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Application of a force-velocity-endurance model to cycling, rowing and running locomotion. *

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Introduction. The production of force during brief maximal effort is limited by a force-velocity relationship, which is characterized by a negative linear function and determined by the theoretical maximum force (F_0) and velocity (V_0) [1]. For longer efforts, the intensity-duration relationship has been described mathematically by an asymptotic decay function, with the critical intensity being the asymptote [3]. The force and velocity produced during an exercise can be modified by changing the cadence during cycling, for example, which alters the intensity-duration relationship [4]. As the effort is prolonged, changes in force and velocity capacities may occur differently. To account for the influence of the force-velocity and intensity relationships on each other, we developed a three-dimensional model that describes the force production capacity as a function of velocity and time, $F(v, t)$. In addition, we designed a test to determine the $F(v, t)$ relationship for an individual based on a 3-min all-out interspersed with a stop-start sprint (IFLET test) [2]. The aim of this study was to evaluate the parameters of the $F(v, t)$ relationship for various types of human locomotion (cycling, rowing and running) and to compare the parameters obtained for different populations based on their training status.

Methods. The IFLET test was administered to 49 participants across cycling, rowing, and running. During cycling, 21 moderately active individuals who were not cyclists (NC), 19 subelite trained cyclists (SC), and nine elite cyclists (EC) participated. Twelve elite rowers participated for the rowing task and 16 U21 elite rugby players participated for running locomotion. The test involved a 3-minute all-out effort, with conditions changing every 30s to assess the force-velocity relationship at a specific point in time. During cycling, this was achieved by suddenly blocking the flywheel, while in rowing, a motor replaced the flywheel and was controlled to produce varying force-velocity conditions. During running, the test was conducted in shuttle mode, which required participants to start sprinting at zero speed. The force-velocity-time data recorded or computed during the various locomotions was fitted to the $F(v, t)$ model's parameters to obtain the initial force (F_{0_i}), velocity (V_{0_i}), critical force (F_{0_c}), and velocity (V_{0_c}) capacities, as well as the time constant (τ).

Results and discussion. The goodness of fit of the model from experimental data was excellent for all locomotion (all $r^2 > 0.93$). Considering the group effect for cycling task locomotion, no difference was observed for V_{0_c} (NC : 58.9 ± 12.3 %; SC : 59.3 ± 9.7 %; EC: 55.7 ± 6.3 %). However, all groups were statistically different in terms of F_{0_c} (NC : 51.4 ± 11.2 %; SC : 64.2 ± 7.3 %; EC: 71.6 ± 10.4 %).

Conclusions and perspectives. This is the first time a model has been developed that simultaneously considers both velocity and time to describe the force capacity. This model accurately fits the experimental data obtained from the IFLET test, which is a 3-minute all-out sprint exercise interspersed with different locomotion types, such as running, cycling, or rowing. The applications of this approach are numerous and can be used in the evaluation of physical capacities as well as for performance enhancement through training or optimization of human-material interactions.

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