



**Neuromuscular, metabolic and ventilatory fatigue threshold from an incremental cycling test using 1-min exercise periods**

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**AIM:** Extensive research has been directed towards the identification of the threshold that demarcates fatiguing from non-fatiguing exercise during an incremental workout on a cycle ergometer. As the exercise intensity increases, fatigue compromises not only the cardiovascular and respiratory systems, but also the neuromuscular system. The objective of this work was to calculate the neuromuscular fatigue threshold from surface electromyographic amplitude (EMG-FT) and determine possible associations between this threshold and the metabolic (onset of blood lactate accumulation, OBLA) and ventilatory (ventilatory threshold, VT, and respiratory compensation point, RCP) thresholds.

**METHODS:** Sixteen cyclists performed incremental cycle ergometer rides to exhaustion with bipolar surface sEMG signals recorded from the vastus lateralis. The participants were road cyclists engaged in regular training and amateur road races. On average, cyclists trained at least four times a week covering a weekly distance ranging between 400 and 600 km, plus competition or Sunday training. Cyclists had a national competitive experience of 4.3 (1.7) years and had performed an average of 20,000 km

riding. Before the incremental exercise test started, cyclists performed 5 min of unloaded cycling. The test was initiated at a workload of 125 W and the load was increased by 25 W every 1 min until the subjects could no longer continue to exercise (Fig. 1a). At this time, the power achieved was referred to as the maximal power. To calculate the EMG-FT, the deVries' model was employed using 1-min exercise periods. Blood samples were taken every two minutes during the test. OBLA was calculated as the power output corresponding to a blood lactate concentration of 4.0 mmol/L. During the incremental exercise, breath by breath analysis was performed using a turbine flow-meter connected to a face mask and data of oxygen uptake and carbon dioxide production and ventilatory parameters. One-way repeated-measures ANOVA was used to determine whether there were significant differences in average power output among the EMG-FT, OBLA, VT, and RCP. Pearson correlation coefficients were calculated to determine the relationships among EMG-FT, OBLA, VT, and RCP.

**RESULTS:** The maximal power tolerated was  $403.8 \pm 36.5$  W. The power output at EMG-FT ( $372 \pm 25$  W) was comparable ( $P>0.05$ ) to that of RCP ( $381 \pm 36$  W), but significantly higher ( $P<0.05$ ) than those of VT ( $337 \pm 31$  W) and OBLA ( $306 \pm 32$  W). During the incremental test, the power output at EMG-FT was not correlated with that of OBLA ( $0.31, P>0.05$ ), but it was positively correlated with those of VT ( $0.78, P<0.001$ ) and RCP ( $0.85, P<0.001$ ).

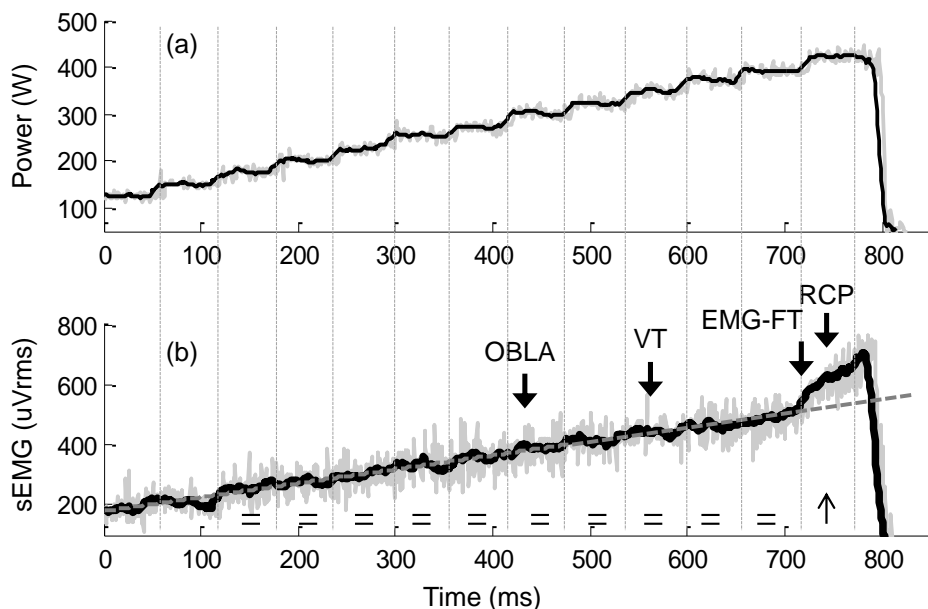


Fig. 1 Time plots of power output (a) and surface electromyographic (sEMG) (b) recordings obtained in one cyclist from the vastus lateralis during the incremental test. The increase in sEMG amplitude is slow for all exercise periods except the last one, when it increased abruptly. In (a) and (b) the black solid lines represent the power and sEMG amplitude, respectively, averaged every 15 bursts. In (b) the grey dashed line is the regression line of the sEMG vs. time relationship considering the data until min 8. Arrows indicate occurrence of the blood lactate (OBLA), ventilatory (VT and RCP), and EMG-FT thresholds.

**CONCLUSIONS:** Our results do not support the existence of a relationship between EMG-FT and lactate concentration. A significant correlation was found between the sEMG-

based threshold and gas exchange thresholds, although this correlation may not be causative. Second, application of deVries' model using of 1-min exercise periods could result in overestimation of the fatigue threshold since such short exercise periods could be insufficient to detect EMG signs of neuromuscular fatigue.