Towards Hip Fracture Prediction using Finite Element Analysis and Machine Learning (NIAMS 1R21AR060811)

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Introduction

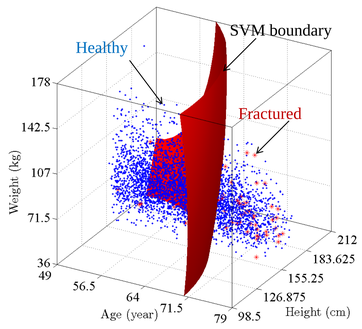
There are a number of techniques and models that can be used for the prediction of hip fracture based on clinical data (Logistic regression, Cox proportional, FRAX model, etc.). However, these tools do not incorporate fundamental mechanical quantities (such as stresses or strains) which could potentially, and this is our hypothesis, significantly improve the predictive ability of the model.

Objectives

- Improve the predictive ability (AUC) of fracture prediction models by combining clinical data and Finite Element Analysis (FEA) data.
- Understand the influence of geometric parameters on hip fracture prediction.

Methods

Figure 1: SVM classifying WHI OS cohort by weight, age, and height



Methods

A fully parameterized FE model of a femur:

- The model can accommodate any geometry. Enables stress and strain prediction from participants of the WHI cohort.
- Weight, cross-sectional areas of shaft and neck, average thickness of cortical bone of shaft, intertrochanter and neck, as well as outer diameter of intertrochanter can be provided to the FE model.

Prediction model based on Support vector machine (SVM):

- SVM is a flexible classification-based machine learning technique that can tackle highly nonlinear dependencies (Fig 1).

Hip fracture risk estimation using probabilistic SVM (PSVM):

- Based on a constructed SVM model, PSVM estimates the probability of hip fracture.

WHI clinical data:

- Participants in observational study (OS, model development) arm (n=6,224) and clinical trial (CT, model validation) arm (n=5,016) from the WHI BMD sub-cohort were selected for this analysis. The Hip Structural Analysis (HSA) was used to evaluate patient-specific geometric parameters.

Validation of FE model using WHI data

Combining clinical and FEA data:

- Outputs from FEA (e.g., strains) are added as covariates along with the clinical database. Improvements in predictive ability are studied.

Results

Figure 2: FEM of a femur

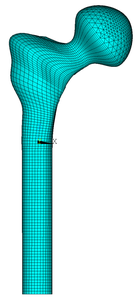


Figure 3: Contour of principal strain from FEA

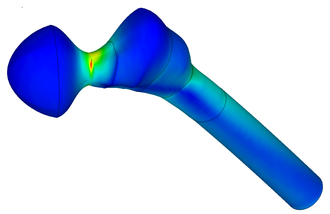


Figure 4: Parameters of the FEM of a femur

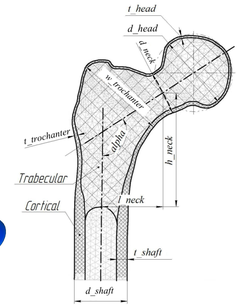


Figure 5: Principal strains in tension and compression of all participants from WHI cohort using FEA

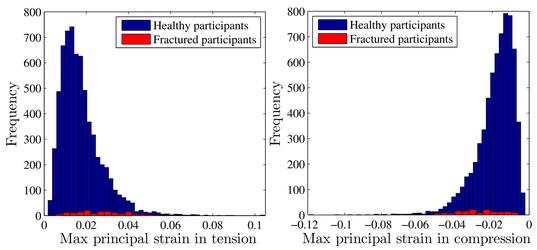


Figure 6: AUC obtained from FEA using WHI for various principal strain thresholds

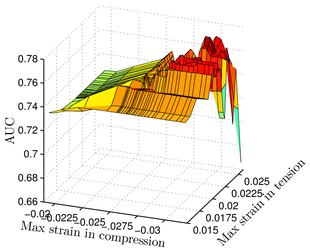
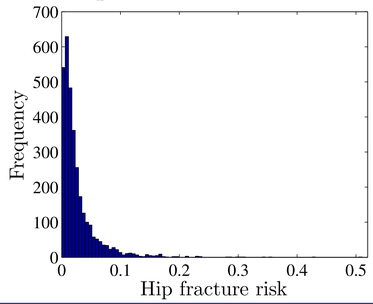


Table 1: 10 year prediction using SVM with and without strains from FEA as predictors

SVM constructed with	OS (105/3391)[1]		CT (53/3233)	
	AUC	95% CI	AUC	95% CI
Weight + 6 geometric parameters	0.79	[0.74, 0.83]	0.76	[0.70, 0.83]
Weight + 6 geometric parameters + strains from FEA	0.79	[0.74, 0.83]	0.80	[0.73, 0.85]

1, # of fractures / # of participants with complete information in the group.

Figure 7: Hip risk estimation with PSVM



Conclusions

- A fully parameterized finite element model of a femur is used in conjunction with clinical data.
- Preliminary conclusion: FEA results help improve the predictive ability of SVM on the CT group.

Future Work

- Further validation of the FEA model (material properties).
- Increase dimensionality.
- Include FE data in a transparent manner.

Acknowledgements

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