Axial Rotation is the Dominant Loading of the Female Sacroiliac Joint and Female Motion Qualities are Asymmetric: A Cadaver-Based Biomechanical Study

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INTRODUCTION:
In addition to stabilizing the spine, the sacroiliac joint by means of its morphology and ligamentous complex, facilitates lower extremity to pelvis to spine force transmission by redirecting compressive loads into shear and axial components. As a result of these off-axis load components, there is a high likelihood of coupled off-axis motions during applied loads. Thus, understanding the predominant directions of the joint's on-axis motions in conjunction with their off-axis components and in the context of sexual differentiation will be useful for accurately diagnosing and treating load-mediated pain via stress relief. The goal of this study was to analyze and characterize the rotational motion properties of the sacroiliac joint across both sexes in the largest cadaveric dataset. We aimed to compare the motion qualities: ranges of motion (ROM), and coupled/off-axis motions, in each of the 3 loading planes and six loading directions. We hypothesized that ROMs would be larger and more asymmetric in female joints. We hypothesized that the coupled motions would be asymmetric, and predominantly comprised of axial rotation, in female joints.

METHODS: Twenty-four paired fresh-frozen, asymptomatic human cadaveric sacroiliac joints (1M:1F Age- 48±11:50±13) from L4 to Pelvis, were obtained for this study. Each specimen was screened for sacroiliac joint deformity/bridging, and pubic symphysis diastasis using donor histories and computed tomography (CT) scans. Quasi-static multidirectional bending flexibility tests on each intact joint in a single-leg stance model were performed, and the relative orientations about each anatomic axis, between the sacrum and the iliac during nutation-counternutation (NC), lateral bending (LB), and axial rotation (AR) loads were measured from 0 to 7.5 Nm at 1.5 Nm intervals using an optical tracking system after 3 preconditioning cycles. The Off-Axis ROM, and On-Axis ROM, were calculated as ROM outcome measures. The On-Axis Motion Ratio (OAR = On-axis/Total ROM), was calculated as the alignment outcome measure. Differences in outcome measures between planes, directional pairs, and sexes were tested for significance. Paired t-tests were performed in all comparisons except male-female comparisons which utilized unequal variances t-tests (95% CI, $\alpha=0.05$).

RESULTS: All male and female joints completed testing. Plane Outcomes are shown in Figure 1. Female joints produced the largest On-axis ROMs in all planes of motion ($p<0.01$). The On-axis ROM decreased in the order of NC-AR-LB in both male and female joints ($p<0.01$). In male joints, OAR decreased in the order of NC-AR-LB, while in female joints LB produced the lowest OAR, while NC and AR were equivalent ($p<0.03$). In female joints, off-axis motions are predominantly AR motions during NC and LB ($p<0.03$). While NC contributed the most to off-axis motions during AR in both male and female joints ($p<0.03$). Directional Outcome measures are shown in Figure 2. Female Joints produced the largest On-axis ROMs in all directions of motion ($p<0.01$). Female Joints produced larger counternutation than nutation On-axis ROM, and larger ipsi-lateral (towards the joint) than contra-lateral (away from the joint) bending On-axis ROM and OAR ($p<0.01$). Male Joints exhibited a larger OAR in nutation than counternutation ($p<0.03$).

DISCUSSION AND CONCLUSION: Sacroiliac motions generated by counternutation (sagittal) and contralateral bending (coronal) loads respectively are asymmetric and coupled to axial rotation in women. Counternutation and ipsi-lateral bending in women (and much less so in men) are asymmetrically more mobile. These motions facilitate pregnancy and childbirth. Symmetry of motion may be indicative of joint pathology in women. Similarly, asymmetric motion may indicate pathology in men. We conclude that coupled motions most likely occur during lateral bending which exhibits the lowest on-axis motion ratio. Treatment techniques should aim to examine these sex-dependent asymmetric and coupled motion properties to provide phenotype-matched stability for patients.

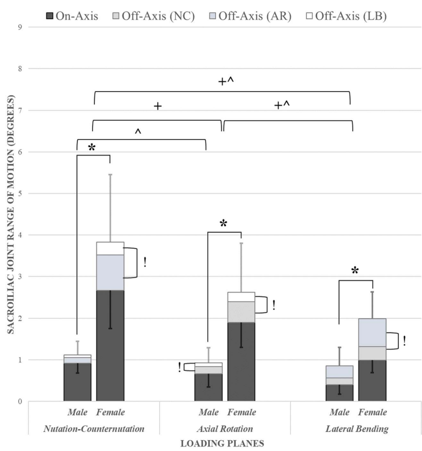

Figure 1. ROM in three planes. The exclamation (!) indicates significant differences between off-axis motions within each loading plane and sex. The asterisks (*) indicates significant differences in On-Axis ROM between sexes. The carat (^) indicates significant differences in OAR between loading planes. The plus (+) indicates significant differences in On-Axis ROM between loading planes.

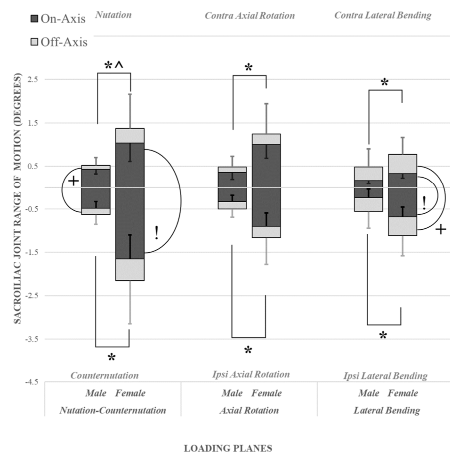

Figure 2. ROM in six directions. The exclamation (!) indicates significant differences in On-Axis ROM between directional pairs. The asterisks (*) indicates significant differences in On-Axis ROM between sexes. The carat (^) indicates significant differences in OAR between sexes. The plus (+) indicates significant differences in On-Axis ROM between directional pairs.