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Force-Velocity-Endurance (FoVE) Model :

A new in situ method for functional muscle evaluation in murine models

M. Bowen[1], C. Hourde[1], A-C. Durieux[2], D. Freyssenet[2], P. Samozino[1] and B. Morel[1*]

LIBM, [1]Savoie-Mont Banc University, Chambéry, France. [2]Jean Monnet University, Saint-Etienne, France

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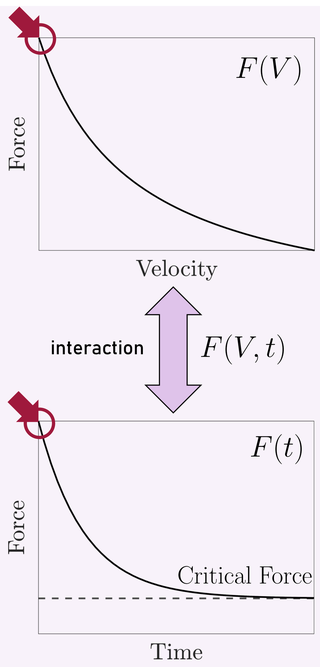
Introduction

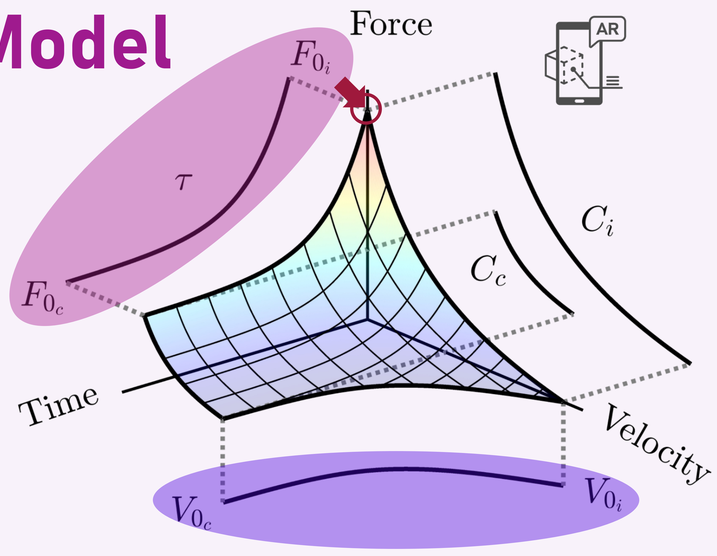
In murine models, muscle evaluation is traditionally based on muscle mass or force capacity under isometric conditions at null velocity.

Maximal isometric force (○) is a specific condition of two relationships: the **Force-Velocity F(V) [1]** at V=0 and **Force-Time F(t) [2]** at t=0 (without fatigue).

F(V) and **F(t)** have been studied separately, while interactions exist. Muscle functional capacities can be explored using a Force-Velocity-Endurance Model **F(V,t).**



Model



Single Integrative FoVE Model :

Explains the evolution of force **F** as a function of 2 variables: Velocity **V** and time **t** (fatigue).

7 FoVE parameters:

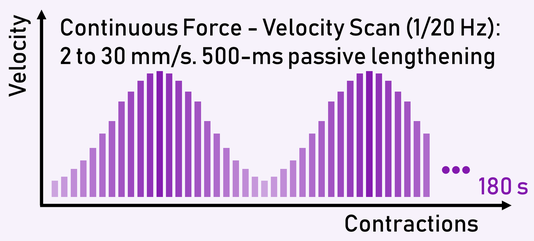
- **F0i** : Initial Isometric Force
- **F0c** : Critical Isometric Force
- **V0i** : Initial Maximal Velocity
- **V0c** : Critical Maximal Velocity
- **Ci** : Curvature of Fi(V) relationship
- **Cc** : Curvature of Fc(V) relationship
- **τ** : Typical decay time of F0 and V0

$$F(V,t) = F_{0_i} \cdot \left(\frac{V_{0_i} - V}{V_{0_i} + C_i \cdot V}\right) e^{-\frac{t}{\tau}} - F_{0_c} \cdot \left(\frac{V - V_{0_c}}{V_{0_c} + C_c \cdot V}\right) \cdot \left(1 - e^{-\frac{t}{\tau}}\right)$$

Protocol

Single in situ FoVE Protocol :

Force measurement during a 3-min continuous scan of imposed velocities, on isokinetic ergometer (Aurora Scientific).



Isolated Muscles (M)

- Tibialis Anterior **TA**
- Gastrocnemius **GA**

Electrical Stimulation (S)

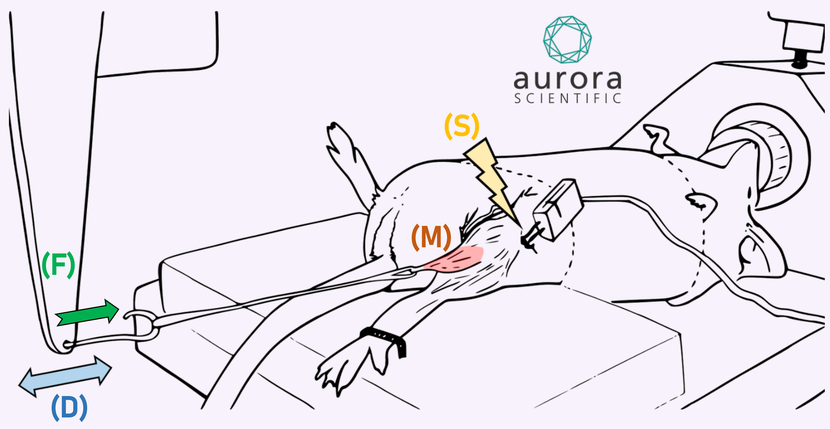
- Tetanic nerve stimulation
- Frequency: 100Hz

Isokinetic displacement (D)

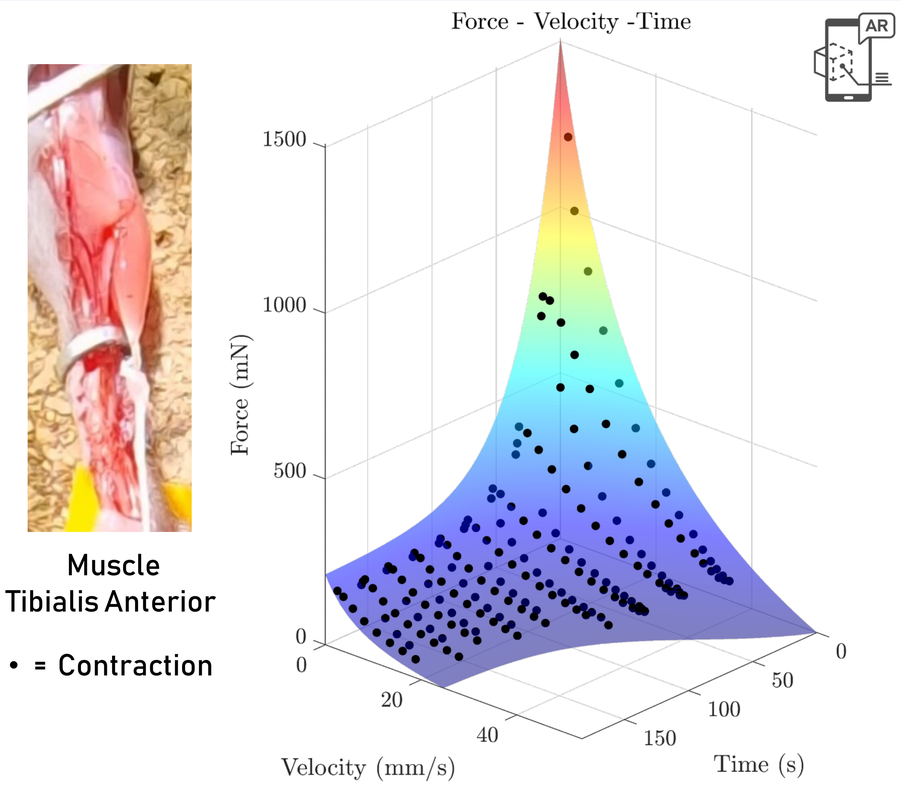
- Range: 2mm/s to 30mm/s
- Shortening: 1.5mm

Force Measurement (F)

- Maximal force
- Concentric phase



n=24 muscles : 12 Mice WT (C57BL/6) (6 ♀; 6 ♂)

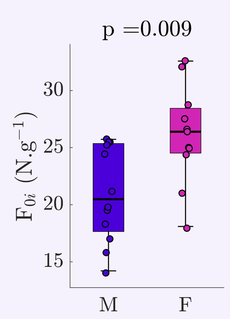


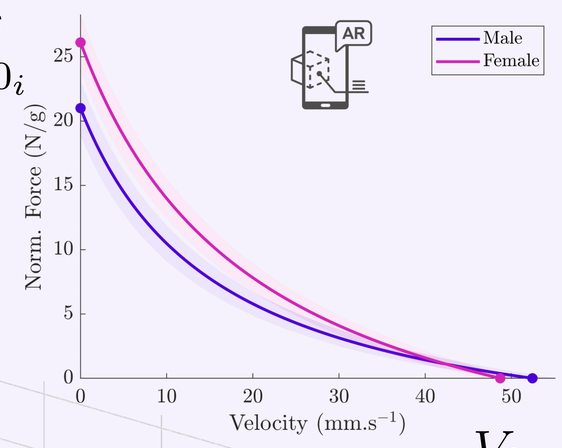
Results

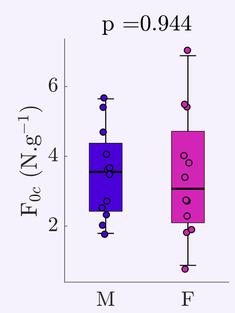
Typical result:
Sexual dimorphism ♀ ♂

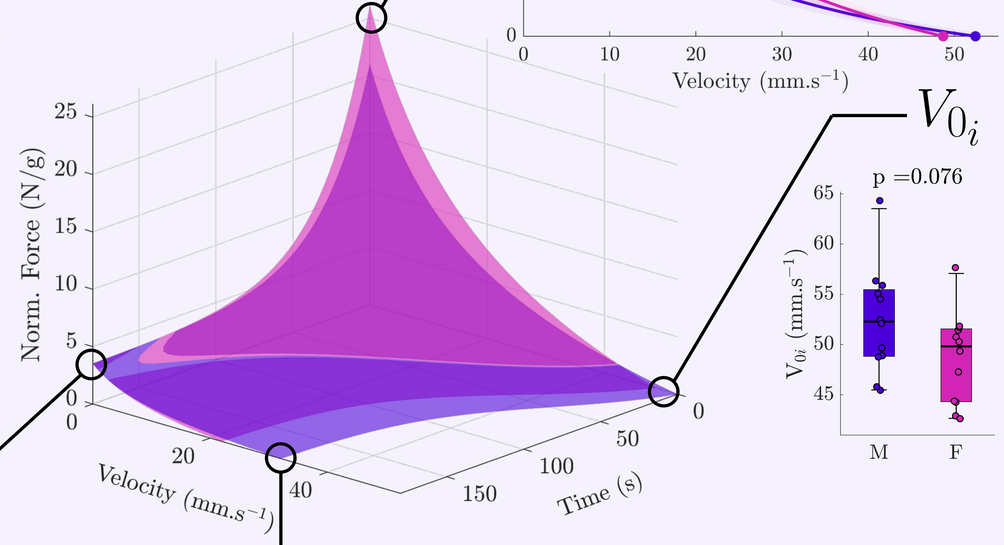
Discrete parameters analysis:

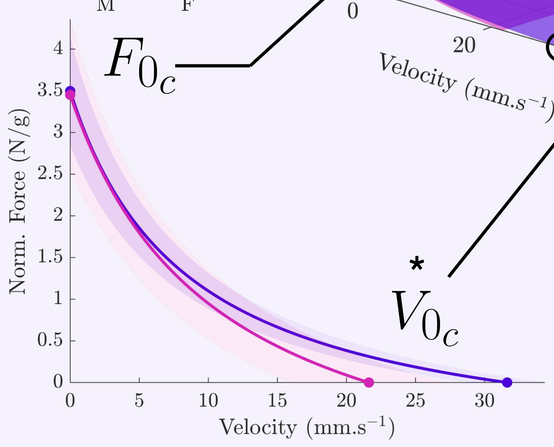
- **F0i** : Female > Male
- **V0c** : Male > Female
- **F0c , V0i , τ** : no diff.

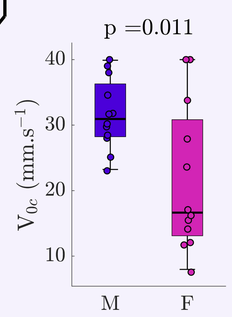












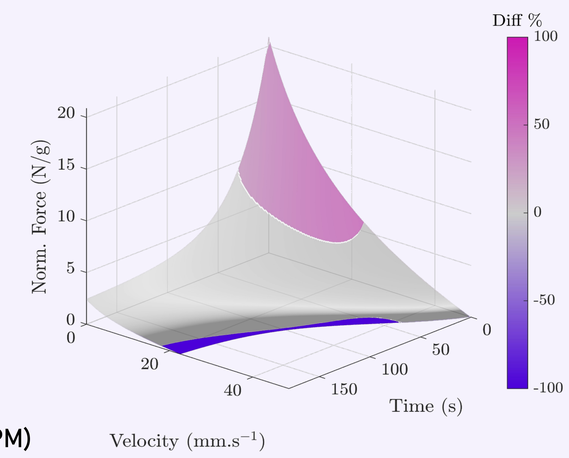
Goodness of fit :
r² = 0,98 ± 0,01
RMSE = 0,3 ± 0,3 N/g

ANOVA 2 factor (Sex / Muscle)

Continuous parameters analysis:

Areas of significant difference between 2 groups (colored area):

Female > Male
Male > Female



ANOVA Statistical Parametric Mapping (SPM)

Conclusion

- The maximal isometric force traditionally assessed does not reflect all muscle contraction capacities.
- FoVE evaluation provides a complete mapping of muscular function by describing the force production capacities at all velocity and fatigue levels.
- FoVE approach can be used in vivo in humans (e.g. translational research).

References

[1] A.V. Hill 1938 The heat of shortening and the dynamic constants of muscle. Proc. R. S.
[2] R.H. Morton 1996 A 3-parameter critical power model. Erg.