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## Force-velocity-endurance relationship: development of a mathematical model and validation of the IFLET test \*

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**Introduction.** Force production capacities during brief maximal efforts are constrained by a force-velocity relationship, a negative linear function characterized by theoretical maximum force ( $F_0$ ) and velocity ( $V_0$ ) [1]. For longer efforts, the intensity-duration relationship is mathematically described by an asymptotic decay function, the asymptote being the critical intensity [2]. Changing the force and velocity produced during an exercise *e.g.* by manipulating cadences in cycling, modifies the intensity-duration relation [3]. When the effort is prolonged, alterations in force and velocity capacities may also be different. Unfortunately, a unified force-velocity-time relationship as a representation of biomechanical and bioenergetical capacities of exercise performance has never been modeled. The aims of this study were to develop a mathematical model of a force-velocity-time relationship and to validate a test to determine the model parameters.

**Methods.** Based on the assumptions that *i*) the force-velocity relationship is linear and remains so when fatigued and that *ii*) both the force and velocity capacities decrease over time following an exponential decay function, a mathematical model has been developed. It is defined by 6 parameters being initial force ( $F_{0_i}$ ) and velocity ( $V_{0_i}$ ) capacities, the critical force ( $F_{0_c}$ ) and velocity ( $V_{0_c}$ ) capacities and the time constants for force ( $\tau_F$ ) and velocity ( $\tau_V$ ) decay. 16 participants realized the IFLET test on two separate days to test the reliability. It consists in a modified cycling 3-min all-out exercise during which the flywheel was instantaneously braked every 30 s so that the participant had to re-accelerate, thus allowing regular evaluation of the force-velocity capacities. The mean force and velocity of each pedal stroke was computed and used to fit the model's parameters.

**Results.** The goodness of the fit of the model from experimental data was excellent (all  $r^2 > 0.93$ ).  $F_{0_i}$  and  $V_{0_i}$  presented no systematic bias, excellent ICC ( $> 0.9$ ), and very low SEM ( $< 5\%$ ).  $F_{0_c}$  and  $V_{0_c}$  demonstrated very good reliability (ICC  $> 0.8$ ) and low SEM (5.4 and 7.6 %, respectively).  $\tau_F$  and  $\tau_V$  showed good reliability (ICC  $> 0.75$ ) but higher SEM ( $\sim 20\%$ ). Overall, when looking at the  $F(v, t)$  surface, independently of the parameters mentioned above, the relative and absolute reproducibility was very good to excellent.

**Discussion.** This is the first time that a model describes the force capacity considering both velocity and time simultaneously. This model fitted very well with experimental data obtained during the IFLET test, a 3-min all-out sprint interspersed exercise which also showed very good test-retest reliability. Applications of this approach could be numerous in the evaluation of physical capacities as well as for performance application through training or the optimization of human-material interactions.

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