

## Relationships between Age, Sex, and Number and Type of Fractures in Human Tibiae

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### I. INTRODUCTION

The tibia is the most commonly fractured lower extremity bone in pedestrian versus motor vehicle crashes [1]. Specifically, the diaphysis is the most frequently fractured region of the tibia [2]. Previous studies have demonstrated considerable variation in number of fractures, fracture type, and fracture group in experimental 4-point bending of human tibiae [3], revealing a critical need to identify factors contributing to these fracture characteristics. The objective of this study was to examine whether relationships exist between sex and age and fracture characteristics in human tibiae.

### II. METHODS

Sixty human tibiae (left or right) were ethically obtained from 60 postmortem human subjects (females  $n = 31$ , 29–102 years, mean = 68.2 years, SD = 20.8 years; males  $n = 29$ , 24–96 years, mean = 59.4 years, SD = 21.7 years), with equal age distributions between sexes ( $p = 0.115$ ). All tibiae were experimentally loaded to failure in a 4-point bending scenario at 6 m/s in a lateral-medial direction, replicating a pedestrian versus motor vehicle crash [3–4]. An anatomical coordinate system was utilized to ensure the same orientation for all tests. Number and type of fractures were documented post-test [5]. Age was examined as both continuous and categorical (Young Adult = 22–40 years; Middle Adult = 41–60 years; Older Adult = 61+ years) and therefore both chi-squared analyses and Kruskal-Wallis with a posthoc Dunn's tests were employed to analyze the trends [6–7]. Notably, the number of fractures were evaluated per individual, but fracture type analyses considered each fracture independently.

### III. INITIAL FINDINGS

The number of fractures per tibia ranged from one to six, and Simple, Wedge, and Multifragmentary fracture types were observed (Table I, Fig. 1). There were no significant relationships between sex and the number ( $p = 0.09$ ) or type ( $p = 0.36$ ) of fractures. There were significant differences in the continuous variable of age and the number of fractures per tibia ( $p = 0.03$ ); though the correlation was negative and weak ( $r = -0.18$ ). Significant differences were identified in the age of individuals exhibiting 1 and 2, 1 and 4, and 1 and 6 fractures, with older adults more likely to experience fewer number of fractures. Age also had a significant relationship with fracture type ( $p = 0.02$ ). Fracture types varied per age category. Wedge fractures occurred most in young adults, simple fractures occurred most in middle adults, and there were more occurrences of multifragmentary fractures in older adults, specifically older female adults, than either middle or young adults (Table II, Fig. 1).

TABLE I DESCRIPTIVE STATISTICS OF FRACTURE CHARACTERISTICS		
<i>Fracture Characteristic</i>	<i>Category</i>	<i>N</i>
<i>Number of Fractures</i>	1	29
	2	18
	3	7
	4	4
	5	1
	6	1
<i>Fracture Type</i>	Simple	46
	Wedge	42
	Multifragmentary	13

\*Longitudinal fractures ( $n=12$ ) were not included in these analyses as they are currently not classified in [5]

Table II  
FREQUENCY OF FRACTURE TYPES BY AGE CATEGORY

Age Category	Fracture Type	N	Frequency (%) per Age Category
Young Adult	Simple	6	33.3
	Wedge	10	55.6
	Multifragmentary	2	11.1
Middle Adult	Simple	17	54.8
	Wedge	12	38.7
	Multifragmentary	2	6.5
Older Adult	Simple	23	44.2
	Wedge	20	38.5
	Multifragmentary	9	17.3

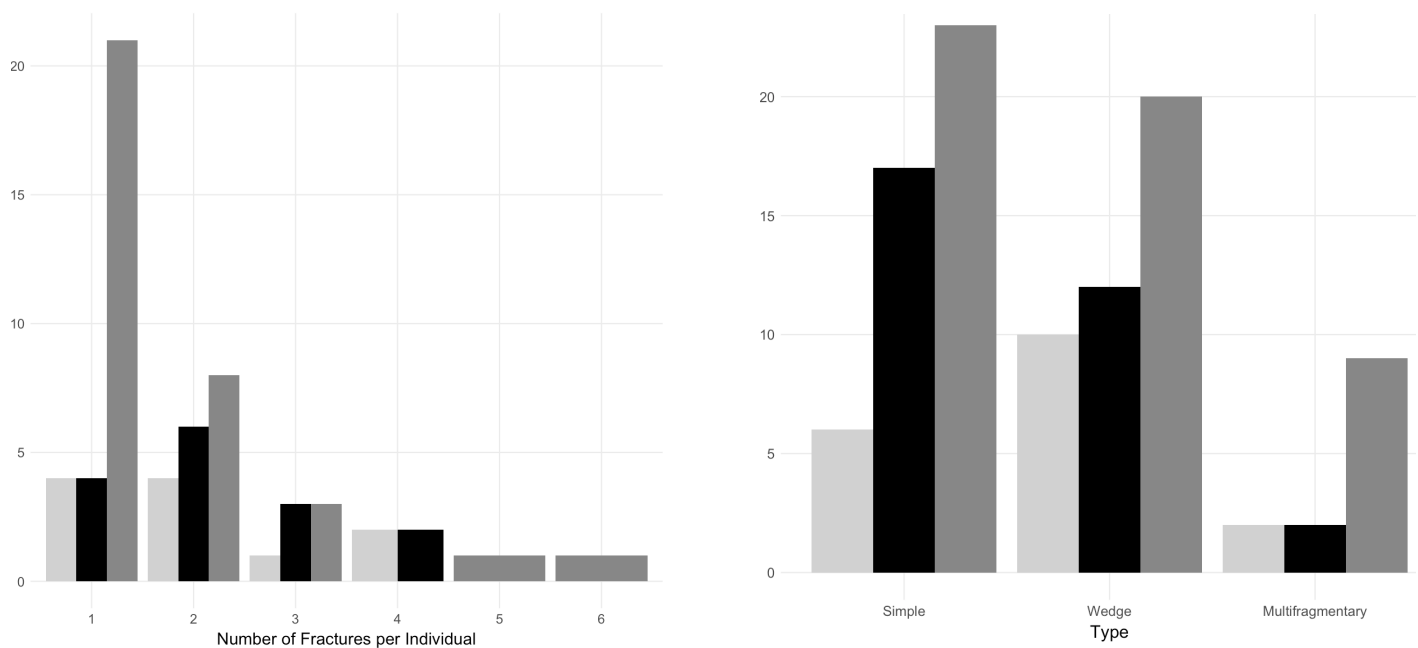


Fig. 1. Bar graphs of number of fractures (left) and fracture type (right) by age category (young adult [light gray], middle adult [black], and older adult [dark gray]) with frequencies on the y-axis.

#### IV. DISCUSSION

Considerable variation in number and type of fractures was observed in this sample. Age demonstrated significant relationships with both number and type of fractures, while sex had no relationship with either when considered independent of age. Older adults demonstrated fewer number of fractures, but those fractures were more complex, i.e., multifragmentary. While this might seem unexpected, younger individuals tend to have more collagen, leading to a different bony response — allowing the bone to bend more prior to fracture. This likely contributed to the higher frequencies of wedge fractures in the young age category. As mineralization increases with time, the bony response in middle adults shifts to more simple fractures. The bone continues to become more brittle in older adults and this may be responsible for the increase in multifragmentary fractures. Future research should explore intrinsic bone variables, e.g., global and cross-sectional geometry, to explain fracture characteristics with an increased focus on bone-level adaptations and differences to more thoroughly explain the variance in number and type of fractures than the weak trends with age shown here.

#### V. REFERENCES

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