Isolated Segment Manipulation: A New Way to Characterize the Dynamic Response of Biomechanical Structures

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ABSTRACT

Traditional methods to characterize the dynamic response of individual biomechanical systems often come with limitations. Crash simulation testing represents a realistic environment where kinematics can be measured, but internal kinetics can only be estimated by inverse dynamics. Component impact tests are more focused to a particular body region but typically lack inertial contributions, don't include internal measurement of kinetics, and require direct impact of some type. Finite element modeling is an efficient way to examine response sensitivity and detailed behavior but the models often rely on tissue properties gathered at rates far below crash speeds. To address the limitations of these traditional methods, a new approach, Isolated Segment Manipulation (ISM), is introduced. ISM unifies principles of system identification, inverse dynamics, and rigid body mechanics to characterize the response of a desired body segment by conducting an iterative series of tests on a single intact PMHS. Each iteration possesses a different set of boundary conditions for multiple locations on the body: (a) forced (the point is loaded directly with both kinematics and kinetics measured), (b) free (kinematics are measured as the point is allowed to move), or (c) fixed (reaction kinetics are measured as the point is held fixed). A proof-of-concept study has been completed in two steps to demonstrate the utility of ISM in characterizing the dynamic response of the upper thoracic spine: (1) validate the approach by deriving the known properties of an upper thoracic spine surrogate in Hybrid III 50th male ATD trial testing, and (2) apply ISM to find the unknown properties of the human upper thoracic spine in PMHS pilot testing. Results from this pilot study indicate that ISM is a promising method for obtaining ATD target responses for the upper thoracic spine and potentially other body segments.