Evidence That Tuning of Muscle Spindles Can Be Decoupled from Muscle Activation

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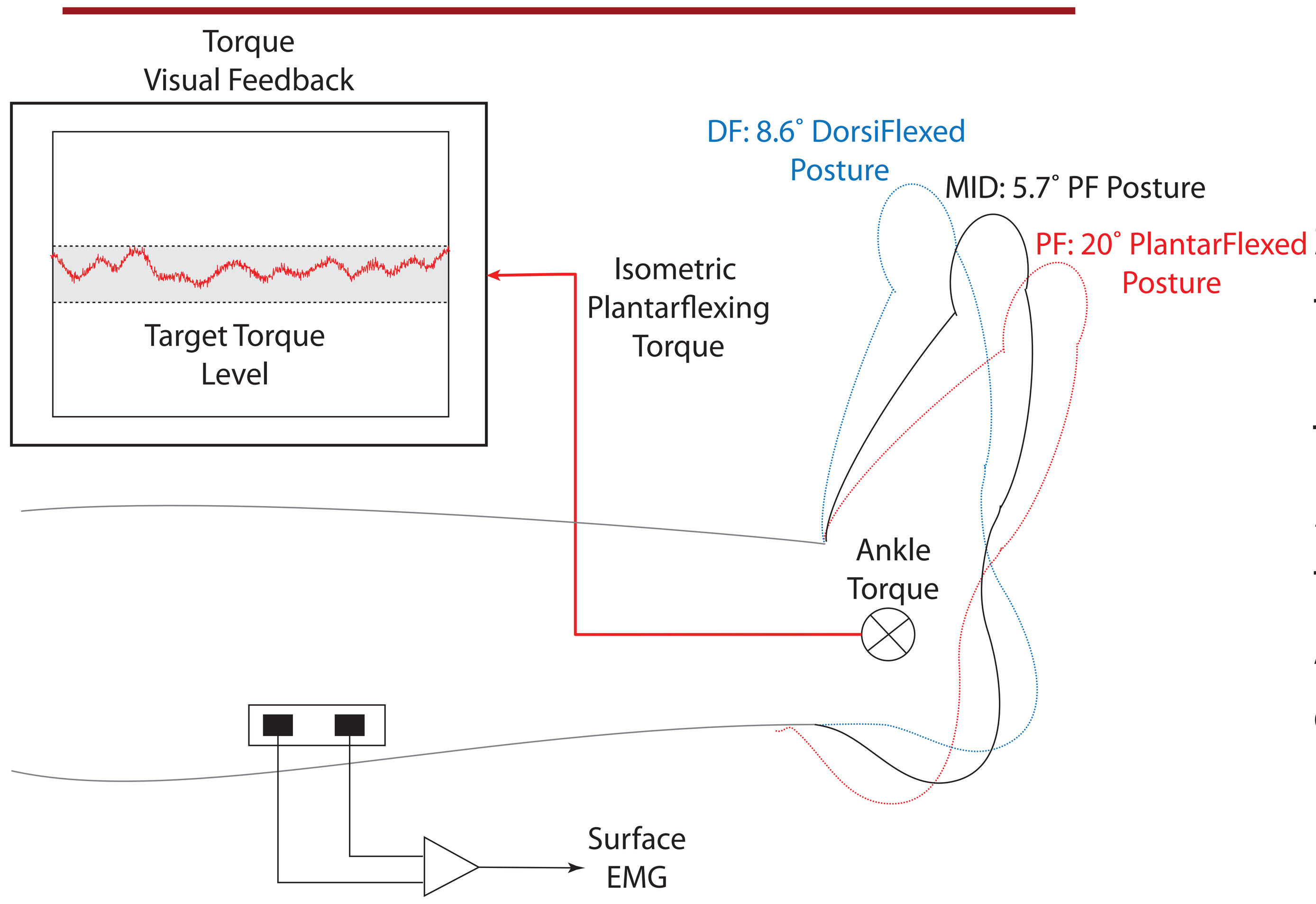
Motivation

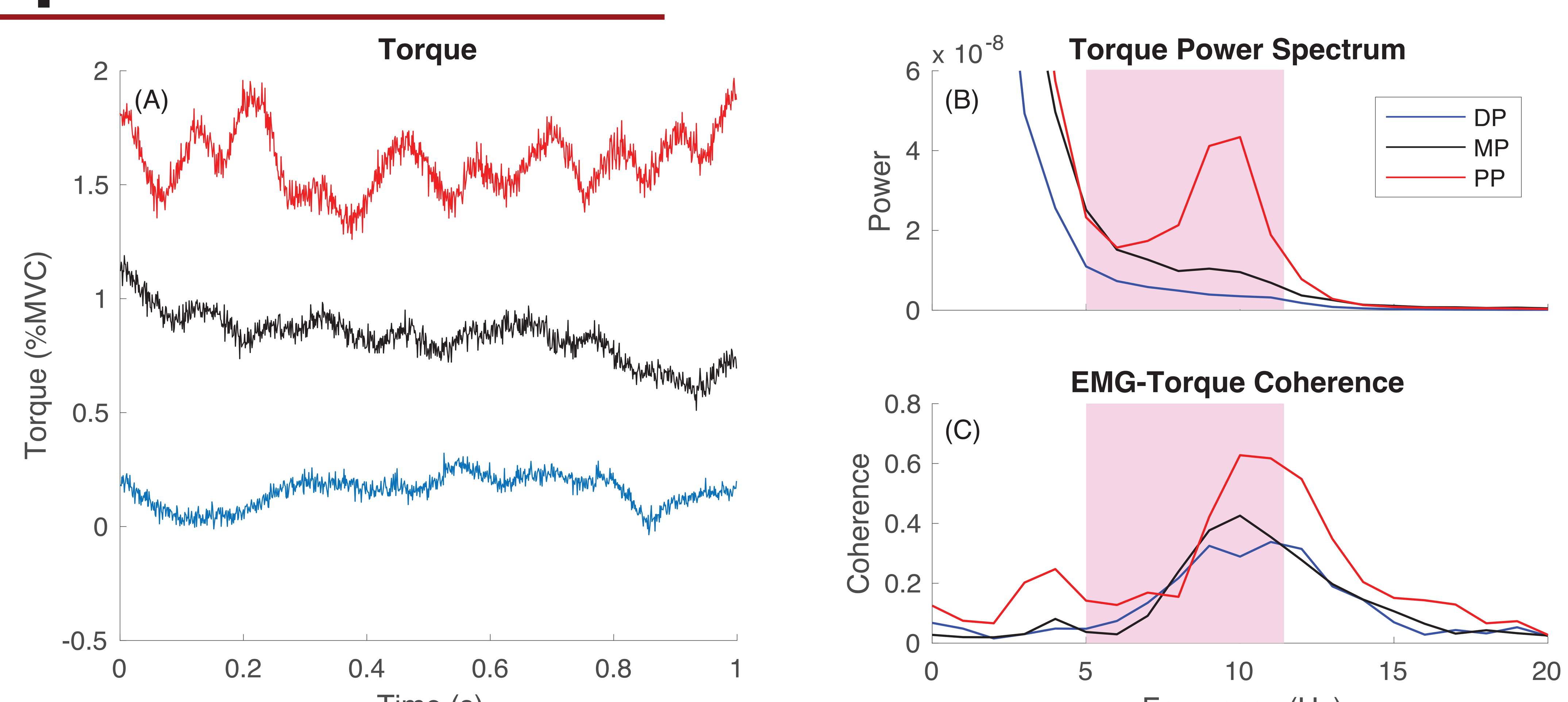
- Involuntary variability in the 6-12 Hz frequency range (physiological tremor) is unavoidable. It is thought to reflect modulation of spinal gains, fusimotor (i.e., γ motorneuron) drive, and excitation-inhibition mechanisms in afferented muscles.
- Neither spinal gains nor γ drive are accessible to study during voluntary activities in humans, without being invasive or disrupting the system.
- This precludes interrogating the system to understand the control of γ drive, which lies at the heart of many theories of healthy and pathological sensorimotor function, but which are not testable.
- We hypothesized that modulation of tremor by muscle stretch would provide a non-invasive and simple means to interrogate fusimotor mechanisms and thus enable us to refine our theories of sensorimotor function..

Experimental Methods



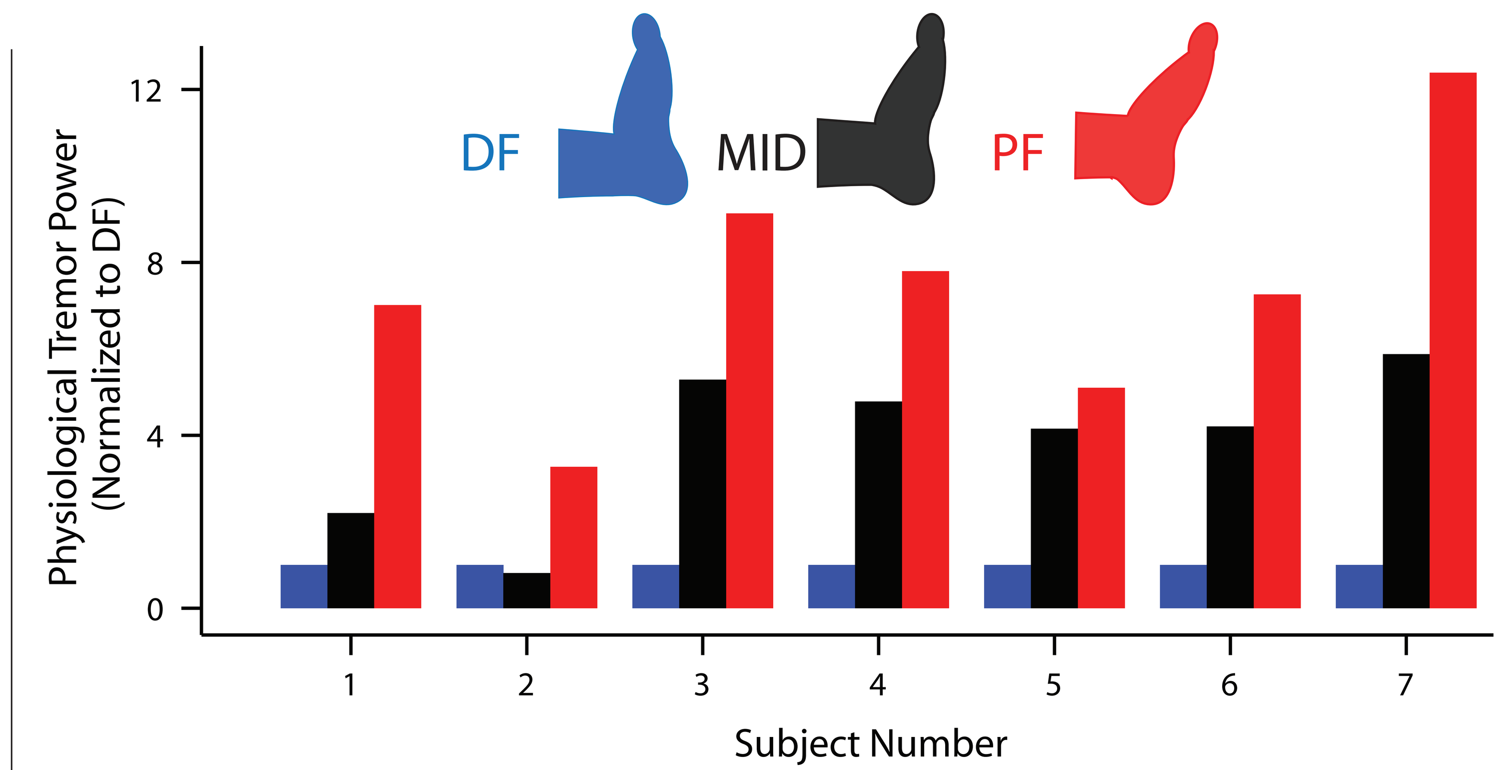
Subjects lay supine and produce a isometric plantarflexing ankle torque of 30% of their maximum voluntary contraction.
Three joint angles were tested: 20° plantarFlexed (PF), 5.7° PF from neutral (MID), and 8.6° dorsiflexed (DF) from neutral.
Ankle torque and EMG from the calf muscles were recorded.

Experimental Results



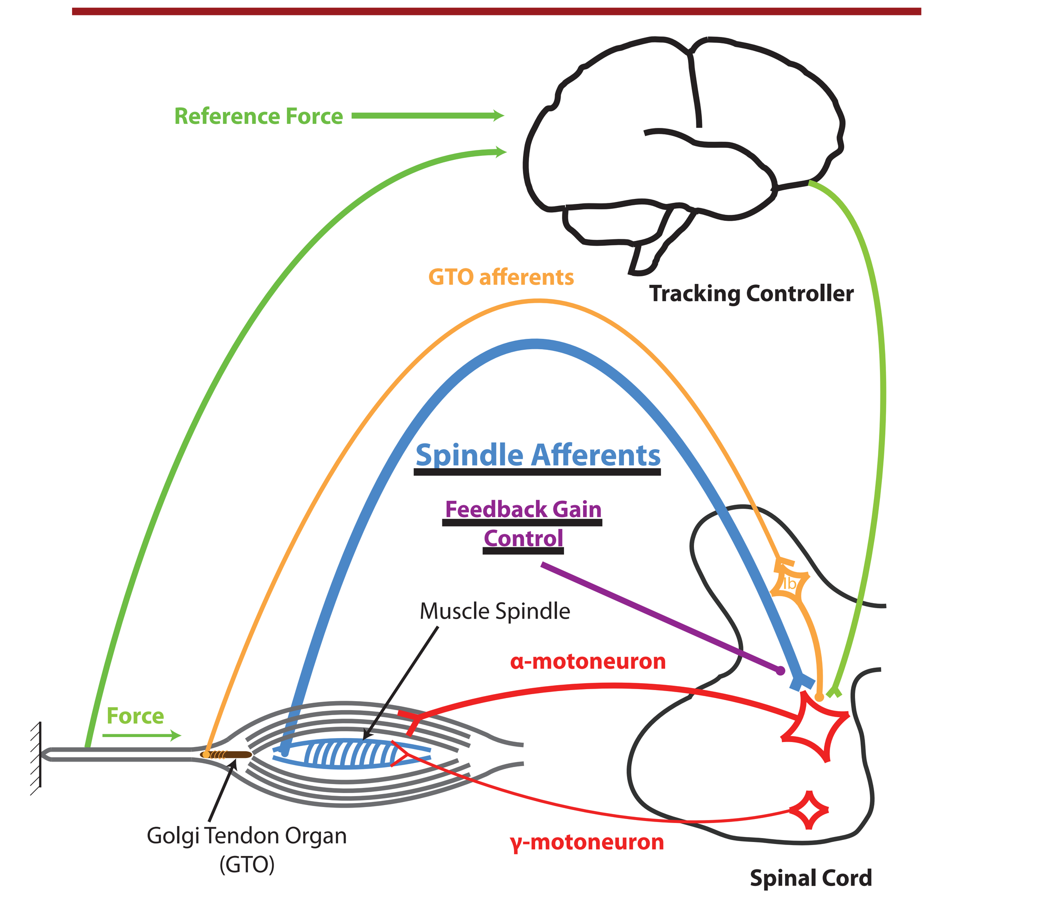
(A) Representative 1 s snapshot of torques recorded at three joint angles (torques were offset for the purpose of visual comparison).

(B-C) Power spectral density of torque shows high power in the physiological tremor frequency range. Torque is highly coherent with EMG in the physiological tremor frequency range.

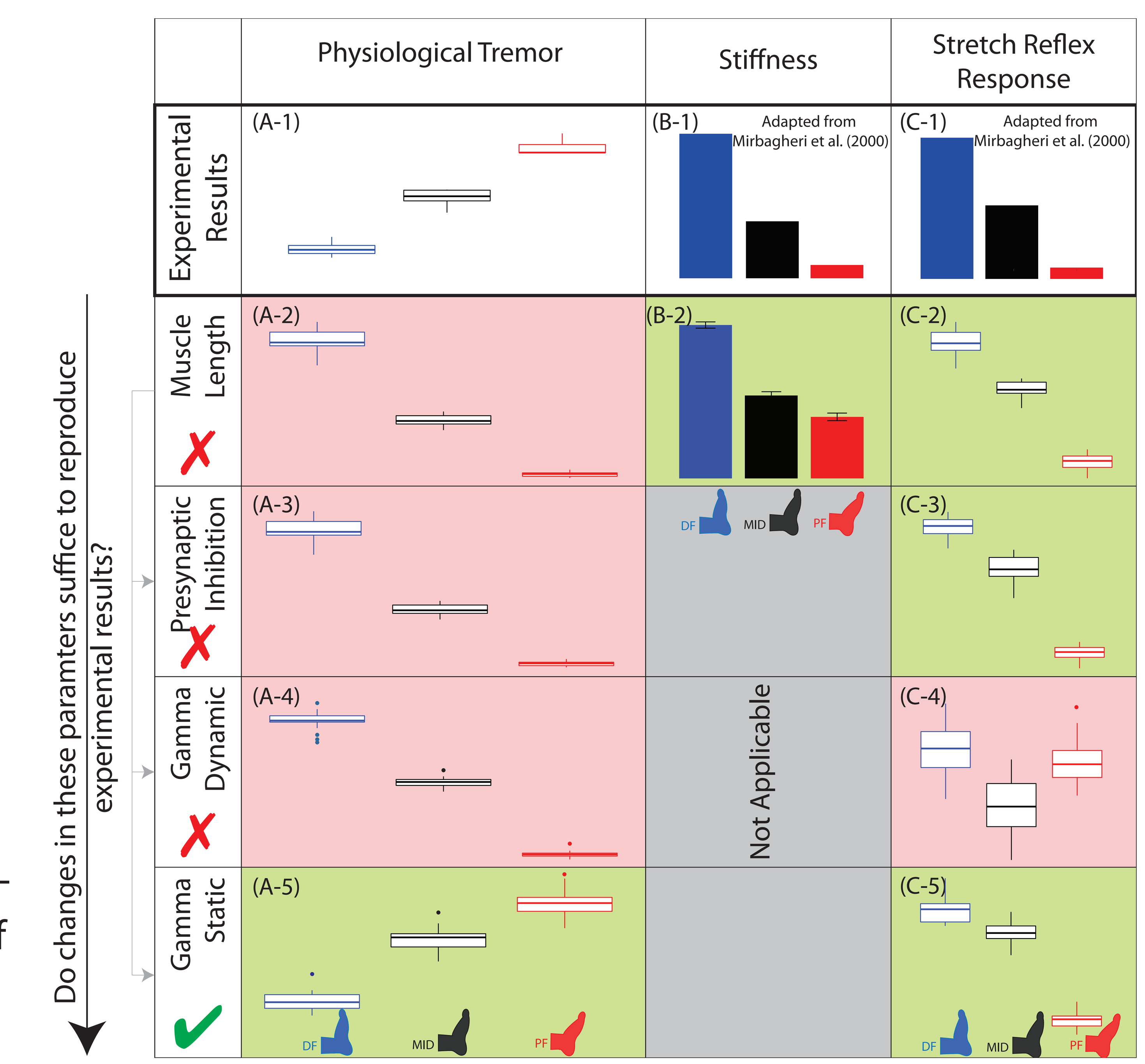


Torque power in the physiological tremor range (5-12 Hz) increases from dorsiflexed to plantarflexed angles.

Simulation Results



Computational model of afferented musculotendon was simulated to investigate neuromechanical factors that might contribute to modulation of physiological tremor with muscle stretch.



Only an increase in γ-static with muscle stretch was able to replicate the experimentally observed muscle length dependence of physiological tremor.

Conclusions

-Physiological tremor increases as the ankle joint becomes plantarflexed. Modulation of physiological tremor as a function of muscle stretch differs from that of the stretch reflex amplitude.
-Amplitude of physiological tremor may be altered as a function of reflex pathway gains.
-Healthy humans likely increase their γ-static fusimotor drive when muscles shorten.
-Quantification of physiological tremor by manipulation of joint angle may be a useful experimental probe of afferent gains and/or the integrity of automatic fusimotor control.

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