Estimating the Basin of Stability for the Human Spine using Forward Dynamic Simulation

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The cause of low back pain (LBP) can sometimes be determined using imaging techniques such as x-rays, computed tomography, or magnetic resonance imaging. However in many cases patients with LBP show no radiological signs of injury or disease. In such cases, this pain may be caused excessive strain and injury to the paraspinal muscles and ligaments due to large local deformations at the intervertebral joint. It is believed by many that spinal instability may be the cause of these excessive local deformations. In this study a new technique is used to determine the basin of stability, the region of state space in which nearby trajectories remain close to the equilibrium state. This basin of stability is evaluated for the human spine during an unstable sitting exercise using a mathematical model. Forward dynamic simulations were employed to determine trajectories based on initial conditions. From these trajectories, a finite time Lyapunov exponent (FTLE) field was found. The FTLE field was examined to locate Lagrangian coherent structures (LCS), ridges in the FTLE field that separate qualitatively different types of motion. As expected, LCS formed at the boundary between the stable and unstable regions indicating the edge of the basin of stability. These simulations are a first step in developing a method to locate state space boundaries for stability of the human spine. Furthermore, the approach presented herein may be adapted to find state space boundaries useful in other biomedical engineering application.