossis et al., 1992), higher and more economical preferred cadence (Marsh and Martin, 1997), and a lesser decrease in cycling efficiency with increasing cadence (Faria et al., 1982; Sidossis et al., 1992) are evidence of more skilled muscle recruitment in highly trained cyclists (MacIntosh et al., 2000; Marsh and Martin, 1995). However, data of cycling efficiency (Boning et al., 1984; Moseley et al., 2004; Nickleberry and Brooks, 1996; Sidossis et al., 1992), preferred cadence (MacIntosh et al., 2000; Marsh and Martin, 1995) and the relationship between cycling efficiency and cadence (Marsh et al., 2000) suggest that these variables are not different between novice and highly trained cyclists. Furthermore, measures of cycling efficiency and cadence are not direct measures of muscle recruitment or neuromuscular control and it is not possible to use these measures to infer differences in muscle recruitment between novice and highly trained cyclists.

Studies that report direct measures of muscle recruitment with electromyography (EMG) also present contradictory findings, and are characterized by methodological limitations. Mohr et al. (1981) reported that muscle recruitment was not different between competitive and non-competitive cyclists. In contrast, McLean (1987) reported that differences did exist, and most significantly that variation in amplitude of muscle activity during the pedal stroke was less in novice cyclists, i.e., novice cyclists utilized longer periods of muscle activation and greater levels of muscle activity between primary EMG bursts. Both studies were limited by small sample sizes ($n = 1$; McLean, 1987 and $n = 2$; Mohr et al., 1981) and the use of surface EMG (sEMG) techniques with poor selectivity, such as the use of one single differential recording to represent EMG activity in both medial and lateral portions of GA. Others have investigated muscle recruitment during cycling, but comparisons are difficult because these studies have included cyclists with varying levels of experience (Mohr et al., 1981) or training histories, e.g., triathletes (Cruz and Bankoff, 2001), or have not detailed participant inclusion criteria (Gregor et al., 1991; Gregor et al., 1987; Neptune and Herzog, 2000). In addition, interpretation of these sEMG recordings is complicated by the potential for cross-talk (Mangun et al., 1986; Solomonow et al., 1994) and movement artifact (Rainoldi et al., 2000; Roy et al., 1986) resulting from non-selective sEMG recordings (Gregor et al., 1991; Jorge and Hull, 1986; Li and Caldwell, 1998; Ryan and Gregor, 1992) and movement of the muscle relative to the recording electrode (Rainoldi et al., 2004; Rainoldi et al., 2000; Roy et al., 1986). Moreover, findings have been described in limited detail, such as the percentage of activity duration in each quadrant (90° portion) of the pedal stroke without more specific detail of timing or amplitude of muscle activation (Eisner et al., 1999). There has also been inadequate definition of data management and analysis techniques such as criteria for EMG onset and offset detection (Clarys et al., 1988; Ericson, 1986; Suzuki et al., 1982).

In a recent study, we investigated leg muscle recruitment using selective intramuscular EMG and a homogeneous sample of highly trained cyclists (Chapman et al., 2006). Variation in muscle recruitment between these highly trained cyclists, i.e., population variance, was ~33% less than the variation reported in previous studies of experienced cyclists (Ryan and Gregor, 1992). Furthermore, population variance was ~86% less than that reported in previous studies of recreational cyclists (Ericson et al., 1985). These findings suggest that population variance may be related to training. However, definitive conclusions are not possible because of methodological inconsistencies between studies that limit interpretation and comparison of results. Furthermore, specific differences in muscle recruitment and coactivation have not been addressed in previous studies. We expect selective EMG recordings from well defined participant samples to demonstrate that novice and highly trained cyclists use different patterns of leg muscle recruitment and coactivation, and greater population variance in novice cyclists. Preliminary data from McLean (1987) suggest that variation in amplitude of muscle activity during the pedal stroke may be less in novice cyclists. Individual variance, i.e., variability in muscle recruitment between pedal strokes for individual cyclists, is considered to be a manifestation of inherent noise in the neuromotor system (Schmidt et al., 1979) that is greater in unskilled movement (Broderick and Newell, 1999). We hypothesize that novice cyclists will display greater individual variance and less variation in amplitude of muscle activity during the pedal stroke than highly trained cyclists.

There has also been considerable debate regarding the relationship between muscle recruitment, cadence and cycling experience. This relationship provides insight into the mechanisms of movement control and may provide further explanation for the selection of high cadences by trained cyclists (Coast and Welch, 1985; Hagberg et al., 1981). Our recent study of highly trained cyclists (Chapman et al., 2006) reported linear increases in EMG amplitude with increasing cadence but no change to the timing or duration of muscle activity or coactivation. MacIntosh et al. (2000) reported similar increases in EMG amplitude with increasing cadence in novice cyclists but did not investigate EMG timing or duration. These linear increases in peak EMG amplitude suggest that muscle activity is not minimized at preferred cadences in either novice or highly trained cyclists. Neptune et al. (1997) reported increases in the duration of EMG activity with increasing cadence but studied a poorly defined sample of cyclists. Thus, their finding of increased duration of muscle activity may have been influenced by the inclusion of novice cyclists. Further investigation is required to determine the influence of cadence on the timing and duration of muscle activity in novice cyclists.

The aim of the present study was to compare cycling muscle recruitment between novice and highly trained