CAN OSTEOPOROSIS AND BODY WEIGHT ALONE EXPLAIN THE OCCURRENCE OF SPONTANEOUS HIP FRACTURES? A POPULATION BASED FINITE ELEMENT STUDY

Ilaria Palmadori[1], Enrico Schileo[1], Matteo Cataldi[1], William R. Taylor[2], Markus O. Heller[3], Fulvia Taddei[1]

[1]Istituto Ortopedico Rizzoli, Italy; [2]ETH Zürich, Switzerland; [3]University of Southampton, United Kingdom

Introduction

Despite being difficult to diagnose, spontaneous hip fractures (i.e. without falling) are reported in 1-10% of all hip fractures [Parker, 1997]. Spontaneous fractures pose an interesting biomechanical question: can they be caused only by osteoporosis, or are altered loading patterns needed to explain them?

Low Bone Mineral Density (BMD) is considered the major risk factor for all non-traumatic fractures. Higher body weight (BW) could be a risk factor since bones will be exposed to higher loads but its effect is less clear. The variability of loads acting on bones is an additional risk factor, usually neglected.

A recent probabilistic FE study [Viceconti, 2012] suggested that low BMD alone cannot explain spontaneous fractures when considering muscle stress-optimised loads, but: (i) only one femoral anatomy, (ii) normal body weight, and (iii) no load variability were considered in that study.

The aim of this work was to evaluate, through validated FE models combined with a large musculoskeletal loading database, the possible occurrence of spontaneous hip fractures in an aging, overweight, osteopenic population.

Methods

CT scans of 200 overweight patients (115 women) with normal femoral anatomy were collected from an internal database of Istituto Ortopedico Rizzoli. DXA T-score was simulated from CT (Table 1). A validated procedure was used to build FE models of the femur from CT [Schileo, 2008].

Table 1: Characterisation of the sample population

	mean	range
Age	57	[23,84]
BMI	26.4	[17,37]
T-score	-1.8	[-3.6,1]

To model the possible loading variations associated with two frequent motor tasks (normal walking; NW and stair climbing; SC), an indexed and searchable database of joint and muscle loads was obtained from the results of musculoskeletal models on 90 patients.

A joint and muscle loading spectrum for NW and SC was associated to each femur by querying the database with the individual characteristics (height, weight, femoral antetorsion, CCD angle and neck length): 78 possible loading combinations for NW and 50 for SC were defined for each subject, for a total of 25,600 FE analyses.

Risk of fracture (RF) was defined for each subject as the maximum principal strain / limit strain (1.04% compressive, 0.73% tensile) ratio among the whole loading spectrum.

Results and Discussion

No fracture was predicted by the FE models (Figure 1) throughout the entire population, yielding an average safety coefficient from 4 to 5. The individuals with high BW and low BMD showed the highest risk values, but they seldom exceeded an RF of 0.5.

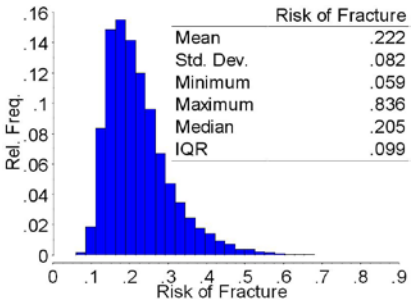

Figure 1: RF distribution and descriptive statistics (overall data, NW and SC, 25600 FE analyses).

The mean difference in RF for NW and SC was only 3% (statistically significant, but not relevant). The difference in RF for men and women was surprisingly not significant, suggesting a gender-equivalent bone response to physiological loads. According to the present study, spontaneous fractures seem not to be associated with body weight, but rather to severely impaired musculoskeletal conditions leading to bone overloading, that warrant further studies and new modelling approaches.

References

Parker *et al*, Acta Orth Scand, 68:325-6, 1997.
Schileo *et al*, J Biomech, 41:356-67, 2008.
Viceconti *et* al, J Biomech 45:421-6, 2012