

PREDICTING POPULATION LEVEL-HIP FRACTURE RISK: A NOVEL PROBABILISTIC MODELING APPROACH INCORPORATING FACTOR-OF-RISK PRINCIPLES



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This novel approach moves beyond individuals to predict fracture risk at the population level. A valuable tool for a-priori prediction of intervention approaches.

INTRODUCTION

Fall related injuries are a serious concern for older adults, specifically for hip fractures (fx), where 95% are due to falls [1]. In Canada alone, there are ~25000 hip fx/year [2], accounting for over one third of all fall-related hospitalizations, costing

METHODS

Model Structure

As seen in **Figure 1**, the model is separated into two main portions:

1. Subject Characterization 2. Modelling

RESULTS

Population Application Outcomes

- Male Mean (SD) FOR: 0.940 (0.314)
- Female Mean FOR: 0.469 (0.296)
- Age Effect Male mean FOR: R² 0.995
- Age Effect Female mean FOR: R²0.925

\$650 million annually [3].

Currently, there exists no model to predict hip fx risk on a population level. Such a model would be valuable in developing prevention and intervention policies.

This study's main goal was to develop and validate a mechanistic, probabilistic model to predict population-level hip fracture risk for older adults.

METHODS

Model Development

Factor of Risk (FOR) principles were applied, where:

FOR = *Impact Force Fracture Threshold* When $FOR \ge 1$, hip fx assumed.

The first portion generates virtual individuals (VI) that represent a given population. The physical characteristics of the VIs are used as the inputs for the predictive equations in the second portion.

Generating Virtual Individuals (VIs)

A sample of VIs was generated to represent the population of interest (Canadians \geq 60 yrs of age).

Physical characteristics assigned to VIs for mechanistic model included: - mass, height, etc.

- Population probability distributions defined for each characteristic
- With the exceptions of age and sex,



Figure 2: Group mean FOR by age (5-year bins) and sex

DISCUSSION

- Novel model of population level hip fracture risk developed
- Model validated against epidemiological data (within 5%)
- Model predicted population-level hip fx risk for entire Canadian older adults FOR increases with age for both • males and females • FOR greater for males (aligns with Dufour et al, 2012), but counter to current fx rates.

To predict net impact force, we took the difference between

Peak Impact Force $(N) = \sqrt{2ghmk}$, [4] and Soft Tissue Force Attenuation (N) =71 * *tstt*. [5]

Fracture Threshold is then calculated by Fracture Threshold (N) = 8207 **Femoral neck BMD* – 568.62.[6]



- normal distribution were employed.
- Pseudo-random sampling ensured representative values assigned.

Model Validation

- We compared our FOR output to retrospective study values (Dufour et al, 2012) from four groups:
 - Male, No Fracture), N = 399
 - Male (Fracture), N = 26
 - Female (No Fracture), N = 565
- Female (Fracture), N = 110
- Acceptable difference threshold = 5%

Population Application

- 100 000 VI samples generated.
- Distributions drawn from Statistic Canada data for adults 60-100 years. Mean (SD) FOR calculated by age (5 year bins) and sex.

FUTURE WORK

- *Intervention submodule* explore the effects of prevention approaches.
 - Pilot work indicates that 'safety flooring' substantially reduces FOR and hip fx risk
 - Fall Risk submodule apply to each VI

REFERENCES

- Wolinsky et al. (2009). Recent Hospitalizations and the risk of hip [1] fracture among older Americans, Journal of Gerontology 64(2); 249-55.
- Statistics Canada. Canadian community health survey annual [2]
- Sex-specific linear regression models generated for age-related FOR changes.

RESULTS

Validation Results Male Male Female Female (No (Fracture) (No Fracture) (Fracture) Fracture) **Reported Mean** 0.41 (0.21) 0.49 (0.17) 0.87 (0.16) 1.00 (0.17) (SD) [7] 0.410 (0.25) 0.485 (0.25) Model 0.875 (0.21) 1.048 (0.22) Mean (SD) Mean 0.575 % 4.8% 0% -1.02% **Difference (%)**

component (CCHS). Health Survey. Ottawa: Statistics Canada; 2012. Report No.: 3226

- Wiktorowicz et al. (2001). *Economic implications of hip fracture:* [3] health service use, institutional care and cost in Canada, Osteoporosis International 12(4); 271-78;
- Robinovitch SN, Hayes WC, McMahon TA (1991) Prediction of [4] femoral impact forces in falls on the hip. J Biomech Eng 113:366– 374
- [5] Robinovitch SN, McMahon TA, Hayes WC (1995) Force attenuation in trochanteric soft tissues during impact from a fall. J Orthop Res 13:956–962
- Roberts BJ, Thrall E, Muller JA, Bouxsein ML (2010) Comparison [6] of hip fracture risk prediction by femoral aBMD to experimentally measured factor of risk. Bone 46:742–746
- Dufour et al. (2012), *The factor-of-risk biomechanical* [7]
 - approach predicts hip fracture in men and women: The Framingham Study, Osteoporosis International 23(2); 513-20.

ACKNOWLEDGEMENTS







Table 1: Reported vs Model Group Mean (SD) FOR