Postnatal Development of the Goat Phalanges and Metacarpal Trabecular Architecture

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Introduction: Trabecular Bone Development

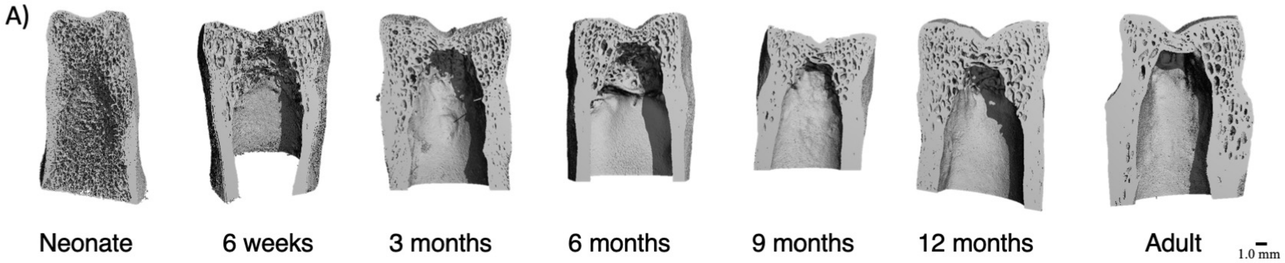
- Trabecular bone (TB) is the main load-bearing bone and calculating 3D trabecular microstructural indices improves accuracy of mechanical properties assessment [1].
- Goats were used as models in previous bone development studies [2]. Their morphology allows us to easily overload one phalanx and underload the other.

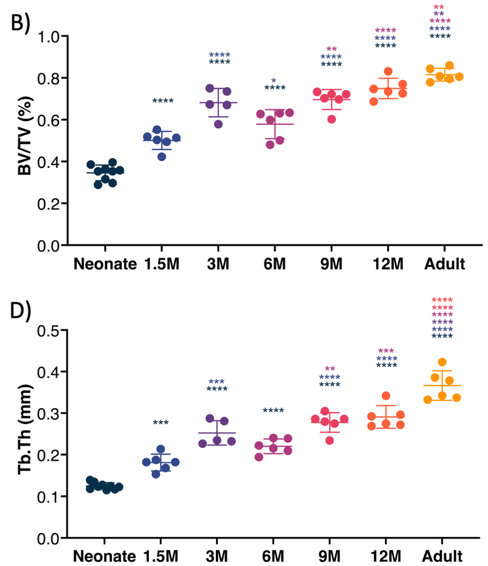
Objective: Investigate the change in trabecular microarchitecture in goat distal phalanges (P1) and metacarpi (MC) through postnatal development to encourage future research on the underlying mechanobiology and effects of mechanical cues on bone development.

Methods:

- **Sample preparation:** bone samples from 44 goats at ages 3 days (neonate, n=9), 1.5 months (1.5M, n=6), 3 months (3M, n=5), 6 months (6M, n=6), 9 months (9M, n=6), 12 months (12M, n=6), and 3.5 years (adult, n=6) were wrapped in gauze and submerged in PBS.
- **Microcomputed tomography (MicroCT):** bones from 44 goats were imaged with X-ray intensity of 145 μA, energy of 55 kVp, integration time of 400 ms, and resolution of 10.4 μm.
- **Statistical analysis:** one-way analysis of variance (ANOVA) with a Tukey's post-hoc test (α = 0.05) was conducted to identify significant differences between groups.

Results: P1 bones continually develop new trabecular structures through 12M





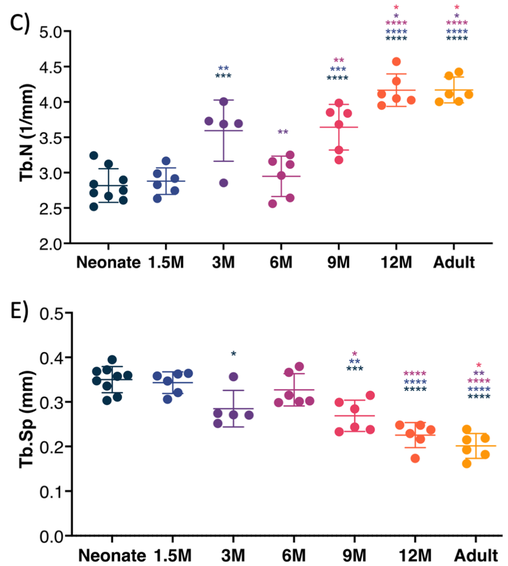
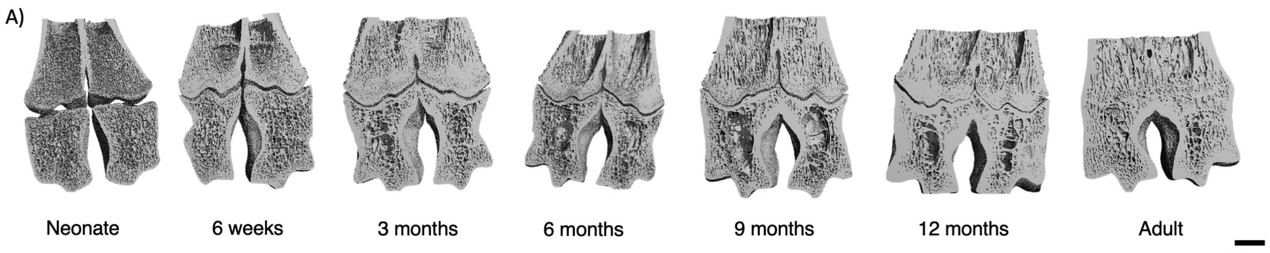
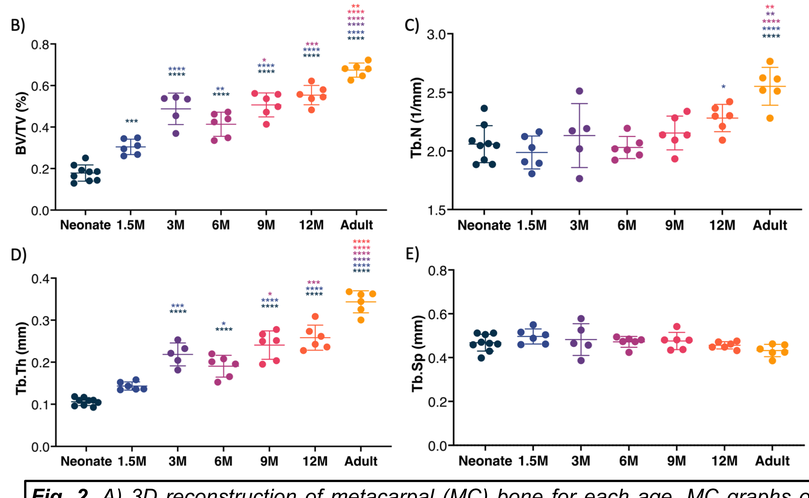


Fig. 1. *A) 3D reconstruction of phalanges 1 (P1) bone for each age. P1 graphs of B) bone volume fraction (BV/TV) C) trabecular number (Tb.N), D) trabecular thickness (Tb.Th), and E) trabecular separation (Tb.Sp). * indicates significant differences between group and group with corresponding star color.*

Results: Existing trabecular structures thicken during MC postnatal development





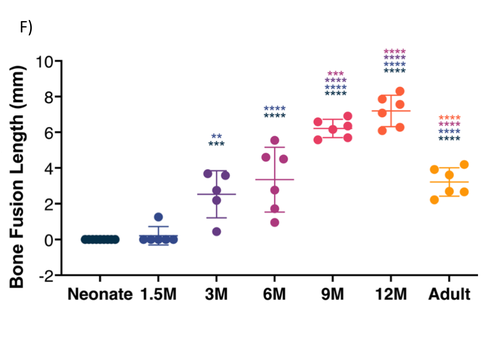


Fig. 2. *A) 3D reconstruction of metacarpal (MC) bone for each age. MC graphs of B) bone volume fraction (BV/TV) C) trabecular number (Tb.N), D) trabecular thickness (Tb.Th), E) trabecular separation (Tb.Sp), and F) epiphyseal bone fusion. * indicates significant differences between group and group with corresponding star color.*

Discussion and Conclusion

- **Morphometric indices:** more rapid increase in P1 with roughly all parameters significantly changing at all ages. However, changes in MC bone indices were overall less significant, specifically for Tb.N and Tb.Sp. This suggests that P1 growth is dynamic with major alterations, while MC growth is characterized by reinforcement of existing trabecular networks rather than forming new one.
- **Epiphyseal Fusion:** fusion length increases from 3M to 12M. Between 12M and 3.5Y, growth plates close and the epiphyseal region undergoes remodeling. This fusion event makes the MC a useful model for research on bone fusion disorders, such as craniosynostosis [3] and spondylocostal dysplasia [4].

These findings indicate that caprine P1 and MC bones are promising models for studying long bone development and trabecular development, respectively, under experimentally altered loading conditions.
These new models can be used to further understand bone growth mechanobiology and explore regenerative therapies for bone disorders.

References

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