**Computer Modeling of the Motion and Ligaments of the Sacro-Iliac Spine**

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## INTRODUCTION:

Form and function have long been synergistic in the understanding of skeletal kinematics. For example, the understanding of thumb carpometacarpal motion has been interpreted based upon the toroidal shape of the first metacarpal and trapezial joint surfaces. Resultant axes extrapolated from these shapes are two non-orthogonal, non-intersecting lines – one for flexion-extension motion running through the trapezium and the other for abduction-adduction running through the base of the first metacarpal (the AbAd axis is linked to the FE axis). [1] Iterative adjustment of these axes with a detailed, interactive, real-time kinematic data structure assists in definition of the joint kinematics including limits in the ranges-of-motion. This becomes true for many other joints and coupled with a variety of experiments lends well to the iterative improvement of kinematic simulation.[1] Can this method be applied to improve our understanding of the sacroiliac (SI) joint? What will the strain in the ligaments be? What level(s) of detail will be required? Does the Sacrum really rotate about some effective axis? This report investigates these questions through the definition of SI effective motion and ligament fibers in a kinematic simulation using a hierarchical structure developed from the highest density CT scans available from the male Visible Human Data Set.

## METHODS:

Using the interactive 3D kinematic simulation (Kinsim[2]) developed in our lab, the sacroiliac ligaments were defined as cubic B-spline curve paths (Figure 1). Bone polygons for the simulation are derived from axial computerized tomography (CT) slices of the National Library of Medicine Visible Human (male). With standard graphic interactive tools (mouse, spaceball, keyboard) control points representing origins, insertions and intermediate constraints are defined for central and boundary fibers of the sacro-iliac ligaments (Anterior sacroiliac, Interosseous sacroiliac, Posterior sacroiliac long and short, Sacrotuberous, and the Sacrospinous ligaments). Also, the fundamental motions of the sacrum with respect to the innominate bone described in the literature are defined in the simulation. These include flexion and extension (also called nutation and counter-nutation) and displacements in the three primary dimensions. These motions are replicated with the simulation and the joint form and functions as well as predicted strains in the ligaments are studied.

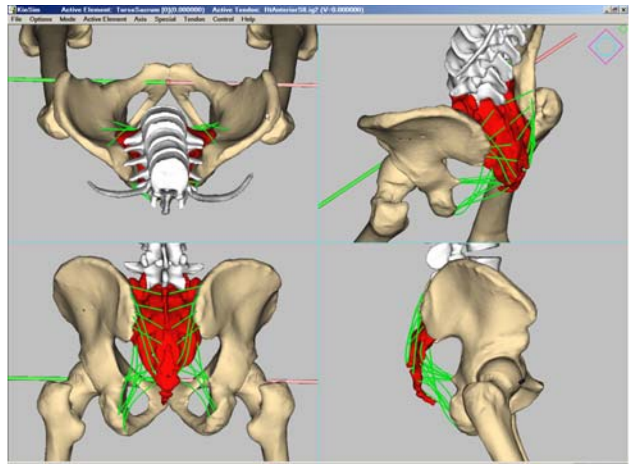

**Figure 1.** Orthogonal views (Sup., Post, Lat) and an oblique view of the hip with the rotation axis and cubic B-spline curve definitions for the main ligaments of the sacroiliac joint.

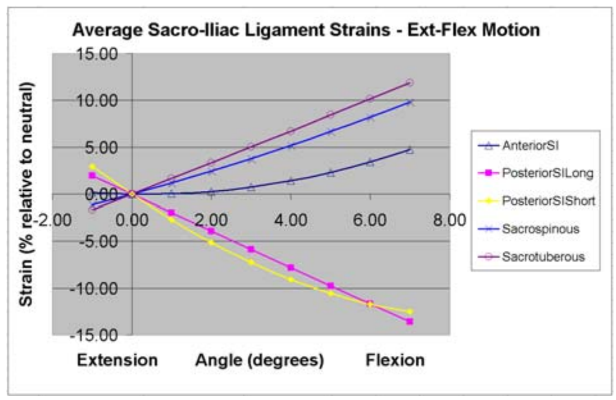


**Figure 2.** Average predicted strains (relative to the neutral or 0° position) for the SI ligaments for motion from extension to flexion (also called nutation motion). The lengths of the cubic B-Spline models depicted in Figure 1 were averaged following simulated motion.

## RESULTS and DISCUSSION:

This simulation study predicted the ligament strains to range from -14 to 12 % (Figure 2) for extension to flexion (the largest apparent motion of the sacrum with respect to the innominate [3, 4]). The complexity of the sacro-iliac joint surface structure (form) is well illustrated when studying the motions (function) within the limits described in the literature.[3, 4] The limited ranges of motion are the most obvious result to be drawn from the interactive study. For example, the maximum extension position for the sacrum when modeled based upon the work of Weisl[4] was 1 degree (see Figure 2) before bony interaction became apparent. Extrapolating joint congruence throughout the range of motion is not a comparable interactive procedure compared to study of a joint like the thumb CMC joint. Clearly, improved models of SI motion are necessary to adequately answer the queries posed in the Introduction.

## References:

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