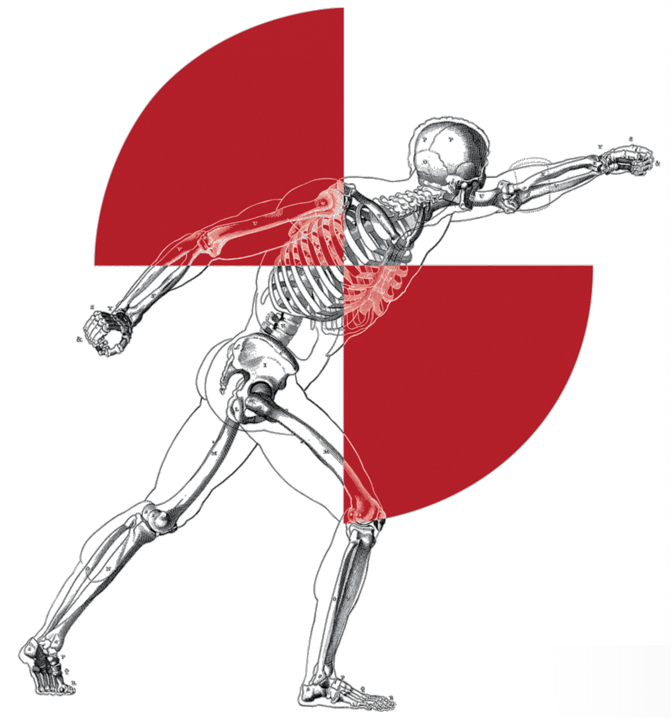

Variability in Fracture Force and Cross-sectional Geometry between Male and Female Tibiae in Lateral Impacts

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INTRODUCTION

- In 2017, an estimated 137,000 pedestrians were treated in emergency departments in the United States for injuries related to motor vehicle crashes[1–2]. The most frequently injured region in a pedestrian versus vehicle crash is the lower extremity, with tibia fractures being the most common[3].
- As the trend of pedestrians involved in motor vehicle crashes increases, the need for understanding fracture risk factors increases as well. **Therefore, the objective of the study was to identify the relationships between fracture force and cortical bone cross-sectional geometric parameters of dynamically impacted tibiae in males and females.**

MATERIALS and METHODS

- Ten tibiae from adult males (avg. 89 yrs) and females (avg. 70 yrs) were included in this study
- Prior to testing, whole bone computed tomography (CT) scans of each tibia were obtained and cortical bone morphometric parameters (Table 2) were calculated from a 6.7mm Volume Of Interest (VOI) at the 50% site (Fig. 1)
- All tibiae were rigidly potted utilizing an anatomically relevant coordinate system[4] at the proximal and distal ends, 80% and 20% sites, respectively, based on the total length of the tibia (Fig. 1)
- Tri-axial rectangular rosettes and uni-axial linear strain gages were attached to the diaphysis on the medial, lateral, and posterior surfaces at the 55% and 45% sites, respectively (Fig. 1)
- All tibiae were impacted in a dynamic 6 m/s lateral-medial 4-point bending scenario utilizing a custom-built material testing system equipped with an adjustable impactor to contact tibiae at the 40% and 60% sites (Fig. 2)

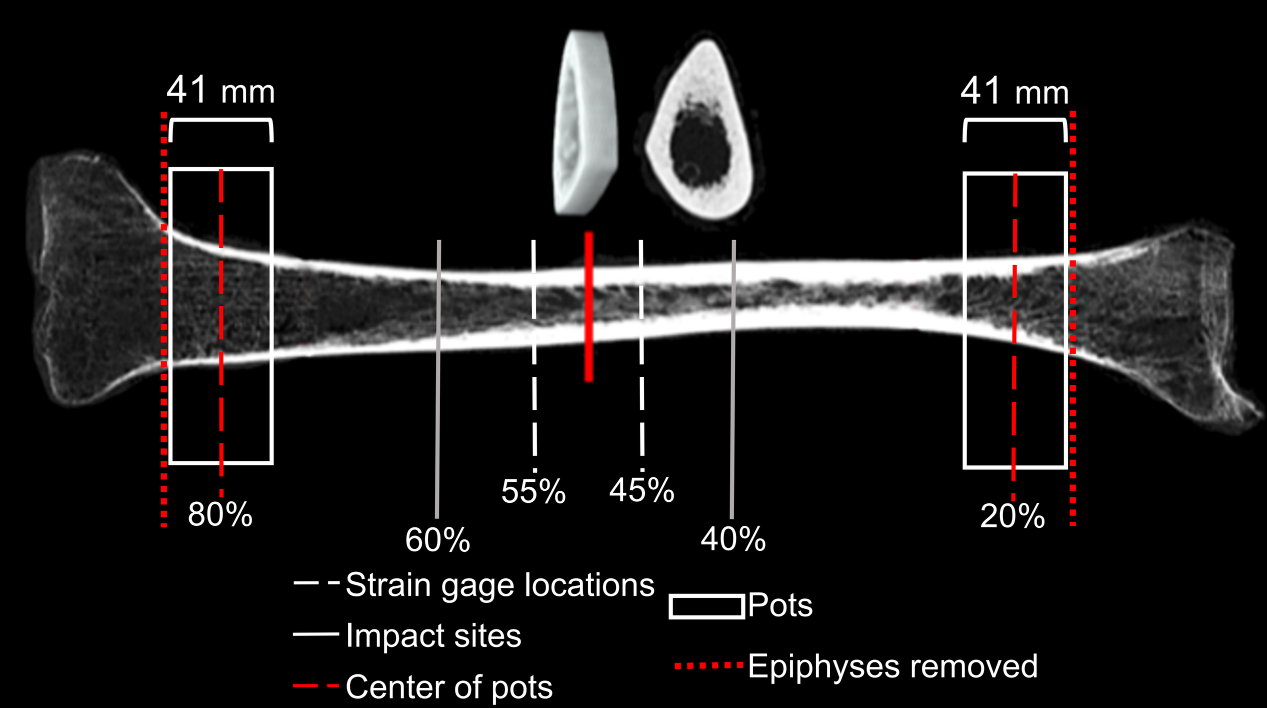

Figure 1. Exemplar CT image with 50% VOI shown by solid red line and inset. Also shown are pot, strain gage, and impact locations in testing position (view is of posterior surface).

Table 2. Cortical Bone Morphometric Variables and Definitions

Variable (abbreviation, units)	Definition
Total Area ($Tt.Ar$, mm^2)	Total area within the periosteal border
Robustness (R, mm)	Tt.Ar/Total Length
Cortical Area ($Ct.Ar$, mm^2)	Area of bone within the periosteal and endosteal borders
Cortical Thickness (Ct.Th, mm)	Linear distance between the periosteal and endosteal border averaged across the cross-section
Area Moment of Inertia (I, mm^4)	Resistance to bending of a cortical bone cross-section about the principle axes
Volumetric Bone Mineral Density (vBMD, mg/cm^3)	Calculation of bone mineral density (BMD) for the entire volume of interest using scan-specific calibration curves

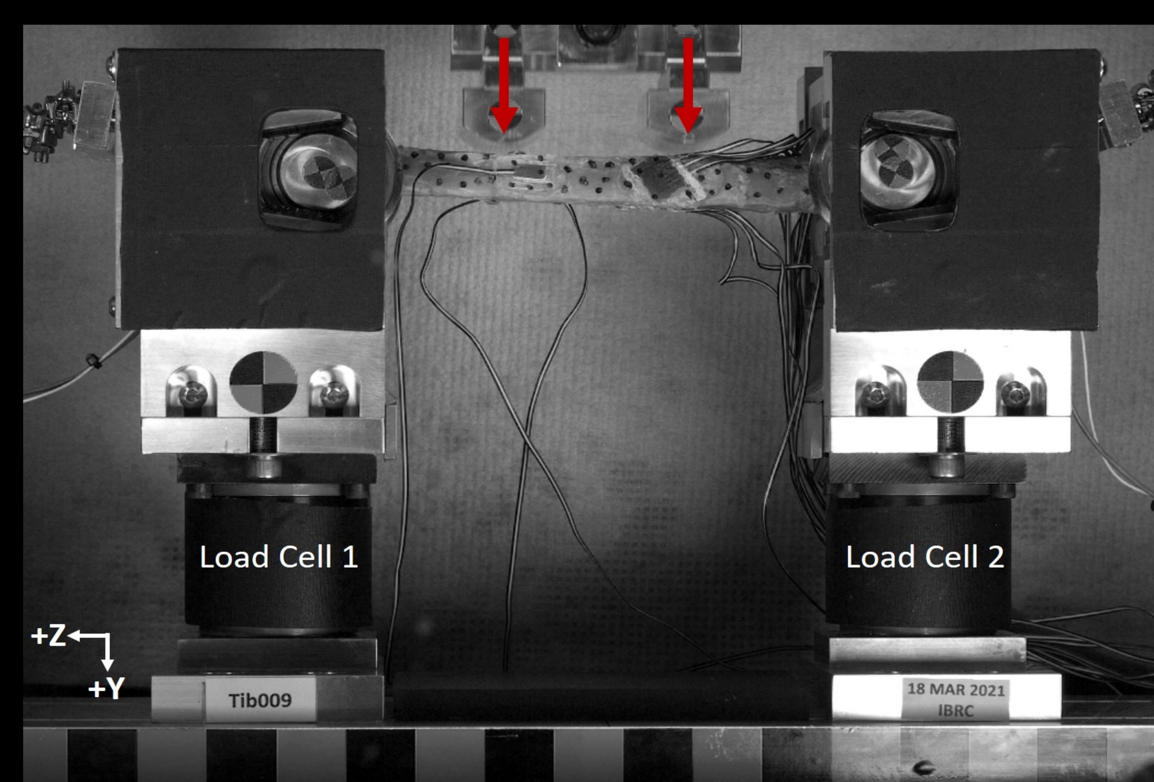

Figure 2. Exemplar of left tibia in testing fixture. Red arrows indicate impact location on lateral surface.

RESULTS and DISCUSSION

- No significant differences in fracture force were identified between female (12.5–21.9 kN, mean 17.1 ± 3.5 kN) and male (12.7–20.2 kN, mean 17.1 ± 2.9 kN) tibiae ($p=0.99$) (Fig. 3)
- Males demonstrated significantly larger cortical bone morphometrics than females ($p<0.049$), except R ($p=0.26$) and vBMD ($p=0.34$) (Fig. 4), which is similar to a previous study (n=128) that demonstrated male tibiae have significantly larger Tt.Ar, Ct.Ar, Ct.Th, I, and R than females at the 50% site[5].
- An unexpected finding was no significant relationships were identified between fracture force and any cortical bone morphometric parameters ($p>0.42$)

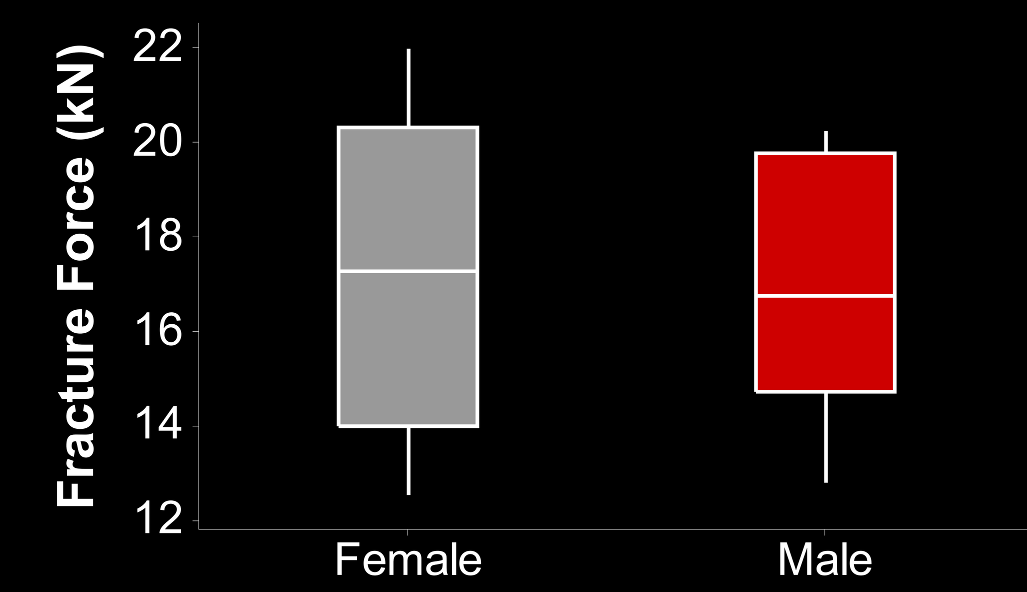

Figure 3. Comparison of fracture force between females and males (p=0.99)

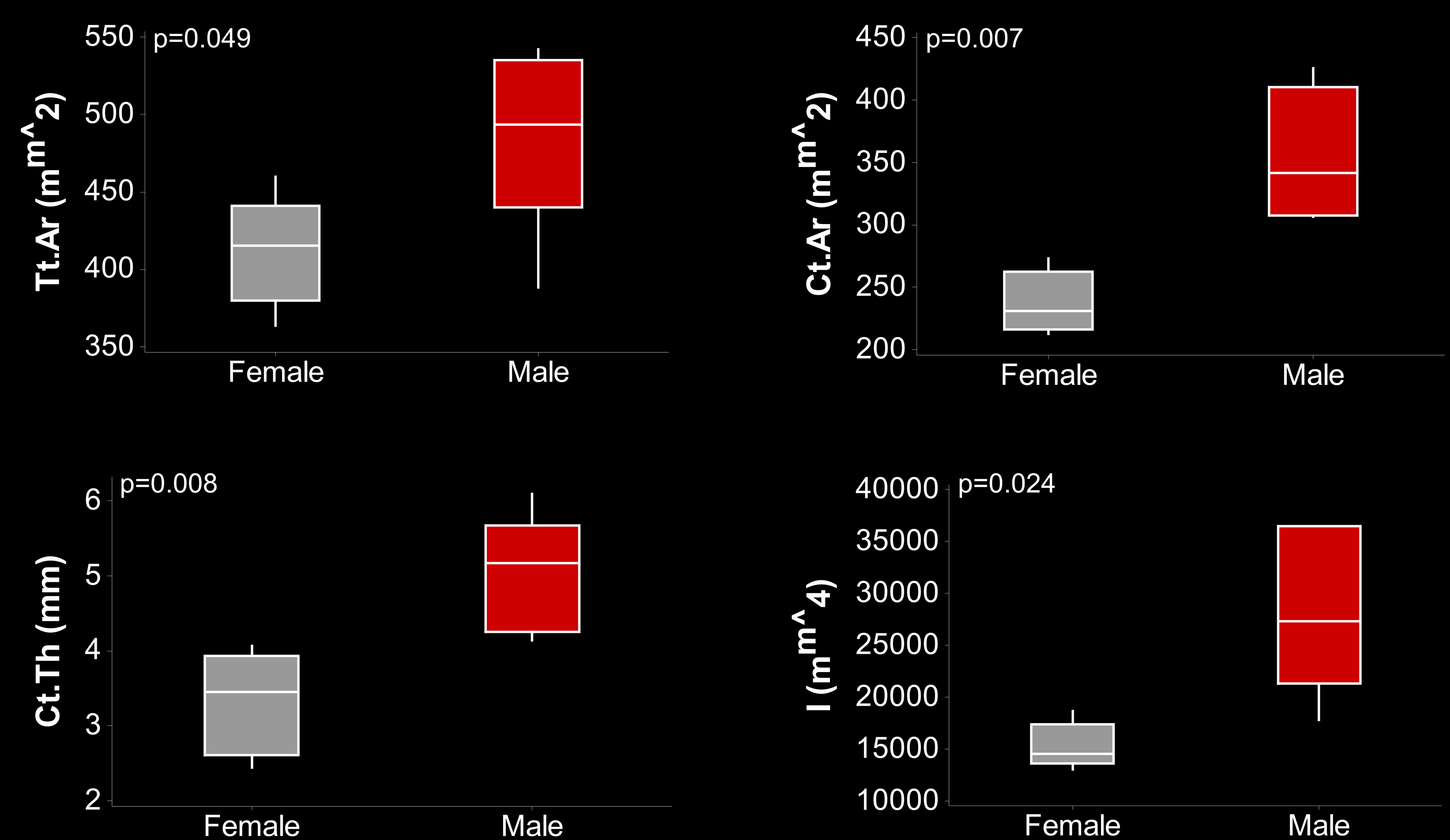

Figure 4. Cortical bone morphometric comparisons between females and males (Tt.Ar [top left], Ct.Ar [top right], Ct.Th [bottom left], I [bottom right])

- While fracture force was not significantly different between sexes, there was a large amount of variation within the samples. In fact, the greatest fracture force was measured for a female tibia (see Fig. 3). Significant differences in Tt.Ar, Ct.Ar, Ct.Th, and I highlight differences in tibia bone size, amount, and distribution between females and males (see Fig.4).
- Absence of sex differences in fracture force and significantly larger values for the majority of cortical bone morphometric parameters demonstrate the importance of utilizing bone specific parameters rather than simply sex for scaling and injury predictions. Future work should investigate all variables in a larger sample in order to validate these relationships.

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