MODULE 1-P5: Accuracy of 3D DXA-based femoral strength prediction from finite element analysis (FEA)

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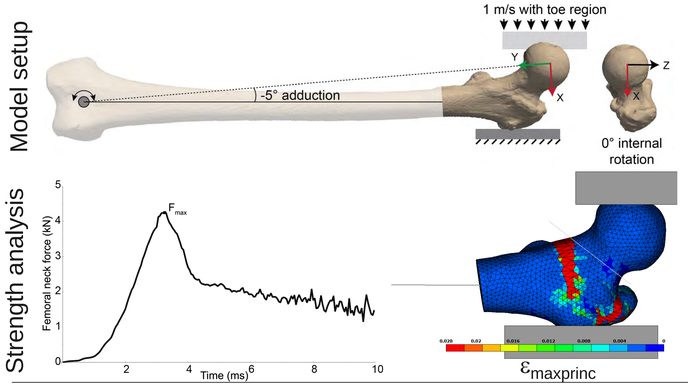
1 Clinical burden

- Hip fracture incidence is expected to increase to 6.3 million in 2050 due to ageing population, with 50% of them in Asia.
- Better predictor of hip fracture risk is needed as prediction accuracy based on gold standard dual-energy X-ray absorptiometry computed areal bone mineral density (DXA-aBMD) is 75% or less.
- 3D-2D algorithms that model the 3D bone shapes and distributions from 2D planar DXA projections can provide a more direct assessment of the resistance to fracture.
- Problem: 3D-DXA based finite element (FE) models of bone strength have not been validated against computed-tomography, CT-based FE models.

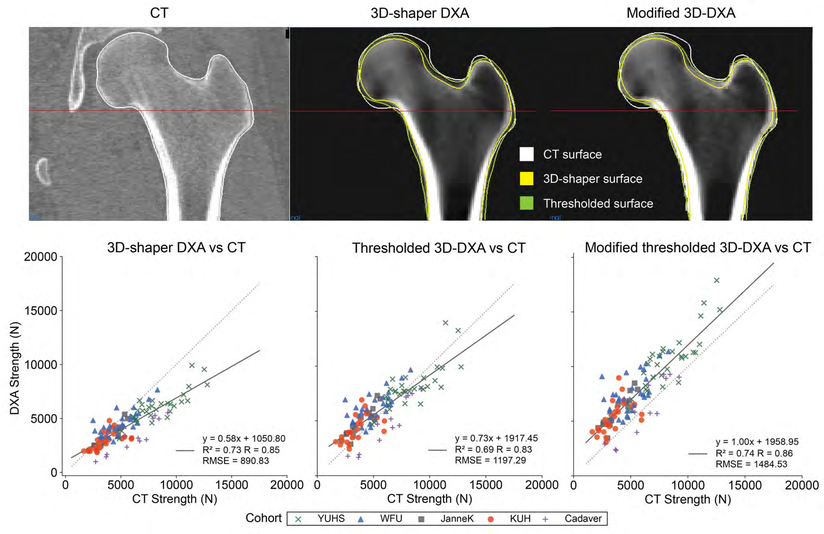
2 Finite element modelling

Geometry	Smooth, continuum, second-order tetrahedral elements
Material	Bone properties mapped from HU values (K_2HPO_4 phantom) Compression-tension asymmetry, strain-rate dependency
Contact conditions	Frictionless, no rotation at contact



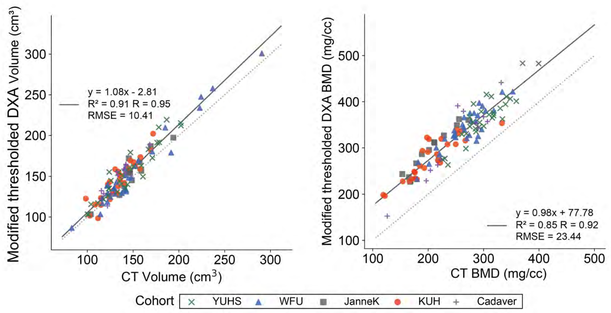
3 Validation results and data-driven model

- 112 paired 3D-DXA (3D-shaper, Galgo Medical) and CT images from five cohorts (age 20-88; absence of bone disease treatment) were evaluated.
- 3D-shaper DXA surfaces (yellow) were smaller than CT segmented surfaces (white), leading to an under-prediction of femoral neck strength.
- New geometries created by binarisation of 3D shaper DXA images (green) increased the similarity of surface shapes but improved correlation of CT-DXA strength only slightly.
- A novel data-driven model that modifies the 3D-DXA bone mineral density (BMD) at the new geometries obtained a 1:1 correlation but with a systematic offset.



4 Morphometric analysis

Total bone volume shows a good correlation but BMD is over-predicted with the new model.



5 Discussion & conclusions

- A novel methodology that modifies 3D-DXA images to predict femoral strength with better accuracy has been developed.
- Good correlation between DXA-CT strength has been achieved, but the over-prediction of strength in the novel model may be driven by the systematically higher BMD in the new models.
- Further optimisation of data-driven model is required to match BMD to improve the strength prediction.
- 3D-DXA combined with novel data-driven model has the potential to be used in place of CT-based models to estimate the risk of hip fracture.

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