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Application of a force-velocity-endurance model to in situ muscle evaluation in mouse model. *

M. Bowen^{1,*}, C. Hourde¹, A-C. Durieux², D. Freyssenet², P. Samozino¹ and B. Morel¹

¹Interuniversity laboratory in Biology of Movement, Savoie-Mont Blanc University, Chambéry, France

²Interuniversity laboratory in Biology of Movement, Jean Monnet University, Saint-Etienne, France

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*maximilien.bowen@univ-smb.fr

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Introduction. The muscular contractile capacity is essential for human and animal movement and locomotion. Owing to their molecular structure, striated skeletal muscle cells produce a force that is a function of their rate of shortening. When the force production capacity of the neuromuscular system on an isolated muscle is explored, this relationship can be formulated mathematically by a rational function $F(V)$ [1]. Moreover, the intensity of this force decreases as a function of the duration $F(t)$, and converges towards a characteristic critical intensity [2]. The interaction between these two fundamental relationships has been studied only through independent comparisons. Considering them as two projections of a single force-velocity-time relationship [3] would make it possible to describe the force production capacities and their interactions in their entirety. The aim of this conceptual framework is to use an integrative model to unify a new Force-Velocity-Endurance (FVE) relationship that can define muscle properties and fatigability.

Methods. This new theoretical framework proposes a model that is a function of two variables (time t and velocity V), and seven major parameters to describe muscle properties: initial fatigue-free capacities (initial force (F_{0_i}), initial velocity (V_{0_i}), initial curvature (C_i) coefficients), critical capacities (F_{0_c} , V_{0_c} , C_c) and a characteristic time τ corresponding to the rate of capacity decline. To measure these parameters, a new 3 min all-out test with velocity variation was developed on an isokinetic ergometer (Aurora Scientific 300C) to scan the maximum capacities of the FVE surface, on both the velocity and time dimensions. The model was tested on 12 wild-type mice (six males and six females) for the *tibialis anterior* (TA) and *gastrocnemius* (GA) muscles.

Results and discussion. The goodness of fit of the model from the experimental data was excellent for all muscles ($r^2 > 0.97$). The proposed model revealed significant differences between the TA and GA muscle groups. For males, F_{0_i} , F_{0_c} and τ were higher for GA compared to TA. Considering females, F_{0_i} was significantly higher for GA but relative F_{0_c} was higher for TA. This new model also revealed differences in the muscle capacity as a function of sexual dimorphism. For instance, F_{0_i} was significantly higher for males compared to female only for TA but not GA muscles.

Conclusions and perspectives. These results demonstrate that it is possible to determine the individual parameters of the proposed model (F_{0_i} , V_{0_i} , C_i , F_{0_c} , V_{0_c} , C_c and τ) from the experimental data obtained from the proposed all-out test. Validating the existence of a universal FVE relationship and its theoretical foundations would open a new conceptual framework for improving our understanding of muscle function. Although this project is fundamental, the practical applications resulting from this new framework could be numerous, such as functional analysis of gene therapy in myology or the impairment of neuromuscular function in patients.

[1] A. V. Hill. The heat of shortening and the dynamic constants of muscle. *Proceedings of the Royal Society of London. Series B-Biological Sciences*, 126(843):136–195, 1938.

[2] R. Hugh Morton. A 3-parameter critical power model. *Ergonomics*, 39(4):611–619, 1996.

[3] B. Morel, M. Bowen, S. Dorel, and P. Samozino. Force-velocity-endurance relationship: development of a mathematical model and validation of the iflet test 28th annual congress of the ECSS, paris, france. 2023.