Development of In Silico Pediatric Femur Model to Evaluate Bed Falls

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Background: When attempting to determine whether a child's injuries are accidental or non-accidental, biomechanical evidence is needed to determine the likelihood of observed injuries associated with a stated cause. Household falls are a commonly reported accidental injury mechanism as well as a common falsely reported cause in cases of abuse.1,2 In non-ambulatory children, femur fractures are more likely to be due to abuse.3 Previous testing with a modified CRABI 12-month-old anthropomorphic test device (ATD) with an improved biofidelic femur was conducted to measure femur loading in a simulated fall from a bed. A finite element model of the pediatric femur can be used to evaluate the likelihood of fracture based on loading conditions from ATD experimental fall data. The objectives of this study are to evaluate the stress and strain of the femur associated with a bed fall and to consider the influence of different material applications in the *in-silico* femur model on these outcomes.

Methods: A post-mortem diagnostic CT scan of an 11-month old femur, which was used as the basis of the model for the modified ATD femur, was imported into Mimics v15.0.1. Since this scan lacked a calibration phantom, other CT scans with a calibration phantom were used to develop a phantom-less calibration equation to relate Hounsfield Unit (HU) to bone material properties. The resulting meshed femur model which was created in 3-matic v7.01 is composed of 10-node tetrahedron elements with a total of 604,817 elements. Material properties were applied using three different methods: application of (1) median HU of the cortical and trabecular mask to the respective elements, (2) five equally sized bins, and (3) 50 equally sized bins across the distribution of HU.

Table 1. Boundary conditions applied at each load cell location.

Load Cell Location to Torso	Fx (N)	Fy (N)	Fz (N)	Mx (N·m)	My (N·m)	Mz (N·m)
Proximal	232.12	-77.73	-101.09	1.01	-23.10	0.26
Distal	148.23	18.96	-71.26	3.55	-1.06	0.51

Note: X-axis is medial to lateral. Y-axis is posterior to anterior. Z-axis is inferior to superior.

The bed fall is from a height of 60.96cm onto padded carpet. The ATD femur included two load cells located at the distal and proximal ends of the shaft. Boundary conditions and peak loads were applied to the femur FE model in ANSYS v17.1 (Table 1) to represent the fall scenario. Each end of the femur was fixed. Differences between the three material application methods on the maximum stress and maximum principal strain were determined.

Results: A summary of the percent differences with respect to the 50 bins material application method of the biomechanical outcomes can be found in Table 2. The location of the maximum principal strain was in the distal region of the shaft for the five and 50 bins method and the proximal region for the two bins method.

Table 2. Percent difference of material application methods one and two with respect to three for the maximum biomechanical outcomes.

	Percent Difference		
Method for Comparison	**Max Stress (Von-Mises)**	**Max Principal Stress**	**Max Principal Strain**
2 bins (1)	74	58	88
5 bins (2)	-337	-144	-530

<u>Conclusion:</u> The two and five bins were unable to accurately reflect the outcomes of using 50 bins. These results indicate that the five bins method's resulting distribution of material properties would yield outcomes that vastly differed from using 50 bins. Future work will include improving the boundary conditions to better model the conditions of the ATD's femur. The differences in these outcomes will be compared to determine whether using two or five bins could be used in place of 50 to create a FE femur model to evaluate bed falls.

References

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