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► To cite this version:

Mylène Vonderscher, Maximilien Bowen, Pierre Samozino, Baptiste Morel. A force-endurance model able to describe the muscle fatigability in the severe domain: validation on electrically stimulated adductor pollicis. 28th annual congress of the European College of Sport Science, Paris, France, Jul 2023, Paris, France. hal-04084709

HAL Id: hal-04084709

<https://hal.science/hal-04084709>

Submitted on 28 Apr 2023

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A force-endurance model able to describe the muscle fatigability in the severe domain: validation on electrically stimulated *adductor pollicis*

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*This work was supported by French National Research Agency [ANR-22-CE14-0073]

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Keywords: critical force, nerve stimulation, PID control, fatigue prediction

Introduction. Muscle fatigue refers to the decay in muscles' ability to generate force. The Critical Power concept [1] predicts the point at which fatigue develops in such a way that the required constant intensity will no longer be sustainable, *i.e.*, time to exhaustion (TTE). However, this model only distinguishes two states: when it is possible to continue the exercise or not depending on whether W' (fixed amount of work that can be performed above the critical power) is emptied or not. Recently, Bowen et al. [2] extended the Morton's 3-parameters model [3] to describe maximal force decrease over time in the severe domain, whatever the intensity being constant or variable:

$$F_{\max}(t) = -\frac{1}{\tau} \int_0^t (F(T) - F_c) dT + F_i \quad (1)$$

This study aimed at testing the predictive capacity of this model for constant, ramp, and oscillatory intensities on electrically stimulated *adductor pollicis* in isometric condition

Methods. A custom ergometer coupled with an electrical nerve stimulation system was developed to study the *adductor pollicis* isometric force production capacities, independently of participants' voluntary activation. While participants remained passive, a PID control regulated ulnar nerve stimulation discharge frequency between 6 and 30 Hz to follow a force target. Maximal capacities F_{\max} were assessed every 15 s with 100 Hz tetanus of 500 ms duration. Eight participants realized 3 experimental sessions. The individual parameters F_i , F_c and τ were determined by adjusting the model to F_{\max} and time data from constant intensity tests. Model's validity was tested through the accuracy of the model's prediction of i) exhaustion times during increasing ramp tests and ii) $F_{\max}(t)$ during an oscillatory force exercise (sinus function between F_c and $F_c + 0.1F_i$ with a 120 s period).

Results. The model's goodness of the fit on constant exercise experimental data was excellent (median adjusted $R^2 = 0.96$; interquartile range = 0.15; RMSE = $4.4 \pm 2.7 \%F_i$). Mean \pm SD F_i , F_c and τ were respectively $95.9 \pm 1.2 \%F_i$, $22.4 \pm 4.1 \%F_i$ and 39.9 ± 15.5 s. Mean difference between predicted and observed TTE was 8.9 ± 18.2 s (RMSE = $9.7 \pm 5.2 \%F_i$). The RMSE between predicted and observed F_{\max} during the oscillatory test was $6.1 \pm 3.1 \%F_i$.

Discussion. The present results evidenced that it is possible to determine individual model's parameter F_i , F_c and τ from experimental data obtained during electrically induced isometric contractions of the *adductor pollicis*. Moreover, once individually fitted, the model showed very good predictions of the time to exhaustion in an increasing ramp test. Finally, the proposed model allowed for the accurate prediction of fatigue, *i.e.*, decrease in maximal force, over an oscillatory fatiguing exercise. To conclude, the force-endurance capacities mathematical model seems valid to characterize muscle-level isometric fatigability in the severe domain, independently from central mechanisms.

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