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INTER-MUSCULAR COORDINATION DURING UPHILL CYCLING IN A SEATED POSITION: A PILOT STUDY

MED-MIŠIČNA KOORDINACIJA MED KOLESARJENJEM V KLANEC V SEDEČEM POLOŽAJU: ŠTUDIJA PRIMERA

ABSTRACT

The aim of this case study report was to outline the effects of uphill cycling on the muscle activity pattern and to practically test the methodological approach for the main study. The purpose was to observe the differences in the electromyographic (EMG) activity of eight leg muscles while a subject was cycling under three laboratory conditions: cycling on a level surface, cycling on a 10% incline , and cycling on a 20% incline. A quantitative evaluation of the EMG signals was carried out using (i) the timing of the muscles on-off activity with the 10% of MVC set as a threshold and (ii) calculating the differences between the activations of the same muscle under the three cycling conditions. In both cases, the muscles' activation pattern was observed in the context of the crank-angle position. Preliminary observations suggest that the incline affects the inter- and intra-muscular coordination pattern with greatest modulation in two joint muscles of the thigh. The measurement tool, used to evaluate the differences in timing and amplitude, was found to be a promising evaluation approach and will be used in the main study.

Keywords: cycling, EMG, incline.

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Izvleček

Cilj študije primera je bil predstaviti učinke kolesarjenja v klanec na vzorce mišične aktivnosti in istočasno praktično preizkusiti metodološki pristop za glavno študijo. Namen je bil preveriti razlike v osmih glavnih mišicah nog med: (i) ravninskim kolesarjenjem, (ii) kolesarjenjem v 10 % naklon in (iii) kolesarjenjem v 20 % naklon z dvema različnima analizama. Želeli smo ugotoviti časovno razporejenost mišične aktivnosti, kjer smo vzeli 10 % največje zavestne kontrakcije za prag, ki določa začetek in konec aktivnega dela. Naknadno smo preverili razlike v amplitudi. Generalno je naklon učinkoval na med-mišično in znotraj-mišično koordinacijo. Metodološki pristop je dobro prikazal razlike v časovnih in amplitudnih lastnostih mišične aktivnosti in bo zato uporabljen tudi v glavni študiji.

Ključne besede: kolesarstvo, EMG, naklon.

INTRODUCTION

The first studies on cycling were launched in the early 20th century, when a pioneer cycling ergometer was used for research purposes (Krogh & Lindhard, 1913). Since then, cycling has become one of the most studied sports activities, with the focus on muscle fatigue and EMG (for review, see Hug & Dorel, 2009), mechanical forces (for review, see Bini & Diefenthaeler, 2009), ergonomics, physiology etc. The majority of biomechanical studies have been conducted on level ground and in seated position. However, the data for uphill cycling, especially on steeper inclines, is lacking.

The few existing uphill cycling studies combined EMG and biomechanical analyses. Bertucci, Grappe, Girard, Betik, and Rouillon (2005) showed a 26% increase in the monitored crank torque when 8% uphill incline cycling was compared to level cycling. Duc, Bertucci, Pernin, and Grappe (2008) reported that, in comparison with the level cycling conditions, no changes in the muscles' activation pattern occurred during 4%, 7% and 10% incline cycling. They observed only a small increase in activity for the trunk extensors and the gluteals in the 10% incline conditions, which was consistent with previous reports (Li & Caldwell, 1998). Moreover, Clarys, Alewaeters, and Zinzen (2001) recorded generally increased leg muscle activation when changing the inclination from 0% to 12%. A more detailed review of these study reports reveals methodological gaps, including (i) non-standardized cycling conditions, apart from incline steepness, which could affect the results, inconstant cadence or power output, and (ii) a missing analytical approach in studying the EMG activity.

The aim of our pilot study was, therefore, to compare inter- and intra-muscular activation present in level, 10% and 20% incline cycling. It was an introductory study to gather preliminary information needed for the decision making on the final methodological approach to be used in the main study.

METHODS

Participants

One male subject (age 21 years, body height 185 cm, body weight 68 kg), an ex-competitive mountain biker at the national level, participated in this study. The interview, during which the details on the study protocol were presented to him, was carried out prior to the start of the experiment. The study was approved by the National *Medical Ethics* Committee and the subject signed a statement of informed consent at his enrolment.

Instruments

The experiment was conducted on a mountain bike (Energija Lemon, Slovenia), which was placed into the electronically adjustable cycling ergometer (Tacx Flow, Netherlands). After a ten-minute warm-up at self-selected intensity, the subject performed the measurement trials at three different inclinations: (i) level, (ii) 10% inclination and (iii) 20% inclination cycling. The acquisition of the data started after the subject had progressively reached the constant cycling intensity (power = 200 W, cadence = 90 rpm) and lasted for 50 complete pedalling cycles. After each pedalling trial, the subject had five-minute low-intensity active breaks. Between the warm-up and the test trials, the subject performed three maximal voluntary contractions (MVCs) with each of the muscles/ muscle groups, to be used for further normalization purposes.

Procedure

Acquisition of the EMG signals and the crank trigger signal (optical sensor, Leuze Electronic, Germany) was carried out at a sampling rate of 4,000 Hz, using a wireless EMG device (Noraxon-TeleMyo 2400 G2, USA). According to the international standards (Zipp, 1982; SENIAM), pairs of single-use bipolar electrodes were glued over the pre-treated skin (shaving, abrasion (Nuprep Gel, Bio-Medical Instruments, USA) and 70% methyl alcohol) above the motor points of the following muscles: tibialis anterior (TA), gastrocnemius lateralis (GA), soleus (SO), vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), and semitendinosus (ST). The electrodes and wires were fixed to the body using an elastic net in order to avoid mechanical noise.

The EMG signals were zero aligned, band-pass filtered (20–750 Hz, Butterworth, 2 order), full-wave rectified and smoothed. Averaged stores for each of the muscles were composed from the 50 consecutive traces, using the digital trigger as the beginning of the crank cycle. These averaged signals were then normalized to the MVCs (mean amplitude for a 1-second interval) and the time-to-crank angle transformed. In this way, we obtained comparable angle-to-muscle activity curve expressed as a function of the crank angle as it rotates from the highest crank position (TDC) to the lowest crank position (BDC) and back to TDC to complete a 360° cycle.

Finally, quantification of the EMG patterns was performed in two ways: (i) using a threshold of 10% MVC and muscle activity presented as an on-off indication on the circular graph, and (ii) calculating the difference between the cycling on a level surface and each of the two incline cycling conditions for an individual muscle.

RESULTS

The processed EMG signals for all three cycling conditions and all eight muscles are summarized in Figure 1a. The intermediate stage was to align the signals for each muscle on the same graph for all of the three cycling conditions (Figure1c). Based on that, the difference between the level surface and the 10% incline as well as the level surface and the 20% incline were derived for each of the eight muscles (Figure 1d). A more simplified timing analysis is presented in Figure 1b, which gives a quick overview of the muscles' activity timing and how it changes according to the conditions.

A detailed analysis reveals that the hamstring muscles (BF and ST) changed most noticeably when changing from level to the inclined cycling conditions. Under inclined cycling conditions, these muscles were activated earlier in the crank cycle and with greater intensity, which resulted in a peak difference at the crank cycle phase between TDC and 90° (the change in percentage of the MVC values was 7 and 15 for BF and ST, respectively). Single-joint knee extensors (VL and VM) as well as all the lower leg muscles (TA, SO and GA) showed no systematic change. RF, however, was depressed in its activity under the incline conditions showing the highest inter-conditions difference during the 270°-to-TDC phase.

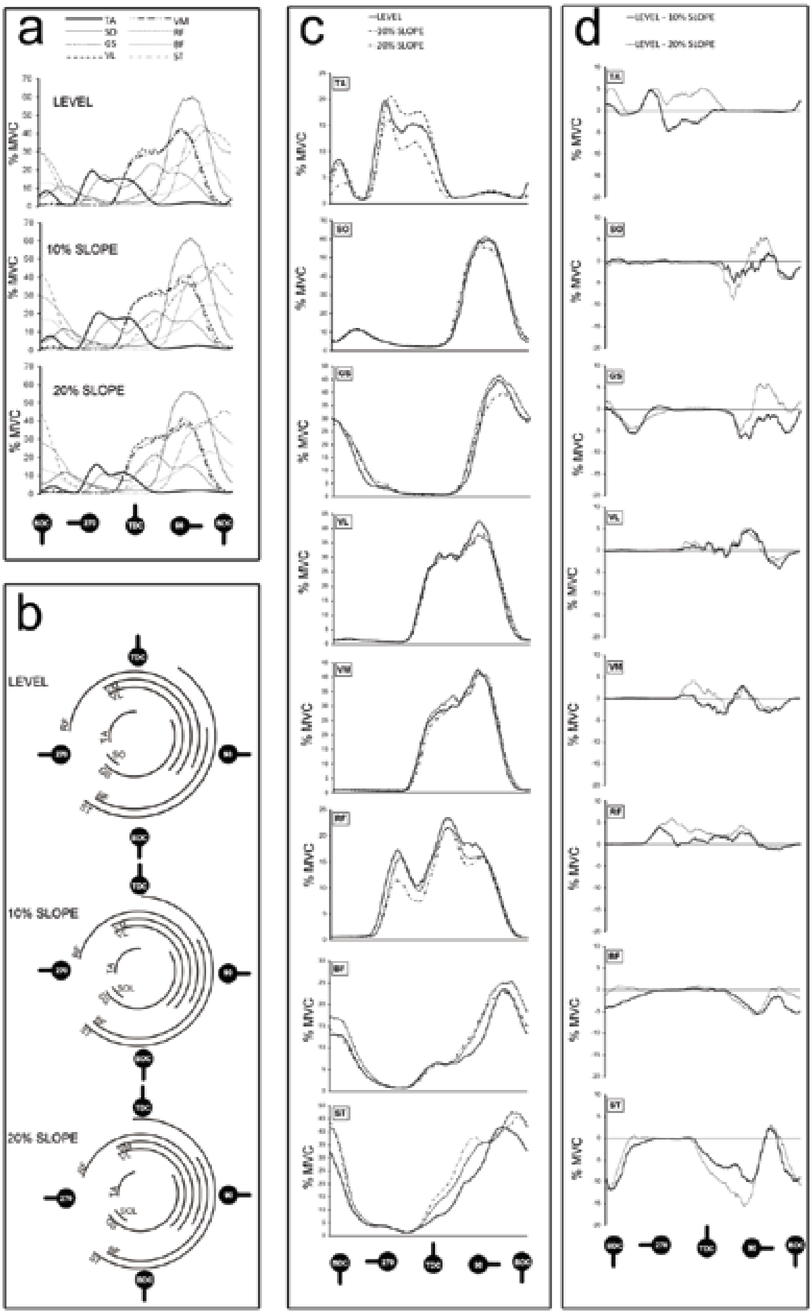

Figure 1: Different ways of EMG analysis for three cycling conditions (level, 10% and 20% incline). A common legend is used for a single set of graphs. The black symbols indicate the crank position cycle. The set of graphs "a" summarizes all eight muscles under the same cycling condition. Based on that, the circular on-off (10% of MVC criteria) is extracted in the set "b", as well as the intra-muscular comparisons in the set "c" and the between-condition differences in the set "d".

If we look only at the range of movement in which the muscles were active more than 10% of MVC, we can see that under the inclination conditions some muscles did not change their timing at all (2°, 3° and 5° for SO, VL and VM, respectively); the others shortened their activity (10° for RF), while some prolonged it primarily by switching on earlier (30° and 39° for BF and ST respectively).

DISCUSSION

The majority of previous studies that researched muscle activation during uphill cycling examined only the effects of inclines that were not steeper than 12%. Because of the nature of cycling races, where a cyclist often needs to race on very steep inclines (20% and more), we would like to investigate the effects of steeper inclines on muscular activity. In this study, the effect of the incline on muscle activity was studied by having the subject ride his own bicycle on an electronically adjustable cycling ergometer at constant speed, incline, cadence and gear ratio, which eliminated the effect of air and ground resistance to ensure standard conditions for all measurements.

The preliminary observations drawn from this pilot study indicate that inter- and intra-muscular coordination is changed during the 10% and 20% inclines when compared to the level cycling conditions. The most inclination-induced modulation of muscle's activity was observed for the long two-joint thigh muscles (RF decrease and ST and BF increase, respectively). During uphill cycling, posture is adjusted and therefore the muscles' length/force relation can be altered (Enoka, 2008). We can conclude that the higher activity of the two-joint hamstring muscles (BF and ST) is due to the better conditions for contracting when the subject is bent further forward. In contrast, RF is less activated and its function as a hip flexor is probably taken over by the single-joint hip flexors (m. iliopsoas). TA does not reflect any systematic changes across different inclines, which could be a result of a rather low total activity (~20% of MVC). Both VL and VM are surprisingly equal in their timing, as well as in amplitude. They do not change significantly in different cycling conditions. The peak activity of VL and VM is at approximately a 90° crank angle, where the highest forces applied on pedals were found (Hoes, Binkhorst, Smeekes-Kuyl, & Vissers, 1968). We can also see that in this same crank position, the majority of monitored muscles are active (threshold 10% of MVC, see Figure 1b). Similar to the knee extensor muscles, the peak activity in plantar flexor muscle (SO) was found at around 90°. GS reached its peak activity latter in the crank cycle, probably due to its two-joint muscle characteristics (extension over the knee joint).

The aim of this study was to examine changes of the leg muscles' EMG activity during uphill cycling in a seated position. For this purpose, two different methodological approaches were applied: (i) the on/off timing and (ii) the processing of the muscle's signal difference among the cycling conditions. Both methods proved to be promising ways to be conducted in the main study, since they allow a well-quantified evaluation and sensitivity relevant to the topic of the study.

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