

## Tensiomyographic Characteristics of Rectus Femoris after a Single Bout of Intense Exercise

<sup>1</sup>Luis Carrasco Paez, <sup>1</sup>Borja Sañudo Corrales and  
<sup>1</sup>Moises de Hoyo Lora, <sup>2</sup>Gabriela Ochiana

<sup>1</sup>Department of Physical Education and Sport, University of Seville, Spain

<sup>2</sup>Department of Sports and Human Movement Sciences, Faculty of Health,  
University "Vasile Alecsandri" of Bacau, Romania

**Abstract: Problem statement:** It is not well known how local fatigue can impair the contractile properties of skeletal muscle, so the aim of this study was to determine the Tensiomyographic (TMG) characteristics of Rectus Femoris (RF) after a single bout of intense exercise. **Approach:** Twelve healthy male volunteers (mean±SEM; age, 24.16±0.62 years, height 172.02±1.21 cm, body mass 71.84±2.19 kg, BMI 24.42±0.70 kg m<sup>-1</sup>) were recruited. **Results:** In session 1, a graded exercise test on cycle ergometer was performed in order to determine subject's maximal oxygen uptake (VO<sub>2max</sub>) and power at this key point (pVO<sub>2max</sub>). In a second testing session, TMG rest values were assessed and then all subjects carried out 2 min of cycling at pVO<sub>2max</sub> after which TMG analysis was applied again. The results showed subject's VO<sub>2max</sub> values of 53.44±2.67 ml kg<sup>-1</sup> min<sup>-1</sup>, reaching a mean pVO<sub>2max</sub> of 270.83±8.61 W. Maximal radial displacement (Dm) and time from the onset of electrical stimulus to 10% of Dm (Td) were significantly lower at post-test (from 7.577.57±0.92-4.37±0.67 mm; p = 0.01, for Dm and from 25.25±0.57-22.44±0.89 ms; p≤0.05, for Td). **Conclusion/Recommendations:** It can be concluded that a brief and intense exercise consisting in 2 min of cycling at pVO<sub>2max</sub> provokes a reduction in contractile properties of RF considering TMG parameters such as Dm and Td. More studies are needed to clarify the role of muscle fatigue on temporal TMG parameters.

**Key words:** Intense exercise, Tensiomyography (TMG), maximal radial displacement, radial displacement, muscle's belly, self-adhesive, contractile parameters, Rectus Femoris (RF)

### INTRODUCTION

Tensiomyography (TMG) is a relatively novel technique based on the quantification of radial muscle belly displacement in response to a single electrical stimulus. In this way, the basis of TMG is focused on enlargement of muscle's belly during its contraction. Using a specific displacement sensor, the radial enlargement of the muscle belly can be measured, drawing a displacement-time curve which allows analyzing the muscle contractile properties from different parameters (Valencic and Knez, 1997). These parameters are: Maximal radial Displacement (Dm), time from the onset of electrical stimulus to 10% of Dm (Td), time from 10-90% of Dm in the ascending curve (Tc), time between 50% of Dm on both sides of the curve (Ts) and time from 90-50% of Dm on the descending curve (Tr) (Fig. 1). Recently, reliability of TMG has been established, reaching a good to excellent inter-rater reliability level for practically all contractile parameters (Tous-Fajardo *et al.*, 2010; Carrasco *et al.*, 2011).

In the last few years, measurements of contraction time by TMG have been successfully implemented on

different muscle groups (Valencic and Knez, 1997) to investigate endurance and muscle belly stiffness among other muscular responses (Grabljevec *et al.*, 2005; Pisot *et al.*, 2008). However, muscle contractile properties during or after fatiguing exercise remains unclear (Letafatkar *et al.*, 2009; Hosseinimehr *et al.*, 2010) mainly due to a lack of adequate assay system. Thus, the purpose of this study was to evaluate the TMG responses of exercised muscles after a single bout of intense exercise.

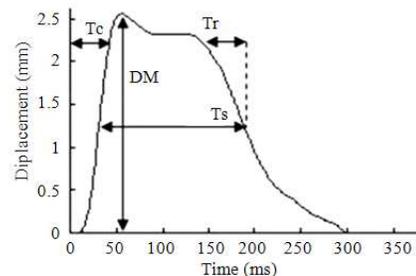


Fig. 1: Graphical representation of some TMG parameters

**Corresponding Author:** Luis Carrasco Páez, Department of Physical Education and Sport. University of Seville. Spain

## MATERIALS AND METHODS

**Participants:** Twelve healthy male volunteers (mean  $\pm$  SEM; age,  $24.16 \pm 0.62$  years, height  $172.02 \pm 1.21$  cm, body mass  $71.84 \pm 2.19$  kg, BMI  $24.42 \pm 0.70$  kg·m<sup>-2</sup>) were recruited for this study. All were recreationally active who were not engaged in a systematic exercise programmed. Participants were asked to abstain for food and caffeine beverages for 2 h before testing and to not perform heavy exercise during the 24 h preceding the tests. After being fully informed about the purpose of the experiments, each participant signed an informed consent. The Local Research Ethical Committee approved the experimental protocol and the procedures involved.

**Testing procedures:** All participants reported to laboratory for two visits. The first one was dedicated to determine participants'  $\text{VO}_{2\text{max}}$  and power associated with  $\text{VO}_{2\text{max}}$  ( $\text{pVO}_{2\text{max}}$ ); for that, the participants carried out a maximal graded test on a cycle ergometer. Then, on a separate session (48 h) and both before and after 2 min of cycling at  $\text{pVO}_{2\text{max}}$  (intense exercise) TMG measures were assessed. All testing procedures were performed at the same hour interval (between 9:00-11:00 am) in a room at an ambient temperature of 22-24 °C.

**Maximal graded exercise test:** After a standardized warm-up consisting of 5 min of pedaling on a cycle ergometer (Kettler Axiom P2, GmbH and Co.KG, Ense-Parsit, Germany) at a load of 50 W, participants performed a maximal graded exercise test. The initial load was 50 W and increased by 25 W every min until exhaustion with a pedaling frequency of 60 rpm. Gas analyses were performed using a breath-by-breath gas analyzer (VO2000 Portable Metabolic System, Medgraphics, St. Paul, MN), whose validity was previously proved by Byard and Dengel (2002). Before each test VO2000 was manually calibrated according to manufacturer guidelines.  $\text{VO}_{2\text{max}}$  corresponded to the highest  $\text{VO}_2$  attained in two successive 15 s periods for the maximal graded test. In addition, HR was continuously monitored (Polar 800 CX, Polar Electro, Kempele, Finland). It was considered that participants had reached their  $\text{VO}_{2\text{max}}$  when three or more of the following criteria were met: (a) a steady state of  $\text{VO}_2$  despite increasing load (changes in  $\text{VO}_2$  at  $\text{VO}_{2\text{max}} \leq 150$  mL); (b) a final respiratory exchange ratio higher than 1:1; (c) visible exhaustion; (d) an HR at the end of the exercise ( $\text{HR}_{\text{max}}$ ) within the 10 bpm of the predicted maximum ( $220 - \text{age}$ ). Also,  $\text{pVO}_{2\text{max}}$  was defined as power output (W) developed by the participants on the cycle ergometer when  $\text{VO}_{2\text{max}}$  was reached.



Fig. 2: TMG assessment in RF of right leg

**Intense exercise and TMG measurement:** In session 2, the participants performed 2 min of cycling at  $\text{pVO}_{2\text{max}}$  keeping a pedaling frequency of 60 rpm. In our study, before (pre) and after intense exercise (post), tensiomyography analysis of Rectus Femoris (RF) of the right leg was performed. Radial displacements were measured under static and relaxed conditions, with the participant in the supine position and the knee joint fixed at a 120 angle (180 corresponding to full extension of the knee). The measured limb was positioned on a triangular wedge foam cushion to keep a fixed knee angle. A digital displacement transducer (GK 40, Panoptik d.o.o., Ljubljana, Slovenia), which incorporates a spring of  $0.17 \text{ N}\cdot\text{mm}^{-1}$ , was set perpendicular to the muscle belly to acquire RF radial displacement. Sensor location was determined anatomically according to Delagi *et al.* (1975) and marked with a dermatological pen. Two square ( $5 \times 5$  cm) 2 mm thick self-adhesive electrodes (Compex Medical SA, Ecublens, Switzerland) were placed symmetrically 5 cm ( $\pm 5$  cm) distal and proximal to the sensor tip. A TMG-S1 (EMF-Furlan and Co. d.o.o., Ljubljana, Slovenia) stimulator was used (Fig. 2).

Regarding electrical stimulation procedures, pulse duration was 1 ms and the initial current amplitude was 30 mA. For each of the TMG assessment, current amplitude was progressively increased by 10 mA increments until there was no further increase in Dm or maximal stimulator output (110 mA). Rest periods of 15 were interspersed between consecutive measurements to minimize the effects of fatigue and

potentiation. For each participant, two consecutive measurements were performed at the highest current amplitude and they were recorded and averaged for subsequent analyses. In any case, none of the participants reported discomfort during electrical stimulation.

In the present study Dm, Ts and Tr were registered so these parameters seem to show largest influence to muscle fatigue rate and are also expected to be the best measure of the fatigue rate (Krizaj *et al.*, 2008).

**Statistical analyses:** Means and standard errors of the mean were calculated for each variable. Normality assumption was checked using the Kolmogorov-Smirnov test and all variables were normally distributed. One way analysis of variance was used to compare pre- and post-values. Moreover, Eta-squared ( $\eta^2$ ) was used for the calculation of effect size. Statistical significance was set at  $p \leq 0.05$ .

### RESULTS

In session 1, mean  $VO_{2max}$  measured during maximal graded exercise test was  $53.44 \pm 2.67$  mL·kg<sup>-1</sup>·min<sup>-1</sup>, reaching a mean  $pVO_{2max}$  of  $270.83 \pm 8.61$  W.

Table 1 shows TMG data obtained before and after intense exercise. The mean electric stimulus applied to RF before intense exercise was  $98.89 \pm 4.60$  mA, similar to that applied just at the end of exercise. It is important to note that only Dm and Td were significantly lower at post-test (from  $7.577.57 \pm 0.92$ - $4.37 \pm 0.67$  mm;  $p = 0.01$ , for Dm and from  $25.25 \pm 0.57$ - $22.44 \pm 0.89$  ms;  $p \leq 0.05$ , for Td), showing also small-moderate effect sizes by attending to the Cohen's effect size criteria (Cohen, 1988). On the other hand, Ts and Tr didn't show significant alterations, although TS increased from  $141.06 \pm 18.01$ - $165.32 \pm 20.79$  ms and Tr decreased lightly (from  $54.84 \pm 6.37$ - $52.73 \pm 8.28$  ms).

Table 1: TMG assessment

|         | Pre-test           | Post-test         | F     | sig   | $\eta^2$ |
|---------|--------------------|-------------------|-------|-------|----------|
| Dm (mm) | $7.57 \pm 0.92$    | $4.37 \pm 0.67$   | 7.930 | 0.010 | 0.265    |
| Ts (ms) | $141.06 \pm 18.01$ | $165.32 \pm 0.79$ | 0.770 | 0.390 | 0.034    |
| Tr (ms) | $54.84 \pm 6.37$   | $52.73 \pm 8.28$  | 0.041 | 0.842 | 0.002    |
| Td (ms) | $25.25 \pm 0.57$   | $22.44 \pm 0.89$  | 7.088 | 0.014 | 0.244    |

Data are expressed as mean  $\pm$ SEM. Pre-test: before intense exercise; Post-test: after intense exercise; F, sig and  $\eta^2$  (eta-squared) values are related to one-way ANOVA analysis

### DISCUSSION

An innovation of the present study is the use of TMG to evaluate the effects of intense cycling on contractile properties of exercised muscles. From all TMG parameters, Dm, Ts and Tr seem to provide the most useful information in evaluation of muscle fatigue (Krizaj *et al.*, 2008). Dm, which could be equated to electrically evoked peak twitch torque, is determined by both the number and the type of muscle fibers recruited by the electrical stimulus, being considered as a measure of muscle belly stiffness (Pisot *et al.*, 2008). In the present study TMG analysis of RF of right leg was performed before (pre-test) and after intense exercise (post-test), reported significant decreases in Dm and Td values, although no statistical differences were observed when Tr and Ts assessed in pre-test and post-test were compared. Decreases in Dm and Td after intense exercise could indicate a lower contractile capacity of RF due to a fatigue state, that is to say, a lower enlargement of muscle's belly during its contraction and a slower reaction after electrical stimulus, respectively. However, it seem difficult to explain RF fatigue from Tr (time from 90-50% of Dm on the descending curve) and Td (time from the onset of electrical stimulus to 10% of Dm) values observed in post-test assessment, since under fatigue state these data should be higher compared to those obtained in resting conditions.

### CONCLUSION

Brief and intense exercise consisting in 2 min of cycling at  $VO_{2max}$  power output provokes a reduction in contractile properties of RF muscle considering TMG parameters such as Dm and Td. However, more studies are needed to clarify how muscle fatigue can affect to temporal TMG parameters related to muscle contraction maintenance and relaxation.

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