

# Multivariate Injury Risk Criteria for Fractures to the Distal Radius

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## ABSTRACT

*Forward fall-related distal radius fractures account for approximately 20% of all fractures and continue to be the most commonly seen by orthopaedic surgeons [1]. Regardless, our understanding of how these injuries result from dynamic, three dimensional impacts is limited. Duma et al. in 2002 [2] presented an injury risk criteria model for these fractures that included peak axial force; however, no further attempts have been made to include variables that better represent the dynamic, multi-directional nature of load application typical of forward falls. Therefore, the purpose of the current study was to identify injury risk criteria, with a focus on the dynamic variables, for distal radius fractures. Eight fresh-frozen, isolated human cadaveric radii were potted at a 75° angle up to the distal third of the radius. A custom designed pneumatic impact system [3] was used to apply impulsive impacts to the specimen at increasing energy levels, starting at 20 J (pre-fracture) and increasing in 10 J increments, until a crack (non-propagating damage) and fracture (specimen separated into at least two fragments) were recorded. Peak forces, load rates, impulses, and impulse durations, along all three force axes (Fx-medial/lateral direction; Fy-volar/dorsal direction; Fz-axial direction), impact velocities, energies and specimen donor demographics (age, height, weight and bone mineral density) were included in a best subset analysis to develop multivariate injury risk models. The model that best represented the crack and fracture events, separately, were chosen based on a combination of the highest R<sup>2</sup>, low Variance Inflation Factors (<5 to ensure no multicollinearity) and the significance of each variable that was included (p<0.05), such that the final models accounted for the highest explained variance in injury with the fewest variables. For comparison, Fz-only models were also created. Weibull plots were created to extract the beta (slope of the Weibull plot) and alpha (Eq.1) coefficients, which were subsequently used to establish the shape of the cumulative distribution functions. The risk scores at 10%, probability of injury were also determined.*

$$\alpha = e^{-\left(\frac{b}{\beta}\right)} \text{ where } b = \text{the y axis intercept. (1)}$$

*The best subsets analyses resulted in 17 and 14 different models for the crack and fracture events, respectively. The model that best represented the crack event (Adj. R<sup>2</sup> = 0.69) included Fy Impulse, Fz Load rate, velocity and ln(Fz) while the best predictive model of the fracture event (Adj. R<sup>2</sup>=0.82) included peak Fz, Fy Impulse and velocity (Eq. 3). In contrast, Fz alone accounted for only 55% and 29% of the variance in the crack or fracture outcomes, respectively. The multivariate survivability curves suggest that there is a 10% probability of crack and fracture at risk scores of 0.5 and 0.6, respectively.*

$$\text{Crack} = 5.0 + 0.2 * FyImp + 5.0E-7 * FzLR + 0.1 * Vel - 0.9 * LnFz \text{ (2)}$$

$$\text{Fracture} = -1.1-2.7E-4 * FzPeak + 0.2 * FyImp + 6.6E-1 * Vel \quad (3)$$

*Overall, the multivariate models provided better failure predictions compared to the models that only incorporated the axial (Fz) force. The results presented here highlight the importance of considering the dynamic multidirectional nature of distal radius loading, and are therefore an important step toward developing more effective injury prevention strategies.*