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# Inter- and intra-session reliability of muscle activity patterns during cycling

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ABSTRACT

The aim of this study was to determine the inter- and intra-session reliability of the temporal and magnitude components of activity in eight muscles considered important for the leg cycling action. On three separate occasions, 13 male non-cyclists and 11 male cyclists completed 6 min of cycling at 135, 150, and 165 W. Cyclists completed two additional 6-min bouts at 215 and 265 W. Surface electromyography was used to record the electrical activity of tibialis anterior, soleus, gastrocnemius medialis, gastrocnemius lateralis, vastus medialis, vastus lateralis, rectus femoris, and gluteus maximus. There were no differences ($P > 0.05$) in the muscle activity onset and offset or in the iEMG of any muscles between visits. There were also no differences ($P > 0.05$) between cyclists and non-cyclists in the variability of these parameters. Overall, standard error of measurement (SEM) and intra-class correlation analyses suggested similar reliability of both inter- and intra-session muscle activity onset and offset. The SEM of activity onset in tibialis anterior and activity offset in soleus, gastrocnemius lateralis and rectus femoris was markedly higher than in the other muscles. Intra-session iEMG was reliable (coefficient of variation (CV) = 5.3–13.5%, across all muscles), though a CV range of 15.8–43.1% identified low inter-session iEMG reliability. During submaximal cycling, the temporal components of muscle activity exhibit similar intra- and inter-session reliability. The magnitude component of muscle activity is reliable on an intra-session basis, but not on an inter-session basis.



## 1. Introduction

Surface electromyography (EMG) has been used to describe the activity pattern of the muscles involved in cycling exercise (Hug and Dorel, 2009; So et al., 2005). The magnitude of muscle activation is often described using the root mean square (RMS) of the EMG signal or by integrating the signal over a certain period (iEMG). However, such methods fail to provide an insight into the temporal characteristics of muscle function. Such information is provided by measurement of the onset and offset of muscle activity (Hug and Dorel, 2009).

A number of studies have focused on within-session variations in muscle activity due to manipulation of factors such as cycling position, pedalling technique, and exercise intensity (Baum and Li, 2003; Chapman et al., 2008; Dorel et al., 2009; Mornieux et al., 2010). In order for such observations to be robust, EMG must provide a reliable measure. The intra-session reliability of muscle recruitment during low intensity (200 W) cycling was investigated by Dorel et al. (2008). They showed that muscle recruitment remained largely unchanged following 53 min of a non-fatiguing exercise protocol. Dorel et al. (2008) therefore concluded that the intra-session reliability of both magnitude and temporal EMG measurements of cycling-related muscle activity are high.

Aspects of the inter-session reliability of muscle activity during cycling exercise have been examined by Laplaud et al. (2006). These authors reported a high level of reproducibility in the magnitude component of muscle activity (measured as RMS) during incremental exercise-to-exhaustion trials carried out on multiple occasions across multiple days. However, Laplaud et al. (2006) did not consider the reliability of the temporal components of muscle activity. Furthermore, to the authors' knowledge, no studies have investigated the inter-session reliability of muscle activity during constant intensity exercise.

The reliability of inter-session EMG measurement in cycling is important for researchers for several reasons. Good inter-session reliability will allow researchers to circumvent the limitations of single session designs. For example, fatigue quickly becomes an issue if an experimental session is prolonged. Such fatigue can be avoided if the session is divided into multiple sessions. Clearly the experimental measure must have high inter-session reliability for such division to be appropriate. Inter-session reliability of EMG measures is also essential when evaluating the possibility of training induced changes in muscle activity. Previous cross-sectional research suggests that training status impacts on muscle activity (Chapman et al., 2008). However, longitudinal data is required to

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ascertain whether or not this is the result of training adaptation or genetic selection. In previously untrained individuals, large training-induced adaptations would be expected and these would likely be detected even with relatively unreliable measurement tools. However, in well-trained individuals, where training-induced adaptations in muscle activity are likely to be small, EMG measurement must be reliable enough for these adaptations not to be hidden by measurement variation.

The present study aimed to determine the inter-session reliability of the temporal components of muscle activity, i.e. onset and offset, in eight muscles considered important for the leg cycling action. Cyclist and non-cyclist groups were examined to determine whether or not this reliability is affected by training status.

## 2. Methods

### 2.1. Participants

Twenty-four healthy males were recruited to participate in this investigation. Thirteen individuals were non-cyclists, having no history of cycle training but being physically active for a minimum of 3 h per week. The remaining 11 individuals were cyclists, performing a minimum of 6 h cycle training per week. Participant characteristics are presented in Table 1 and illustrate a large difference in fitness levels between non-cyclists and cyclists. Prior to participation in the investigation, participants were fully informed of the nature and risks of the study, before providing written consent. The study was approved by the Centre for Sports Studies Research Ethics Committee at The University of Kent, in accordance with the declaration of Helsinki.

### 2.2. Protocol

Participants were required to attend the laboratory on four separate occasions, with a maximum of 1 week between each visit. All visits were completed at the same time of day to minimise the influence of circadian rhythms (Drust et al., 2005). Participants did not exercise for 24 h prior to each visit. During the 24 h prior to visit 1, participants completed a food diary. This was used subsequently to replicate food intake prior to the remaining experimental visits.

During visit 1 participants were familiarised with the laboratory environment and equipment. Participant height was measured to the nearest millimetre (Harpenden Stadiometer, Holtain Ltd, UK) and body mass to within ±50 g (Seca 710, Seca Ltd., UK). In addition, the cycle ergometer (Schoberer Rad Messtechnik, Julich, Germany) configuration for each participant was recorded, such that it could be replicated in subsequent visits. For non-cyclists, their preferred geometry was determined during the familiarisation visit. For cyclists, the geometry of their racing bicycle was transferred to the ergometer. Non-cyclists used sports shoes, secured to the pedal with toe straps. Cyclists used their own clipless pedals and shoes. Although it was not anticipated that the difference in pedal type would affect cycling technique (Mornieux et al., 2008), each participant used the same pedal type across sessions to prevent any influence of pedal type on the inter-session reliability of muscle activity patterns during cycling.

**Table 1**
Participant characteristics.

| | Non-cyclist | Cyclist | Combined |
|---|---|---|---|
| Age (years) | 29 ± 8 | 32 ± 6 | 31 ± 7 |
| Mass (kg) | 79.6 ± 7.6 | 76.5 ± 9.7 | 78.1 ± 8.6 |
| $VO_{2max}$ (l $min^{-1}$) | 3.8 ± 0.6 | 4.8 ± 0.5 | 4.2 ± 0.8 |
| Maximal aerobic power (W) | 279 ± 45 | 369 ± 43 | 320 ± 63 |

Participants then completed a progressive, incremental exercise test to exhaustion. The test started at 100 and 180 W for non-cyclists and cyclists respectively, and increased at a rate of 20 W $min^{-1}$. The accuracy and reproducibility of the SRM system have been demonstrated previously (Jones and Passfield, 1998; Gardner et al., 2004). Maximal aerobic power (MAP) was measured as the highest mean power output recorded over a 60-s period.

For the duration of the test, respiratory gases were recorded on a breath-by-breath basis using a Cortex Metalyzer 3b gas analysis system (Cortex Biophysik, Germany). The Cortex system was calibrated prior to use according to the manufacturers guidelines, using a calibration gas of known composition and a 3-litre syringe (SensorMedics, Yorba Linda, California, USA). Maximal oxygen consumption ($VO_{2max}$) was determined as the highest mean oxygen consumption recorded over a 60-s period. $VO_{2max}$ was identified as a plateau in $VO_2$, defined as an increase of less than 1.5 ml $kg^{-1}$ $min^{-1}$, and/or as a respiratory exchange ratio >1.10 (Doherty et al., 2003).

At each of visits 2–4, participants carried out a 5-min warm-up at 125 W and 90 rev $min^{-1}$, followed by three 6-s sprints at 90 rev $min^{-1}$ over a period of 10 min using the SRM ergometer's cadence controlled (i.e. isokinetic) mode. Between sprints, participants were instructed to return to 90 rev $min^{-1}$ at preferred power output in the minute following the sprint. All participants then completed 6 min of cycling at 90 rev $min^{-1}$ at each of three power outputs (135 W, 150 W, and 165 W). Cyclists completed two additional 6-min bouts at 215 and 265 W. The order of the power outputs were randomised.

Surface electromyography (EMG) was used to record the electrical activity of eight muscles of the right lower limb (tibialis anterior (TA), soleus (SOL), gastrocnemius medialis (GM), gastrocnemius lateralis (GL), vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), and gluteus maximus (Gmax)). Single differential EMG-sensors (Delsys Bagnoli, Delsys, Boston, MA, USA) were attached over each muscle according to the recommendations by SENIAM (Hermens et al., 2000). The skin was shaved and cleaned with alcohol prior to placement. Wires were secured to prevent movement-induced artefacts with a strap just below the knee and with the participant's cycling shorts. In order to ensure repeatable sensor placement across the visits, the location of the sensors was marked using Henna tattooing (Wurstbauer et al., 2001). EMG recordings were synchronised with crank position using a simultaneously recorded TTL pulse that occurred when the left pedal reached 'the top dead centre' (TDC) (Imago, Radlabor, Freiburg, Germany).

EMG data were recorded during the 6 min of each condition at 1000 Hz. In the assessment of inter-session reliability, a period of 30 s during the final minute (300–330 s) was subsequently analysed. Three periods of EMG activity (90–120 s, 180–210 s, 300–330 s) during the 165 W condition of visit 3 were analysed for the determination of intra-session reliability.

### 2.3. Data treatment

All EMG data were analysed using custom Matlab (MatLab, The Mathworks Inc., MA, USA) scripts. EMG data were filtered using a band pass filter (20–450 Hz) as per the manufacturer's recommendations. Raw EMG was rectified and filtered using a low pass, zero-lag, 4th-order Butterworth filter with a cut off frequency of 15 Hz. Visual inspection was performed and data showing artefacts was excluded from the analysis. The period being analysed was resampled using the TTL pulse and by linear interpolation converted to a linear envelope representing every degree of crank angle. The EMG linear envelope for each muscle was described for the right leg during the up stroke (i.e. Bottom Dead Centre [BDC, 180°] to TDC [0°]) and the down stroke (i.e. TDC to BDC). After resampling, these data