

Effects of Exercise During Growth on Bone Strength and Morphology

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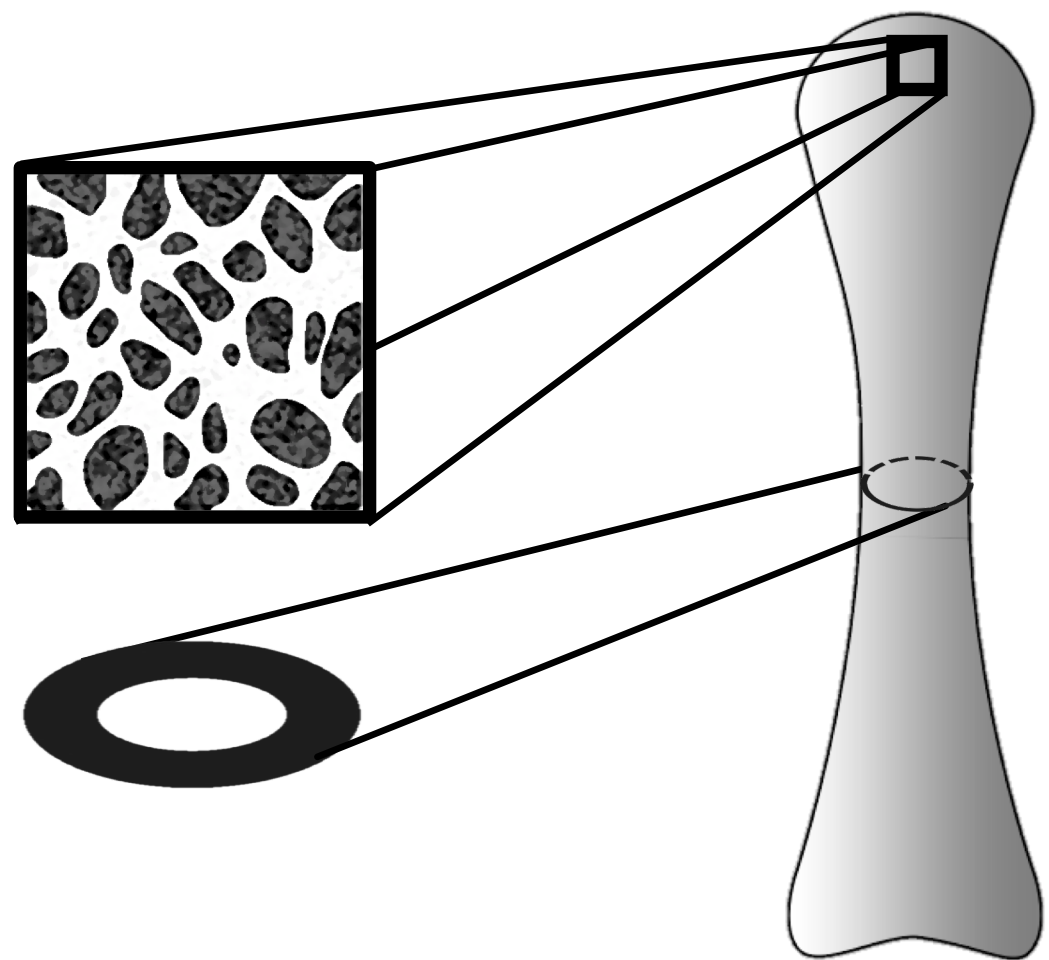
Can inactivity alter long-term skeletal health?

- Amount of physical activity in children is in decline over the past 30+ years [1].
- How growth-period inactivity alters adult musculoskeletal phenotype, and its impact on adult locomotion is not well studied.

What we know – Loading during Growth

Well-Established

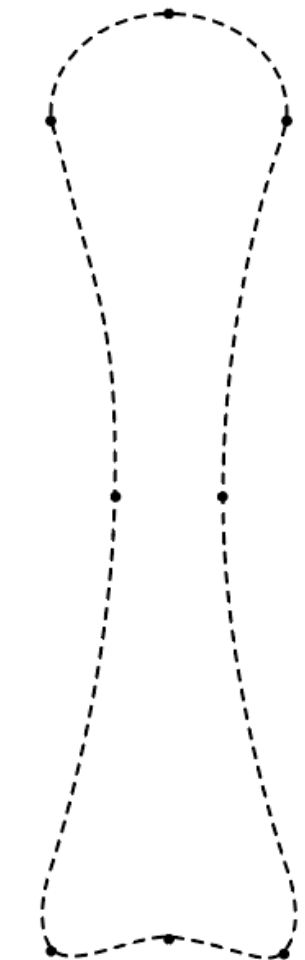
Strength



- Thicker and denser trabecular structure
- Increased cross-sectional area
- Increased strength & rigidity in both bending & torsion

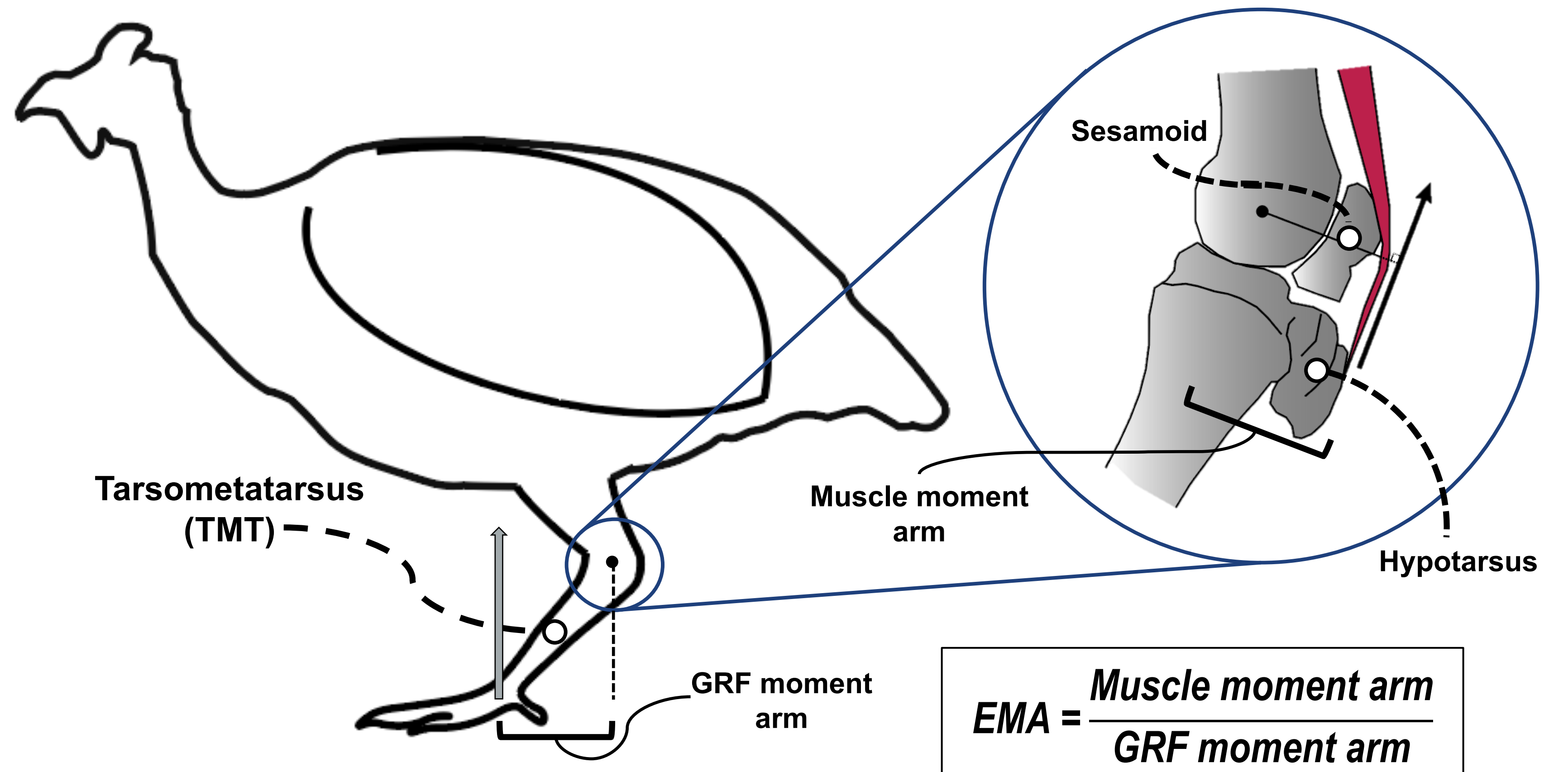
Less Explored

Morphology



- Few studies have explored morphological changes in response to load
- Scapular shape and femoral head curvature [2,3] affected, but not articular surface area [4]

Morphology influences joint structure & locomotor function



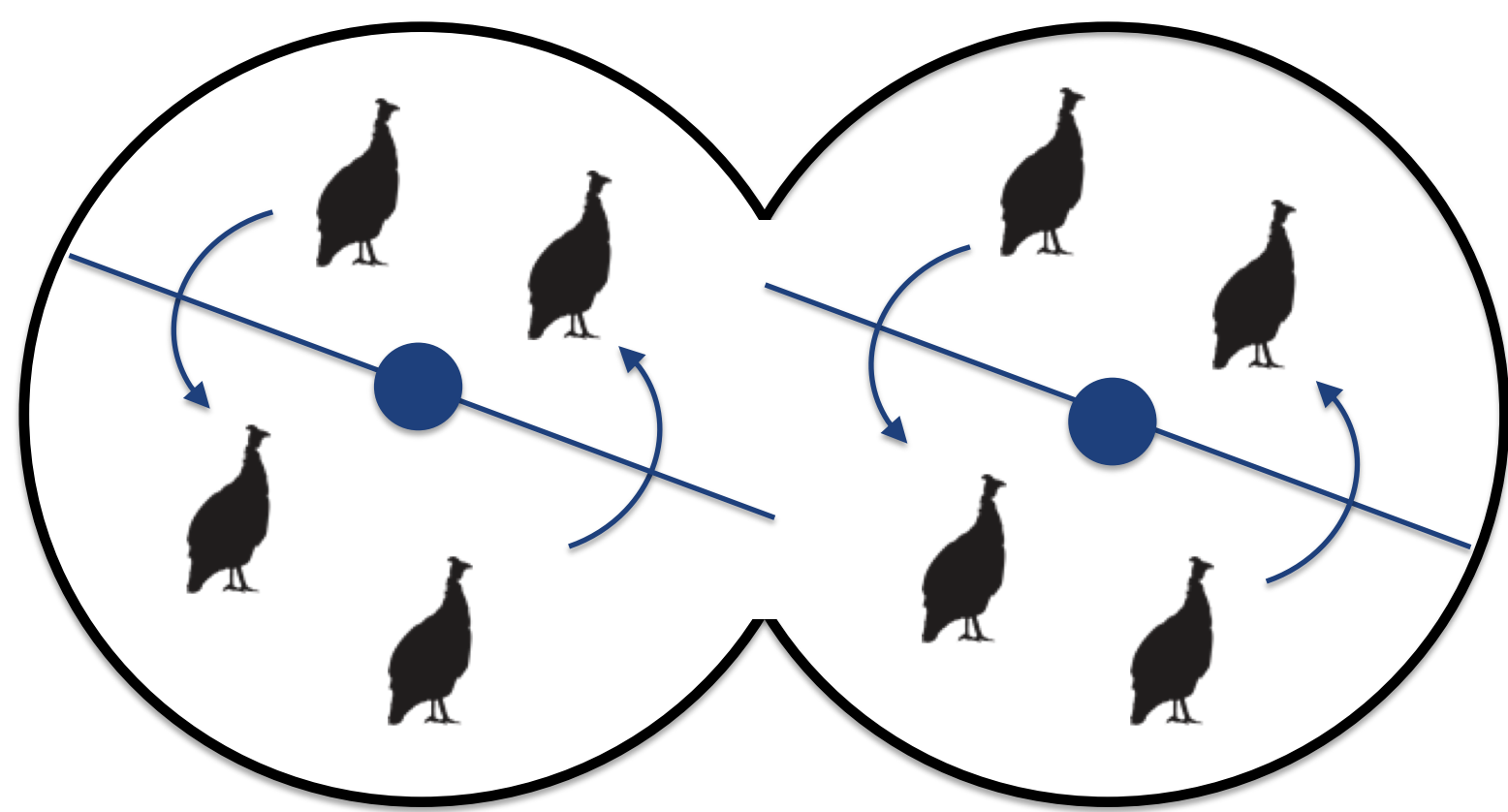
- Bony projections acting as points of attachment determines muscle moment arm [5]
- Limb segment length influences moment arm of GRF
- Effective mechanical advantage (EMA) is ratio muscle-to-GRF moment arms

Experimental Protocol

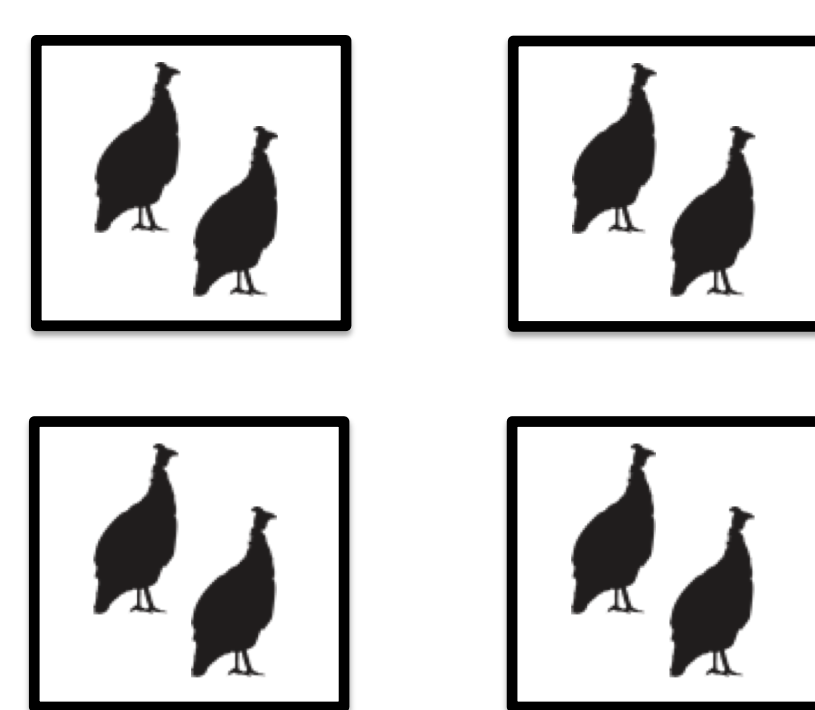
4 weeks – 14 weeks
(90% skeletal maturity)

Exercise
(EXE)
n = 15

Sedentary
(SED)
n = 15

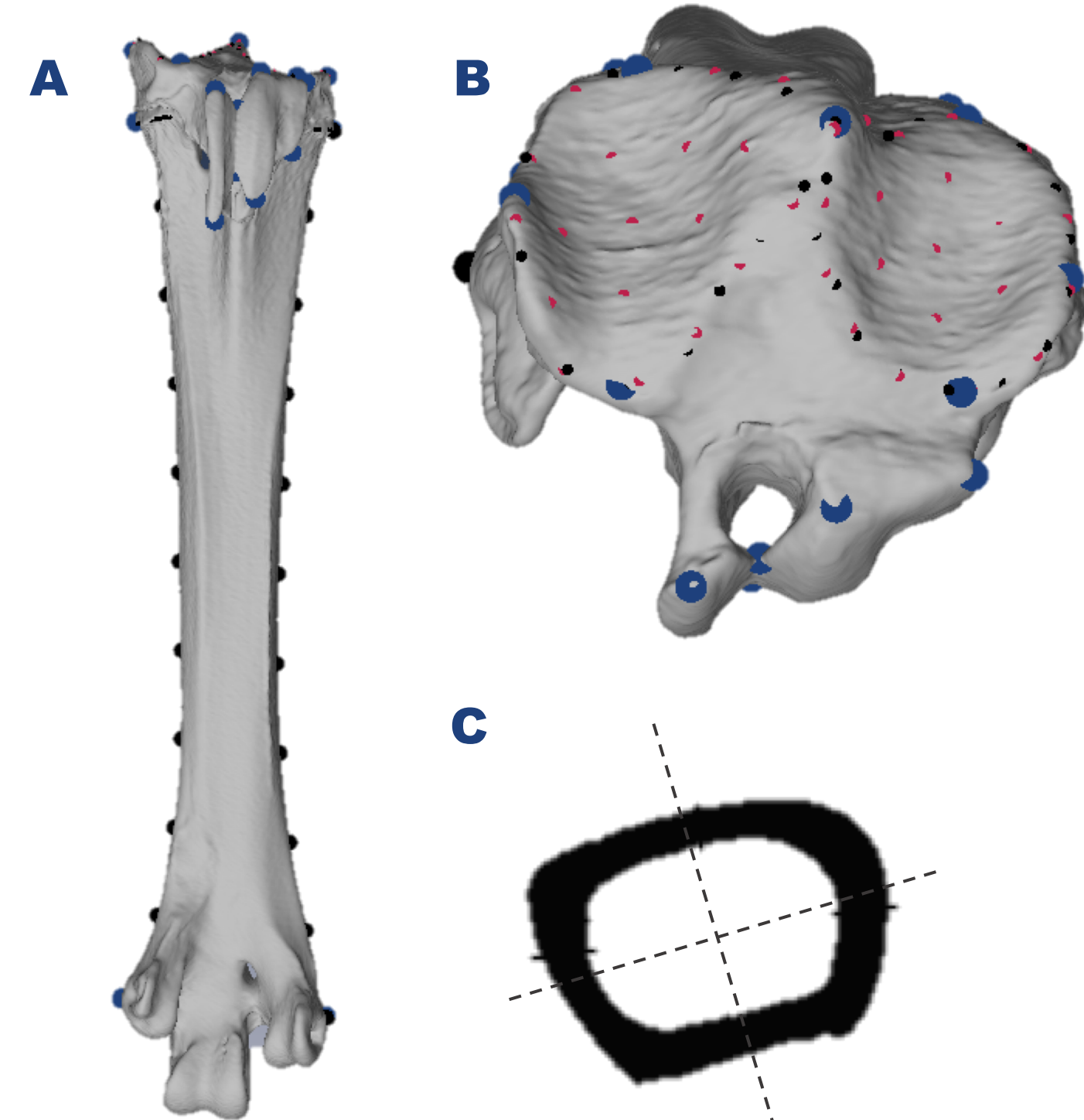


- Large, free-range pens
- Rotating motivator to induce daily movement
- Running training (4x/wk for 30 min.)

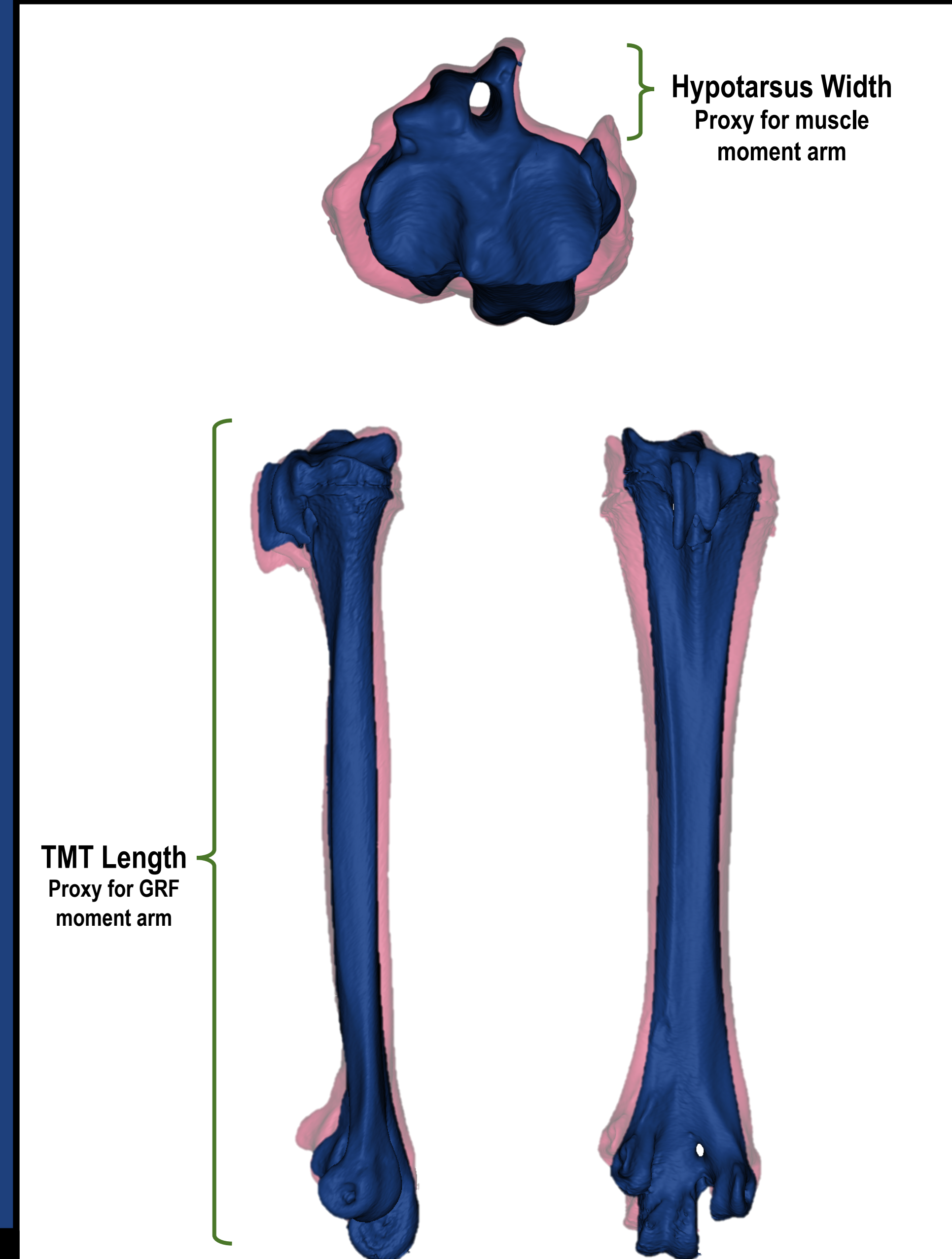


- Small pens to restrict movement
- No training

microCT scans used to assess shape and strength differences

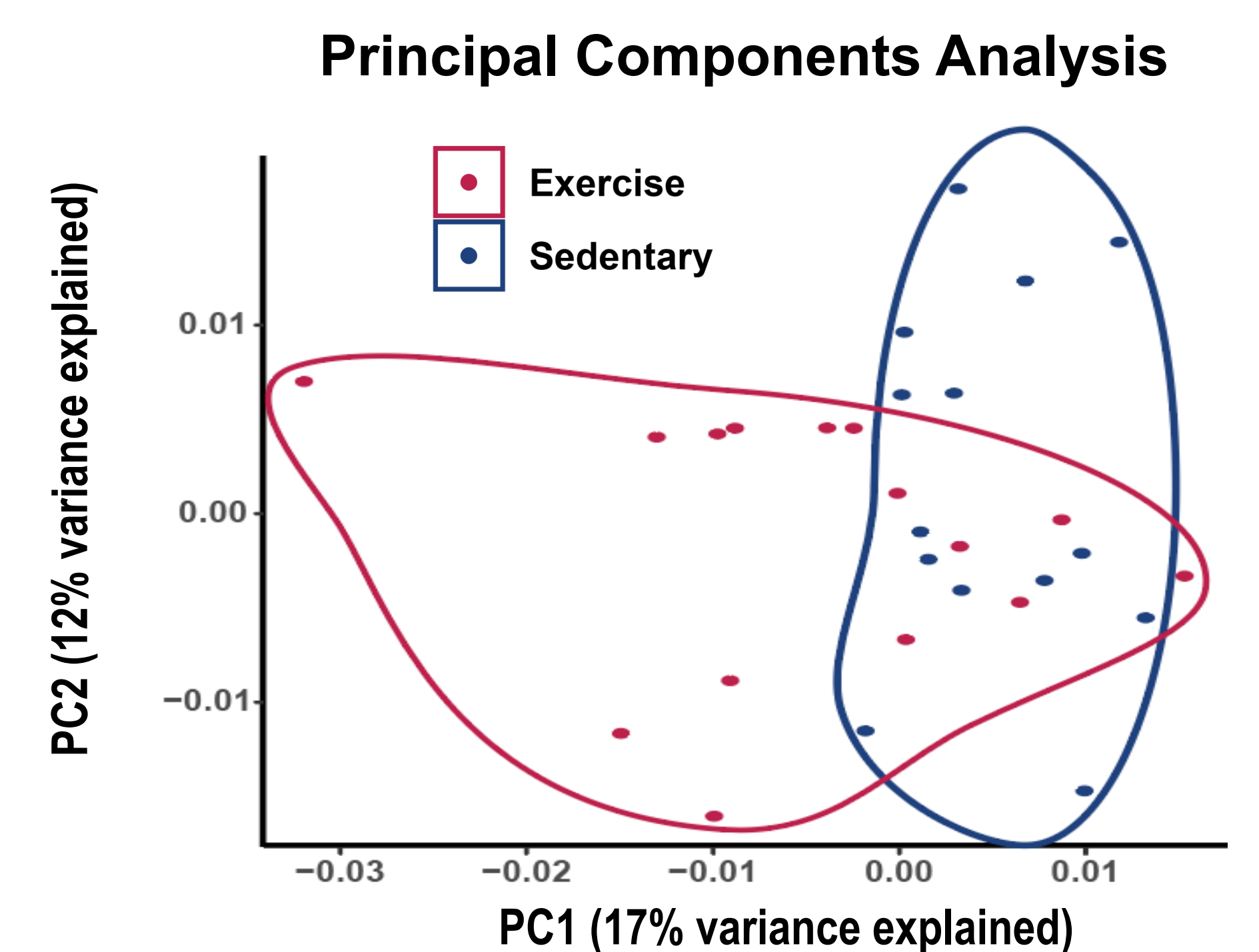
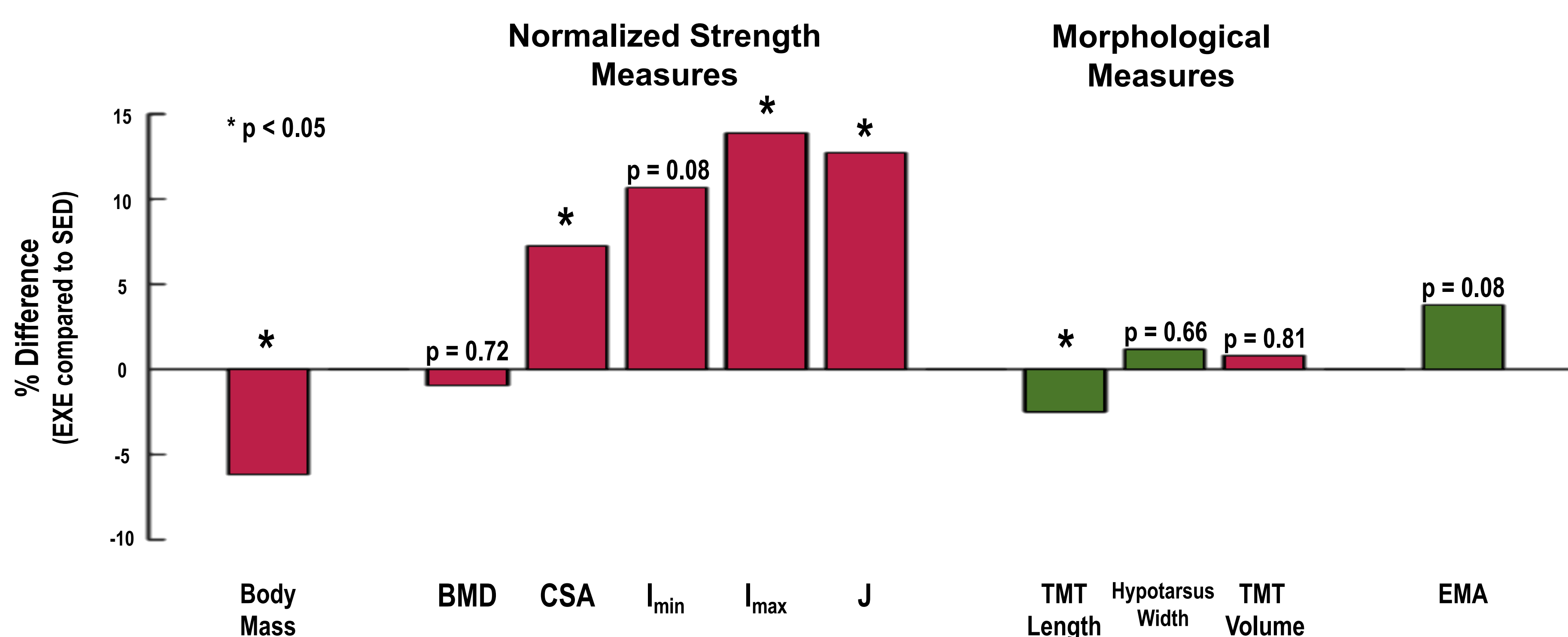


Examples of landmarks used for geometric morphometrics on microCT scans from the posterior (A) and superior (B) views. (C) Example of TMT cross-section from ImageJ.



EXE (red) and SED (blue) TMT comparison. Bone of an average specimen across all animals was warped to PC1 min and max, respectively. Warping was exaggerated in both directions to aid in visualization. Hypotarsus width used as proxy for muscle moment arm and TMT length * cos(48) [6] used as proxy for GRF moment arm in EMA calculation.

Exercise during growth influences relative bone strength and morphology, and may increase mechanical advantage of ankle extensor muscles



References

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Conclusion

- Bone strength and morphology reflect loading history during growth
- Differences in morphology may result in changes in functional capacity
- Larger EMA in EXE suggests greater force capacity but also faster shortening velocity, though longer plantarflexor fiber lengths [7] may help preserve shortening velocity.
- Shorter TMT in EXE indicates lower moment of inertia, and thus may facilitate lower energy requirements in rapid and frequent leg swing.