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DEFORMITY

The Clinical Correlation of the Hart-ISSG Proximal Junctional Kyphosis Severity Scale With Health-Related Quality-of-life Outcomes and Need for Revision Surgery

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Study Design. Retrospective analysis of prospective data.
Objective. Evaluate the utility of the Hart-International Spine Study Group proximal junctional kyphosis severity scale (Hart-ISSG PJKSS).
Summary of Background Data. Proximal junctional kyphosis (PJK) and failure (PJF) are well-described complications after long-segment instrumentation. The Hart-ISSG PJKSS was recently developed and incorporates neurological deficit, pain, instrumentation issues, degree of kyphosis, presence of fracture, and level of upper-most instrumented vertebrae.
Methods. All adult spinal deformity patients with PJK or PJF were identified from two academic centers over a 7-year period. Health-related quality-of-life (HRQOL) outcomes were prospectively collected: Oswestry Disability Index (ODI), visual analogue scale (VAS) pain, SF-36 questionnaire, and SRS-30 questionnaire. Patients were retrospectively assigned Hart-ISSG PJKSS scores. Correlation between the Hart-ISSG PJKSS and outcomes was assessed with linear regression, Pearson correlation coefficients, and χ^2 analysis.
Results. A total of 184 cases were included; 21.2% were men and mean age was 65.0 years. Weakness and/or myelopathy were present in 11.4% of patients and 88.6% had pain. Instrumentation issues occurred in 44.0% and 64.1% had PJK-associated fractures. PJK occurred in the upper thoracic spine in 21.7% of cases. Mean PJKSS score was 5.9. The Hart-ISSG PJKSS was significantly and strongly associated with ODI ($P < 0.001$, $r = 0.611$), VAS pain ($P < 0.001$, $r = 0.676$), SRS-30 function ($P < 0.001$, $r = -0.401$), SRS-30 mental health ($P < 0.001$, $r = -0.592$), SRS-30 self-image ($P < 0.001$, $r = -0.511$), SRS-30 satisfaction ($P < 0.001$, $r = -0.531$), and SRS-30 pain ($P < 0.001$, $r = -0.445$). Higher scores were associated with higher proportion of patients undergoing revision surgery ($P < 0.001$); scores of 9 to 11 and 12 to 15 underwent revision 96.0% and 100.0% of the time, respectively.
Conclusion. The Hart-ISSG PJKSS was strongly correlated with validated functional outcomes and higher scores were associated with higher rates of revision surgery. The Hart-ISSG PJKSS may be a useful clinical tool in the treatment of patient with PJK.
Key words: classification, instrumentation, proximal junctional failure, proximal junctional kyphosis, quality of life, revision surgery, severity scale.
Level of Evidence: 3
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Proximal junctional kyphosis (PJK) is a common complication after long-segment instrumentation for spinal deformities,[1] and can be associated with poor functional and pain outcomes.[2] Approximately 20% to 40% of patients who undergo long-segment instrumentation for deformity develop PJK.[2–9] PJK can occur as early as 8-weeks

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after surgery.[7] Greater than half of the patients who develop PJK are effected within 3-months after surgery and the majority (80%) experience it within 18 months.[5,6] PJK is a progressive process that can result in proximal junctional failure (PJF) in which patients become symptomatic secondary to vertebral column fracture and/or posterior ligament complex (PLC) failure, leading to spinal instability and increased risk for neurological injury.[6,10–12]

The risk factors for PJK have been well established:older age,[7,10,13,14] large abnormal preoperative sagittal radiographic parameters,[3–6,8,15,16] use of pedicle screws,[5,8,15,17,18] thoracoplasty procedures,[5,8,15] greater curvature correction,[4,8,13,14,19,20] disruption of the PLC,[3,6,7,13,18,21] fusion to the lower lumbar vertebra and sacrum,[3,5,6,22] and nonanatomic restoration of thoracic kyphosis.[21,23] However, there remains a lack of evidence supporting prevention strategies such as the use of vertebral body cement augmentation and hooks.[12,17] Therefore, PJK is an ongoing issue and needs to be properly addressed. There are no established classification system for PJK and no standardized indications for surgical revision. More recently, Hart and the International Spine Study Group (ISSG) developed a PJK severity scale (PJKSS) that takes into account six PJK and PJF characteristics: neurological deficit, focal pain, instrumentation problem, change in kyphosis/PLC integrity, fracture location, and level of uppermost instrumented vertebrae (UIV).[24] This study aims to evaluate whether the Hart-ISSG PJKSS is correlated with quality-of-life measures and need for revision surgery in patients with PJK.

MATERIALS AND METHODS

Patients

From 2006 to 2013, all adult spinal deformity patients (18 years or older) who underwent long-segment instrumentation and were diagnosed with PJK or PJF were retrospectively identified from two large academic centers. Patients included in this study were individuals who received their management at these centers and were not inclusive of patients from other centers who were referred. This study was approved by the University of California, San Francisco Committee of Human Research. The medical record was reviewed for clinical characteristics: age, sex, neurological status, and pain severity (visual analogue scale (VAS)). Data regarding whether the patient underwent revision surgery was collected.

Radiographic Evaluation

Hart-ISSG PJKSS scores were based on scoliosis radiographs in which PJK and/or PJF was diagnosed. The presence of PJK was defined as kyphosis of 10 or more degrees greater than preoperative measurements.[25] PJK was measured by utilizing the angle between the inferior endplate of the UIV and the superior endplate of the second vertebral body above the UIV (two levels above) by the sagittal Cobb method.

Outcomes Data

Health-related quality-of-life (HRQOL) outcomes were prospectively collected at the time of patient clinic visits. HRQOL outcomes were measured in the form of Oswestry Disability Index (ODI), VAS pain, Short Form (SF)-36 questionnaire, and Scoliosis Research Society (SRS)-30 questionnaire.[26,27]

Hart-ISSG PJKSS

Hart-ISSG PJKSS scores were assigned retrospectively by chart review focusing on the clinical and radiographic evaluation at the time of PJK diagnosis. All images were reviewed and scored by a senior spine surgeon and a fellow. An inter- and intraobserver correlation analysis was not performed between the two individuals reviewing films because of restrictions in accessing images from outside institutions. Rather raw data were provided from participating institutions. A detailed discussion among the reviewers and participating institutions was held *a prior* to reviewing patient films to ensure consistency. The Hart-ISSG PJKSS encompasses six distinct scoring components and each component is further stratified and assigned a specific point value (Table 1). Thoracolumbar junction was defined as T8 to T12 and upper thoracic levels were defined as T1 to T7. The final Hart-ISSG PJKSS score is the sum of the points from all six components.

Statistical Analysis

Patients were stratified into five groups: scores 0 to 2, 3 to 5, 6 to 8, 9 to 11, and 12 to 15. Analysis of variance models were used to test for differences in measured HRQOL outcomes among the categorized Hart-ISSG PJKSS score groups. Pearson correlation coefficients were calculated to measure linear correlation between the Hart-ISSG PJKSS score and HRQOL outcomes. To assess the importance of each component in the Hart-ISSG PJKSS, removal of each competent and subsequent calculation of Pearson correlation coefficients were performed. Two-way Student *t* test was used to compare the mean Hart-ISSG PJKSS scores between patients who underwent revision surgery and patients who did not undergo surgery. χ^2 analysis was used to test for differences in revision rates among the five categorized Hart-ISSG PJKSS score groups. A P value of 0.050 was used as the threshold for statistical significance. All statistical analysis was performed with SAS 9.3 (NC, USA).

RESULTS

Patient Clinical Characteristics

A total of 184 patients were included. Men made up 21.2% and the mean age was 65.0 years. Mean Hart-ISSG PJKSS score was 5.9 (range 1–15). Among the cohort, 6.5% of patients had scores of 0 to 2, 41.3% of patients had scores of 3 to 5, 37.0% of patients had scores of 6 to 8, 13.6% of patients had scores of 9 to 11, and 1.6% of patients had scores of 12 to 15. Of the 184 patients, 32.1% of patients

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TABLE 1. Definitions of the Hart-ISSG PJKSS Components and the Respective Points Assigned

Proximal Junctional Kyphosis Severity Scale	
Characteristic	**Severity Score (points)**
Neurological deficit	
None	0
Radicular pain	2
Myelopathy/motor deficit	4
Focal pain	
None	0
VAS 4 or less	1
VAS greater than or equal to 5	3
Instrumentation problem	
None	0
Partial fixation loss	1
Prominence	1
Complete fixation loss	2
Change in kyphosis/PLC integrity	
0–10°	0
10–20°	1
>20°	2
PLC failure	2
UIV/UIV + 1 fracture	
None	0
Compression fracture	1
Burst/Chance fracture	2
Translation	3
Level of UIV	
Thoracolumbar junction	0
Upper thoracic	1

presented with neurological symptoms: 11.4% motor weakness and/or myelopathy and 20.7% had radiculopathy. A majority (88.6%) of patients presented with pain (mean VAS pain 5.1). Of the 184 patients, 44.0% had instrumentation failures and 64.1% had fractures. PJK occurred in the upper thoracic spine in 21.7% of cases.

Hart-ISSG PJKSS and ODI

Hart-ISSG PJKSS scores were significantly associated with ODI scores (Table 2, $P < 0.001$). Pearson correlation coefficient demonstrated a strong linear correlation between the two ($r = 0.611$): scores 0 to 2 (ODI 25.8), scores 3 to 5 (ODI 35.3), scores 6 to 8 (52.8), scores 9 to 11 (ODI 64.6), and scores 12 to 15 (ODI 80.0) (Figure 1A).

Hart-ISSG PJKSS and VAS Pain

Higher Hart-ISSG PJKSS scores were significantly associated with higher VAS pain scores (Table 2, $P < 0.001$). The Pearson correlation coefficient was 0.676 which meant a strong linear positive correlation exists: scores 0 to 2 (VAS pain 1.6), scores 3 to 5 (VAS pain 3.5), scores 6 to 8 (VAS pain 6.5), scores 9 to 11 (VAS pain 7.9), and scores 12 to 15 (VAS pain 7.5) (Figure 1B).

Hart-ISSG PJKSS and SF-36

We then evaluated the relationship between Hart-ISSG PJKSS scores and SF-36 physical and mental component scores (Table 3). There was no significant association between Hart-ISSG PJKSS scores and SF-36 physical component scores ($P = 0.129$, $r = -0.108$) (Figure 2A). There was a significant association between the Hart-ISSG PJKSS scores and the mental component of SF-36 ($P = 0.006$); lower Hart-ISSG PJKSS scores were generally associated with higher SF-36 mental component scores (Figure 2B). However, the Pearson correlation coefficient only demonstrated a weak negative correlation ($r = -0.234$).

Hart-ISSG PJKSS and SRS-30

Hart-ISSG PJKSS scores were significantly associated with scores of all components from the SRS-30 questionnaire: function ($P < 0.001$), mental health ($P < 0.001$), self-image ($P < 0.001$), satisfaction ($P < 0.001$), and pain ($P < 0.001$) (Table 4). Hart-ISSG PJKSS scores had a strong negative correlation to SRS-30 function score ($r = -0.401$): scores 0 to 2 (function 3.7), scores 3 to 5 (function 3.2), scores 6 to 8 (function 2.8), scores 9 to 11 (function 2.6), and scores 12 to 15 (function 2.4) (Figure 3A). The Hart-ISSG PJKSS scores had a strong negative correlation to SRS-30 mental health scores ($r = -0.592$): scores 0 to 2 (mental health 4.3), scores 3 to 5 (mental health 3.8), scores 6 to 8 (mental health 2.9), scores 9 to 11 (mental health 2.9), and scores 12 to 15 (mental health 2.3) (Figure 3B). The Hart-ISSG PJKSS scores had a strong negative correlation to SRS-30 self-image scores ($r = -0.511$): scores 0 to 2 (self-image 4.0), scores 3 to 5 (self-image 3.5), scores 6 to 8 (self-image 2.9), scores 9 to 11 (self-image 2.5), and scores 12 to 15 (self-image 2.2) (Figure 3C). The Hart-ISSG PJKSS scores had a strong negative correlation to SRS-30 satisfaction scores ($r = -0.531$): scores 0 to 2 (satisfaction 4.5), scores 3 to 5 (satisfaction 3.9), scores 6 to 8 (satisfaction 3.3), scores 9 to 11 (satisfaction 2.4), and scores 12 to 15 (satisfaction 2.3) (Figure 3D). The Hart-ISSG PJKSS scores had a strong negative correlation to SRS-30 pain scores ($r = -0.445$): scores 0 to 2 (pain 3.4), scores 3 to 5 (pain 3.1), scores 6 to 8 (pain 2.4), scores 9 to 11 (pain 2.2), and scores 12 to 15 (pain 3.0) (Figure 3E). A mean of 3.0 for SRS-30 pain component in patients with Hart-ISSG PJKSS scores of 12 to 15 is most likely an outlier because of the relatively fewer number of patients in that subgroup.

Components of the Hart-ISSG PJKSS

The Pearson correlation coefficient was calculated for the Hart-ISSG PJKSS and HRQOL outcomes when all 6 Hart-ISSG PJKSS components were included and when each component was removed from the scale (Tables 5 and 6). Neurological deficits and pain were the most influential components of the Hart-ISSG PJKSS in correlating with HRQOL outcomes. The removal of neurological deficit

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TABLE 2. Correlation of the Hart-ISSG PJKSS With Oswestry Disability Index and Visual Analogue Scale Pain

Oswestry Disability Index Score				
	Mean	**SD**	***P***	***r***
Hart-ISSG PJKSS			<0.001	0.611
0 to 2	25.8	15.7		
3 to 5	35.3	20.2		
6 to 8	52.8	14.8		
9 to 11	64.6	14.8		
12 to 15	80.0	8.5		
Visual Analogue Scale Pain Score				
	Mean	**SD**	***P***	***r***
Hart-ISSG PJKSS			<0.001	0.676
0 to 2	1.6	1.5		
3 to 5	3.5	2.7		
6 to 8	6.5	2.0		
9 to 11	7.9	1.4		
12 to 15	7.5	3.5		

Hart-ISSG PJKSS indicates Hart-International Spine Study Group proximal junctional kyphosis severity scale.

leads to a decrease in Pearson correlation coefficients for all outcome measures, except for VAS pain. When pain was removed from the Hart-ISSG PJKSS, the Pearson correlation coefficients decreased for all outcomes. Instrumentation, degree of kyphosis, fracture, and level of UIV demonstrate a mixed trend of changes. The removal of instrumentation or fracture increased the Pearson correlation coefficients for the SF-36 physical component, SF-36 mental component, VAS pain, SRS-30 function, and SRS-30 Pain. Similarly, the removal of kyphosis increased the Pearson correlation coefficients for the same outcomes except for SRS-30 function. The removal of UIV from the Hart-ISSG PJKSS increased Pearson correlation coefficients for SF-36 physical, VAS pain, and SRS-30 function. All other Pearson correlation coefficients were decreased when each component was removed.

Hart-ISSG PJKSS and Revision Surgery

Of the 184 patients, 41.4% underwent revision surgery (Table 7). Patients who underwent revision surgery had a significantly higher mean Hart-ISSG PJKSS score than patients who did not undergo revision surgery (7.8 *vs.* 4.6, $P < 0.001$). There was a significant trend for patients with worse Hart-ISSG PJKSS scores to undergo revision surgery more often ($P < 0.001$) (Table 8): scores 0 to 2 (0.0%), scores 3 to 5 (17.1%), scores 6 to 8 (52.9%),

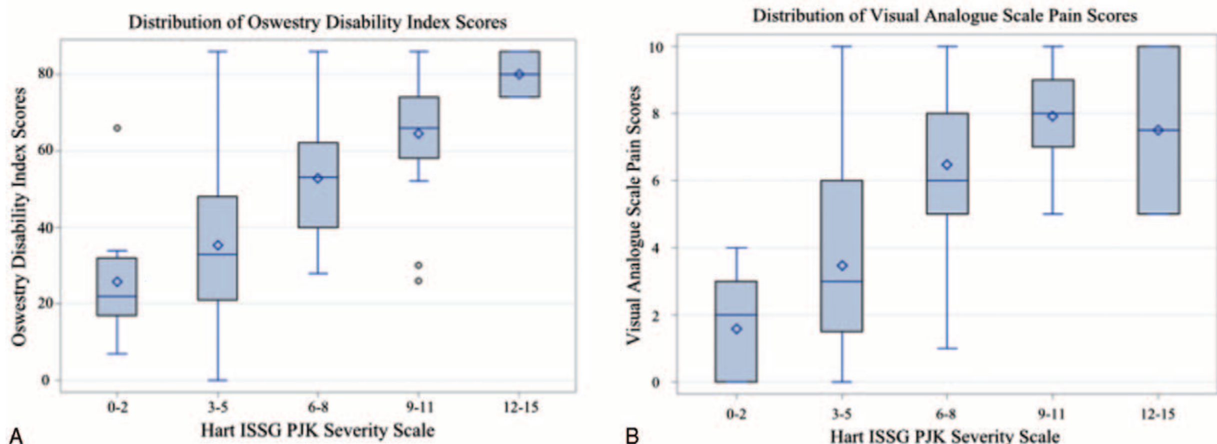

Figure 1. Correlation of the Hart-ISSG PJKSS with Oswestry Disability Index and visual analogue scale pain. (A) Distribution graph showing a strong positive linear trend between the Hart-ISSG PJKSS with Oswestry Disability Index ($P < 0.001$, $r = 0.611$). (B) Distribution graph showing a strong positive linear trend between the Hart-ISSG PJKSS with visual analogue scale pain ($P < 0.001$, $P = 0.676$).

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TABLE 3. Correlation of the Hart-ISSG PJKSS With Short Form-36 Physical and Mental Components

SF-36 Physical Component Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			0.129	−0.108
0 to 2	31.8	8.5		
3 to 5	35.6	10.8		
6 to 8	32.3	9.2		
9 to 11	31.3	9.8		
12 to 15	42.4	6.4		
SF-36 Mental Component Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			0.006	−0.234
0 to 2	57.6	6.5		
3 to 5	49.6	12.4		
6 to 8	48.0	13.0		
9 to 11	41.6	10.7		
12 to 15	49.3	18.8		

Hart-ISSG PJKSS indicates Hart-International Spine Study Group proximal junctional kyphosis severity scale; SF-36, short form-36.

scores 9 to 11 (96%), and scores 12 to 15 (100.0%) (Figure 4).

DISCUSSION

There have been limited attempts to classify PJK and PJF.[3,28,29] Boachie-Adjei and colleagues[3] performed a retrospective review of 32 patients with PJK who underwent long instrumented spinal fusion (greater than five vertebrae) for scoliosis. They presented a PJK classification scheme based on two components: type (1-ligamentous failure, 2-bone failure, or 3-implant/bone interface failure) and grade (A-10 to 14 degrees of kyphosis, B-15 to 19 degrees of kyphosis, or C-20 degrees or greater of kyphosis). Six patients (two patients with type 1, three patients with type 2, and one patient with type 3) were symptomatic and four patients (two patients with type 2 and two patients with type 3) underwent revision surgery. The same group described a similar classification for PJF.[29] Grade was slightly modified and the presence of spondylolisthesis above the UIV was added to the classification system. The Boachie-Adjei classification schemes are simple, easy to use, and characterize radiographic severity of PJK.[3,6,29] However, its clinical utility may be limited because of the lack of incorporation of clinical parameters. Similarly, Hart *et al* attempted to define a classification system that would provide decision criteria for revision surgery among patients with PJF.[28] But they were not able to formulate a classification system because factors such as pain and neurological deficit were

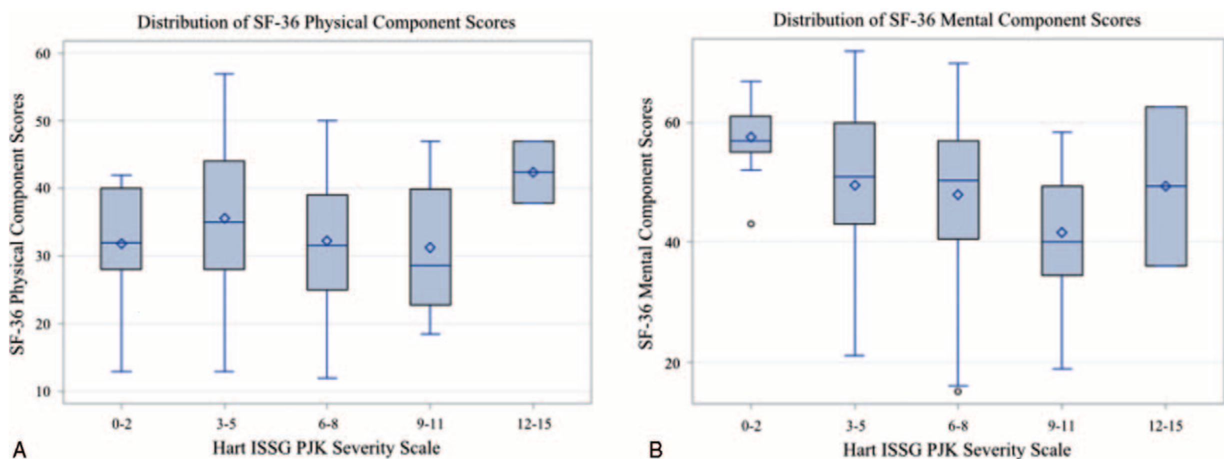

Figure 2. Correlation of the Hart-ISSG PJKSS with Short Form-36 physical and mental components. (A) Distribution graph showing no trend between the Hart-ISSG PJKSS with the physical component of the Short Form-36 questionnaire ($P < 0.129$, $r = -0.108$). (B) Distribution graph showing a weak negative linear trend between the Hart-ISSG PJKSS with the mental component of the Short Form-36 questionnaire ($P < 0.006$, $P = 0.234$).

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TABLE 4. Correlation of the Hart-ISSG PJKSS With Scoliosis Research Society-30 Components

SRS-30 Function Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			<0.001	−0.401
0 to 2	3.7	0.5		
3 to 5	3.2	0.7		
6 to 8	2.8	0.6		
9 to 11	2.6	0.8		
12 to 15	2.4	0.4		
SRS-30 Mental Health Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			<0.001	−0.592
0 to 2	4.3	0.4		
3 to 5	3.8	0.9		
6 to 8	2.9	1.0		
9 to 11	2.9	0.8		
12 to 15	2.3	0.1		
SRS-30 Self-Image Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			<0.001	−0.511
0 to 2	4.0	0.6		
3 to 5	3.5	0.8		
6 to 8	2.9	0.7		
9 to 11	2.5	0.9		
12 to 15	2.2	0.6		
SRS-30 Satisfaction Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			<0.001	−0.531
0 to 2	4.5	0.7		
3 to 5	3.9	1.0		
6 to 8	3.3	0.9		
9 to 11	2.4	1.1		
12 to 15	2.3	0.3		
SRS-30 Pain Score				
	Mean	SD	*P*	*r*
Hart-ISSG PJKSS			<0.001	−0.445
0 to 2	3.4	0.8		
3 to 5	3.1	0.8		
6 to 8	2.4	0.7		
9 to 11	2.2	0.7		
12 to 15	3.0	0.2		

Hart-ISSG PJKSS indicates Hart-International Spine Study Group proximal junctional kyphosis severity scale; SRS-30, scoliosis research society-30.

not available and deemed to be critical components. In the evaluation of patients with PJK, surgeons take into consideration symptom severity, neurological deficits, radiographic findings, and anatomical differences.

Shortly thereafter, Hart and the ISSG presented the Hart-ISSG PJKSS based on expert review.[24] Fourteen surgeons participated in a modified Delphi approach to identify key clinical and radiographic features of PJK in determining the treatment course of PJK and PJF. Then the utility and reproducibility of the Hart-ISSG PJF severity scale was tested. The proposed Hart-ISSG PJKSS was proven to have promising reliability and reproducibility; mean intrarater (0.74) and inter-rater (0.71) agreement were moderate to very good. Mean total inter-rater (0.47) and intrarater

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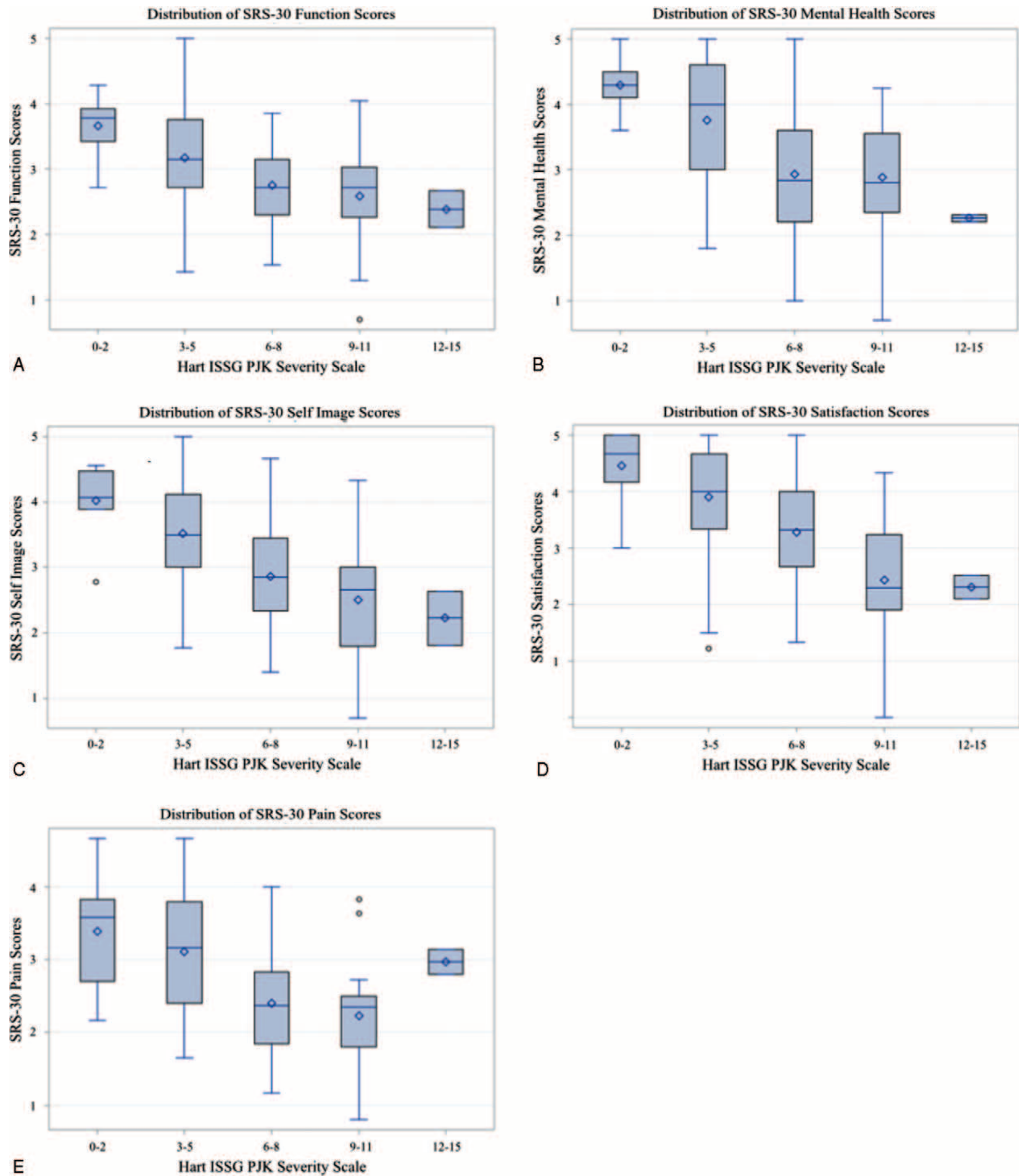

Figure 3. Correlation of the Hart-ISSG PJKSS with the Scoliosis Research Society-30 components. *Distribution graphs showing strong negative linear trends between the Hart-ISSG PJKSS with Scoliosis Research Society-30 questionnaire for all components: (A) function ($P < 0.001$, $r = -0.401$), (B) mental health ($P < 0.001$, $r = -0.592$), (C) self-image ($P < 0.001$, $r = -0.511$), (D) satisfaction ($P < 0.001$, $r = -0.531$), and (E) pain ($P < 0.001$, $r = -0.445$).

(0.43) severity scores were moderate. In addition, uniformly a score 7 or more resulted in recommendation for revision surgery.

The aim of this study was to validate whether the Hart-ISSG PJKSS was correlative of prospectively collected HRQOL outcomes in a large cohort of patients with PJK and PJF. The findings from this study demonstrate that worse Hart-ISSG PJKSS scores were correlative to all HRQOL outcomes, except for the SF-36 physical and mental components; the reasoning for this remains unclear, but may be related to the specificity of each measure. Both questionnaires (SF-36 and SRS-30) aim to gauge overall functionality, but the SRS-30 questionnaire is developed to concentrate its questions to spine-related issues.[26,27] The SF-36 is a much more general questionnaire and does not specify spine-related issues.[27] In fact, it has been shown

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TABLE 5. Pearson Correlation Coefficient After Removal of Each Hart-ISSG PJKSS Scoring Component

	All Six Components	Removal of: Neurological	Pain	Instrumentation	Kyphosis	Fracture	UIV
Oswestry Disability Index	0.611	0.554	0.452	0.564	0.603	0.597	0.607
SF-36 Physical Component Score	−0.108	−0.070	−0.007	−0.151	−0.140	−0.143	−0.118
SF-36 Mental Component	−0.234	−0.199	−0.146	−0.235	−0.244	−0.261	−0.231
Visual Analogue Scale Pain	0.676	0.701	0.363	0.692	0.686	0.681	0.677
SRS-30 Function	−0.398	−0.318	−0.273	−0.401	−0.389	−0.416	−0.401
SRS-30 Pain	−0.445	−0.391	−0.256	−0.460	−0.454	−0.452	−0.444
SRS-30 Self Image	−0.511	−0.499	−0.375	−0.460	−0.499	−0.496	−0.493
SRS-30 Mental Health	−0.592	−0.440	−0.32515	−0.434	−0.436	−0.456	−0.455
SRS-30 Satisfaction	−0.531	−0.486	−0.428	−0.471	−0.513	−0.511	−0.521

that the correlation of HRQOL outcomes is more sensitive with more specific measures.[30] The responses to the SF-36 questionnaire may be confounded by the presence of other concurrent comorbidities and chronic diseases; therefore, correlation outcomes measure by the SF-36 questionnaire may not be accurately representing only the effects of PJK and PJF. In a study of 3482 patients who underwent lumbar spine surgery, Slover *et al*[31] demonstrated that medical and psychosocial comorbidities had a negative impact on the SF-36 survey (*i.e.*, SF-36 scores worsened as the number of comorbidities increased).

Each component of the Hart-ISSG PJKSS was demonstrated to be valuable to the Hart-ISSG PJKSS. Neurological deficit and pain severity seemed to be more important than radiographic findings in regard to HRQOL outcomes. Removal of neurological deficit decreased the correlation of the Hart-ISSG PJKSS to all HRQOL outcomes, except for VAS pain. VAS pain was not affected because VAS pain itself is a component of the Hart-ISSG PJKSS. The removal of neurological deficit results in five components left in the Hart-ISSG PJKSS, allowing the pain component of the Hart-ISSG PJKSS to be weighed more heavily (1 of 5 instead 1 of 6). The removal of pain decreased the correlation of the Hart-ISSG PJKSS to all HRQOL outcomes; suggesting pain is a critical component to the Hart-ISSG PJKSS.

Structural and radiographic components (instrumentation, kyphosis, fracture, and UIV level) of the Hart-ISSG PJKSS were less important than neurological deficit and pain, but overall valuable to the grading scale. An important observation is that removal of instrumentation, kyphosis,

TABLE 6. Representation of Changes in Pearson Correlation Coefficient After Removal of Each Hart-ISSG PJKSS Scoring Component

	Removal of:											
	Neurological		Pain		Instrumentation		Kyphosis		Fracture		UIV	
Outcomes	Change	Difference	Change	Difference	Change	Difference	Change	Difference	Change	Difference	Change	Difference
ODI	(−)	0.057	(−)	0.159	(−)	0.048	(−)	0.008	(-)	0.014	(−)	0.005
SF-36 Physical	(−)	0.037	(−)	0.101	(+)	0.043	(+)	0.032	(+)	0.036	(+)	0.010
SF-36 Mental	(−)	0.035	(−)	0.088	(+)	0.001	(+)	0.010	(+)	0.028	(−)	0.002
VAS Pain	(+)	0.025	(−)	0.313	(+)	0.016	(+)	0.010	(+)	0.005	(+)	0.002
SRS-30 Function	(−)	0.080	(−)	0.125	(+)	0.003	(−)	0.009	(+)	0.018	(+)	0.003
SRS-30 Pain	(−)	0.055	(−)	0.190	(+)	0.014	(+)	0.008	(+)	0.006	(−)	0.002
SRS-30 Self Image	(−)	0.013	(−)	0.136	(−)	0.051	(−)	0.013	(−)	0.015	(−)	0.018
SRS-30 Mental Health	(−)	0.151	(−)	0.267	(−)	0.158	(−)	0.156	(−)	0.136	(−)	0.136
SRS-30 Satisfaction	(−)	0.045	(−)	0.103	(−)	0.060	(−)	0.019	(−)	0.020	(−)	0.010

(−) indicates decrease in Pearson correlation coefficient; (+), increase in Pearson correlation coefficient; ODI, Oswestry Disability Index; SF-36, short form-36; SRS-30, Scoliosis Research Society-30; VAS, visual analogue scale.

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TABLE 7. Mean Hart-ISSG PJKSS Scores

	N	%	Mean	SD	*P*
Revision surgery	184	—	5.9	—	<0.001
Yes	76	41.3	7.8	2.3	
No	108	58.7	4.6	1.7	

TABLE 8. Association Among Higher Hart-ISSG PJKSS Scores and Higher Revision Rates for in Patients With PJK

HART ISSG PJK Severity Scale			Revision		
	n	%	n	%	*P*
Total	184	–	76	41.3	<0.001
0 to 2	12	6.5	0	0.0	
3 to 5	76	41.3	13	17.1	
6 to 8	68	37.0	36	52.9	
9 to 11	25	13.6	24	96.0	
12 to 15	3	1.6	3	100.0	

fracture, or level of UIV resulted in a comprehensive decrease in correlation coefficients for ODI, SRS-30 self-image, SRS-30 mental health, and SRS-30 satisfaction. As expected, removal of each of the structural components of the Hart-ISSG PJKSS increased the correlation coefficient for HRQOL pain outcomes (VAS pain and SRS-30 pain) for the same reasoning the correlation coefficient increased when neurological deficit was removed; pain proportionally had more influence on the Hart-ISSG PJKSS when five components were left.

Reported rate of revision surgery for PJK and PJF ranges between 13% and 47%.[3,28,29] The variability is secondary to a multitude of factors, including a lack of a standard indication for surgical revision. When the Hart-ISSG PJKSS was retrospectively applied, there was a significant association between higher Hart-ISSG PJKSS scores and revision surgery. More than half the patients (52.9%) with scores of 6 to 8 underwent revision surgery. In patients who have scores greater than 8, revision surgery should be considered because scores of 9 to 11 and 12 to 15 underwent revision surgery 96.0% and 100.0% of the time, respectively. While this association is quite significant, it is difficult to definitively conclude that the Hart-ISSG PJKSS is able to predict the likelihood for the need for surgical revision because of the small number of patients in the highest scoring groups (three patients with Hart-ISSG PJKSS scores of 12 to 15). But given the promising trend, the Hart-ISSG PJKSS may be a useful tool in the future.

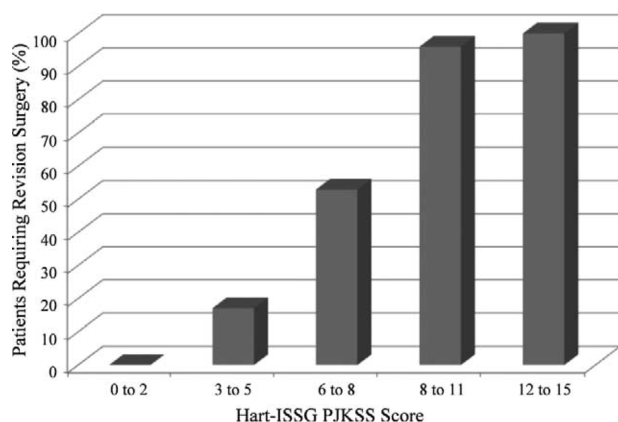

Figure 4. Proportion of patients requiring revision surgery for Proximal Junctional Kyphosis Stratified by Hart-ISSG PJKSS score. *Bar graph demonstrating significantly higher rates of revision surgery in patients with higher Hart-ISSG PJKSS scores ($P < 0.001$): scores 0 to 2 (0.0%), scores 3 to 5 (17.1%), scores 6 to 8 (52.9%), scores 9 to 11 (96.0%), and scores 12 to 15 (100.0%).

A limitation to this study is the partial retrospective nature. While HRQOL measures were collected prospectively, the Hart-ISSG PJKSS scores were assigned retrospectively by reviewing medical records and radiographs. As this is a retrospective study, exposure on outcome assessments was dependent on accurate record-keeping. Inherently, this places the study at risk for information bias. However, the presence of such bias is unlikely because all of the components assessed by the Hart-ISSG PJKSS were available and concrete. To address this issue, a prospective, multicenter validation of the Hart-ISSG PJKSS is currently ongoing.

The Hart-ISSG PJKSS is not free from drawbacks. Clinically, it is straightforward that patients with PJK associated with neurological deficits and/or significant hardware failure will likely require surgical revision. These patients will have high Hart-ISSG PJKSS scores. It is also clear that patients with isolated radiographic findings of mild PJK do not warrant revision surgery. The problem lies with the difficulty in interpreting and utilizing "less clear-cut" Hart-ISSG PJKSS scores (3 to 8). Currently, the management of these patients still relies mainly on clinical judgement. This

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issue of ambiguity is not unique only to the Hart-ISSG PJKSS; most scoring systems for disease processes are at fault as well. However, there still remains an advantage of utilizing the Hart-ISSG PJKSS in "less clear-cut" patients because the Hart-ISSG PJKSS allows consistent categorization of PJK for prospective observations. In the future, the Hart-ISSG PJKSS may allow clinicians to highlight a subset population of "less clear-cut" patients who will ultimately go on to develop severe PJK and/or need revision surgery. Currently, the Hart-ISSG PJKSS acts mainly as a descriptive tool, but with ongoing prospective studies we hope it will eventually lead to the development of a system that is able to guide the clinical management of patients with PJK of all scores.

CONCLUSION

The findings from this study are suggestive that the Hart-ISSG PJKSS is strongly correlated with HRQOL outcomes. Worse (higher) Hart-ISSG PJKSS scores were associated with worse (higher) ODI, worse (higher) VAS pain, and worse (lower) SRS-30 scores for all components. In addition, higher Hart-ISSG PJKSS scores were significantly associated with higher rates of revision surgery rates; scores greater than 8 are associated with revision rates of 96% to 100%. The Hart-ISSG PJKSS should be considered a method of assessing PJK and PJF severity. It will be a useful tool for communicative purposes and predicting quality of life. In addition, it may highlight the subset of patients who undergo revision surgery.

➢ Key Points

- ❑ Proximal junctional kyphosis and failure are common adverse outcomes after long-segmentation instrumentation, but there is a spectrum disease severity.
- ❑ The Hart-ISSG PJKSS incorporates six important components of PJK and PJF when assessing disease severity.
- ❑ The Hart-ISSG PJKSS is strongly correlated with validated functional outcomes, particularly ODI, VAS pain, and SRS-30 outcomes.
- ❑ Higher Hart-ISSG PJKSS scores are correlated with higher rates of revision; scores of 9 to 11 and 12 to 15 underwent revision 96.0% and 100.0% of the time, respectively.

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