



# Changes in health-related quality of life measures associated with degree of proximal junctional kyphosis

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## Abstract

**Purpose** To explore the changes in health-related quality of life parameters observed in patients experiencing varying degrees of proximal junctional kyphosis following corrective adult spinal deformity fusions.

**Methods** Inclusion: adult spinal deformity patients > 18 y/o, undergoing spinal fusion. PJK:  $\geq 10^\circ$  measure of the sagittal Cobb angle between the inferior endplate of the UIV and the superior endplate of the UIV + 2. Severe PJK:  $> 28^\circ$  PJK. Mild PJK:  $\geq 10^\circ$  and  $\leq 28^\circ$ . ANOVA, followed by ANCOVA, compared the change in HRQoLs between time points (BL, 1Y, 2Y) among PJK groups. Correlation-related change in PJK and change in HRQoL for mild and severe groups.

**Results** 969 patients (age: 64.5 y/o, 75% F, posterior levels fused: 12.3) were studied. 59% no PJK, 32% mild PJK, 9% severe PJK. No differences in HRQoLs were seen between no PJK and PJK groups at baseline, one year, and 2 years. Adjusted analysis revealed Severe PJK patients improved less in SRS-22 Satisfaction (NoPJK: 1.6, MildPJK: 1.6, SeverePJK: 1.0;  $p = 0.022$ ) scores at 2 years. Linear regression analysis only found clinical improvement in SRS-22 Satisfaction to correlate with the change of the PJK angle by 2 years ( $R = 0.176$ ,  $P = 0.008$ ). No other HRQoL metric correlated with either the incidence of PJK or the change in the PJK angle by one or 2 years.

**Conclusions** These results maintain that patients presenting with and without proximal junctional kyphosis report similar health-related qualities of life following corrective adult spinal deformity surgery, and SRS-22 Satisfaction may be a clinical correlate to the degree of PJK. Rather than proving proximal junctional kyphosis to have a minimal clinical impact overall on HRQoL metrics, these data suggest that future analysis of this phenomenon requires different assessments.

**Level of evidence** Level of evidence: III.

**Keywords** Proximal junctional kyphosis · Adult spinal deformity · HRQoL · Oswestry Disability Index · SF-36 · SRS-22

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## Introduction

Proximal junctional kyphosis (PJK) is a post-operative phenomenon that has been defined radiographically as a greater than  $10^\circ$  change in the kyphosis angle between the inferior endplate of the uppermost-instrumented vertebra (UIV) and the superior endplate of the vertebra positioned two vertebral bodies above the UIV [1, 2]. In the setting of adult spinal deformity (ASD), the reported prevalence of PJK ranges from 10%–41% [2–6], and associated risk factors include pre-existing low bone mineral density, older age, increased change in the sagittal vertical axis, and fusion to the sacrum [3, 7, 8]. Revision is often pursued based on the presence of patient pain and disability [1], thus a greater understanding of how patient-reported outcome metrics reflect this complication is highly relevant.

Previous research comparing the health-related quality of life data (HRQoL) in patients experiencing PJK and those without this complication has shown little difference between the Oswestry Disability Index (ODI) and Scoliosis Research Society (SRS) scores of these populations [1, 2, 7, 9]. These findings bring into question the clinical impact of this occurrence [10] and suggests that our current radiographic PJK threshold requires reconsideration. Additionally, the patient-reported outcome metrics typically utilized in the setting of ASD may be inadequate in capturing the full experience of individuals presenting with proximal junctional kyphosis, however, more research is needed to validate these hypotheses. Therefore, we stratified patients by severity of proximal junctional kyphosis to explore differences in the patient experiences of these groups.

This highly inclusive quality of life analysis expands upon current research by exploring how incremental increases in PJK (no PJK; mild PJK:  $\geq 10^\circ$  and  $\leq 28^\circ$ ; severe PJK:  $> 28^\circ$  [3, 11, 12]) affect patient performance on commonly utilized ASD HRQoL assessments (ODI, SRS-22 domains, and Short Form-36 component scores and domains). By analyzing different severities of proximal junctional kyphosis and determining which HRQoL metrics most successfully capture this complication, we can effectively understand the patient experience associated with PJK and eventually utilize patient-reported outcome metrics in decision-making for surgical revision.

## Methods

### Patient population and data collection

This study was a retrospective review of a multi-center database including ASD patients consecutively enrolled from 2008–2018. Institutional Review Board (IRB) approval was

obtained prior to study enrollment at each of the 14 participating sites and informed patient consent was acquired prior to enrollment, as well. Patients undergoing spinal fusion for ASD were included in this analysis with full baseline and two-year data. Inclusion criteria for this database included the following: patients  $\geq 18$  years of age seeking treatment, operative or otherwise, for ASD. Radiographic parameters used to define adult spinal deformity in this database were coronal Cobb angle  $\geq 20^\circ$ , sagittal vertical axis  $\geq 5$  cm, pelvic tilt  $\geq 25^\circ$ , and/or thoracic kyphosis  $> 60^\circ$ . Patients with spinal deformity of neuromuscular etiology, and those experiencing active infection or malignancy were excluded from this database.

Descriptive variables collected for study consisted of demographic data (age, sex, body mass index (BMI), Charlson Comorbidity Index (CCI), and race) as well as surgical variables (approach, levels fused, osteotomy use). Pelvic incidence, as measured radiographically, was collected and utilized in propensity score matching (PSM) as a control for baseline deformity.

Outcome measures in this study consisted of health-related quality of life (HRQoL) data. The following HRQoL metrics were included in the study: Oswestry disability index (ODI), Scoliosis Research Society-22 outcomes questionnaire (SRS) total score and individual component scores (activity, pain, appearance, mental, satisfaction), physical component score (PCS), and Short Form-36 physical function health survey. The mental component score (MCS) and SF-36 mental health assessment were also included for analysis because of previous research showing significant difference between the SRS-mental scores of PJK and non-PJK patients [13]. These metrics were collected at baseline (BL), 1-year (1Y) post-operative, and 2-year (2Y) post-operative time points for analysis. Percentage of patients achieving a minimal clinically important difference (MCID) in ODI (MCID:  $\pm 15$ ), SRS-activity (MCID:  $\pm 0.375$ ), SRS-pain (MCID:  $\pm 0.587$ ), SRS-appearance (MCID:  $\pm 0.8$ ), SRS-mental (MCID:  $\pm 0.42$ ), and PCS (MCID:  $\pm 5.2$ ) between BL and 1Y and BL and 2Y time points was recorded, as well [14, 15].

### Study groups: no PJK, mild PJK, and severe PJK

Patients were stratified according to the presence and degree of proximal junctional kyphosis, as determined radiographically within two years post-op. Radiographic determination of PJK was defined as  $\geq 10^\circ$  measure of the sagittal Cobb angle between the inferior endplate of the UIV and the superior endplate of the vertebra positioned two vertebral bodies above the UIV [1, 2]. We specified PJK type according to severity. Mild proximal junctional kyphosis was defined as PJK  $\geq 10^\circ$  and  $\leq 28^\circ$ , and severe PJK patients exhibited proximal junctional kyphosis  $> 28^\circ$  with  $\geq 22^\circ$  change following

surgery [3, 11, 12]. Our analysis consisted of three cohorts: no PJK, mild PJK, and severe PJK. After stratification, the individuals in each of these groups were propensity score matched for baseline age, frailty, PI, T1PA, number of levels fused, and ODI.

## Data analysis

Descriptive data and surgical variables were compared amongst study groups with chi-squared and unpaired t-test analyses. Paired t-tests compared baseline and 1Y HRQoL data and baseline and 2Y HRQoL data. Baseline to 1-year change, and baseline to 2-year was determined for each HRQoL assessment. ANOVA compared the BL-1Y change and the BL-2Y change in each HRQoL metric among the no PJK, mild PJK and severe PJK groups. This analysis was followed by ANCOVA controlling for the corresponding HRQoL, frailty, number of levels fused, and the use of a three-column osteotomy. Correlation analysis relating the change in PJK angle to the change in each HRQoL assessment was performed within the mild PJK cohort and the severe PJK cohort. Chi-squared analysis compared percentages of patients reaching MCID between baseline and 1Y and baseline and 2Y time-points across study groups. A sub-analysis was conducted among patients in each PJK group not undergoing reoperation between index surgery and two years. All data analysis was performed with SPSS software (version 28.1.1, Armonk, NY, USA).

## Results

### Descriptive data of overall patient population

969 patients were included for analysis (mean age:  $60.3 \pm 14.3$  y/o; 76% Female; BMI:  $27.9 \pm 5.9$  kg/m [2]; CCI:  $1.8 \pm 1.7$ ). Race was distributed in the following manner within our population: 83.5% White, 3.2% Black, 3.2% Hispanic, 1.4% Asian, 8.6% other. 68.0% of patients underwent posterior-only approaches, while 32.0% underwent the combined approach. Mean posterior levels fused were  $10.8 \pm 4.3$ , while mean anterior levels fused were  $2.1 \pm 1.8$  in our population (Table 1).

### Descriptive data of PJK and non-PJK cohorts

Initial stratification by presence and degree of PJK yielded 571 patients (58.9%) in the no PJK group, 310 individuals (32.0%) in the mild PJK group, and 88 patients (9.1%) in the severe PJK group. Study cohorts exhibited statistically different mean age (no PJK: 58.5 y/o; mild PJK: 62.4 y/o; severe PJK: 65.2 y/o;  $p < 0.001$ ), and frailty (no PJK: 7.2; mild PJK: 7.6; severe PJK: 8.8;  $P = 0.017$ ) at baseline.

**Table 1** Descriptive data for total study population

Demographic variables	
Age	$60.3 \pm 14.3$ years
Sex	76% female
Baseline BMI	$27.9 \pm 5.9$ kg/m <sup>2</sup>
Baseline CCI	$1.8 \pm 1.7$
Race	
White	83.5%
Black	3.2%
Hispanic	3.2%
Asian	1.4%
Other	8.6%
Surgical variables	
Approach	
Posterior only	68%
Anterior–posterior	32%
Levels fused	
Posterior	$10.8 \pm 4.3$
Anterior	$2.1 \pm 1.8$

BMI Body mass index, CCI Charlson comorbidity index

Baseline measures of BMI, CCI, osteoporosis and PI were statistically similar between groups (all  $p > 0.2$ ). Distributions of the race were statistically similar amongst these cohorts (all  $p > 0.4$ ). PJK stratification groups were different in baseline radiographic and surgical parameters, as depicted in Tables 2 and 3. Study groups exhibited different measures of mean posterior levels fused (no PJK: 10.2; mild PJK: 11.4; severe PJK: 12.4  $P < 0.001$ ), but similar percentages of posterior approach surgeries (no PJK: 69.2%, mild PJK: 63.9%, severe PJK: 75.0%;  $p = 0.363$ ). After propensity score matching for baseline age, frailty, PI, T1PA, ODI, and number of levels fused, 87 individuals remained in each cohort. There were no differences in any demographic, surgical, or radiographic baseline characteristics after PSM.

### HRQoL data of patient population

Following propensity score matching, the patient population reported the following HRQoL values at baseline, one year, and two years. When comparing HRQoL data between time points, the overall population exhibited no change in SRS satisfaction between baseline and two years (2.7 v 4.0,  $P = 0.784$ ). All other HRQoLs improved significantly between time points (all  $p < 0.001$ ).

### HRQoL data of PJK and Non-PJK cohorts

No significant differences were observed among the HRQoL values of each study cohort at baseline (all  $p > 0.3$ ). When comparing HRQoL data at one-year post-op, no differences

**Table 2** Comparison of baseline demographics and radiographics among no PJK, Mild PJK, and severe PJK individuals

	No PJK	Mild PJK	Severe PJK	<i>p</i> -value
Baseline demographics				
Age	58.5 ± 15.5	62.4 ± 12.4	65.2 ± 9.9	< 0.001
Gender (% female)	74%	80%	83%	0.043
BMI (kg/m <sup>2</sup> )	27.8 ± 6.0	28.1 ± 5.9	28.2 ± 5.0	0.712
CCI	1.7 ± 1.7	1.9 ± 1.7	2.0 ± 1.7	0.253
Frailty (ASD-mFI)	7.2 ± 4.9	7.6 ± 4.9	8.8 ± 5.5	0.017
Osteoporosis	15.6%	16.1%	19.3%	0.676
History of previous fusion	28.0%	29.4%	34.1%	0.499
Surgical/admission characteristics				
Number of levels fused	10.2 ± 4.6	11.4 ± 3.5	12.4 ± 3.6	< 0.001
Estimated blood loss (mL)	1619 ± 1537	1721 ± 1337	1834 ± 1275	0.338
Operative time (min)	419 ± 179	455 ± 183	459 ± 166	0.007
Osteotomy	66%	79%	81%	< 0.001
Three-column osteotomy	17%	20%	21%	0.476
Invasiveness index	81 ± 35	98 ± 35	107 ± 35	< 0.001
Length of stay (days)	7.4 ± 4.9	8.2 ± 4.1	8.7 ± 4.8	0.008
SICU admission	62%	70%	82%	< 0.001

\*Bold indicates significance of  $P < 0.05$

**Table 3** Comparison of surgical details among no PJK, Mild PJK, and severe PJK individuals

	No PJK	Mild PJK	Severe PJK	<i>p</i> -value
Baseline demographics				
PI	56.1 ± 13.8	54.5 ± 11.6	55.5 ± 12.8	.248
PI-LL	14.2 ± 21.1	20.2 ± 20.6	21.4 ± 21.7	< 0.001
PT	23.1 ± 11.0	25.7 ± 9.9	28.3 ± 12.0	< 0.001
SVA	57.7 ± 70.3	77.4 ± 71.7	90.6 ± 76.8	< 0.001
T1PA	21.5 ± 13.0	25.2 ± 12.7	28.4 ± 14.2	< 0.001
GAP score	6.3 ± 4.0	8.0 ± 3.8	9.0 ± 3.6	< 0.001
PJK angle	-2.6 ± 12.4	-3.6 ± 7.0	-4.8 ± 6.0	.094

\*Bold indicates significance of  $P < .05$

in HRQoL data were observed. At two years post-op, no significant differences were observed in HRQoL data among study groups. There were also no differences seen in meeting MCID in any HRQoL tested.

### Unadjusted and adjusted baseline to 1- and 2-year change in HRQoLs

Unadjusted ANOVA analysis was utilized to compare the change in HRQoLs from baseline to 1 year and 2 years within each PJK cohort. This analysis revealed a significant difference between baseline to 1-year change (NoPJK: 1.6, MildPJK: 1.7, SeverePJK: 1.2;  $p = 0.039$ ) and 2-year change (NoPJK: 1.5, MildPJK: 1.5, SeverePJK: 1.0;  $p = 0.031$ ) in SRS-22 satisfaction scores, along with 1-year change (NoPJK: 9.7, MildPJK: 4.6, SeverePJK: 4.4;  $p = 0.015$ ) in

SF-36 MCS scores. No other significant differences were seen in the HRQoL changes between baseline and 1 or 2 years. Adjusted analysis in Tables 4 and 5 controlling for the baseline value for the corresponding HRQoL, frailty, number of levels fused, and the use of a three-column osteotomy only revealed significant differences between groups in 2-year SRS-22 Satisfaction (NoPJK: 1.6, MildPJK: 1.6, SeverePJK: 1.0;  $p = 0.022$ ).

### Correlation analysis: change in HRQoL metrics and PJK angle

Baseline to 1-year and 2-year change in PJK angle was assessed with change in HRQoL metric change over the same period in Table 6. Baseline to 1-year change in SRS-22 Satisfaction correlated significantly with change in the PJK angle ( $R = 0.160$ ;  $p = 0.018$ ), with an even better correlation seen in the change of SRS-22 Satisfaction and PJK angle at 2 years ( $R = 0.176$ ;  $p = 0.008$ ). There was no other significant correlation between any HRQoL metrics and the change in PJK angle at one or two years. No association was seen between the change in PJK angle and meeting MCID in any HRQoL metric.

### Sub-analysis: change in HRQoL metrics and PJK angle amongst patients not undergoing reoperation

Unadjusted and adjusted ANOVA analysis was utilized to baseline to one-year and two-year change in HRQoL metric over the same period in patients of each PJK cohort (NoPJK: 63, MildPJK: 71, SeverePJK: 46) avoiding reoperation. No

**Table 4** Comparison of change in HRQoL data between baseline and 1-year post-op among No PJK, Mild PJK, and severe PJK individuals

	No PJK	Mild PJK	Severe PJK	P value
Δ BL-1Y ODI	-19.3	-17.1	-15.7	0.404
Δ BL-1Y SRS-activity	0.6	0.7	0.6	0.610
Δ BL-1Y SRS-pain	1.1	1.2	1.0	0.421
Δ BL-1Y SRS-appearance	1.3	1.3	1.1	0.293
Δ BL-1Y SRS-mental	0.4	0.4	0.4	0.766
Δ BL-1Y SRS-satisfaction	1.6	1.6	1.3	0.186
Δ BL-1Y SRS-total	0.9	1.0	0.8	0.351
Δ BL-1Y PCS	8.6	11.1	8.3	0.119
Δ BL-1Y MCS	8.3	5.7	4.8	0.109
Δ BL-1Y SF-36 physical function	8.7	10.6	7.4	0.124
Δ BL-1Y SF-36 mental health	7.1	6.2	4.3	0.182

*PJK* proximal junctional kyphosis, *SRS* Scoliosis Research Society outcomes questionnaire, *PCS* physical component score, *MCS* mental component score, *SF-36* Short From-36 health survey

\*Bold indicates significance of  $P < 0.05$

**Table 5** Comparison of change in HRQoL data between baseline and 2-year post-op among no PJK, Mild PJK, and severe PJK individuals

	No PJK	Mild PJK	Severe PJK	P value
Δ BL-2Y ODI	-20.3	-16.5	-17.9	0.371
Δ BL-2Y srs-activity	0.7	0.7	0.7	0.980
Δ BL-2Y SRS-pain	1.2	1.1	1.2	0.770
Δ BL-2Y SRS-appearance	1.3	1.2	1.1	0.501
Δ BL-2Y SRS-mental	0.5	0.4	0.5	0.398
Δ BL-2Y SRS-satisfaction	1.6	1.5	1.0	<b>0.022</b>
Δ BL-2Y SRS-total	1.0	0.9	0.9	0.706
Δ BL-2Y PCS	8.4	9.5	7.8	0.587
Δ BL-2Y MCS	6.3	4.3	5.6	0.468
Δ BL-2Y SF-36 physical function	8.5	9.0	7.6	0.639
Δ BL-2Y SF-36 mental health	5.9	3.8	5.6	0.300

*PJK* Proximal junctional kyphosis, *SRS* Scoliosis Research Society outcomes questionnaire, *PCS* physical component score, *MCS* mental component score, *SF-36* Short From-36 health survey

\*Bold indicates the significance of  $P < 0.05$

differences were seen between PJK groups and one-year or two-year change, or meeting MCID in any HRQoL metric (all  $p > 0.08$ ).

## Discussion

Previous research comparing patient-reported outcome data between populations with and without proximal junctional kyphosis has revealed little difference between the two groups [1, 2, 7, 9]. Contrary to this, Hassanzadeh et al. reported statistically worse ODI and SRS-22 scores (pain, image, activity, and mental health) in PJK adults when compared to those without this complication, however, the impact of these findings is limited as this analysis only included 47 individuals [13]. In our current work, we build upon these previous studies by comparing post-operative

HRQoL changes in a larger population ( $n = 969$  patients) stratified by varying degrees of PJK (no PJK, mild PJK, severe PJK). We report minimal differences amongst these cohorts and conclude that the parameters currently used to analyze these phenomena are ineffective.

Change in patient-reported outcome data from baseline to 1 year revealed no differences in improvement of ODI, SF-36, EQ-5D, and most SRS-22 domain scores, even when examining those who did not undergo reoperation by the two-year timepoint. This same data trend was consistent with a baseline to 2-year change. These results are perplexing and may reflect the inability of the Oswestry Disability Index to capture pain and disability in PJK individuals, as this phenomenon most often occurs in the mid or upper thoracic region and the ODI is typically used to assess low back pain [11, 16]. Previously, the SF-36 has been unsuccessful in reflecting differences between ASD populations with and

**Table 6** Correlation analysis of change in PJK angle to change in baseline and 1-year and 2-year post-op HRQoL scores

	Change in PJK angle	
	Δ BL-1Y PJK	Δ BL-2Y PJK
Δ BL-1Y ODI		
<i>R</i>	−0.105	−0.044
<i>P</i> Value	0.115	0.500
Δ BL-1Y SRS-activity		
<i>R</i>	−0.016	−0.007
<i>P</i> Value	0.809	0.911
Δ BL-1Y SRS-pain		
<i>R</i>	0.116	0.018
<i>P</i> Value	0.084	0.784
Δ BL-1Y SRS-appearance		
<i>R</i>	0.080	0.085
<i>P</i> Value	0.233	0.201
Δ BL-1Y SRS-mental		
<i>R</i>	0.080	−0.023
<i>P</i> Value	0.233	0.732
Δ BL-1Y SRS-satisfaction		
<i>R</i>	0.160	0.176
<i>P</i> Value	<b>0.018*</b>	<b>0.008*</b>
Δ BL-1Y SRS-total		
<i>R</i>	0.109	0.059
<i>P</i> Value	0.105	0.374
Δ BL-1Y PCS		
<i>R</i>	0.056	0.046
<i>P</i> Value	0.418	0.500
Δ BL-1Y MCS		
<i>R</i>	0.048	0.005
<i>P</i> value	0.487	0.947
Δ BL-1Y SF-36 physical function		
<i>R</i>	0.005	0.032
<i>P</i> value	0.938	0.626
Δ BL-1Y SF-36 mental health		
<i>R</i>	0.013	−0.079
<i>P</i> value	0.850	0.236

*PJK* proximal junctional kyphosis, *SRS* Scoliosis Research Society outcomes questionnaire, *PCS* physical component score, *MCS* mental component score, *SF-36* Short Form-36 health survey

\*Bold indicates the significance of  $P < 0.05$

without post-operative complication, therefore it may be the case that this metric is too generic to be utilized in the setting of PJK. [17]

Further analysis revealed associations between changes in the angle of proximal junctional kyphosis and HRQoL data. In the overall cohort, greater baseline to 1-year change in the PJK angle correlated with lower SRS-22 Satisfaction scores at 1 year. Additionally, baseline to two-year increase in PJK angle correlated with less improvement in SRS-22

Satisfaction by 2 years. Despite this relation, all study groups exhibited statistically similar levels of change in pain scores, and so, degree of PJK did not directly influence this metric either. In the setting of ASD, the SRS-22 HRQoL have had little success in differentiating between patients that have experienced perioperative complications and those that have not [18, 19]. However, the Scoliosis Research Society-22 Satisfaction domain may have sensitivity to differentiate between patients with and without PJK.

Comparing HRQoLs amongst individuals with varying degrees of proximal junctional kyphosis showed that the severity of PJK has little effect on patient-reported quality of life data [4, 20]. These results are fairly typical, and so it may be the case that the radiographic criteria used to define PJK does not lead to increased disability or pain. This seems unlikely, as regional changes in sagittal alignment, like PJK, can facilitate reciprocal alterations in global alignment. In extreme cases, this can lead to increased disability and loss of function associated with adult spinal deformity [21, 22]. Thus, it may not be the radiographic diagnosis of PJK that requires reconsideration, but more so, the way we analyze this phenomenon.

This data confirms that there are minimal differences in the health-related quality of life data of patients experiencing no PJK, mild PJK, and severe PJK. In fact, patients experiencing mild PJK groups often demonstrated similar improvement when compared with the no PJK cohort post-operatively, and only severe PJK was statistically different across certain clinical outcomes. Rather than proving that PJK has little effect on the quality of life, these findings more appropriately suggest that our current HRQoLs are not specific enough to reflect the experience of PJK individuals. With future research, more refined outcome metrics can be developed for this population and a more accurate study of proximal junctional kyphosis can be achieved.

## Limitations

Despite our findings, this study did carry several limitations. We utilized a multi-center database to minimize bias and increase the generalizability of our findings. However, patients were not consecutively enrolled, increasing the opportunity for selection bias in our study. Alongside this mention, we would like to address there were many separate indications for which patients underwent surgery. Although we conducted a sub-analysis examining the patients not undergoing reoperation to better stratify the effects of PJK on HRQoL change, it would be helpful to examine the change up until the time of reoperation in the remaining patients and compare that change amongst PJK groups to more clearly define the effects of PJK on change in patient-reported outcomes. Additionally, this study took

an exploratory, retrospective approach examining these phenomenon in adult spinal deformity and the possible presence of expertise and additional reasons for selection bias should be acknowledged and heeded during surgical planning. Therefore, prospective studies with more rigorous protocols and more detailed follow-up would further aid the current literature in characterizing the effect of this recovery-altering complication. Despite these limitations, we maintain that this study is an important step towards understanding this unique population, as well as highlighting significant, and insignificant, correlation between radiographic and clinical outcomes following surgical intervention for adult spinal deformity.

## Conclusions

Analysis revealed the mild PJK group to experience the largest improvement in ODI and SF-36 physical function between baseline and 2Y, while the non-PJK group experienced the least improvement. Rather than a reflection of the clinical impact that proximal junctional kyphosis has on affected individuals, these findings imply that our current HRQoLs are not reliable parameters for analyzing this phenomenon. Patient-reported outcome metrics specifically used to reflect pain and loss of function in the upper thoracic or cervical spine may prove most successful in capturing the patient experience of PJK individuals, however, future study is needed to confirm this.

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**Data availability** Data are available from the corresponding author upon request.

## Declarations

**Ethical review committee statement** Each institution obtained approval from their local Institutional Review Board to enroll patients in the

prospective database and informed consent was obtained from each patient.

**Statement of approval** All authors have read and approved the manuscript and all requirements for authorship have been met by each author and each author believes the manuscript represents honest work.

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