Dynamic Contact Modeling of Hip Impacts: Characterization of Viscoelastic and Geometric Properties

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Abstract

Fall-related lateral impacts to the hip have commonly been modeled as a simple single-degree-of-freedom (SDF) mass-spring (MS) model. However, these models predict impact characteristics less accurately for experimental participants outside a body mass index (BMI) range of 21-24 kg/m^2. SDF models limit prediction accuracy through two proposed avenues: 1) exclusion of viscoelasticity of biological tissues, and 2) simplified representation of load distribution. Solutions for these limitations range from simple addition of a damper (Voigt, VG) or distributed contact (Hertzian, HZ), both a damper and distributed contact (Hunt-Crossley, HC) to a Volumetric (VO) model, which allows three-dimensional interaction between contacting bodies based on individual material and geometric properties.

However, no published literature has characterized HZ or VO model parameters for fall-related lateral impacts on the hip region. The objective of this study is to characterize the geometric and material parameters for novel HZ and VO models of the pelvis, alongside the more common MS and VG models, during a lateral hip impact scenario.

At the time of abstract submission, four out of forty-eight proposed university-aged participants (24 male, 24 female, wide variance of body geometry and composition) underwent lateral pelvis release trials from 5 cm, which involved the lateral aspect of the hip impacting a force plate overlaid with a pressure plate, while motion of the pelvis was tracked using 3D motion capture. To characterize stiffness parameters in a negligible damping situation, participants also underwent quasi-static trials, with an identical starting position, and an incremental pelvis lowering process. Trochanteric soft tissue thickness (STT) was measured via ultrasound. Model parameters were derived using optimization techniques, and models were implemented within MapleSim, and compared against experimental impact data. The primary anticipated outcomes of this study are the geometric, stiffness and damping parameters, as well as how they differ between male and female participants of differing body composition characteristics.

Based on initial pilot results from four participants, no consistent gender or STT effects were noted for any stiffness parameters. Based on our current parameter characterization methods, damping was found to be negligible for males in the VG and VO models, and for females in the VO models. Despite this, VG predicted peak forces within 5% of experimental results for males, but only within 30% for females. No one model currently performs best for all participants, however, VO predicted peak forces within 20% for all participants to date, except for one participant with extremely low STT (less than 25% of typically observed values). With accuracy in peak force prediction as close as <1% for some participants, VO may show promise as a more accurate predictor of hip impact characteristics than simpler models. However, inconsistent *performance of all models indicates that other body composition characteristics or methods of parameter characterization should be explored.*