Spine

SPINE Volume 37, Number 7, pp 592–598
©2012, Lippincott Williams & Wilkins

DEFORMITY

Correlation of Radiographic and Functional Measurements in Patients Who Underwent Primary Scoliosis Surgery in Adult Age

Felisa Sánchez-Mariscal, MD, Alejandro Gomez-Rice, MD, Enrique Izquierdo, MD, PhD, Javier Pizones, MD, PhD, Lorenzo Zúñiga, MD, and Patricia Álvarez-González, MD

Study Design. Prospective radiographic and clinical analysis.

Objective. To evaluate whether radiographic spinopelvic parameters correlate with health-related quality of life (HRQOL) measures, in the long run, in patients operated on scoliosis in adult age.

Summary of Background Data. There are papers that correlate sagittal radiographic parameters with HRQOL scores for healthy spine as well as for some spinal disorders. However, there are limited studies evaluating correlations between HRQOL measures, radiographic spinopelvic parameters, and age in patients operated on scoliosis in adult age.

Methods. Fifty-nine patients, older than 21 years at surgery time (median: 50.2 years), were operated upon at a single center. All of them suffered mainly frontal deformity, idiopathic or degenerative curves, and long fusions, with more than a 2-year follow-up (median: 8.5 years). Full-length freestanding radiographs, including the spine and pelvis, and SRS22 and SF36 instruments, were available for every patient at final follow-up. Sagittal and frontal radiographic parameters and age were analyzed for correlation with HRQOL. A multivariate analysis was performed.

Results. No significant correlation was found between frontal parameters and HRQOL measures. Spearman rank order test showed correlation ($P < 0.001$) between Scoliosis Research Society (SRS) activity and sagittal vertical axis (SVA) ($r = -0.44$), pelvic tilt (PT) ($r = -0.49$), and age ($r = -0.5$). SRS total was correlated ($P < 0.004$) with PT ($r = -0.32$) and age ($r = -0.41$). SF36 physical function correlated ($P < 0.001$) with SVA ($r = -0.44$), PT ($r = -0.45$), and age ($r = -0.56$). After multivariate analysis, only age and PT persisted as possible predictors of worse SRS activity scores.

Conclusion. After primary surgery for adult scoliosis, frontal radiographic parameters did not correlate with HRQOL measures. In univariate analysis, patient age, SVA, and PT correlated with activity scores, although the correlation coefficients did not reach high values. After multivariate analysis, SVA was not a predictor of function.

Key words: adult scoliosis, age, frontal plane, HRQOL measures, sagittal plane. **Spine 2012;37:592–598**

The search for correlations between radiographic measures and clinical tests is a constant concern in clinical practice nowadays.[1–5] The aim of this search is to associate objective measures (radiographic parameters) with subjective outcomes (clinical results).

Schwab *et al*[6] published findings that L3 and L4 frontal vertebral obliquity, thoracolumbar kyphosis, intervertebral subluxation, and loss of lumbar lordosis were correlated with pain in nonoperated adult scoliosis. Positive sagittal balance[1] has been considered the most reliable predictor of clinical symptoms in operated, as well as nonoperated, patients with scoliosis bigger than 30°. Sagittal spinal (C7 plumbline) and global balance (gravity line)[3] were strongly related to Oswestry Disability Index (ODI) in adults with unoperated scoliosis. A reduced lumbar lordosis and an increased lumbosacral scoliosis can affect the general health status of older patients with degenerative scoliosis.[4] Pelvic position measured *via* PT as well as global sagittal alignment measured *via* T1 spinopelvic inclination have shown high correlations with health-related quality of life (HRQOL) measures.[5]

However, multivariate analysis is lacking in most of those studies. Also, most of them were carried out in a mixed series of operated and unoperated patients or with a mixture of different etiologies. We are not aware of any other study regarding the relationships between pelvic parameters, spinopelvic alignment, and age with HRQOL measurements in an adult population operated on for scoliosis.

The aim of this work was to evaluate if radiographic spinopelvic parameters correlate with HRQOL measures, in the long run, in adult patients operated on for scoliosis.

From the Spinal Unit, University Hospital of Getafe, Getafe, Madrid, Spain.

Acknowledgment date: February 24, 2011. First revision date: May 11, 2011. Acceptance date: May 27, 2011.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Address correspondence and reprint requests to Felisa Sánchez-Mariscal E, C/Zurita, 9, 1 B, 28012, Spain; E-mail: F3130@hotmail.com

DOI: 10.1097/BRS.0b013e318227336a

MATERIALS AND METHODS

The study included a consecutive series of 59 patients operated on for adult scoliosis at a single center by the senior author (Izquierdo E). The inclusion criteria for this study were as follows: patients older than 21 years at first surgery time, frontal Cobb greater than 40°, idiopathic or degenerative curves, more than 4 motion levels of fusion, and a minimum 2-year postoperative follow-up.

At final follow-up, every patient completed a clinical questionnaire and SRS22[7] and SF36[8] instruments.

New radiographs were undertaken in every patient except in patients with more than 5-year postoperative follow-up, with a radiographic study of less than 24 months and without clinically significant changes. Our standard postoperative follow-up included office visits and radiographs at 2, 6, and 12 months postoperative, yearly until the fifth year, and every 2 years thereafter. Radiographic data collected consisted of full-length standing coronal and sagittal radiographs including the spine and pelvis obtained in freestanding posture with fingers on the clavicles and shoulders in 40° of forward elevation.[9]

Radiographic data collected included percentage of frontal correction achieved and final follow-up standardized parameters.[10,11]

The Spearman correlation coefficient was used to evaluate the linear relationship between continuous variables. A multiple linear regression analysis was performed as multivariate analysis. The collinearity of the maximal model was evaluated.

TABLE 1. HRQOL Scores (Median, 25–75 Percentile)

	Median	25th Percentile	75th Percentile
SRS function	3.6	2.8	4.2
SRS pain	3.2	2.2	4.2
SRS self-image	3.4	3.0	4.0
SRS mental health	3.6	3.0	4.0
SRS satisfaction	4.0	3.5	5.0
SRS total	3.6	2.8	4.1
SF36 physical functioning	60.0	35.0	75.0
SF36 physical role	50	0	100
SF36 bodily pain	51.0	22.0	72.0
SF36 general health	50.0	35.0	47.2
SF36 vitality	45.0	30.0	60.0
SF36 social functioning	75.0	50.0	87.5
SF36 emotional role	100	0	100
SF36 mental health	64.0	48.0	76.0

RESULTS

Group Description

The study group consisted of 8 men and 51 women; the median age of the study population, at questionnaire filling, was 50.2 years (39–63.5 years). The breakdown of patients by primary diagnosis was 48 idiopathic curves and 11 degenerative curves. The median postoperative follow-up was 8.5 years (4.0; 13.0) Thus, 42 patients (71.2%) had a follow-up longer than 5 years, 24 patients (40.7%) had a follow-up longer than 10 years, and 11 patients (18.6%) had a follow-up longer than 15 years. HRQOL scores obtained are recorded in Table 1. Radiographic results are recorded in Table 2. The median preoperative major curve Cobb angle was 59° (44°; 74°). Lateral bending radiograph showed a correction to 42.5° (21.2°; 64°) in the major curve Cobb angle. After surgery, the major curve median Cobb angle was 27° (16°; 38°) with a median correction of 54.7%. The final median main curve Cobb after follow-up was 30° (18°; 37°). A double approach was performed in 45.8% of the patients, fusion to the sacrum in 22.1%, and fusion proximal to T9 vertebra in 64.4% of the patients.

TABLE 2. Radiographic Parameters

	Median (Final)	25th Percentile (Final)	75th Percentile (Final)
Major curve Cobb angle	30°	18°	37°
Coronal balance	3 mm	−15 mm	4 mm
Apical rotation (Perdriolle)	15°	5°	25°
Apical vertebral (translation)	5	−21 mm	28
Lower instrumented (vertebral tilt)	9.5°	4.5°	12°
Upper instrumented (vertebral tilt)	5°	0°	13°
Thoracic kyphosis	40°	30°	52°
Maximum kyphosis	43°	32.3°	55°
Thoracolumbar kyphosis	3°	−1°	10.5°
Lumbar lordosis	48.0°	40.0°	57.2°
Proximal junctional angle	1°	0°	10°
Sagittal difference (LL–TK)	7°	−5.5°	22°
Pelvic incidence	55°	48.7°	61°
Pelvic tilt	21.5°	12.7°	31.5°
Sacral slope	35°	25.0°	40°
Sagittal vertebral axis	12 mm	8 mm	4 mm
T1 spinopelvic inclination	−4.5°	−7.7°	−3.0°
T9 spinopelvic inclination	−12°	−16.0°	−9.0°

SRS22 and SF36—Age Correlations

Older patients had worse results in every Scoliosis Research Society (SRS) domain: function ($r = -0.50$; $P \leq 0.000$), pain ($r = -0.31$; $P = 0.01$), self-image ($r = -0.28$; $P \leq 0.02$), mental health ($r = -0.45$; $P \leq 0.000$), satisfaction ($r = -0.15$; $P = 0.25$), and global score ($r = -0.41$; $P = 0.001$). The most significant correlations were found with function, mental health, and total scores, without particularly high values of correlation coefficients, but still highly significant.

Also, older patients had worse results in every SF36 domain, especially bodily pain ($r = -0.32$; $P = 0.01$), mental health ($r = -0.43$; $P = 0.001$), and physical functioning ($r = -0.56$; $P \leq 0.000$). In the latter 2, we found a medium correlation coefficient with high significance, as happened with SRS domains.

SRS22 and SF36—Coronal Plane Correlations

Neither the coronal plane radiographic parameters evaluated nor the percentage of frontal Cobb correction showed any correlation with any of the SF36 domains or SRS22 subscales (Table 3).

SRS22 and SF36—Sagittal Plane Correlations

SRS22: A greater lumbar lordosis had a correlation with increased function. Positive sagittal balance correlated with

TABLE 3. Correlation Coefficients Between SRS22 and SF36 Scores and Frontal Radiographic Measures

	Cobb	CB	AR	AVT	LIVT	UIVT	MCC (%)
SRS22							
Function	*R* = −0.04 (*P* = 0.74)	*R* = −0.07 (*P* = 0.58)	*R* = 0.05 (*P* = 0.71)	*R* = −0.03 (*P* = 0.81)	*R* = 0.58 (*P* = 0.71)	*R* = 0.16 (*P* = 0.22)	*R* = 0.05 (*P* = 0.67)
Pain	*R* = −0.05 (*P* = 0.67)	*R* = −0.01 (*P* = 0.98)	*R* = −0.09 (*P* = 0.56)	*R* = −0.10 (*P* = 0.47)	*R* = 0.04 (*P* = 0.79)	*R* = 0.21 (*P* = 0.12)	*R* = 0.11 (*P* = 0.41)
Self-image	*R* = 0.05 (*P* = 0.69)	*R* = −0.15 (*P* = 0.28)	*R* = 0.08 (*P* = 0.57)	*R* = −0.06 (*P* = 0.65)	*R* = −0.02 (*P* = 0.86)	*R* = 0.05 (*P* = 0.69)	*R* = 0.04 (*P* = 0.77)
Mental	*R* = −0.13 (*P* = 0.33)	*R* = 0.03 (*P* = 0.78)	*R* = −0.02 (*P* = 0.88)	*R* = 0.02 (*P* = 0.87)	*R* = −0.01 (*P* = 0.91)	*R* = 0.11 (*P* = 0.40)	*R* = 0.14 (*P* = 0.27)
Satisfaction	*R* = 0.12 (*P* = 0.90)	*R* = −0.10 (*P* = 0.45)	*R* = −0.02 (*P* = 0.89)	*R* = 0.01 (*P* = 0.97)	*R* = −0.05 (*P* = 0.74)	*R* = −0.01 (*P* = 0.99)	*R* = −0.02 (*P* = 0.86)
Total	*R* = −0.07 (*P* = 0.59)	*R* = −0.06 (*P* = 0.67)	*R* = −0.02 (*P* = 0.89)	*R* = −0.05 (*P* = 0.71)	*R* = 0.25 (*P* = 0.87)	*R* = 0.14 (*P* = 0.31)	*R* = 0.10 (*P* = 0.43)
SF36							
Physical functioning	*R* = −0.15 (*P* = 0.24)	*R* = 0.10 (*P* = 0.44)	*R* = −0.01 (*P* = 0.96)	*R* = −0.05 (*P* = 0.72)	*R* = 0.11 (*P* = 0.49)	*R* = 0.10 (*P* = 0.45)	*R* = 0.12 (*P* = 0.35)
Role physical	*R* = −0.08 (*P* = 0.52)	*R* = 0.06 (*P* = 0.65)	*R* = −0.16 (*P* = 0.28)	*R* = −0.23 (*P* = 0.09)	*R* = −0.03 (*P* = 0.86)	*R* = −0.06 (*P* = 0.64)	*R* = 0.15 (*P* = 0.24)
Bodily pain	*R* = 0.01 (*P* = 0.92)	*R* = 0.02 (*P* = 0.84)	*R* = −0.01 (*P* = 0.52)	*R* = 0.05 (*P* = 0.72)	*R* = 0.07 (*P* = 0.63)	*R* = 0.16 (*P* = 0.23)	*R* = −0.01 (*P* = 0.94)
General health	*R* = −0.03 (*P* = 0.82)	*R* = 0.10 (*P* = 0.46)	*R* = −0.17 (*P* = 0.27)	*R* = −0.08 (*P* = 0.55)	*R* = −0.02 (*P* = 0.90)	*R* = 0.01 (*P* = 0.95)	*R* = −0.01 (*P* = 0.93)
Vitality	*R* = 0.05 (*P* = 0.69)	*R* = 0.15 (*P* = 0.27)	*R* = −0.09 (*P* = 0.56)	*R* = 0.01 (*P* = 0.91)	*R* = −0.01 (*P* = 0.97)	*R* = 0.08 (*P* = 0.55)	*R* = −0.01 (*P* = 0.98)
Social functioning	*R* = −0.01 (*P* = 0.93)	*R* = 0.04 (*P* = 0.74)	*R* = −0.15 (*P* = 0.35)	*R* = −0.05 (*P* = 0.68)	*R* = 0.03 (*P* = 0.84)	*R* = 0.10 (*P* = 0.46)	*R* = 0.08 (*P* = 0.53)
Role emotional	*R* = −0.19 (*P* = 0.15)	*R* = −0.07 (*P* = 0.61)	*R* = −0.18 (*P* = 0.25)	*R* = −0.07 (*P* = 0.62)	*R* = −0.14 (*P* = 0.38)	*R* = 0.15 (*P* = 0.26)	*R* = 0.23 (*P* = 0.07)
Mental health	*R* = −0.20 (*P* = 0.12)	*R* = 0.09 (*P* = 0.49)	*R* = −0.12 (*P* = 0.44)	*R* = −0.02 (*P* = 0.88)	*R* = −0.13 (*P* = 0.40)	*R* = −0.01 (*P* = 0.90)	*R* = 0.23 (*P* = 0.08)

Correlation coefficients between SRS22 and SF36 scores and frontal radiographic measures.

Cobb indicates major curve Cobb angle; CB, coronal balance; AR, apical rotation (Perdriolle); AVT, apical vertebral translation; LIVT, lower instrumented vertebral tilt; UIVT, upper-instrumented vertebral tilt; MCC, major curve correction (percentage); R = Spearman coefficient.

worse scores for SRS22 function domain, pain domain, and total score. Patients with lower pelvic incidence had significantly higher function scores. An increased PT was associated with worse results in all SRS22 domains; the strongest correlations were noted in function domain and total score (Table 4).

SF36: Significant correlations between sagittal plane parameters and SF36 scores were identified. A high degree of correlation was found between positive sagittal balance and a decrease in physical functioning domain and social functioning domain. In other words, there was evidence of decreasing physical activity and social functioning as the magnitude of positive sagittal balance increased. Patients with lower pelvic incidences were shown to have higher physical functioning scores. Having a greater PT was associated with a decrease in mental health domain, social functioning domain, and bodily pain domain and a highly significant decrease in physical functioning domain (Table 5).

In summary, Spearman rank-order test showed highly significant ($P < 0.001$) correlations between SRS function and sagittal vertical axis (SVA, $r = -0.44$), PT ($r = -0.49$), and age ($r = -0.5$). SRS total was also significantly ($P < 0.004$) correlated with PT ($r = -0.32$) and age ($r = -0.41$). There was also a significant relationship ($P < 0.001$) between SF36 physical function and SVA ($r = -0.44$), PT ($r = -0.45$), and age ($r = -0.56$).

Multivariate Analysis for SRS22 Function Domain

Because a highly significant inverse correlation existed between the SRS22 function domain and age, SVA, and PT, a multivariate analysis was performed to evaluate the combined effect of these 3 parameters. A multiple linear regression was performed in which SRS22 function domain was the dependent variable and sagittal vertical axis (SVA), PT, and age were independent variables. The presence of collinearity between the independent variables was assessed and was not found. In the final model, only age and PT persisted as significant variables. Thus, for each year older the patient was, SRS22 function decreased by 0.022 points (confidence interval [CI]: 95% 0.005; 0.038; $P = 0.014$), and for each degree of final PT, SRS22 function decreased 0.0021 points (CI: 95%, 0.003; 0.039; $P = 0.026$). The corrected determination coefficient (R^2) was 0.294, thus, 29.4% of the variability of the SRS22 function scale could be explained by age and PT.

We also noticed that, patient age correlated with PT ($r = 0.57$; $P < 0.000$) and that, through simple linear regression, patient age explained 30% of the variability of PT.

The presence of interactions between age, PT, and SVA was also evaluated. No interactions were found between these variables, despite the correlation found between age and PT.

DISCUSSION

Recent publications on adult scoliosis have highlighted the correlation between sagittal parameters and HRQOL tests,[2–5] but no correlations have been found between QOL measures and frontal parameters.[1,3–5] However, Jackson *et al*,[12] in a population older than 20 years (36 years average) with idiopathic scoliosis, correlated pain with a frontal Cobb angle greater than 40°. More recently, in more than 146 adult scoliosis patients[13] (treated operatively or conservatively) with an average age of 47 years, no correlations were found between SF36/SRS22 instruments and sagittal balance, coronal balance, main Cobb angle, or number of fused levels.

In adult scoliosis[14] for patients younger than 50 years, the decision for surgical management depends on the magnitude of the curve in the frontal plane. On the other hand, in patients older than 50 years, this decision depends on preoperative HRQOL measures despite frontal or sagittal radiographic measures.

The clinical results obtained in our patients, after evaluating SRS22 as well as SF36 results, are similar to those found in other series of patients operated on for adult deformity.[8,15,16] In our study, no correlations were found between the quality-of-life test results and any of the frontal parameters evaluated, as in other series.[1,3–5] We noticed that clinical results were worse in older[15,16] patients, especially regarding physical activity, and that a higher lumbar lordosis, a lower anterior disbalance, and a lower PT correlated with better scores for the different subscales[2–4,6,17,18] of the quality-of-life tests, especially the function domain. A lower pelvic incidence correlated with better activity. It has been published[17] that a postoperative optimum sagittal balance is associated with better quality-of-life test results as well as lower pelvic incidences. Up to 30% of the variability of PT could be determined by age. It is known that there is an increase of PT with age.[19] However, because no interactions were found, age and PT act as independent factors to determine SRS22 function scores.

Thus, for the analyzed population, there exists an association between sagittal profile and quality-of-life test results. If a gross interpretation of the mathematical results is done, we could acknowledge that a decrease of lumbar lordosis, a positive sagittal balance, and a higher PT, as well as patient age, are the key parameters to determine surgical results (health survey results) in the long term. However, a more insightful analysis shows us the following:

(1) Even when a highly significant correlation was found (between sagittal balance or PT and activity subscale), the correlation coefficient did not reach high values[1–3] with the clinical limitations that this fact carries. We should not forget that correlation analysis measures linear association between 2 variables but cannot be interpreted as establishing cause-and-effect relationships.

(2) After performing a multivariate analysis, only age and PT were identified as predictors of results, with the sagittal balance[4] losing its role as a potential predictor.

Another fact that may limit the role of the sagittal plane as a clinical outcome predictor is that, nowadays, an "adequate sagittal balance" is not easy to define. There is a wide range of values accepted as normal for some radiographic measurements, and there is no agreement regarding to the reference points that should be used for these measurements. The SVA, which is one of the most commonly used radiographic parameters, seems to have a more than questionable role to determine the spinal sagittal alignment. We also should not ignore the limited value of static measurements used in the

TABLE 4. Correlation Coefficients Between SRS2 Scores and Sagittal Plane Measures

	TK	TLK	MK	LL	SVA	T1SI	T9SI	PI	SS	PT	PJA
SRS22											
Function	R = −0.93 (P = 0.49)	R = 0.02 (P = 0.83)	R = 0.11 (P = 0.42)	R = 0.30 (*P = 0.02)	R = −0.44 (*P = 0.001)	R = −0.24 (P = 0.07)	R = 0.06 (P = 0.63)	R = −0.32 (*P = 0.01)	R = 0.15 (P = 0.49)	R = −0.49 (*P = 0.001)	R = 0.07 (P = 0.60)
Pain	R = −0.21 (P = 0.11)	R = 0.79 (P = 0.56)	R = −0.24 (P = 0.07)	R = 0.16 (P = 0.22)	R = −0.28 (*P = 0.03)	R = −0.07 (P = 0.56)	R = 0.16 (P = 0.22)	R = −0.17 (P = 0.20)	R = 0.16 (P = 0.22)	R = −0.31 (*P = 0.01)	R = 0.07 (P = 0.61)
Self-image	R = −0.18 (P = 0.18)	R = 0.03 (P = 0.80)	R = −0.18 (P = 0.18)	R = 0.13 (P = 0.31)	R = −0.24 (P = 0.07)	R = −0.06 (P = 0.64	R = 0.10 (P = 0.45)	R = −0.08 (P = 0.52)	R = 0.25 (P = 0.06)	R = −0.25 (*P = 0.05)	R = −0.03 (P = 0.98)
Mental	R = −0.19 (P = 0.14)	R = 0.20 (P = 0.13)	R = −0.13 (P = 0.34)	R = 0.09 (P = 0.50)	R = −0.14 (P = 0.27)	R = 0.01 (P = 0.99)	R = 0.06 (P = 0.62)	R = −0.16 (P = 0.23)	R = 0.14 (P = 0.27)	R = −0.31 (*P = 0.01)	R = −0.06 (P = 0.67)
Satisfaction	R = −0.32 (P = 0.81)	R = −0.01 (P = 0.91)	R = −0.05 (P = 0.72)	R = −0.01 (P = 0.93)	R = −0.22 (P = 0.10)	R = −0.08 (P = 0.52)	R = 0.09 (P = 0.50)	R = −0.25 (*P = 0.05)	R = 0.10 (P = 0.45)	R = −0.29 (*P = 0.02)	R = −0.15 (P = 0.28)
Total	R = −0.17 (P = 0.19)	R = 0.09 (P = 0.47)	R = −0.17 (P = 0.19)	R = 0.19 (P = 0.15)	R = −0.33 (*P = 0.01)	R = −0.12 (P = 0.37)	R = 0.10 (P = 0.43)	R = −0.22 (P = 0.08)	R = 0.20 (P = 0.12)	R = −0.37 (*P = 0.004)	R = 0.06 (P = 0.65)

*Statistically significant.

TK indicates thoracic kyphosis; TLK, thoracolumbar kyphosis; MK, maximum kyphosis; LL, lumbar lordosis; SVA, sagittal vertical axis; T1SI, T1 spinopelvic inclination; T9SI, T9 spinopelvic inclination; PI, pelvic incidence; SS, sacral slope; PT, pelvic tilt; PJA, proximal junctional angle.

TABLE 5. Correlation Coefficients Between SF36 Scores and Sagittal Plane Measures

	TK	TLK	MK	LL	SVA	T1SI	T9SI	PI	SS	PT	PJA
SF36											
Physical functioning	R = −0.16 (P = 0.22)	R = 0.11 (P = 0.41)	R = −0.16 (P = 0.22)	R = 0.26 (*P = 0.05)	R = −0.44 (*P = 0.001)	R = −0.17 (P = 0.20)	R = 0.06 (P = 0.62)	R = −0.29 (*P = 0.03)	R = 0.22 (P = 0.09)	R = −0.45 (*P < 0.000)	R = 0.01 (P = 0.49)
Role physical	R = −0.03 (P = 0.78)	R = 0.22 (P = 0.10)	R = 0.01 (P = 0.97)	R = 0.07 (P = 0.59)	R = −0.09 (P = 0.47)	R = −0.03 (P = 0.81)	R = −0.16 (P = 0.23)	R = −0.07 (P = 0.59)	R = 0.02 (P = 0.88)	R = −0.13 (P = 0.32)	R = 0.15 (P = 0.30)
Bodily pain	R = −0.12 (P = 0.35)	R = 0.11 (P = 0.41)	R = −0.12 (P = 0.38)	R = 0.10 (P = 0.45)	R = −0.22 (P = 0.10)	R = −0.01 (P = 0.99)	R = 0.09 (P = 0.49)	R = −0.24 (P = 0.07)	R = 0.13 (P = 0.32)	R = −0.34 (*P = 0.01)	R = −0.06 (P = 0.65)
General health	R = −0.08 (P = 0.53)	R = 0.24 (P = 0.07)	R = −0.08 (P = 0.57)	R = 0.71 (P = 0.59)	R = −0.14 (P = 0.29)	R = −0.04 (P = 0.76)	R = −0.12 (P = 0.36)	R = −0.05 (P = 0.69)	R = −0.01 (P = 0.94)	R = −0.12 (P = 0.36)	R = −0.02 (P = 0.90)
Vitality	R = −0.11 (P = 0.40)	R = 0.23 (P = 0.08)	R = −0.06 (P = 0.66)	R = 0.05 (P = 0.69)	R = −0.11 (P = 0.42)	R = −0.01 (P = 0.92)	R = 0.01 (P = 0.98)	R = −0.08 (P = 0.56)	R = 0.05 (P = 0.71)	R = −0.13 (P = 0.33)	R = 0.09 (P = 0.51)
Social functioning	R = −0.01 (P = 0.43)	R = 0.32 (*P = 0.01)	R = 0.57 (P = 0.68)	R = 0.06 (P = 0.65)	R = −0.31 (*P = 0.02)	R = −0.18 (P = 0.19)	R = −0.11 (P = 0.41)	R = −0.26 (*P = 0.05)	R = −0.04 (P = 0.78)	R = −0.27 (*P = 0.04)	R = 0.03 (P = 0.82)
Role emotional	R = −0.28 (*P = 0.03)	R = 0.13 (P = 0.34)	R = −0.24 (P = 0.07)	R = −0.11 (P = 0.40)	R = −0.10 (P = 0.45)	R = −0.04 (P = 0.76)	R = −0.03 (P = 0.80)	R = −0.10 (P = 0.46)	R = −0.12 (P = 0.36)	R = −0.07 (P = 0.16)	R = 0.11 (P = 0.43)
Mental health	R = −0.13 (P = 0.33)	R = 0.14 (P = 0.30)	R = −0.08 (P = 0.52)	R = 0.14 (P = 0.28)	R = −0.19 (P = 0.16)	R = −0.09 (P = 0.52)	R = −0.03 (P = 0.83)	R = −0.21 (P = 0.11)	R = 0.10 (P = 0.46)	R = −0.30 (*P = 0.03)	R = 0.22 (P = 0.13)

*Statistically significant.

TK indicates thoracic kyphosis; TLK, thoracolumbar kyphosis; MK, maximum kyphosis; LL, lumbar lordosis; SVA, sagittal vertical axis; T1SI, T1 spinopelvic inclination; T9SI, T9 spinopelvic inclination; PI, pelvic incidence; SS, sacral slope; PT, pelvic tilt; PJA, proximal junctional angle.

context of a disbalance that may have a dynamic component. All these factors[20–22] limit the accurate and full understanding of the sagittal profile.

We think that when deformity mainly affects the sagittal plane, the purpose of surgery should be the correction of that plane. In adult deformity, preventing flat-back syndrome and correcting and maintaining sagittal alignment are far more important than coronal correction.[23] Sagittal disbalance is very badly[24] tolerated in adult scoliosis patients. We are under the impression that PT correlates better with patients' activity than the SVA.

However, we believe that when we face a mainly frontal deformity in a middle-aged population, even knowing the importance of achieving balance in both sagittal and coronal planes, there are other factors, yet to be determined and non-related to the sagittal plane, that determine surgical results.

There are several limitations to this study. It would have been desirable to have a bigger sample size to stratify results by age groups. A very common limitation in clinical studies is the use of the freestanding position to assess sagittal profile because knees and ankle position are not included on a single radiographic cassette. However, it is a widespread technique used in several recent studies.[1,4,21,25] Although current standards in patient evaluation with radiographs can permit quantification of the plumbline offset, position of the lower extremities and feet remains elusive.[11]

Surgical technique was not included in our analysis because we did not feel that our study sample afforded us the power to analyze the various types of treatment and their influence on outcomes. Preoperative radiographic values and their modifications through surgery were not included in this study because the purpose of our study was not to evaluate the clinical improvement reached through surgery.

Nevertheless, we had a homogeneous group regarding diagnosis (idiopathic or degenerative frontal deformity) with a long-enough follow-up. We were able to update radiographic and clinical studies for the sake of achieving an exhaustive correlation analysis. Relationships between pelvic parameters and spinopelvic alignment with HRQOL measurements in an adult population operated on for scoliosis have not yet been accurately evaluated until now. We also carried out a multivariate analysis that permits an insightful analysis of the results obtained. The clinical interpretation of those mathematical results strengthens the fact that when we are facing a tridimensional deformity in a middle-aged population, just achieving a correct sagittal alignment through surgical management will not ensure good clinical results. We must try to gain a deeper knowledge of patients' motives for seeking surgery. Probably, some clinical aspects[17] may have as much or even more importance than the sagittal profile in this group of patients.

CONCLUSION

After primary surgery for adult scoliosis, in the long run, frontal radiographic parameters do not correlate with HRQOL measures. Using univariate analysis, patient age, SVA, and PT correlate with SRS22 and SF36 physical activity, but with low correlation coefficients.

After multivariate analysis, SVA was no longer a predictor of activity. PT and age resulted as predictors of activity. A deeper knowledge of patients' motives for seeking surgery is needed. Probably, some clinical aspects may have as much importance as the sagittal profile in this group of patients.

➢ Key Points

- ❑ After primary surgery for adult scoliosis, in the long run, frontal radiographic parameters do not correlate with HRQOL measures.
- ❑ Using univariate analysis, patient age, SVA, and PT correlate with SRS22 and SF36 physical activity but with low correlation coefficients.
- ❑ After multivariate analysis, SVA was no longer a predictor of activity. PT and age resulted as predictors of activity.

Acknowledgment

The authors thank Ana Royuela, Ramon y Cajal University Hospital, Madrid, Spain, Department of Statistics, for her support and assistance with the statistical analysis.

References

1. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine (Phila Pa 1976)* 2005;30:682–8.
2. Glassman SD, Bridwell KH, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976)* 2005;30:2024–9.
3. Mac-Thiong JM, Transfeldt E, Mehbod A, et al. Can C7 plumbline and gravity line predict health related quality of life in adult scoliosis? *Spine (Phila Pa 1976)* 2009;34:E519–27.
4. Ploumis A, Liu H, Mehbod A, et al. A correlation of radiographic and functional measurements in adult degenerative scoliosis. *Spine (Phila Pa 1976)* 2009;34:1581–4.
5. Lafage V, Schwab F, Patel A, et al. Pelvic tilt and truncal inclination. Two key radiographic parameters in the setting of adult spinal deformity. *Spine (Phila Pa 1976)* 2009;34:E599–606.
6. Schwab FJ, Smith VA, Biserni M, et al. Adult scoliosis: a quantitative radiographic and clinical analysis. *Spine (Phila Pa 1976)* 2002;27:387–92.
7. Asher MA, Lai SN, Burton DC. Further development and validation of the Scoliosis Research Society (SRS) outcomes instrument. *Spine (Phila Pa 1976)* 2000;25:2381–6.
8. Albert TJ, Purtill J, Mesa J, et al. Health outcome assessment before and after adult deformity surgery. A prospective study. *Spine (Phila Pa 1976)* 1995;20:2002–5.
9. Vedantam R, Lenke LG, Bridwell KH, et al. The effect of variation in arm position on sagittal spinal alignment. *Spine (Phila Pa 1976)* 2000;25:2204–9.
10. Bridwell KH, Hamill CL, Horton WC, et al. Adult deformity. In: O´Brien MF, Kuklo TR, Blanke KM, et al, eds. *Radiographic Measurement Manual. Spinal Deformity Study Group*. Memphis, TN: Medtronic Sofamor Danek; 2008:72–102.
11. Lafage V, Schwab F, Skalli W, et al. Standing balance and sagittal spinal deformity. Analysis of spinopelvic and gravity line parameters. *Spine (Phila Pa 1976)* 2008;33:1572–8.
12. Jackson RP, Simmons ED, Stripinis D. Coronal and sagittal plane spinal deformities correlating with back pain and pulmo-

nary function in adult idiopathic scoliosis. *Spine (Phila Pa 1976)* 1989;14:1391–7.
13. Berven S, Deviren V, Demir-Deviren S, et al. Studies in the modified Scoliosis Research Society outcomes instruments in adults: validation, reliability and discriminatory capacity. *Spine (Phila Pa 1976)* 2003;28:2164–9.
14. Bess RS, Boachie-Adjei O, Burton DC, et al. Pain and disability determine treatment modality for older patients with adult scoliosis, while deformity guides treatment for younger patients. *Spine (Phila Pa 1976)* 2009;34:2186–90.
15. Berven SH, Deviren V, Mitchell B, et al. Operative management of degenerative scoliosis: an evidence-based approach to surgical strategies based on clinical and radiographic outcomes. *Neurosurg Clin N Am* 2007;18:261–72.
16. Baldus C, Bridweel KH, Harrast J, et al. Age-gender matched comparison of SRS instrument scores between adult deformity and normal adults. Are all SRS domains disease specific? *Spine (Phila Pa 1976)* 2008;33:2214–8.
17. Kim YJ, Bridwell KH, Lenke LG, et al. An analysis of sagittal spinal alignment following long adult lumbar instrumentation and fusion to L5 or S1: can we predict ideal lumbar lordosis? *Spine (Phila Pa 1976)* 2006;31:2343–52.
18. Schwab FJ, Ashok D, Murali P, et al. Adult scoliosis: a health assessment analysis by SF-36. *Spine (Phila Pa 1976)* 2003;28:602–6.
19. Schwab F, Lafage V, Boyce R, et al. Gravity line analysis in adult volunteers. Age-related correlation with spinal parameters, pelvic parameters, and foot position. *Spine (Phila Pa 1976)* 2006;31:E959–67.
20. Choon-Sung L, Choon-Ki L, Yung-Tae, et al. Dynamic sagittal imbalance of the spine in degenerative flat-back. *Spine (Phila Pa 1976)* 2001;26:2029–35.
21. El Fegoun AB, Schwab F, Gamez L, et al. Center of gravity and radiographic posture analysis: a preliminary review of adult volunteers and adult patients affected by scoliosis. *Spine (Phila Pa 1976)* 2005;30:1535–40.
22. Stagnara P, De Mauroy JC, Dran G, et al. Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. *Spine (Phila Pa 1976)* 1982;7:335–42.
23. Ali RM, Boachie-Adjei O, Rawlins BA. Functional and radiographic outcomes after surgery for adult scoliosis using third-generation instrumentation techniques. *Spine (Phila Pa 1976)* 2003;28:1163–70.
24. Kuklo TR. Principles for selecting fusion levels in adult spinal deformity with particular attention to lumbar curves and double major curves. *Spine (Phila Pa 1976)* 2006;31:S132–8.
25. Schwab FJ, El-Fegoun AB, Gamez L, et al. A lumbar classification of scoliosis in the adult patient: preliminary approach. *Spine* 2005;30:1670–3.