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Clinical studies

Effect of sacroiliac fusion on gait, standing balance, and pelvic mobility for unilateral sacroiliac joint dysfunction

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ABSTRACT

Background: Sacroiliac joint fusion (SIF) has been shown to effectively alleviate pain and improve functional deficits associated with sacroiliac joint dysfunction (SIJD). Previous studies have demonstrated significant improvements in gait function, however, none have reported both over-ground walking and quiescent standing, and additionally, none have included analysis of pelvic kinematics which may contain important information regarding pain avoidant compensatory behaviors. The purpose of this study was to identify objective functional differences between symptomatic and asymptomatic sides of unilateral sacroiliac joint dysfunction (SIJD) patients and to demonstrate the effectiveness of unilateral sacroiliac fusion (SIF) to improve gait and balance function compared to matched controls.

Methods: Thirteen unilateral SIJD patients were evaluated before and 6 months after SIF and were compared to matched asymptomatic controls. Pain and disability were assessed using visual analog scales and the Oswestry disability index respectively. Over ground walking and standing balance were assessed using 3D joint kinematics and kinetic ground reaction force analyses.

Results: Preoperatively, SIJD patients reported high levels of pain and disability and exhibited significant deficits in gait including elevated step width, reduced hip flexion/extension, and elevated pelvic motion as well as elevated center of pressure sway characteristics during standing. After unilateral SIF, patients reported significant reductions in pain and demonstrated significant improvements in gait including normalization of step width between sides and improved hip motion however elevated pelvic obliquity and rotation motion remained. Improvements in standing balance included reduced coronal sway characteristics and normalization of loading symmetry between sides.

Conclusion: Unilateral SIF resulted in significant improvements in both gait and balance function among SIJD patients to levels comparable to matched controls, however elevated pelvic motion remained. These findings help inform surgeons on the effectiveness of SIF for unilateral SIJD and provide important information regarding interpretation of functional outcomes.

Background

Sacroiliac joint dysfunction (SIJD) has been reported to account for 15% to 30% of all low back pain (LBP) cases, which is a leading cause of disability worldwide [1–3]. The impact of SIJD on health-related quality of life is comparable to hip osteoarthritis and severe chronic obstructive pulmonary disease [4]. SIJD is also associated with high proportions of missed work due to chronic pain [5]. Diagnosis of SIJD is a challenging process that lacks standardization but often includes prior medical history, physical exams, provocation tests and confirmatory diagnostic injections [1,2,6–8]. These challenges are related to the complex anatomy of the joint and the nature of the pain that can mimic several other low back and leg pathologies [1,2]. Sacroiliac joint dysfunction is derived from intra- and extra-articular sources, including arthritis and infection or fractures and ligament injury, respectively [9]. SIJD occurs both unilaterally and bilaterally and is associated with a number of risk factors, including older age, leg-length discrepancies, sacroiliac morphology, scoliosis, and previous spinal fusion [9–11].

Sacroiliac fusion (SIF) is a common treatment for SIJD and is associated with significant improvements in pain and function when compared

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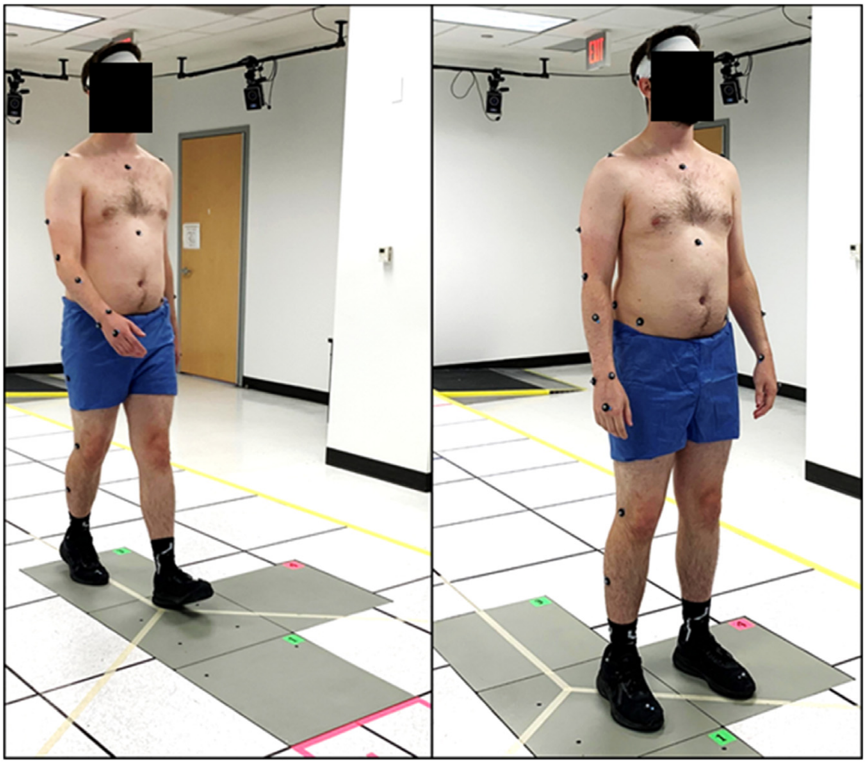

Fig. 1. Example of a participant fitted with reflective markers for 3-dimensional motion tracking and arrangement of force plates for kinetic ground reaction force data for both walking (left) and standing (right) tasks.

to conservative treatment [5,12,13]. The goal of SIF is to stabilize the SIJ and reduce pain driven by motion of the joint [2,12]. SIF can be performed both unilaterally and bilaterally; however, it is most commonly done unilaterally. Previous studies have demonstrated biomechanical differences between unilateral and bilateral SIF, which are suggested to be important factors associated with resulting function of the SIJ [10].

Decreased physical function in activities of daily life (ADL) is a key factor in disability associated with SIJD [14,15]. Gait deficits are recognized as an important factor to consider in the diagnosis of SIJD [7]. Previous studies have demonstrated functional deficits among SIJD patients, however, there is a lack of comprehensive assessments describing both over-ground walking and quiescent standing before and after unilateral SIF [14,16,17]. Additionally, no studies have described pelvis kinematics during over-ground walking, which may better reveal SIJD compensation strategies and impacts of SIF. Improved understanding of functional deficits among unilateral SIJD patients who undergo unilateral SIF may provide surgeons with important information regarding treatment strategies and functional outcomes.

Therefore, the purpose of this study was 3-fold: (1) to elucidate differences in objective gait and balance measures between symptomatic and asymptomatic sides among unilateral SIJD patients, (2) to assess 6-month functional outcomes following unilateral SIF, and (3) to compare SIJD patient functional measures to matched controls at each evaluation.

Methods

This was a prospective, concurrent cohort study of unilateral SIF surgery patients and matched asymptomatic controls at a single institution with a predefined enrollment period of 3 years, from 2020 to 2023. The study was approved by our institutional review board, and informed consent was obtained for all participants prior to starting study procedures. SIJD diagnostic assessments were based on standardized methods for indicating SI derived pain that included a 5-item physical provocation test and the Fortin finger test [2]. In addition to SIJD diagnosis, patients were required to have a minimum of 6 months of failed conservative care, positive response to local SIJ anesthetic injections, and an Oswestry disability index (ODI) score of 30 or greater. Additionally, patients were required to be able to perform the study tasks without assistance and planned to be available for a 6-month post-operative follow-up evaluation. Study exclusion criteria were concurrent back, hip, or leg pain not associated with SIJD, prior lumbosacral or SIJ instrumentation, recent pelvic trauma, metabolic bone diseases, osteoporosis, rheumatoid arthritis, or planning to become pregnant within the 6-month study period.

Testing procedures

SIJD patients were evaluated within one week prior to surgery and 6-months postoperatively. Asymptomatic volunteers, who were intended to be representative of the general adult population, were evaluated a single time. Patients completed self-reported measures, including the ODI, to indicate disability and visual analog scales (VAS) to assess low back and leg pain severity. Functional testing involved standard methods used in our laboratory, which have been described previously [18,19]. Demographic information, including height, weight, anthropomorphic measurements, and pathological side among SIJD patients, was collected. Prior to testing, patients were fitted with a full-body Plug-In Gait reflective marker set by trained lab staff [20]. Participants were then instructed on 2 functional tasks and were asked to complete a minimum of 3 trials of each: 1) a 10 m over-ground walking test at a comfortable, participant-selected speed, and 2) a 60 s standing test with the participant's eyes open and arms down at their sides. During each task, 3-dimensional kinematic motion data was recorded by a Vicon motion tracking system (Vicon, Oxford, UK), and kinetic ground-reaction force data was recorded by in-ground AMTI force plates (Advanced Mechanical Testing Inc, Watertown, MA, USA). Analyses were done using Vicon Nexus and Matlab (The Math Works, Natick, MA, USA). Fig. 1 shows the

Table 1
Demographics of study participants including sacroiliac joint dysfunction (SIJD) and matched asymptomatic controls.

Variable	SIJD	Controls	p-value
Gender	2M, 11F	2M, 11F	
Age (yr)	47.9+13.2	48.3±13.3	.468
Height (m)	1.7+0.1	1.7±0.1	.445
Weight (kg)	86.9+19	74.5±16.1	.010*
Body mass index (kg/m^2)	30.2+4.6	26.5±3.3	.007*
SIJD/fusion side	8R, 5L		
SIJD etiology	Degenerative sacroiliitis: 61.5% (8/13) Sacroiliac joint disruption: 38.5% (5/13) 5 trauma 0 Postpartum		
Prior rhizotomy	100% (13/13)		
Prior surgery	53.8% (7/13) 4 lumbar decompressions 2 lumbar anterior interbody fusions 1 lumbar disc replacement 1 total hip arthroplasty		

SIJD = sacroiliac joint dysfunction, SIF = sacroiliac joint fusion.
Age, height, weight, and body mass index reported as means ± one standard deviation.
* Indicates significance at p<.05.

placement of motion-tracking markers and the test equipment arrangement.

Outcome measures

Gait measures from kinematic data included spatiotemporal parameters and joint range-of-motion (ROM) for all major joints of both legs and the pelvis. The gait deviation index (GDI) was included as a summary measure for overall gait quality of each leg [21,22]. Kinetic ground reaction force (GRF) data during gait included medial, lateral, heel deceleration, toe-off acceleration, and vertical peak forces for each leg. Additionally, the ratio of peak vertical GRF of the symptomatic to asymptomatic side was computed. Balance measures assessed dynamic characteristics of the center of pressure (COP) from kinetic data and included range and velocity of sway in the coronal and sagittal planes, total sway distance, and integrated symptomatic to asymptomatic vertical GRF ratio [23–25].

Analyses

Preoperatively, SIJD patient gait measures were compared between symptomatic and asymptomatic sides and to side-averaged controls. Pelvic ROM of SIJD patients was assessed on both symptomatic and asymptomatic gait cycles of each side, respectively, and side-averaged gait cycles of controls. Postoperatively, SIJD patient gait measures of the treated side were compared to preoperative values and to side-averaged control data. Balance measures of SIJD patients were compared to controls at each evaluation and between preoperative to postoperative evaluations.

Statistical methods

Descriptive summaries of patient demographics, clinical assessments, and functional outcome measures were done using counts, averages, and standard deviations. Assessments for normality of continuous outcome measures were done using Shapiro-Wilk tests. Statistical comparisons of continuous outcomes were assessed using either paired t-tests or paired Wilcoxon ranked-sum tests where appropriate. Statistical analyses were done using Excel (Microsoft, Redmond, WA, USA) and R (R Foundation for Statistical Computing, Vienna, AT) with significance set at α=0.05.

Results

Among 16 SIJD patients who were enrolled in the study, 3 were lost to follow-up resulting in a total of 13 SIJD patients and 13 matched controls. Participant demographics are summarized in Table 1. SIJD patients were significantly heavier and had a higher BMI than the controls (both p<.050) but were otherwise comparable.

Table 2
Patient-reported outcome measure comparisons before (pre) and 6-months after (P6m) sacroiliac fusion.

PROM	Pre	Post 6m	p value
VAS low back	6.0±2.2	3.4±2.2	.005*
VAS leg	4.0±2.8	1.8±2.1	.036*
ODI	48.1±17.3	38.7±17.9	.186

VAS = visual analog scale, ODI = Oswestry disability index.
* Indicates significance at p<.05.

Table 2 summarizes SIJD patient-reported pain and disability. SIJD patients reported significant postoperative improvements in both VAS low back and leg pain (p=.005 and .036, respectively). While not significant, SIJD patients reported a mean improvement of ten points in their ODI score.

Table 3 summarizes spatiotemporal gait measures for SIJD patients and matched controls. Preoperatively, step width of the symptomatic side was significantly lower (p=.044) than the asymptomatic side, and no significant differences were noted between symptomatic or asymptomatic sides to controls (all p>.050). Significant postoperative improvements of SIJD patients' treated side included cadence (p=.022), walking speed (p=.035), stride time (p=.015), double support time (p=.005), and step width (p=.012). SIJD patient measures of the symptomatic side were not significantly different from controls at either evaluation (all p>.05). Postoperatively, there were no significant differences between treated and nontreated sides (all p>.050). There was a significant difference between nontreated to control subject's step length postoperatively (p=.032).

Table 4 summarizes joint ROM measures for SIJD patients and matched controls. Preoperatively, symptomatic hip flexion+extension was significantly lower than the asymptomatic side (p=.030), and both symptomatic pelvic obliquity and rotation were significantly greater than the asymptomatic side (p=.004 and .001, respectively). Compared to controls preoperatively, SIJD patients exhibited significantly larger pelvic retroversion+anteversion for both symptomatic and asymptomatic sides (p=.015 and .016 respectively). Significant preoperative to postoperative differences of SIJD patients' symptomatic side included hip flexion+extension (p=.02), hip abduction+adduction (p=.005), and hip rotation (p=.021). Both preoperative (p=.015) and postoperative (p=.005) SIJD patient pelvic retroversion+anteversion were significantly greater than controls. Postoperatively, treated side

Table 3
Spatiotemporal gait measures for sacroiliac joint dysfunction (SIJD) patients and matched asymptomatic controls.

Variable	Symptomatic	Asymptomatic	Controls	Sym-Asym p	C-Sym p	C-Asym p
Pre						
Cadence (step/min)	102.0±11.3	101.3±11.5	107.2±12.6	0.274	0.226	0.176
Walking speed (m/s)	0.94±0.10	0.95±0.10	0.98±0.13	0.543	0.412	0.517
Stride time (s)	1.19±0.14	1.20±0.15	1.14±0.13	0.224	0.253	0.196
Step time (s)	0.60±0.07	0.61±0.09	0.57±0.07	0.442	0.225	0.181
Single support time (s)	0.40±0.06	0.40±0.05	0.40±0.05	0.807	0.873	0.996
Double support time (s)	0.39±0.06	0.39±0.06	0.34±0.07	0.790	0.065	0.065
Stride length (m)	1.11±0.04	1.12±0.06	1.09±0.06	0.408	0.378	0.238
Step length (m)	0.56±0.03	0.58±0.05	0.54±0.03	0.588	0.114	0.089
Step width (m)	0.145±0.032	0.151±0.03	0.136±0.054	0.044*	0.617	0.407
Step height (m)	0.149±0.108	0.150±0.122	0.146±0.015	0.803	0.599	0.550
P6m						
Cadence (step/min)	106.2±11.1†	106.1±11.3		0.824	0.804	0.779
Walking speed (m/s)	0.99±0.11†	1.00±0.11		0.368	0.818	0.553
Stride time (s)	1.14±0.13†	1.15±0.14		0.685	0.871	0.836
Step time (s)	0.58±0.06	0.58±0.07		0.946	0.718	0.709
Single support time (s)	0.38±0.04	0.39±0.04		0.305	0.308	0.439
Double support time (s)	0.37±0.07†	0.36±0.07		0.329	0.332	0.391
Stride length (m)	1.11±0.05	1.14±0.06		0.398	0.306	0.111
Step length (m)	0.57±0.04	0.59±0.05		0.528	0.085	0.032*
Step width (m)	0.122±0.029†	0.120±0.029		0.458	0.276	0.160
Step height (m)	0.151±0.125	0.154±0.109		0.258	0.312	0.138

Sym = symptomatic, Asym = asymptomatic, C = controls.
Evaluations of SIJD patients include preoperative (Pre) and 6-months postoperatively (P6m). Values are reported as means ± one standard deviation.
* Indicates a significance difference between symptomatic and asymptomatic sides or to C at p<.05.
† Indicates significant Pre to P6m change in the symptomatic side of SIJD patients at p<.05.

Table 4
Gait joint range-of-motion (ROM, °) measures for sacroiliac joint dysfunction (SIJD) patients and matched asymptomatic controls.

Variable	Symptomatic	Asymptomatic	Controls	Sym-Asym p	C-Sym p	C-Asym p
Pre						
Ankle						
Dorsiflexion+Plantarflexion	29.3±7.6	30.6±7.1	27.0±6.6	0.357	0.427	0.188
Eversion+Inversion	9.1±4.5	9.3±4.4	7.4±3.0	0.704	0.120	0.062
Rotation	30.1±12.1	29.6±13.0	27.5±7.1	0.806	0.368	0.494
Knee						
Flexion+Extension	48.4±10.0	47.2±13.8	54.5±7.6	0.455	0.064	0.078
Varus+Valgus	22.7 ±11.2	26.0±15.6	22.3±8.5	0.329	0.917	0.451
Rotation	17.3±7.1	15.4±4.7	14.9±4.2	0.244	0.218	0.649
Hip						
Flexion+Extension	37.9±2.8	39.4±3.2	38.3±4.7	0.030*	0.790	0.384
Abduction+Adduction	10.1±1.9	10.5±1.9	11.8±2.0	0.394	0.072	0.116
Rotation	36.0±20.6	36.2±21.1	33.7±16.6	0.948	0.712	0.645
Pelvis						
Retroversion+Anteversion	3.9±1.1	3.8±0.8	3.2±1.1	0.376	0.015*	0.016*
Obliquity	6.8±1.9	6.2±1.8	6.5±2.1	0.004*	0.748	0.724
Rotation	8.1±2.7	7.2±3.1	9.1±4.3	0.001*	0.294	0.070
Gait deviation index	93.2±11.1	89.6±10.6	95.1±9.5	0.387	0.568	0.227
P6m						
Ankle						
Dorsiflexion+Plantarflexion	30.9±8.0	30.3±4.6		0.751	0.233	0.119
Eversion+Inversion	11.6±7.0	11.1±5.4		0.710	0.053	0.013*
Rotation	36.9±17.4	36.5±16.0		0.886	0.078	0.054
Knee						
Flexion+Extension	48.0±11.0	43.7±13.5		0.040*	0.103	0.029*
Varus+Valgus	25.7±13.6	32.1±14.9		0.086	0.421	0.056
Rotation	18.4±7.7	18.2±5.9		0.833	0.128	0.089
Hip						
Flexion+Extension	40.4±2.9†	40.3±3.2		0.984	0.083	0.091
Abduction+Adduction	11.9±2.3†	12.6±2.5		0.212	0.920	0.364
Rotation	48.8±24.4†	48.6±22.3		0.950	0.059	0.073
Pelvis						
Retroversion+Anteversion	4.0±1.0	3.8±1.0		0.229	0.005*	0.008*
Obliquity	7.1±2.2	6.3±1.8		0.004*	0.523	0.856
Rotation	6.9±1.9	5.9±1.6		0.001*	0.095	0.025*
Gait deviation index	92.7±8.5	93.2±7.1		0.871	0.495	0.619

Sym = Symptomatic; Asym = Asymptomatic; C = Controls.
Evaluations of SIJD patients include preoperative (Pre) and 6-months postoperatively (P6m). Values are reported as means ± one standard deviation.
* Indicates a significance difference between symptomatic and asymptomatic sides or to C at p<.05.
† Indicates significant Pre to P6m change in the symptomatic side of SIJD patients at p<.05.

Table 5
Gait ground reaction force (GRF, % body weight) measures for sacroiliac joint dysfunction (SIJD) patients and matched asymptomatic controls.

Variable	Symptomatic	Asymptomatic	Controls	Sym-Asym p	C-Sym p	C-Asym p
Pre						
Medial	2.1±1.0	2.6±1.4	3.4±1.7	0.153	0.024*	0.171
Lateral	6.0±1.0	5.9±1.1	5.7±1.6	0.659	0.541	0.667
Deceleration	11.2±1.6	11.6±2.2	11.8±2.7	0.396	0.429	0.843
Acceleration	14.3±2.6	13.8±2.7	14.1±2.4	0.659	0.816	0.695
Vertical	103.1±4.3	104.5±2.9	105.8±4.1	0.319	0.050*	0.332
P6m						
Medial	2.6±1.3	2.8±1.2		0.349	0.175	0.249
Lateral	5.6±1.4	5.4±1.1		0.379	0.873	0.426
Deceleration	11.5±2.4	11.5±2.7		0.928	0.777	0.800
Acceleration	14.3±2.7	14.9±1.9		0.276	0.842	0.253
Vertical	102.9±3.4	104.0±2.9		0.157	0.053	0.162

Sym = symptomatic, Asym = asymptomatic, C: controls.
Evaluations of SIJD patients include preoperative (Pre) and 6-months postoperatively (P6m). Values are reported as means ± one standard deviation.
* Indicates significance at p<.05.

Table 6
Gait ground reaction force (GRF) ratio (%) of sacroiliac joint dysfunction (SIJD) patient's symptomatic and asymptomatic sides before (Pre) and 6 months after (P6m) surgery.

Variable	Pre	P6m	Controls	Pre-P6m p	C-Pre p	C-P6m p
Medial	89.9±47.6	92.0±31.0	90.8±30.1	0.863	0.966	0.933
Lateral	103.3±14.8	10.5±19.0	93.6±17.9	0.704	0.147	0.104
Deceleration	98.1±13.9	102.3±22.5	87.3±19.9	0.505	0.180	0.097
Acceleration	109.8±46.6	95.9±12.1	111.9±10.7	0.283	0.868	0.004*
Vertical	98.7±4.7	98.9±2.6	101.0±2.9	0.903	0.162	0.065

C = controls.
Matched asymptomatic control data is the ratio of right to left sides. Values are reported as means ± one standard deviation.
* Indicates significance at p<.05.

Table 7
Center of pressure (COP) sway measures for sacroiliac joint dysfunction (SIJD) patients and matched asymptomatic controls.

Variable	Pre	P6m	Controls	Pre-P6m p	C-Pre p	C-P6m p
Coronal ROS (mm)	34.2±18.4	17.3±6.4	13.9±6.7	0.004*	0.005*	0.345
Sagittal ROS (mm)	55.3±25.2	41.5±15.3	32.1±13.0	0.065	0.023*	0.225
Total sway distance (mm)	1008.0±472.5	644.7±201.1	565.6±207.0	0.013*	0.015*	0.339
Coronal velocity (mm/s)	8.9±5.0	4.5±1.6	4.3±1.7	0.004*	0.008*	0.902
Sagittal velocity (mm/s)	12.11±5.35	8.8±2.7	7.4±2.8	0.049*	0.029*	0.161

C = controls, ROS = range of sway.
Evaluations of SIJD patients include preoperative (Pre) and 6-months postoperatively (P6m). Values are reported as means ± one standard deviation.
* Indicates significance at p<.05.

knee flexion+extension was significantly larger than the nontreated side (p=.040), and both treated side pelvic obliquity and rotation were significantly larger than the nontreated side (p=.004 and .001, respectively). Compared to controls postoperatively, both treated and nontreated side pelvic retroversion+anteversion of SIJD patients were significantly greater (p=.005 and .008, respectively). Additionally, SIJD patient's postoperative nontreated side ankle eversion+inversion was significantly greater (p=.013), asymptomatic knee flexion+extension was significantly greater (p=.029), and pelvic rotation was significantly lower (p=.025).

Table 5 summarizes gait GRF measures for SIJD patients and matched controls. Preoperatively, SIJD patients indicated no significant differences between symptomatic and asymptomatic sides (all p>.050), however, they did show a significantly lower symptomatic medial GRF (p=.024) and a marginally lower symptomatic vertical GRF (p=.050) compared to controls. Postoperatively, no significant differences were found between SIJD patient sides or compared to controls; although, there was a marginal difference in the treated vertical GRF to controls (p=.053).

Table 6 provides a summary of symptomatic to asymptomatic GRF ratios of SIJD patients and right to left GRF ratios of controls during gait. No significant differences were observed from preoperative to postoperative changes for SIJD patients. SIJD patient toe-off acceleration GRF was significantly lower than controls postoperatively (p=.004).

Table 7 summarizes balance COP measures of SIJD patients and matched controls. SIJD patients showed significant preoperative to postoperative improvements in all balance measures (all p<.050), except for sagittal range of sway (p=.065). Preoperatively, SIJD patients' balance measures were all significantly worse (all p<.050) compared to controls. Postoperative SIJD patients showed resolution of balance issues with no significant differences to controls (all p>.050). Fig. 2 shows a representative example of COP sway behavior from a SIJD patient before and after SIF.

The proportion of integrated vertical GRF of the symptomatic to asymptomatic side during standing was significantly different from 88.0%±17.2% preoperatively to 95.3%±13.7% postoperatively (p=.038) among SIJD patients. Relative to controls, there were no significant differences in integrated vertical GRF at either time point.

Discussion

This study sought to investigate changes in objective functional outcome measures of unilateral SIJD patients between the symptomatic

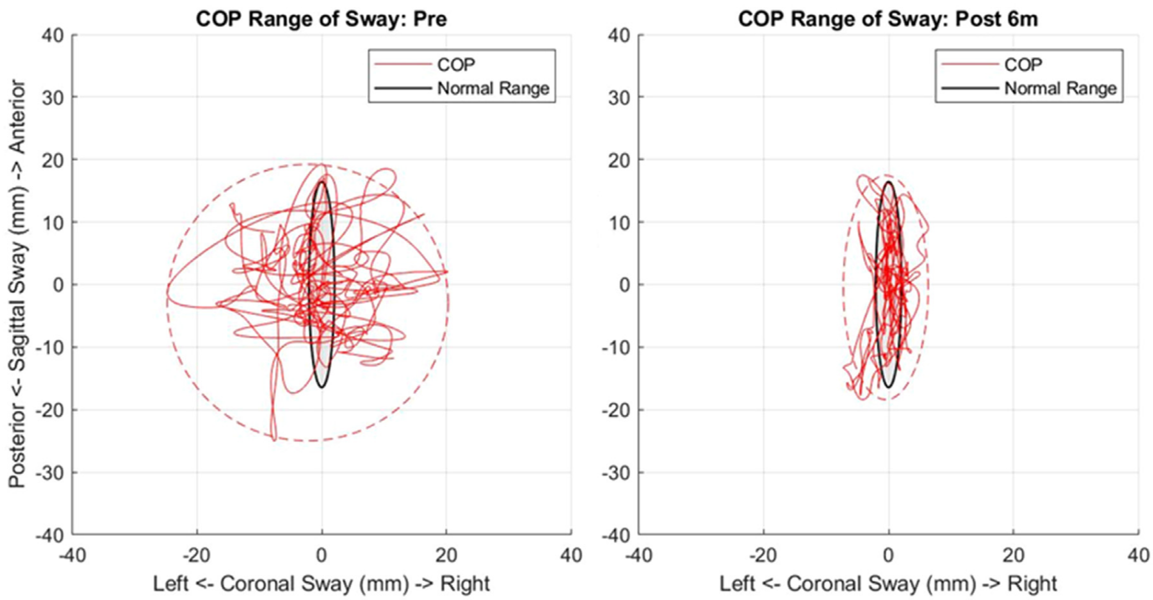

Fig. 2. Representative center of pressure (COP) sway behavior during 60 s standing tests of a single right-sided sacroiliac joint dysfunction (SIJD) patient before (Pre, left) and after (Post 6 m, right) unilateral sacroiliac joint fusion.

and asymptomatic sides, as well as to asymptomatic controls, before and after unilateral SIF. Preoperatively, SIJD patients reported elevated pain and disability. Concurrently, they exhibited significant functional deficits associated with their symptomatic side in both gait and standing balance. Following SIF, SIJD patients demonstrated significant improvements in pain, functional gait, and balance. A 10-point mean improvement in ODI score indicated a clinically relevant improvement in disability, however, this was not statistically significant. This may be due to the limited sample size or the timing of the follow-up evaluation. The functional improvements observed in this study corroborate previous functional outcomes and improve the pool of information by including standing balance [14–17].

The gait deficits observed in our study were similar to a study by Lodin et al. [17], which included ten bilateral SIJD patients. This study found significant deficits in spatiotemporal performance, hip ROM, and gait profile scores (GPS), which is a summary measure similar to the GDI. A key difference, however, was Lodin reporting fewer differences in coronal measures, including step width and hip abduction/adduction ROM compared to our findings. These discrepancies may be due to differences in compensation strategies of bilateral versus unilateral pathologies, as well as low sample sizes in both studies. In our study, we did not see a significant difference in GDI, even in the presence of individual significant differences in leg ROM. These results suggest that the GPS might be a more suitable measure for assessing SIJD-related deficits.

Feeney et al. [26] investigated 6 unilateral SIJD patients and reported significant reductions in symptomatic side loading during gait. However, their testing was done on a treadmill, which is recognized to increase GRF. In the present study, lower differences were observed in peak vertical GRF (~12N/2%BW), which was not significant between sides (p=.392/.319 respectively) and also a lower difference in hip flexion+extension ROM (~2°), which was significant between sides (p=.030). These differences in findings emphasize the importance of considering evaluation method when assessing SIJD patient function. Furthermore, comprehensive assessments, including additional tasks, reduces this bias and provides a stronger overall evaluation.

Preoperatively, SIJD patients demonstrated significant increases in pelvic obliquity and significant decreases in pelvic rotation between symptomatic to asymptomatic gait cycles during over-ground walking. Additionally, elevated pelvic retroversion+anteversion was noted relative to controls. Postoperatively, the differences between sides and to controls remained. Preoperatively, exaggerated medial-lateral shifts with minimized rotation may indicate pain avoidance while the symptomatic side is cyclically loaded and unloaded between gait cycles. Postoperatively, it is plausible to expect this behavior to reduce with the negation of SIJ related pain. However, the presence of SIF confounds interpretability. Similar to lumbosacral fusion, reduced motion between regions is expected. Our findings indicated a consistent mean increase of ~0.8° of pelvic retroversion+anteversion relative to controls. Therefore, the lack of normalization in pelvic motion following negation of pain via fixation of the sacrum and ilium should perhaps be expected as well. Interpretations of this finding are limited by the lack of sensitivity of skin-level marker motion tracking to adequately measure relative sacrum and ilium motion.

During standing, symptomatic SIJD patients exhibited significantly elevated COP sway characteristics compared to controls. Additionally, these patients showed a significant offset of their integrated vertical GRF favoring their asymptomatic side. Hermans et al. [16] investigated ten postpartum SIJD patients and noted elevated coronal COP sway during single-leg stance (SLS), which suggests that the more challenging SLS test may not be necessary to observe balance deficits. Hermans did not differentiate between the symptomatic and asymptomatic side, however, limiting inferences that can be made between the test types. In the present study, the significant difference in coronal sway was found to be reduced to ranges comparable with matched controls after SIF. Postural balance in the coronal and sagittal directions are known to be independent, and in this study, the strong change in coronal sway is likely indicative of successful SIJ stabilization, which reduces pain and the need for exaggerated coronal hip loading behavior [27]. Based on the significant effects that SIJD and subsequent SIF had on balance behavior, we feel that functional balance testing should be considered relevant to this patient population and that it provides a useful alternative to gait-only assessments that can require more space and equipment to conduct.

This study poses several limitations that are important to note. The low number of SIJD patients limited the targeted statistical power and, as such, interpretations of findings should be done so with caution. This study only included unilateral SIJD patients, which may limit comparability to bilateral patients. SIJD patients were significantly heavier than controls, which may have an effect on baseline SIJ loading between groups. Several SIJD patients reported varying degrees of pain during testing, which may have affected their performance across trials and test types. This may be an important consideration for development of functional testing protocols that minimize required physical exertion, such as quiescent standing instead of SLS. Additionally, accuracy errors in motion tracking marker placement and position calculations may affect the kinematic data. It is also important to recognize that the testing was done in a controlled environment, which may not fully indicate physical activity in ADL.

Conclusions

Symptomatic unilateral SIJD patients exhibited significant functional deficits associated with their symptomatic side in both overground walking and quiescent standing. Six months after unilateral SIF, patients demonstrated significant improvements in both gait and balance measures. However, there was not complete normalization of all functional measures relative to matched controls. A lack of change in elevated pelvic kinematics may be due to the confounding nature of discerning functional differences between pain avoidant compensation preoperatively and SIJ fusion. These findings support the use of unilateral SIF to treat SIJD and suggest that further research on nuanced SIJ dynamics is necessary to better understand the impact of SIF on daily function and long-term outcomes.

Declaration of Competing Interest

One or more authors declare potential competing financial interests or personal relationships as specified on required ICMJE-NASSJ Disclosure Forms.

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