# EFFECTS OF FATIGUE ON EMG AND PEDAL FORCES DURING MAXIMAL CYCLING TO EXHAUSTION

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## INTRODUCTION

Muscular fatigue can be defined as a functional inability to maintain a desired performance level, which is especially observed during high intensity exercise such as road cycling races [1]. As in many sports, fatigue during cycling is considered a complex process involving psychological, environmental, physiological and biomechanical factors [2].

There is a lack of studies addressing the effects of fatigue on pedal forces and muscle activity during cycling to exhaustion. Therefore, the aim of the present study was to analyse the pedal forces and lower limb muscle activation during cycling to exhaustion.

## METHODS

Fourteen male cyclists with a mean competitive experience of 4 years followed a two-day protocol. In day 1, each subject performed an incremental maximal cycling test exercise to determine maximal oxygen uptake ($VO_{2MAX}$ = 4710.35 ± 305.21 $ml \cdot min^{-1}$) and peak power output (354.64 ± 23.49 W). In day 2, the athletes cycled to exhaustion at an intensity corresponding to100% of their $VO_{2MAX}$.

Surface electromyography (EMG) was used to measure the muscle activity from gluteus maximus (GMax), rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), long head of biceps femoris (BF), medial head of gastrocnemius (GM), tibialis anterior (TA), and soleus (SO) muscles from the right lower limb during the fatigue test. A bi-dimensional pedal force dynamometer was used to measure the normal (Fz) and tangential (Fx) components of the force applied by the cyclists to the pedal [3]. EMG and pedal force signals were analysed for 10 seconds of the start, middle, and end of the fatigue test. The EMG signal obtained from each muscle was normalized by the average value for that specific muscle at the start of the fatigue protocol. The root mean square (RMS) values were calculated and used as an indicator of the total muscle activation [4,5].

Data normality was confirmed by Shapiro-Wilk's test. RMS, resultant pedal force and cadence were analysed by one-way ANOVA for repeated measures. When main effects were significant the LSD post-hoc test was applied. A significance level of 0.05 was adopted for all tests.

## RESULTS AND DISCUSSION

Fz and Fx increased from the start to the end of the fatigue test (-288 ± 32.56 to -352 ± 41.52 N, $p<0.001$; -79 ± 44.91 to -124 ± 67.65 N, $p=0.005$, respectively). Pedalling cadence decreased from the begging to the end of the fatigue test (96 ± 5.49 to 86 ± 6.43 rpm, respectively, $p<0.001$).

RMS values increased in RF, VL, VM and Gmax with fatigue, whereas they remained about constant in BF, GM, TA and SO (Table 1). RMS in the main power producer muscles was consistent with the expected behaviour under fatigue in dynamic tasks [6], and appear to perform a key role for pedal force application.

## CONCLUSIONS

Despite of muscle fatigue depicted by the RMS values, cyclists were able to increase the force applied to the pedal. However, this increase in force is probably related to the decrease in cadence observed, and probably represents an effort to sustain pedalling effectiveness and maintain the external power output.

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## REFERENCES

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**Table 1:** Normalized RMS values (mean ± SD) from the start, middle and end of the fatigue test of rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), gluteus maximus (GMax), biceps femoris (BF), gastrocnemius (GM), soleus (SO), and tibialis anterior (TA).

| | **RF** | **VL** | **VM** | **GMax** | **BF** | **GM** | **SO** | **TA** |
|---|---|---|---|---|---|---|---|---|
| **start** | 100±0.45 | 100±0.32 | 100±0.36 | 100±0.44 | 100±0.70 | 100±0.47 | 100±0.58 | 100±0.46 |
| **middle** | 116±0.75 | 113±0.35$ | 108±0.49 | 127±0.55$ | 104±0.71 | 98±0.47 | 98±0.74 | 114±0.71 |
| **end** | 151±0.93*# | 127±0.44*# | 120±0.57*# | 176±0.93*# | 100±0.68 | 97±0.45 | 92±0.64 | 117±0.80 |

*Significant differences between start and end ($p=0.008$, $p<0.002$, $p<0.001$, and $p=0.029$, for RF, GL, VL and VM, respectively). $Significant difference between start and middle ($p<0.001$ and $p=0.002$ for GL and VL, respectively) #Significant difference between middle and end ($p=0.013$, $p=0.007$, $p=0.012$, and $p=0.005$ for RF, GL, VL and VM, respectively).