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Changes in muscle architecture after hemispheric stroke can adversely affect efficiency of muscle contraction in pennate muscles:

Origins of muscle weakness

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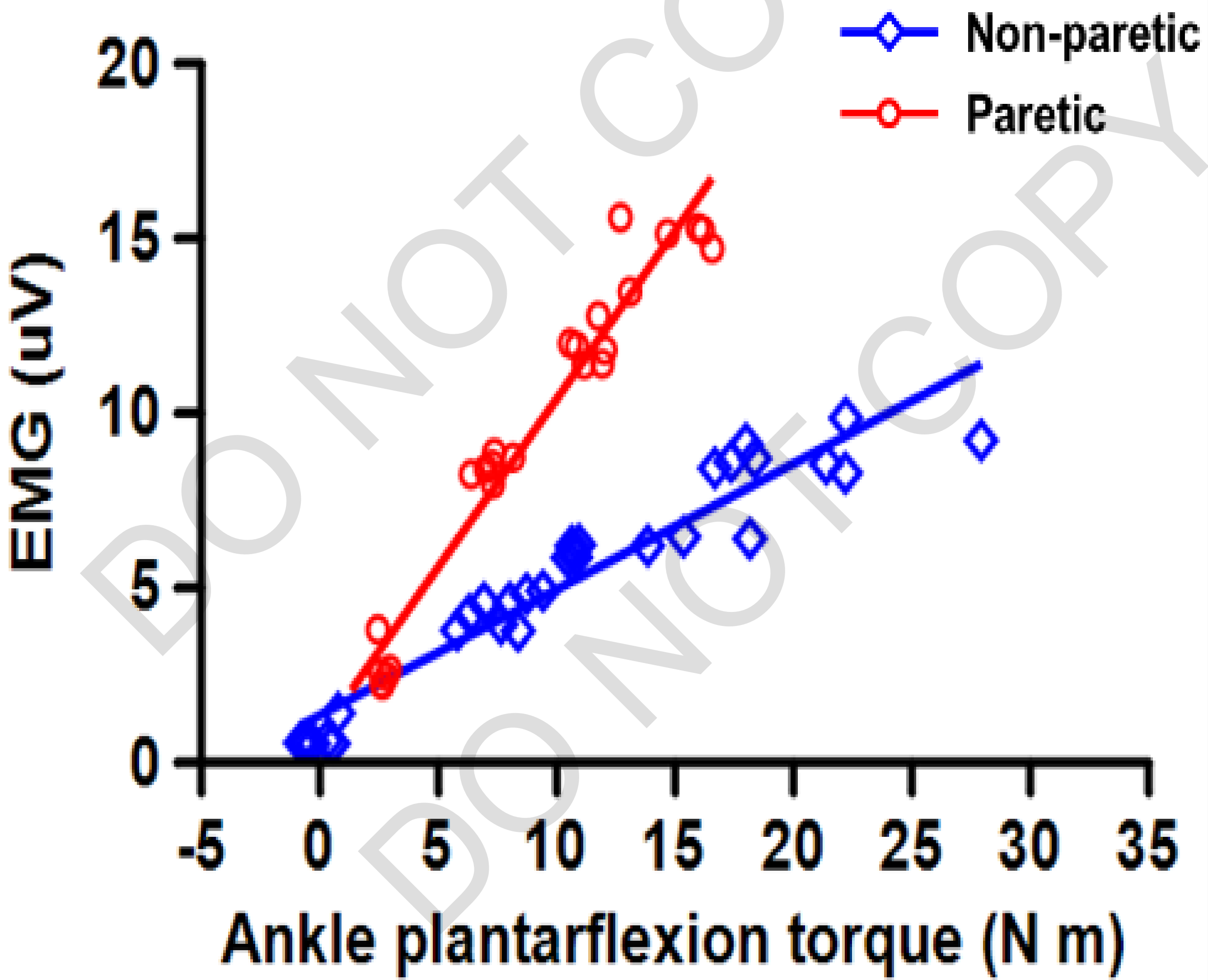
KEY POINTS

1. Muscle contractions are routinely weaker in stroke survivors.
2. Muscle contractions are often inefficient in stroke survivors.
3. This inefficiency sometimes results from steep reductions in motor unit firing rate, but that is not the most common source.
3. **Instead, we now believe that in chronic stroke, muscle fiber/fascicle function can be intrinsically inefficient.**
4. One key mechanism, applicable in pennate muscles may be linked to changes in muscle architecture, or geometry.
5. Example is in the **"GEAR RATIO",** sometimes called anatomical gear ratio, or AGR, which is the ratio of fascicle shortening velocity to the muscle shortening velocity.

EMG-TORQUE RELATIONS FOR PARETIC AND NON-PARETIC MEDIAL GASTROCNEMIUS MUSCLES: ILLUSTRATION OF INEFFICIENT MUSCLE CONTRACTIONS



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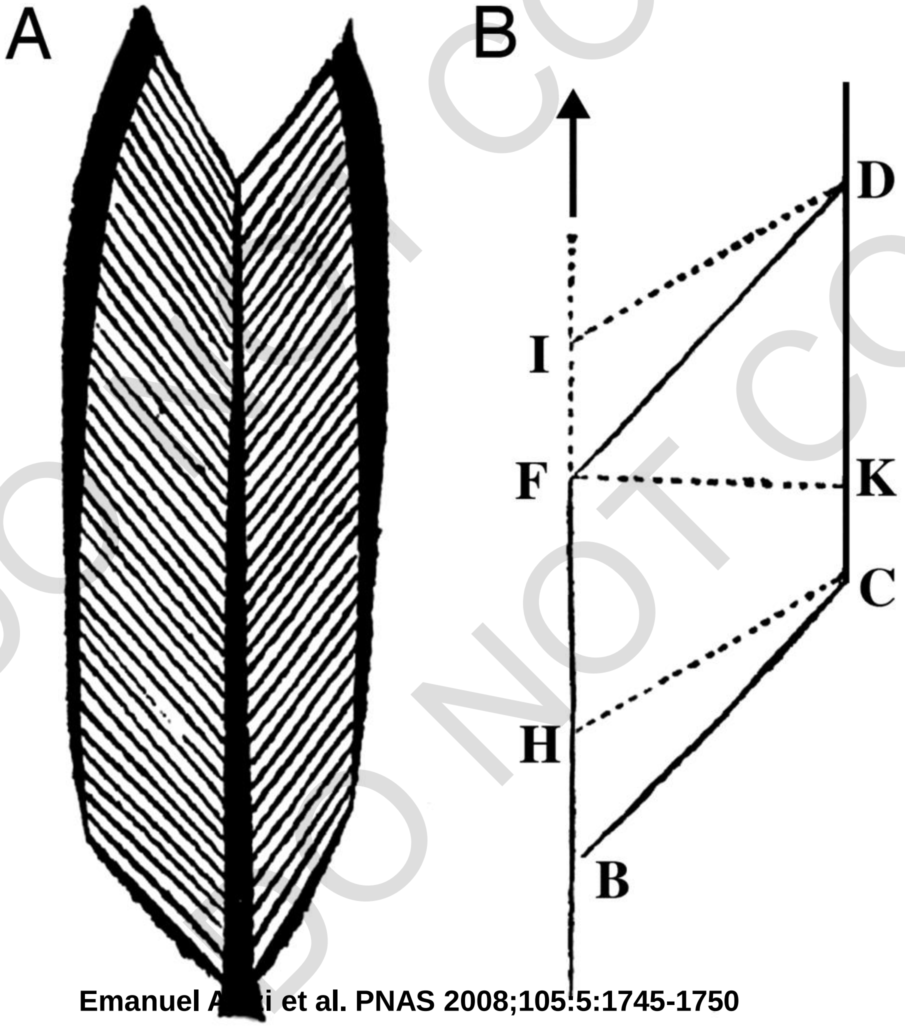
A 17th century geometric examination of muscle architecture



Emanuel A[illegible]i et al. PNAS 2008;105:5:1745-1750

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Architectural Gear Ratio or **Anatomical Gear Ratio** (AGR)

Architectural gear ratio, also called **anatomical gear ratio** (AGR) is a feature of pennate muscle defined by the ratio between the longitudinal strain of the muscle and muscle fiber strain.

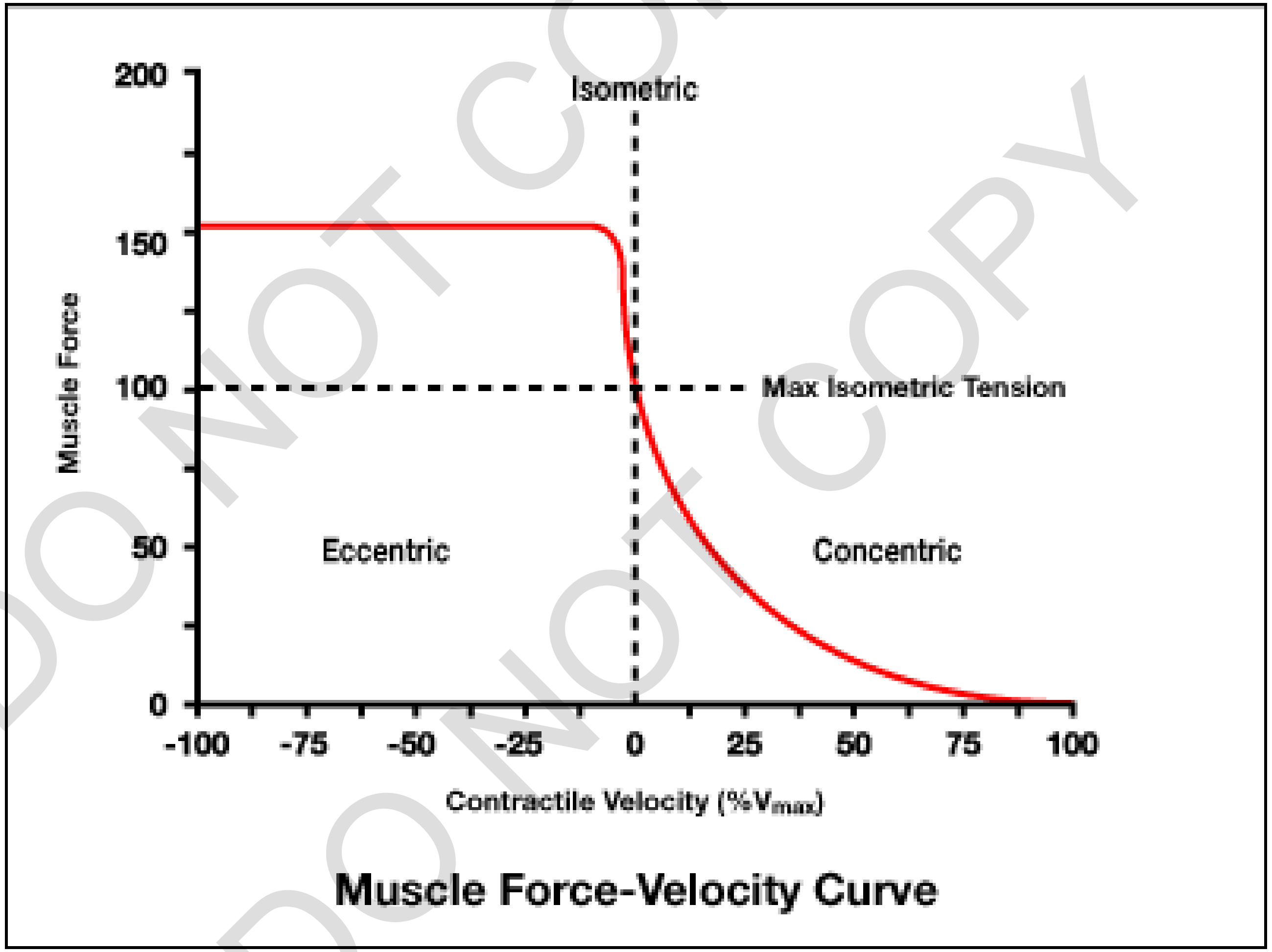
It is sometimes also defined as the ratio between muscle-shortening velocity and fiber-shortening velocity.

$$AGR = \varepsilon_x / \varepsilon_f$$

where ε_x = longitudinal strain (or muscle-shortening velocity) and ε_f is fiber strain (or fiber-shortening velocity)

In fusiform muscle, the fibers are longitudinal, so longitudinal strain is equal to fiber strain, and AGR is always 1.

THE FORCE-VELOCITY RELATION IS KEY



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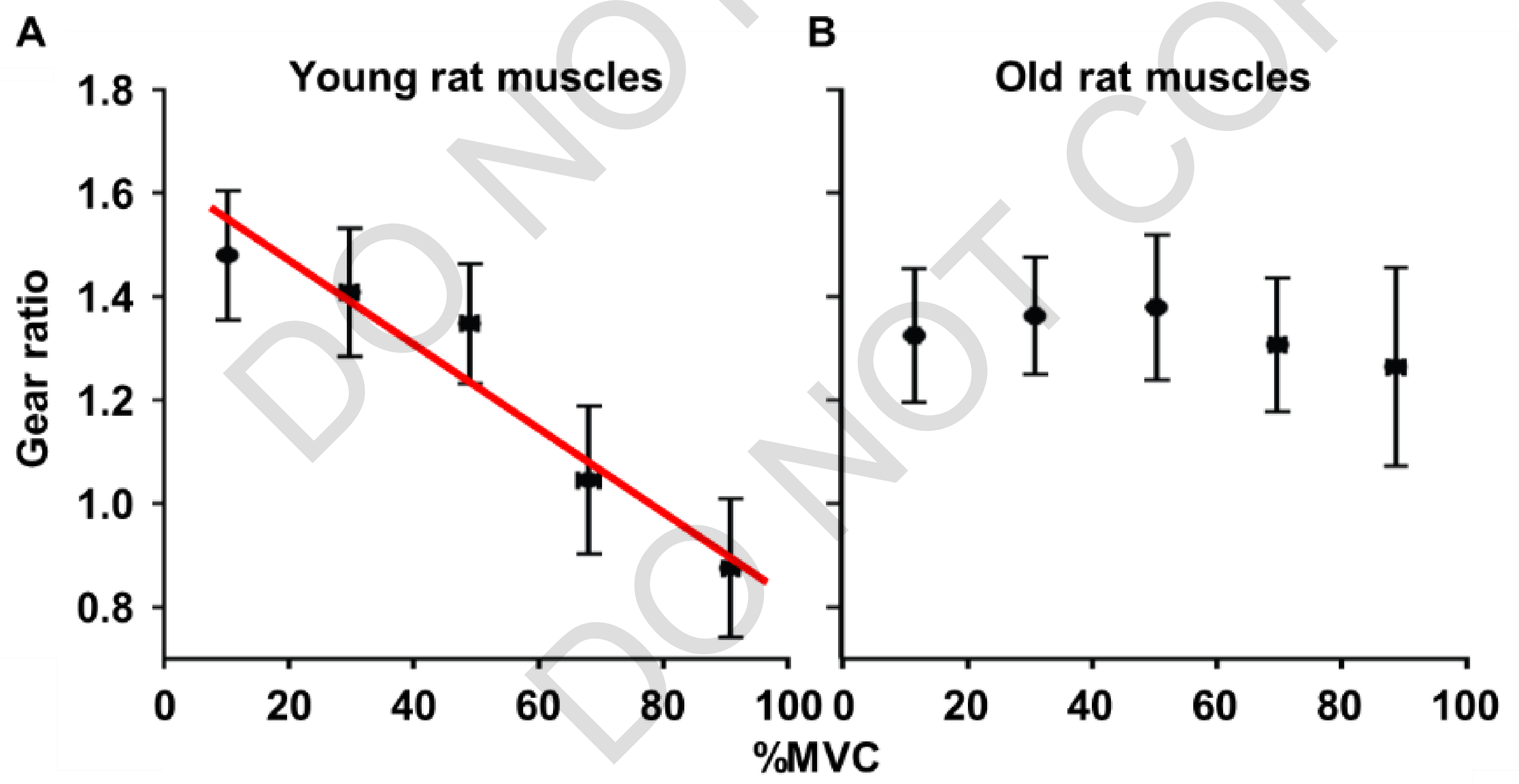
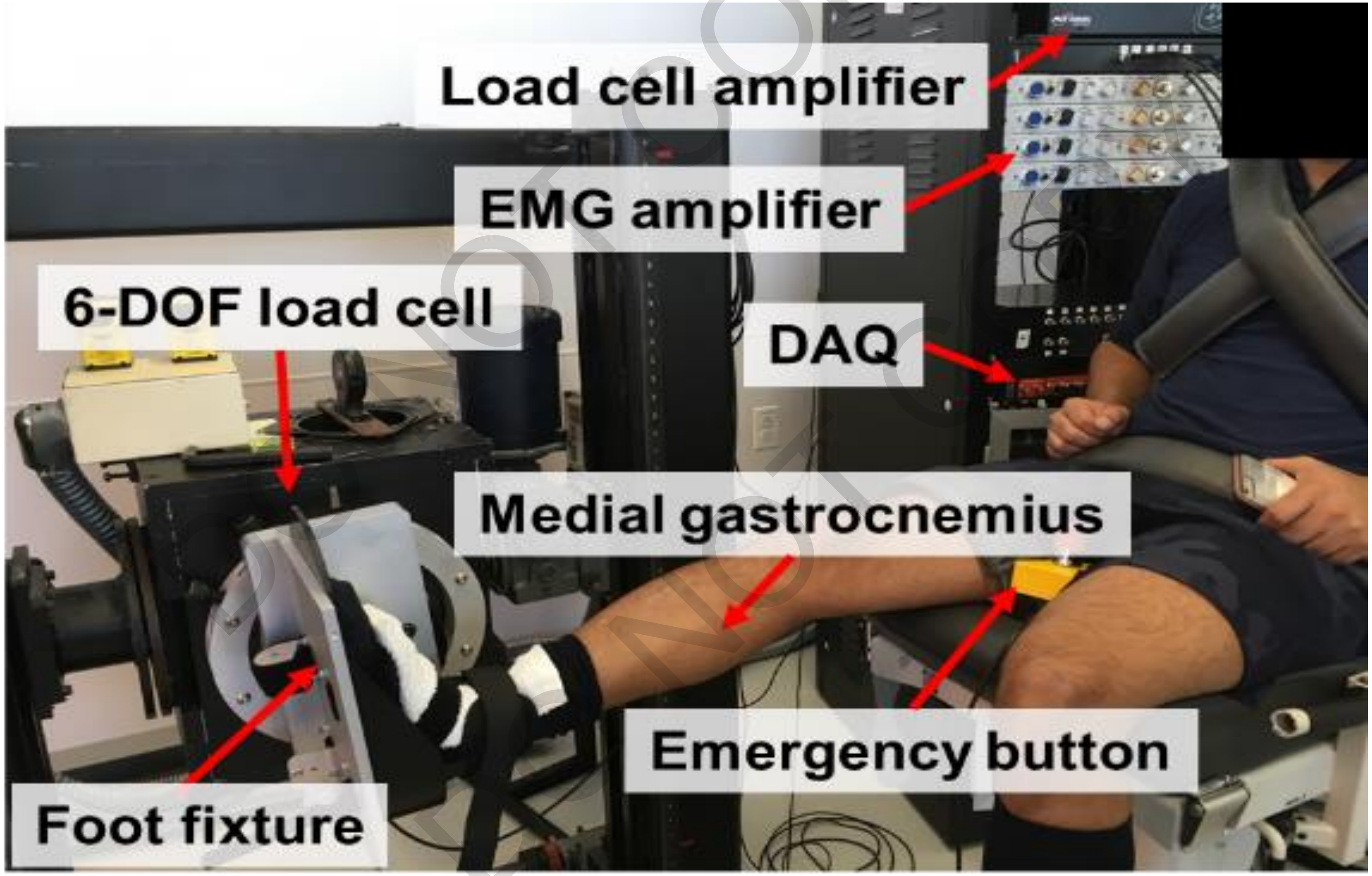
GEAR RATIO VALUES IN YOUNG AND OLD RAT MUSCLES

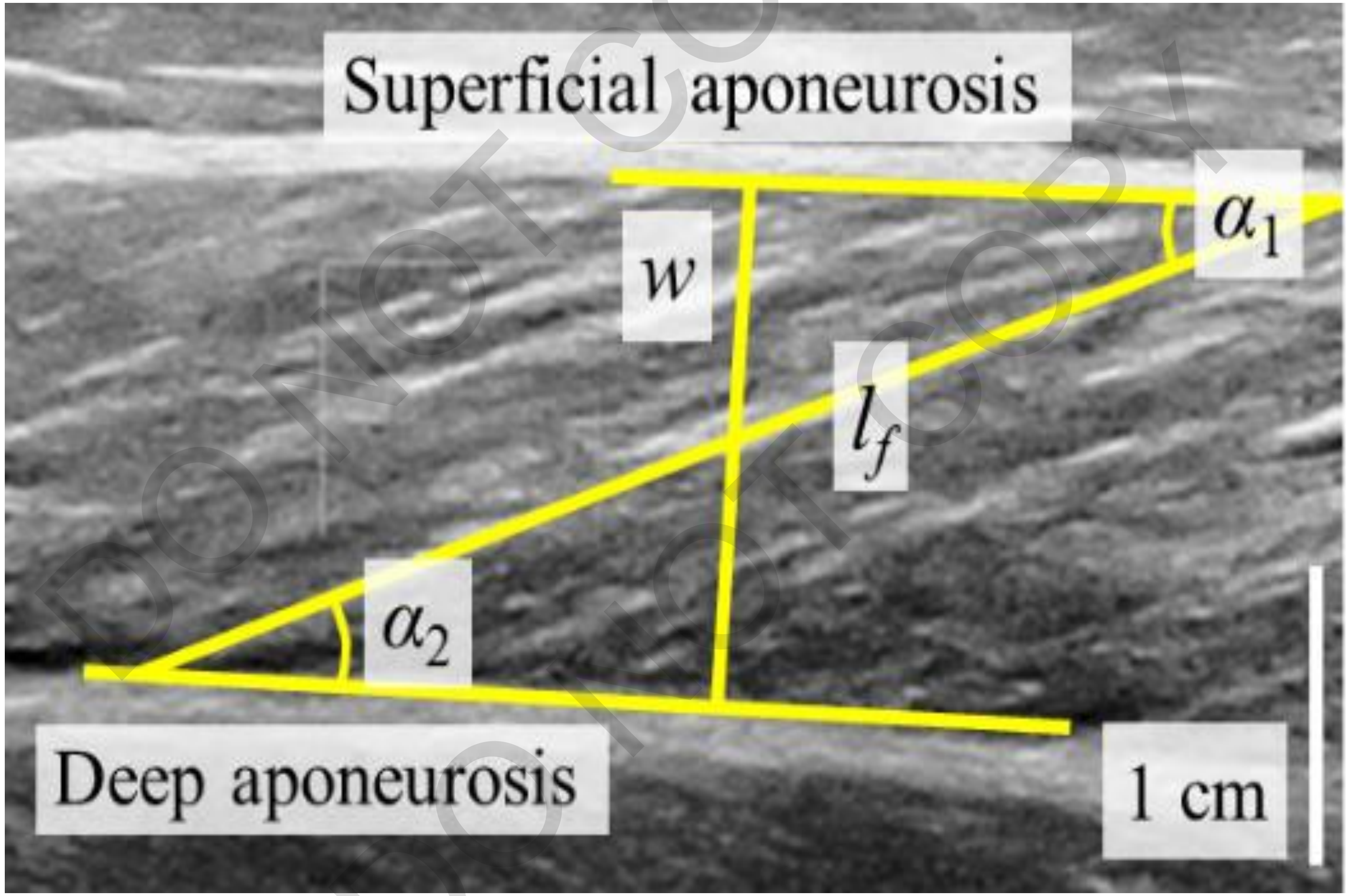
Relationship between gear ratio and muscle force presented as %MVC in young (A) and old (B) rat muscles. Note that there is a clear negative relationship in young (red line), but not in old. The ability to vary gear ratio (i.e., the slope for the relationship between gear ratio and %MVC) could potentially be used characterize muscle functions in response to different force demands. Adopted from [14].



EXPERIMENTAL SET UP



FASCICLE MEASUREMENTS USING B MODE ULTRASOUND

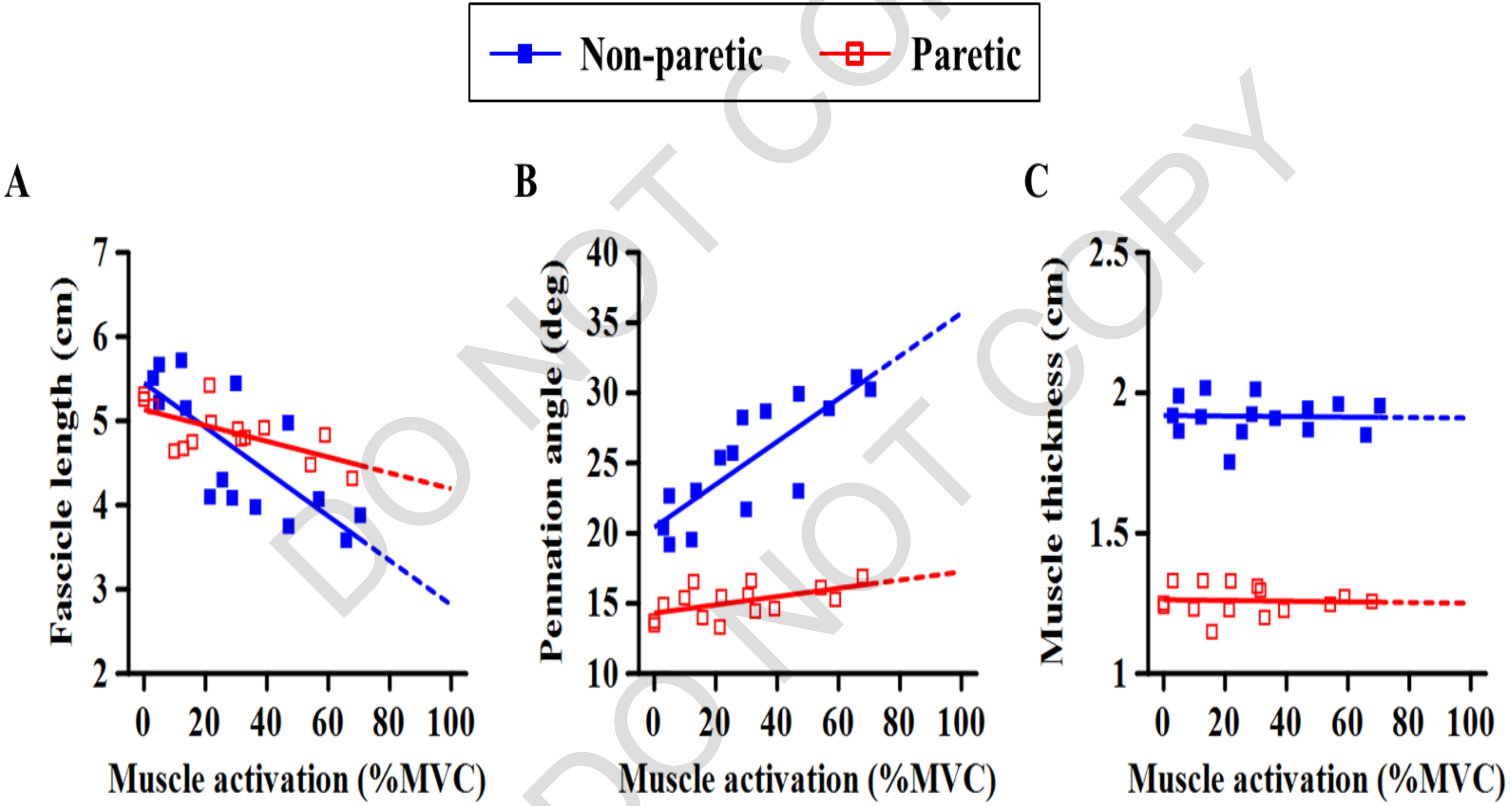


FASCICLE LENGTH AND PENNATION ANGLES IN STROKE

Table: Muscle architecture in rest condition.

Muscle architecture	Non-paretic	Paretic	Percent decrease (%)
Fascicle length (mm)	51.5 ± 5.7 (41.9–57.8)	48.8 ± 6.1* (37.2–56.3)	5.5 ± 3.9 (0.5–11.1)
Pennation angle (°)	19.3 ± 2.4 (15.2–23.2)	16.8 ± 3.2* (12.6–22.0)	12.6 ± 14.5 (-1.1–35.8)
Muscle thickness (mm)	16.9 ± 2.2 (13.8–19.2)	13.8 ± 2.4* (10.8–18.0)	17.5 ± 14.2 (3.2–40.1)

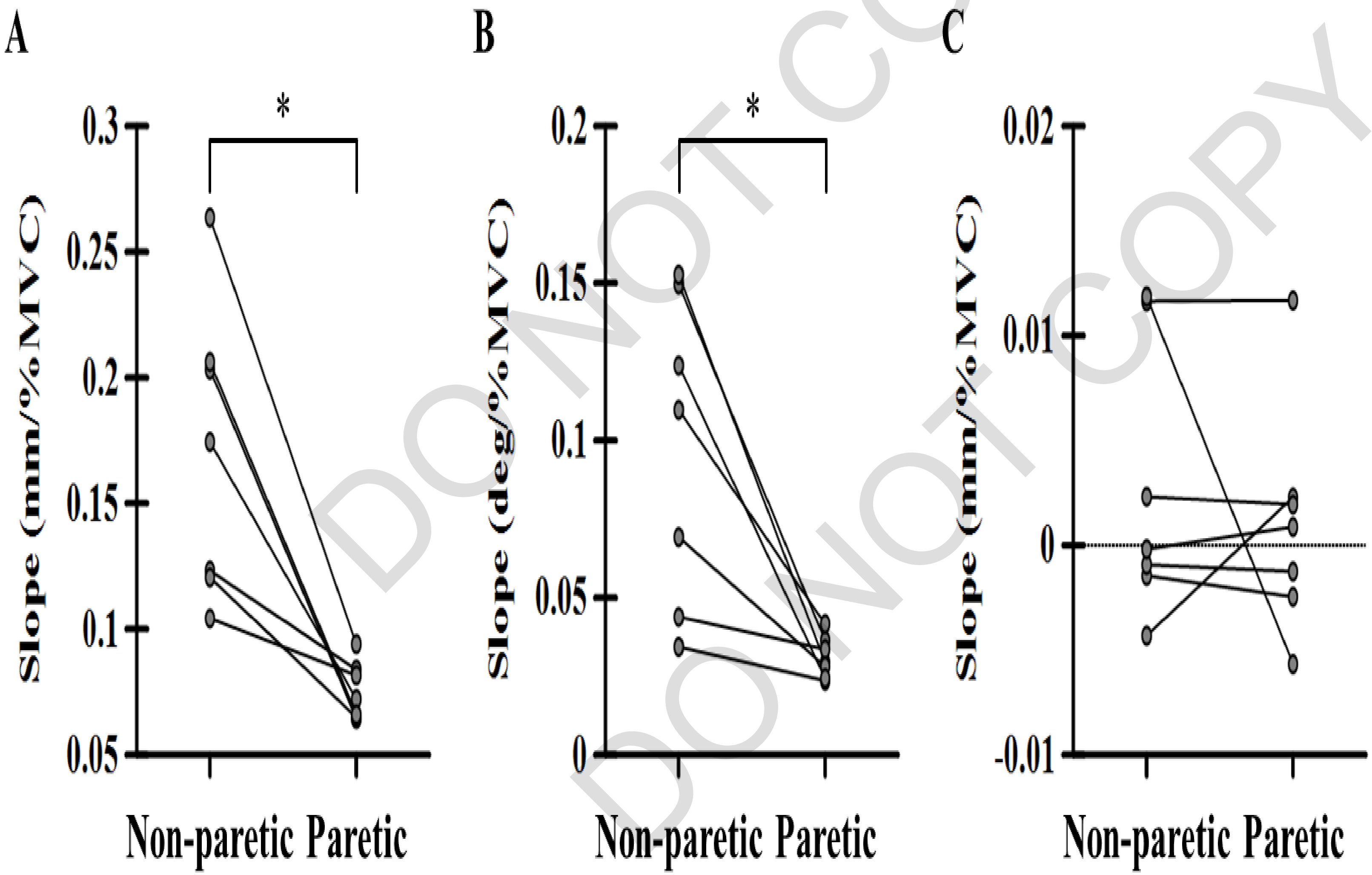
ULTRASOUND PARAMETERS ESTIMATED AT DIFFERENT FORCES



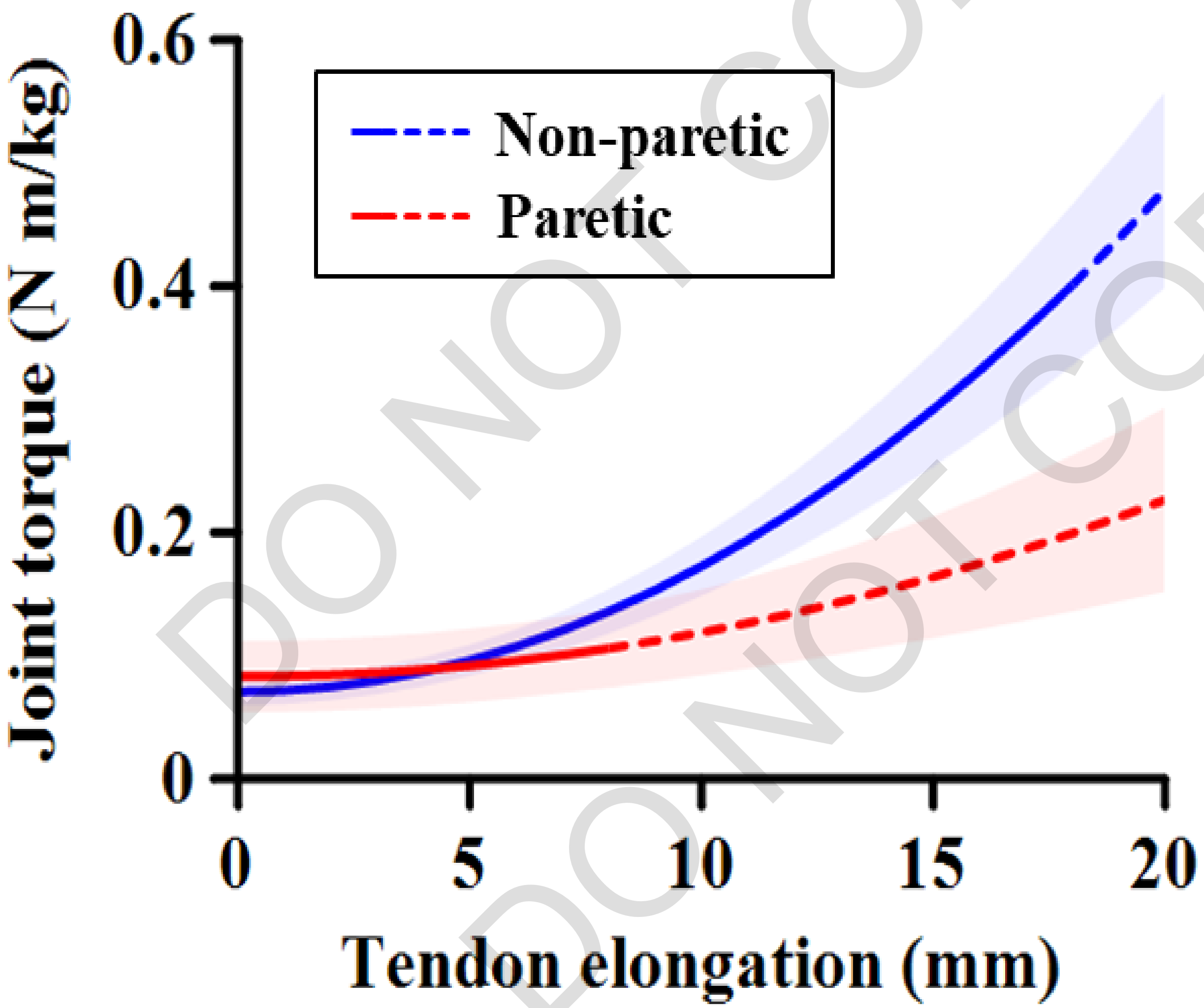
fascicle shortening

fascicle rotation

muscle thickness



DIFFERENCES IN TENDON STIFFNESS IN PARETIC VS CONTRALATERAL MUSCLES



SUMMARY

1. **Anatomical Gear Ratio changes much less with increasing force in stroke-impaired muscle**
2. **Muscle fascicles and fibers show smaller pennation angles and therefore maintain higher shortening velocities, potentially reducing force production**

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