BODY ANTHROPOMETRY AND BONE MICROARCHITECTURE IMPROVES HIP FRACTURE PREDICTION WHILE FALLING ON A SIDE

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Introduction

Most hip fractures are associated with a side fall on the femoral greater trochanter. Fracture onset is determined by the local tissue properties and the dynamic load caused by the fall.
The current standard for assessment of hip fracture risk, areal Bone Mineral Density (aBMD, T-score) obtained by Dual-energy X-Ray Absorptiometry (DXA), takes into account only the tissue properties averaged in 2D and has shown poor sensitivity and specificity [1].
The aims are to replicate a sideways fall scenario *in vitro* and to compare 1) fracture outcomes with predictions using T-score; 2) and a combination of clinical CT measurements of BMD and body anthropometry (BA).

Material and methods

Ten specimens (DXA T-score range: -3.59, 0.77) were scanned (Table 1) with a micro-computed tomography (micro-CT) (29 µm/voxel, Australian Synchrotron Clayton VIC, Australia) [2] to visualise bone microstructure and with a clinical CT (0.7 mm/pixel, Optima CT660, GE, USA) to evaluate BMD.
The femurs were then tested in a sideways fall condition using a drop-tower. Patient-specific energy at touchdown was calculated from donor weight, height and soft-tissue thickness for each specimen [3]. Fracture onset was video-recorded using two high-speed cameras (20,000 Hz, Vision research, Phantom UHS-12), the vertical impact force was recorded using a load cell.
The specimens' strength was estimated using finite-element modelling, embedding CT-based BMD locally isotropic material properties.
The fracture event was predicted using 3D models and a theoretical impact force calculated as

$$F = M*v/t; \qquad (1)$$

where M is the body mass, v is the speed at touchdown and t is the impact duration [3].
Specimens were categorized in high- and low-risk of fracture, based on 1) DXA T-score (high risk: T-score < -2.5) and 2) 3D models and theoretical impact force. Predictions and fracture test outcomes were compared. Fracture onset location was compared to the local internal bone microarchitecture in the micro-CT images.

Results

Six out of 10 specimens (#4, #5, #6, #7, #9, #10) showed either a fracture or no-fracture, in agreement with the DXA-based predictions. However, two specimens identified as non-osteoporotic (#1, #2) did actually fracture, whereas one osteoporotic specimen (#8) did not fracture (Table 1). CT-based BMD and BA correctly predicted nine out of 10 specimens.

Predictors	Specimen #									
	1	2	3	4	5	6	7	8	9	10
DXA T-score	N	N	N	N	Y	Y	Y	Y	Y	Y
CT BMD + BA	Y	Y	Y	N	Y	Y	Y	N	Y	Y
Experiment	Y	Y	N	N	Y	Y	Y	N	Y	Y

Table 1: Comparison of fracture risk estimate based on DXA (if T-score < 2.5 indicated as "Y", otherwise "N"), CT BMD and BA, and experimentally observed fractures (N: non-fractured; Y: fractured).

Two different failure patterns were observed: sub-capital and per-trochanteric (Fig. 1). Examination of the trabecular microstructure suggested that failure onset might be linked to the local trabecular bone architecture.

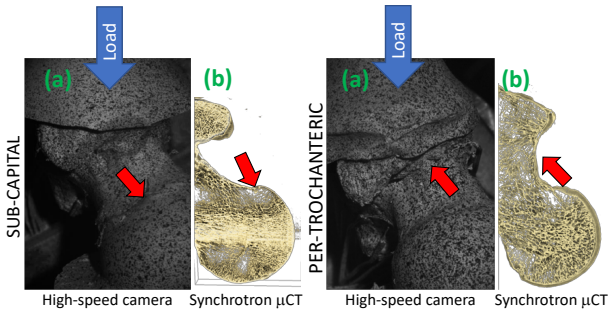

Figure 1: Different failure patterns: sub-capital (left) and per-trochanteric (right). High-speed camera images during the tests (a) and synchrotron micro-CT images of the intact bone (b). Red arrows: failure point; blue arrow: direction of applied load.

Conclusions

The clinical classification of osteoporosis (DXA T-score <-2.5) only partially predicted the actual femoral fracture observed in a simulated sideways fall. Predictions based on CT BMD combined with body anthropometry gave a better prediction (9 cases out of 10). Body anthropometry and bone microstructure may play a fundamental role [4] in identifying the risk of femoral fracture while falling on a side.

References

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Acknowledgements

University of Bologna (Marco Polo grant scheme); Flinders University; ARC (DE140101530); EPSRC (EP/K03877X/1).