# Regional Displacements of the Sacroiliac Joint: Implications for Treatment of Stress-Mediated Pain

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INTRODUCTION: Sacroiliac joint (SIJ) dysfunction is a major cause of chronic low back pain - accounting for 16-30% of cases - and is often theorized to be caused by hyper-loading or hyper/hypo-mobility of the joint. Phenotyping SIJ dysfunction, in terms of mechanism and location, is difficult but significantly impacts treatment efficacy. We theorize that isolating the least and most displaced regions will optimize diagnosis and treatment of SIJ dysfunction. The least displaced would experience the highest stresses and the most displaced would provide the best leverage. We also theorize that the nature of stress on the joint can be determined from the displacement direction. Posterior, lateral, and inferior displacements would compress the joint surface while anterior, medial, and superior displacements would distract surrounding ligaments. Our goal was to evaluate SIJ displacement to better understand the inter-regional variations in displacement magnitudes and directions across both sexes. We hypothesized that the most displaced region would be the bottom of the joint, the least displaced region would be the bottom of ala in female joints, and that axial rotation would induce compressive loads on the joint surface.

METHODS: Twenty-six intact, paired, fresh-frozen, and asymptomatic (screened for deformities and pathology using donor histories and CT scans) human cadaveric sacroiliac joints (L4-Pelvis, 12M:14F, Age- 48±11:51±12) were used for this study. Specimen were carefully dissected such that the pubic symphysis, ligaments, and joint capsules were left intact. Quasi-static multidirectional bending tests were performed on each intact joint in single-leg stance. Relative displacement between the sacrum and the ilium of three points (top of ala, bottom of ala, bottom of joint) was recorded using an optical tracking system under nutation-counternutation, axial rotation, and lateral bending pure bending loads from 0-7.5 Nm. Displacement was differentiated as in-plane (ex. along the superior-inferior or anterior-posterior axes during nutation) or along the normal-axis (ex. along the medial-lateral axis during nutation). The in-plane resultant displacement, the angle of resultant displacement, and the normal-axis displacement were calculated for each loading condition using the 0 Nm and 7.5 Nm points. Significance was tested within a sex (between locations and loading directions) using two-tailed paired t-tests and between sexes using two-tailed two-sample unequal variance t-tests.

RESULTS: Female joints displayed larger ranges of displacement than male joints in the majority of loading types and directions (Fig. 1). This was significant during nutation at the top and bottom of ala ($p<0.03$), counternutation in all three locations ($p<0.001$), contra-axial rotation at the top and bottom of ala ($p<0.02$), and ipsilateral bending at the top of ala and the bottom of joint ($p<0.01$). There are also significant differences between the direction of displacement (angle) between sexes at the top of ala in ipsi- and contra-axial and ipsi- and contra-lateral bending ($p<0.04$), at the bottom of ala in nutation ($p=0.038$), and at the bottom of the joint in all loading directions but nutation ($p<0.05$). The bottom of the joint consistently displayed the most amount of displacement during all bending loads in male joints (significant in extension and ipsilateral bending ($p<0.02$)). The most displaced locations were not as consistent in female joints, with the bottom of the joint being predominantly displaced only during ipsi-axial rotation ($p<0.04$). Female joints also displayed significantly more normal-axis displacement than male joints during full-range axial rotation and lateral bending at the top and bottom of ala ($p<0.05$) and in ipsi-axial rotation and counternutation in the same locations ($p<0.03$) (Fig. 2). Asymmetries are noted between loading pairs in both magnitude ($p<0.001$) and direction ($p<0.02$) in all locations, in both male and female joints, and under all loads except the top of ala, in male joints, during lateral bending.

DISCUSSION: This study shows that female joints exhibit global in-plane superior and posterior displacements during counternutation and ipsi-axial rotations respectively, while the male joint exhibits global in-plane inferior displacements during ipsi-lateral bending. It also indicates the compressive loads and regions of the joint. Normal-axis displacements of counternutation and contra-axial rotation in male joints, and of contra-axial rotation and contralateral bending in female joints, consistently compress the joint at varying regions. In female joints, the bottom of ala was the least displaced in both in-plane and compressive normal-axis displacements (Fig. 3), as was hypothesized, meaning that the highest joint surface and ligament stresses occur at this location. The bottom of the joint exhibited the most in-plane displacements, as was also hypothesized, albeit more consistently in male than female joints.

SIGNIFICANCE/CLINICAL RELEVANCE: Our findings suggest that when pain is present during axial rotation and ipsilateral bending in female sacroiliac joints, SIJ diagnostic injections should target the bottom of ala and if pain occurs during counternutation, ipsilateral bending, and ipsi-axial rotation, fixation devices would be most effective at the bottom of the joint. However, reliably effective fixation at a singular location may not be attainable in female joints.

IMAGES AND TABLES:

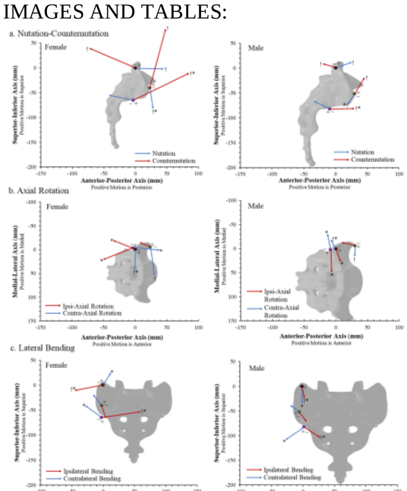

**Figure 1.** Resultant in-plane displacement at three points: top of ala, bottom of ala, and bottom of joint during (a) nutation-counternutation, (b) axial rotation, and (c) lateral bending. The ! and * represent significant differences in magnitude and direction between sexes. The ~ and the + represent significant differences in magnitude and direction between locations of the joint

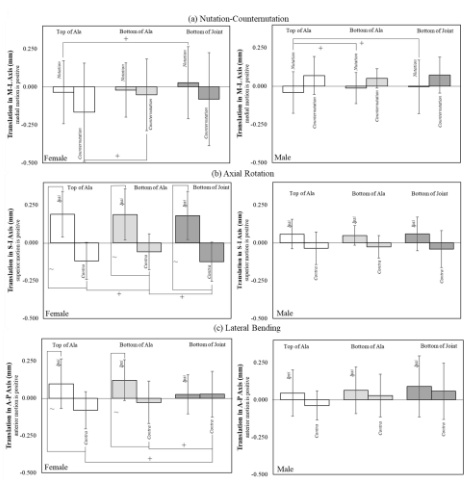

**Figure 2.** Comparison of motion along the axis normal to in-plane motion at three points: top of ala, bottom of ala, and bottom of joint individual motions for (a) nutation-counternutation, (b) axial rotation, (c) lateral bending for female joints (column 1) and male joints (column 2). The ! indicates a significant difference between sexes, the + represents a significant difference between locations of the joint, and the ~ represents a significant difference between loading directions

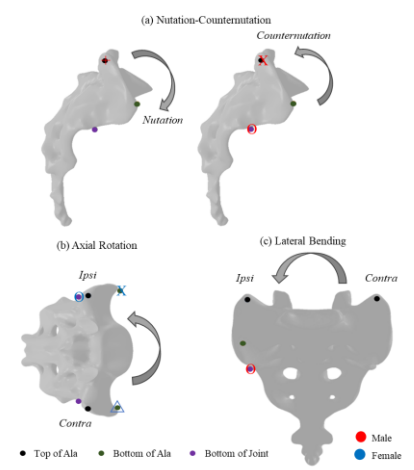


**Figure 3.** Locations of highest stress concentration and greatest motion between locations for (a) nutation-counternutation, (b) axial rotation, (c) lateral bending. The **X** and **O** indicate the location of highest stress and greatest motion for in-plane motion. The ▲ and the + indicate the location of highest stress concentration and greatest motion along the normal axis.