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Relation between spine alignment and scapular position by plain radiograph examination

Jun Kawamata, MD[a], Shoji Fukuta, MD, PhD[b], Daisuke Nakai, MD, PhD[a], Masashi Kano, MD[a], Fumitake Tezuka, MD, PhD[a], Keizo Wada, MD, PhD[a], Koichi Sairyo, MD, PhD[a,*]

[a]Department of Orthopedics, Tokushima University, Tokushima, Japan
[b]Department of Orthopaedic Surgery, National Hospital Organization Kochi National Hospital, Kochi, Japan

A R T I C L E I N F O

Keywords:
Shoulder
Scapula
Glenoid anteversion
Glenoid anterior tilt
Spine alignment
Impingement syndrome

Level of evidence: Level III; Retrospective Cohort Study

Background: Both scapular dynamics and static scapular position are important in the treatment of shoulder dysfunction. This study aimed to create an index that can evaluate scapular position on plain radiographs and evaluate the relation between scapular position and posture accurately.
Methods: Using four fresh frozen cadavers, we developed a glenoid angle grade based on the degree of overlap between the shadow of the coracoid inflection point and the upper edge of the scapula on frontal plain radiographs: grade 1, no overlap; grade 2, overlaps by less than half of the shadow; grade 3, overlaps by more than half. We then performed a retrospective cohort study that included 329 shoulders of 329 patients who underwent spine surgery. Spine alignment parameters (SPAPs), including cervical lordosis (CL), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence, pelvic tilt, sacral slope, and sagittal vertical axis were measured on standing lateral plain radiographs. Glenoid anterior tilt (GAT) and glenoid anteversion angle (GAVA) were calculated on frontal radiographs and three-dimensional computed tomography scans. Correlations between SPAPs and each angle were investigated, and independent influencing factors were sought in multivariate analysis. Individual factors, GAT, GAVA, and SPAPs were compared among the grades.
Results: SPAPs associated with GAT were sagittal vertical axis ($R = 0.14$, $P = .011$), TK ($R = 0.12$, $P = .026$), and LL ($R = -0.11$, $P = .046$). Multivariate analysis identified TK and LL as independent influencing factors (TK, $P = .001$; LL, $P = .008$). SPAPs associated with GAVA were CL ($R = 0.17$, $P = .002$), TK ($R = 0.29$, $P < .001$), and LL ($R = 0.25$, $P < .001$). Multivariate analysis identified CL, TK, and LL as independent influencing factors (CL, $P = .01$; TK, $P = .03$; LL, $P = .03$). There were 183, 127, and 19 cases categorized as grades 1, 2, and 3. GAT (grade 1, 24.0 ± 7.8; 2, 32.4 ± 7.0; 3, 41.0 ± 7.8), GAVA (1, 29.3 ± 7.6; 2, 33.7 ± 9.5; 3, 31.5 ± 8.3), and TK (1, 30.6 ± 13.6; 2, 35.1 ± 14.2; 3, 43.1 ± 20.4) differed significantly according to grade.
Conclusion: We identified factors that influence scapular position and demonstrated that scapular position can be estimated by a grading system using plain radiographs.

Abnormal scapular or clavicular kinematics have been identified in populations with shoulder impingement,[9,13,31] rotator cuff tendinopathy,[17,19] rotator cuff tears,[6,19,25] shoulder instability,[22,24,25] and adhesive capsulitis.[10,18] Abnormal kinematics in that populations induce shoulder outlet impingement. Shoulder dysfunction may result from not only abnormal scapular dynamics but also static scapular position.[12,23,27] Otoshi et al described the relation between thoracic kyphosis (TK) and abnormal flexion at the shoulder joint.[23] Increased TK seems to result in an increase in the scapular anterior tilt angle and the glenoid anteversion angle (GAVA). Although there has been many reports on the position of the scapula estimated from the body surface, there have been no reports on the relation between the scapular position and spine alignment, including TK.

Two randomized clinical trials have compared the effectiveness of a scapula-focused exercise program with that of general shoulder rehabilitation and found that exercises targeting the scapula resulted in favorable patient-reported outcomes.[1,29] There are also reports of a rehabilitation intervention centered on the scapula being effective for shoulder impingement syndrome.[5,30] In those

This study was approved by the institutional review board of Tokushima University (approval number 2069-6, 4429).

*Corresponding author: Koichi Sairyo, MD, PhD, Department of Orthopedics, Tokushima University, 3-18-15 Kuramoto, Tokushima, 770-8503, Japan.
E-mail address: sairyokun@gmail.com (K. Sairyo).

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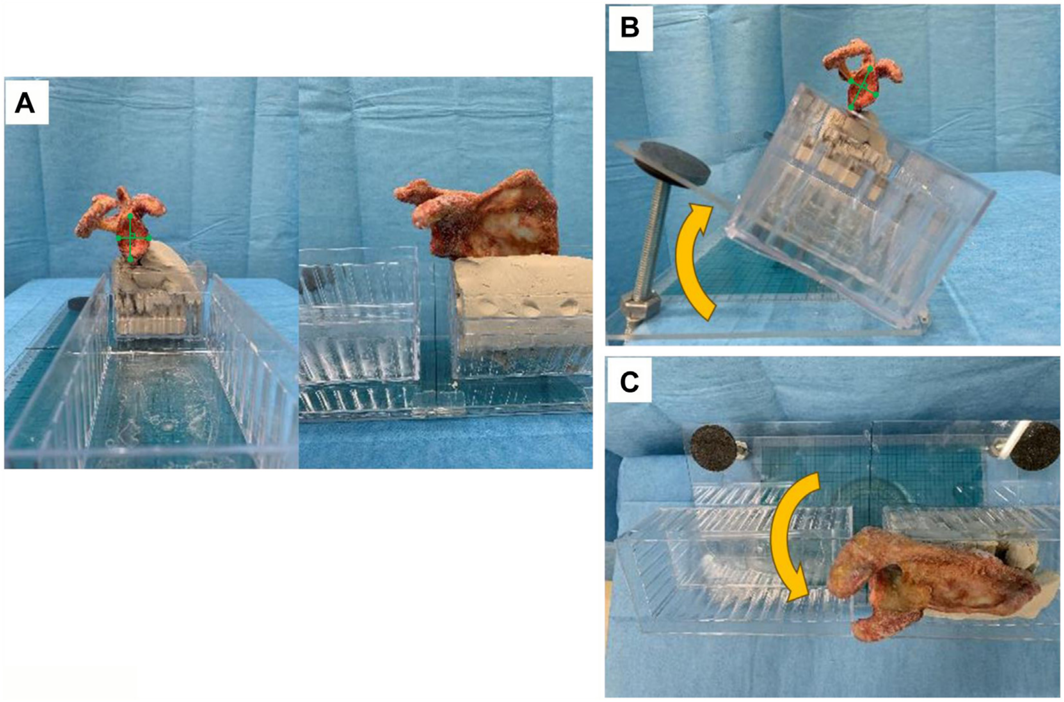

Figure 1 Device used to control the position of the scapula. (**A**) The device used in the cadaver simulation component of this study. We set the scapula to be parallel to the short axis of the glenoid to the ground. (**B**) The degree of glenoid anterior tilt was controlled using the device. (**C**) The degree of glenoid anteversion was also controlled with the device.

studies, a reduction in TK was thought to improve range of motion (ROM) at the shoulder, and physical therapy that included thrust manipulation of the thoracic spine resulted in a statistically significant decrease in self-reported pain measures and disability in patients with shoulder impingement syndrome.[5,30] These results may also be attributed to the scapular position. However, there is still no objective method that can easily evaluate changes in scapular position. Therefore, it has not been possible to judge the true effectiveness of rehabilitation interventions.

The aim of this research was to create a grade that can evaluate the position of the scapula on plain radiographs and accurately evaluate the relation between the position of the scapula and spine alignment parameters (SPAPs).

Materials and methods

Study design

In Part 1 of this study, we developed a glenoid angle grade in cadavers. In Part 2, we retrospectively investigated the correlations of the SPAPs with the position of the glenoid and the associations of the glenoid angle grade with the SPAPs.

Part 1: glenoid angle classification system developed using cadavers

This component of the study was performed using four fresh frozen Japanese cadavers (three male, one female) with a mean age at the time of death of 79.3 (range, 73-92) years. All the cadavers were donated to Tokushima University for research purposes. The study was approved by the institutional review board of Tokushima University. None of the specimens showed signs of previous surgery, trauma, abnormal osseous anatomy, or severe osteoarthritis with whole body computed tomography (CT) as autopsy imaging.

The right scapula was dissected from each cadaver, and frontal plain radiographs were obtained at 5-degree intervals in adduction/abduction (0-50 degrees) and internal/external rotation (0-50 degrees) using a device that can control the angle of the scapula (Fig. 1). We then developed the following classification system based on the degree of overlap between the shadow of the coracoid inflection point and the upper edge of the scapula seen on frontal plain radiographs of the scapula: grade 1, no overlap; grade 2, overlaps less than half of the shadow of the coracoid inflection point; grade 3, overlaps more than half of the shadow of the coracoid inflection point (Fig. 2). Radiographs were classified according to these grades, and the distributions of grade were demonstrated in each specimen.

Part 2: retrospective cohort study

Study population

This part of the study was a retrospective cohort study of patients aged older than 40 years who underwent surgery for chronic degenerative disease of the thoracolumbar spine in our department between 2017 and 2023 and for whom preoperative standing whole-spine plain radiographs (frontal and lateral) and CT scans that included the glenohumeral joint were available. The study was approved by the institutional review board of Tokushima University. Patients with more than a 5-mm difference in shoulder measurements between sides were excluded to avoid the confounding effect of factors such as scoliosis. Patients with a skeletal abnormality at the shoulder, such as osteoarthritis, cuff tear arthropathy, or a history of shoulder surgery, were also excluded. Finally, 329 shoulders of 329 patients (male, n=174; female, n=155) were included. The mean age at the time of surgery was 70.7 (range, 40-87) years.

Evaluations

The radiographer instructed the patient to relax and not tense or flex muscles, especially in the upper extremities when standing plain radiographs were obtained in the frontal view and positioned

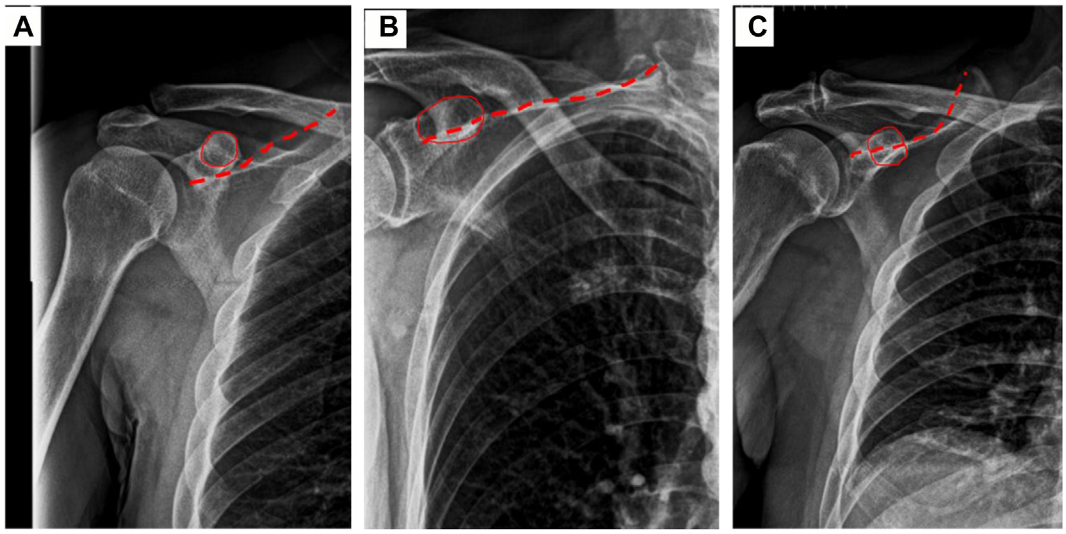

Figure 2 Classification of scapular position. The glenoid angle classification was based on the degree of overlap between the shadow of the coracoid inflection (*red circle*) point and the upper edge of the scapula (*red line*) seen on a frontal plain X-ray image of the scapula. (**A**) Grade 1, no overlap. (**B**) Grade 2, overlaps less than half of the shadow of the coracoid inflection point. (**C**) Grade 3, overlaps more than half of the shadow of the coracoid inflection point.

the shoulder in minimum flexion such that the spine and humerus did not overlap in the lateral view. The X-ray tube was positioned 200 cm from the patient to approximate the X-ray beam angle as in previous reports.[15,20] A calibration marker was applied to radiographs in both views.

The following SPAPs were measured on lateral plain radiographs: cervical lordosis (CL; C3-7), TK (T1-12), lumbar lordosis (LL; T12-S1), pelvic incidence, pelvic tilt, sacral slope, and sagittal vertical axis (Fig. 3). The apparent long and short axes were measured in the frontal view of standing plain radiographs including bilateral shoulder (C and D, respectively, in Fig. 4). The actual axes of the glenoid were measured on three-dimensional CT scans (long axis [A] and short axis [B] in Fig. 4). We also calculated the glenoid anterior tilt (GAT) and GAVA of the glenoid. GAT (∠E in Fig. 4) was defined as the angle formed by C/A and calculated using the following formula: cosE= C/A. GAVA (∠F in Fig. 4) was defined as the angle formed by D/B and calculated using the following formula: sinF= D/B.

Analysis

The correlations between the SPAPs and each angle were investigated, and independent influencing factors were sought in multivariate analysis. Individual factors, GAT, GAVA, and SPAPs were compared according to grade.

Statistical analysis

Examiner A (J.K.) examined the three-dimensional CT scans for 100 randomly selected shoulders in this case series on two occasions separated by an interval of 2 weeks to confirm the intraobserver reliability of our classification of the position of the scapula. Examiner B (M.K., a shoulder surgeon and one of the study investigators) also determined the classification on the same radiographs to ensure interobserver reliability. Intraobserver and interobserver reliability was then evaluated using κ value analysis according to the Landis and Koch criteria (≥0.81, almost perfect agreement; 0.61-0.80, substantial agreement; 0.41-0.60, moderate agreement; 0.21-0.40, fair agreement; and ≤0.20, slight agreement).

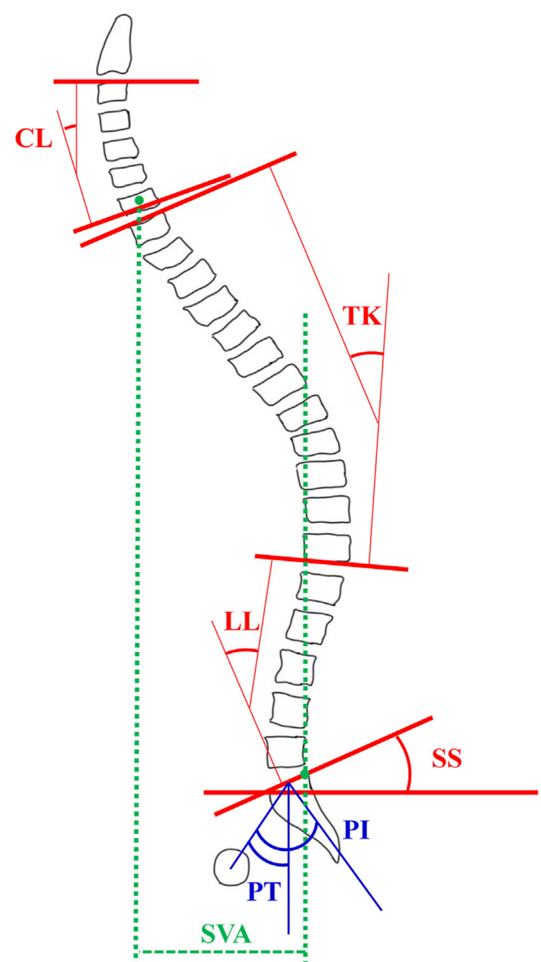

Figure 3 Spinal parameters investigated in this study. From the upper left hand side, cervical lordosis (CL; C3-7), thoracic kyphosis (TK; T1-12), lumbar lordosis (LL; T12-S1), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and sagittal vertical axis (SVA).

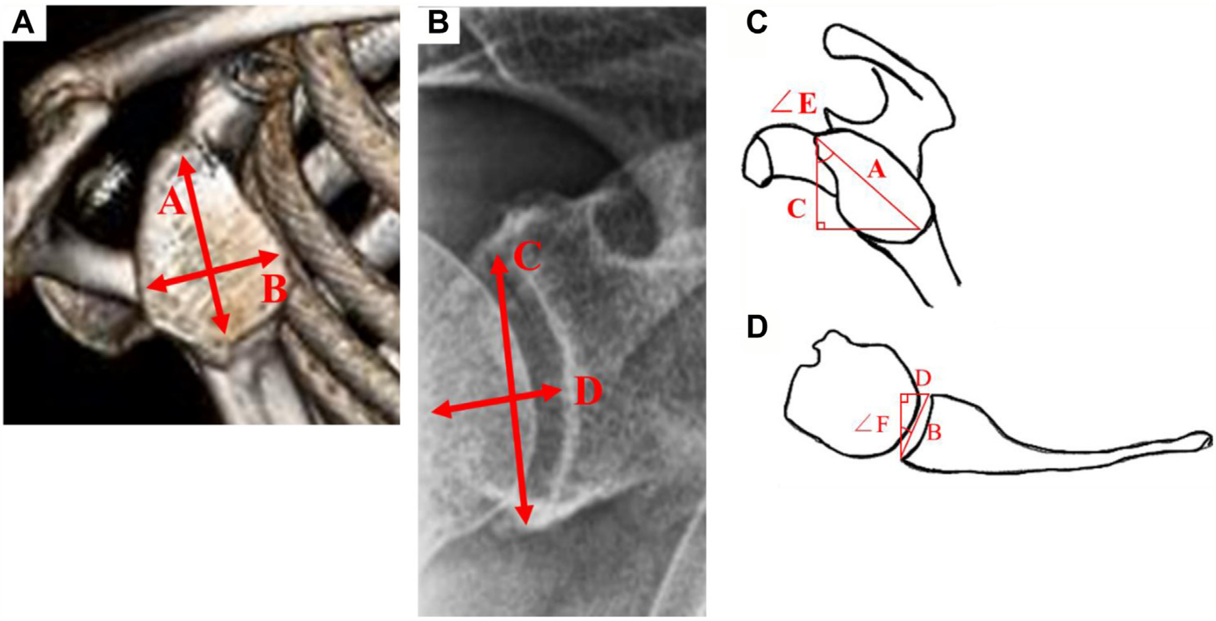

Figure 4 Calculation of the anteroposterior inclination (glenoid anterior tilt [GAT]) and the internal/external rotation angle (glenoid anteversion angle [GAVA]) of the glenoid. (**A**) The actual axes of the glenoid were measured on three-dimensional computed tomography scans (long axis, A; short axis, B). (**B**) Apparent long axis (C) and short axis (D) were measured on the frontal view. (**C**) GAT(∠E) was defined as the angle formed by C/A and was calculated using the following formula: cosE = C/A. (**D**) GAVA(∠F) was defined as the angle formed by D/B and calculated using the following formula: sinF= D/B.

Quantitative data were examined using the Mann–Whitney *U* test and categorical data using Fisher's exact test. The Spearman correlation method was used to assess the relation between SPAPs and each angle to screen for independent variables to be included in the multiple linear regression model. Variables that showed a statistically significant correlation with each angle were entered into the candidate model. Results were compared between three groups with Bonferroni correction. All statistical analyses were performed using SPSS version 27.0.1.0 software (IBM Corp., Armonk, NY, USA). A *P* value < .05 was considered statistically significant.

Results

Cadaveric simulation of glenoid angle grade

The distribution of grades for each cadaver is shown in Figure 5. In all cadavers, the grade became higher with an increasing angle. Intraobserver reliability of the classification of the position of the glenoid was evaluated as substantial (κ = 0.72; 95% confidence interval [CI]: 0.59, 0.85), as was interobserver reliability (κ = 0.64, 95% CI: 0.50, 0.79).

Retrospective cohort study

The correlations among the SPAPs are shown in Table I. All SPAPs were strongly correlated. Those associated with GAT were sagittal vertical axis (R = 0.14; 95% CI: 0.03, 0.25; *P* = .011), TK (R = 0.12; 95% CI: 0.01, 0.23; *P* = .026), and LL (R = −0.11; 95% CI: -0.22, 0.01; *P* = .046) (Table II). Multivariate analysis identified TK and LL as independent influencing factors (TK, t = 3.41, *P* = .001; LL, t = −2.66, *P* = .008) (Table III). SPAPs associated with GAVA were CL (R = 0.17; 95% CI: 0.06, 0.28; *P* = .002), TK (R = 0.29; 95% CI: 0.18, 0.39; *P* < .001), and LL (R = 0.25; 95% CI: 0.15, 0.35; *P* < .001) (Table II). Multivariate analysis identified CL, TK, and LL to be independent influencing factors (CL, t = 2.6, *P* = .01; TK, t = 2.2, *P* = .03; LL, t = −2.2, *P* = .03) (Table III).

A total of 183 cases were categorized as grade 1, 127 cases as grade 2, and 19 cases as grade 3. Significant differences between grades were found for the following: GAT (grade 1, 24.0 ± 7.8; grade 2, 32.4 ± 7.0; grade 3, 41.0 ± 7.8), GAVA (grade 1, 29.3 ± 7.6; grade 2, 33.7 ± 9.5; grade 3, 31.5 ± 8.3), and TK (grade 1, 30.6 ± 13.6; grade 2, 35.1 ± 14.2; grade 3, 43.1 ± 20.4) (Table IV). The distribution of cases is shown in Figure 6. The grade reflected GAT particularly clearly.

Discussion

The relation between spine alignment and joints has been widely investigated, and hip-spine syndrome (HSS), which includes concomitant lumbar spine and hip disorders, has been the relation most often discussed.[21,26] HSS was originally described in 1983 by Offierski and MacNab,[21] who identified four subcategories that they labeled as simple, secondary, complex, and misdiagnosed. As with HSS, a relationship between the thoracic spine and shoulder joint has been reported.[16,23] Otoshi et al assessed the relation between TK and limitation of ROM in flexion at the shoulder joint.[23] Lewis et al compared shoulder movement between a natural and erect thoracic posture[16] and demonstrated that even a small change in TK can improve ROM at the shoulder. The reduced ROM at the shoulder in a slouched sitting position may be explained by a change in the scapular position to a more protracted anteriorly tilted and medially rotated position, potentially acting as a mechanical block to elevation of the shoulder.[7] It has also been reported that a slouched posture results in significantly less posterior tilting of the scapula and less active abduction of the shoulder in comparison with an erect posture[14] and that forward and downward rotation of the scapula depresses the acromial process and changes the direction of the glenoid fossa in patients with TK.[12]

In this study, we investigated the relation between spine alignment and the angle of the scapula on plain radiographs. We identified TK and LL to be independent influencing factors for GAT and CL, TK, and LL to be independent influencing factors for GAVA. TK in particular was associated with malpositioning of the scapula,

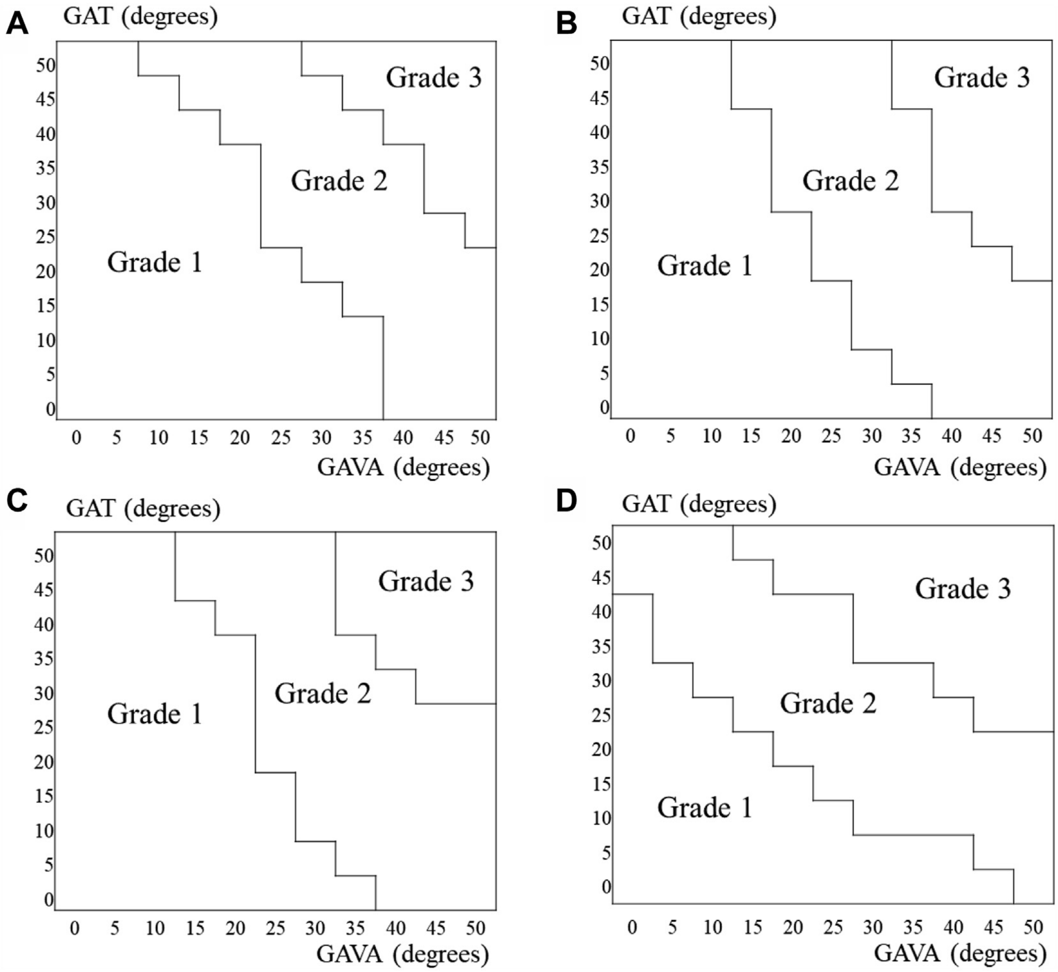

Figure 5 Distribution of grades for each cadaver. Panel (**A**) Data for 73 male cadavers, (**B**) for 76 male cadavers, (**C**) for 76 male cadavers, and (**D**) for 92 female cadavers. The grade became higher with increasing degrees of GAT and GAVA. *GAT*, glenoid anterior tilt; *GAVA*, glenoid anteversion angle.

Table I
Correlations between spine alignment parameters.

	PI	PT	SS	LL	TK	CL
SVA	0.12* (0.01, 0.23)	0.28† (0.17, 0.38)	−0.19† (−0.08, −0.30)	−0.49† (−0.40, −0.57)	−0.18† (−0.06, −0.29)	0.28† (0.17, 0.38)
CL	0.05 (−0.06, 0.16)	0.16† (0.05, 0.27)	−0.08 (−0.18, 0.03)	−0.04 (−0.15, 0.07)	0.35† (0.24, 0.46)	
TK	0.12* (0.01, 0.22)	−0.007 (−0.12, 0.11)	0.22† (0.11, 0.33)	0.56† (0.47, 0.64)		
LL	0.12* (0.01, 0.22)	−0.20† (−0.31, −0.09)	0.76† (0.69, 0.81)			
SS	0.10 (−0.01, 0.21)	−0.28† (−0.38, −0.17)				
PT	0.48† (0.38, 0.57)					

CL, cervical lordosis; *LL*, lumbar lordosis; *PI*, pelvic incidence; *PT*, pelvic tilt; *SS*, sacral slope; *SVA*, sagittal vertical axis; *TK*, thoracic kyphosis.
Data are expressed as the Spearman correlation (95% confidence interval).
* $P < .05$.
† $P < .01$.

which is consistent with a previous report of the effectiveness of shoulder rehabilitation that included an intervention for TK.[5,30] LL and CL were also associated with malpositioning of the scapula. Although they were correlated with TK (Table I), multicollinearity in multivariate analysis was not high (Table III), and interventions for LL and CL were thought to be effective.

The high correlation among SPAPs demonstrated in Table I was predictable. Other reports have also found a moderate to strong correlation between pelvic incidence and LL.[3,8,11,28] Lee et al reported a significant sequential link between pelvic incidence and sacral slope, sacral slope and LL, and LL and TK but found no significant relation between TK and CL.[15] Another study found a decrease in CL with increasing TK.[4] Berthonnaud et al also reported a positive correlation between CL and TK, however, the correlation coefficient was weaker than that between pelvic and lumbar parameters.[2] They stated that the reason for this phenomenon might be that the thoracic spine is less mobile than the cervical spine and lumbar spine.

Considering the previous studies demonstrating the value of a scapula/thoracic approach to shoulder dysfunction,[1,5,29,30] we created the grade that can evaluate the position of the scapula on plain radiographs. Using this grading system, we demonstrated statistically significant differences in GAT, GAVA, and TK according

Table II
Correlations between the glenoid angle and spine alignment parameters.

Variable	Glenoid anterior tilt			Glenoid anteversion angle		
	R	95% CI	*P* value	R	95% CI	*P* value
SVA	0.14	0.03, 0.25	.011*	−0.076	−0.18, 0.02	.19
CL	0.10	−0.02, 0.21	.075	0.17	0.06, 0.28	.002†
TK	0.12	0.01, 0.23	.026*	0.29	0.18, 0.39	<.001†
LL	−0.11	−0.22, −0.01	.046*	0.25	0.15, 0.35	<.001†
SS	−0.10	−0.21, 0.01	.066	0.073	−0.04, 0.19	.19
PT	−0.049	−0.16, 0.05	.37	0.029	−0.03, 0.17	.60
PI	−0.066	−0.18, - 0.04	.23	0.071	−0.03, 0.17	.20

CI, confidence interval; *CL*, cervical lordosis; *LL*, lumbar lordosis; *PI*, pelvic incidence; *PT*, pelvic tilt; *SS*, sacral slope; *SVA*, sagittal vertical axis; *TK*, thoracic kyphosis.
*$P < .05$.
†$P < .01$.

Table III
Correlations between the glenoid angle and spine parameters identified in multivariable analysis.

Predictive variable	Coefficient (95% CI)	Standardized coefficient	t	*P* value	VIF
Dependent variable: glenoid anterior tilt (adjusted R2 = 0.05, *P* < .001)					
SVA	0.11 (−0.11, 0.33)	0.07	1.00	.32	1.52
TK	0.14 (0.06, 0.22)	0.22	3.41	.001*	1.46
LL	−0.11 (−0.20, −0.03)	−0.21	−2.66	.008*	2.08
Dependent variable: glenoid anteversion angle (adjusted R2 = 0.11, *P* < .001)					
Predictive variable	Coefficient (95% CI)	Standardized coefficient	t	*P* value	VIF
CL	0.12 (−0.03, 0.20)	0.17	2.60	.01†	1.48
TK	0.10 (0.01, 0.18)	0.16	2.20	.03†	2.04
LL	0.08 (−0.08, −0.15)	−0.15	2.20	.03†	1.73

CI, confidence interval; *CL*, cervical lordosis; *LL*, lumbar lordosis; *SVA*, sagittal vertical axis; *TK*, thoracic kyphosis; *VIF*, variance inflation factor.
*$P < .01$.
†$P < .05$.

Table IV
Comparison of grades of glenoid angle between multiple groups.

Variable	All (N = 329)	Scapular angle grade			*P* value		
		Grade 1 (n = 183)	Grade 2 (n = 127)	Grade 3 (n = 19)	1 vs. 2	1 vs. 3	2 vs. 3
Age (years)	70.7 ± 9.0	70.1 ± 9.1	71.8 ± 8.0	71.5 ± 9.4	.18	>.99	>.99
Sex (male/female)	174/155	87/96	76/51	11/8	.11	>.99	>.99
BMI	24.9 ± 4.1	24.3 ± 3.7	25.5 ± 4.2	26.1 ± 5.8	.01*	.53	>.99
Glenoid anterior tilt (degrees)	28.2 ± 9.0	24.0 ± 7.8	32.4 ± 7.0	41.0 ± 7.8	<.001†	<.001†	<.001†
Glenoid anteversion angle (degrees)	31.1 ± 8.7	29.3 ± 7.6	33.7 ± 9.5	31.5 ± 8.3	<.001†	>.99	.88
SVA (mm)	5.3 ± 5.4	4.6 ± 5.0	5.7 ± 5.2	9.7 ± 8.5	.14	.013*	.097
CL (degrees)	12.5 ± 12.2	11.4 ± 11.0	12.8 ± 12.1	21.0 ± 19.3	>.99	.097	.24
TK (degrees)	33.0 ± 14.6	30.6 ± 13.6	35.1 ± 14.2	43.1 ± 20.4	.008†	.03*	.34
LL (degrees)	31.4 ± 16.6	31.8 ± 16.4	32.4 ± 14.6	20.4 ± 26.3	>.99	.16	.13
SS (degrees)	23.9 ± 9.6	24.5 ± 9.7	24.0 ± 8.9	18.4 ± 12.4	>.99	.15	.15
PT (degrees)	28.4 ± 10.2	28.4 ± 10.6	28.1 ± 9.3	30.6 ± 11.8	>.99	>.99	>.99
PI (degrees)	69.9 ± 11.2	69.7 ± 11.9	70.2 ± 10.5	70.8 ± 8.5	>.99	>.99	>.99

BMI, body mass index; *CL*, cervical lordosis; *LL*, lumbar lordosis; *PI*, pelvic incidence; *PT*, pelvic tilt; *SS*, sacral slope; *SVA*, sagittal vertical axis; *TK*, thoracic kyphosis.
Data are expressed as number of shoulders or as the mean ± standard deviation.
After Bonferroni correction.
*$P < .05$.
†$P < .01$.

to grade. In each grade, the angles were correctly reflected. There was also a proportional increase in TK, as with the angles. We consider that our grading system can serve as an index for judging the effectiveness of the approach to the glenoid angle and TK. The distribution of each grade mainly reflects GAT, and several different distributions were observed for GAVA. This may reflect the individual shape of the coracoid process.

The main limitation of this study was its retrospective design in the Part 2 component, which raises the possibility of selection bias in that all patients enrolled in the study were investigated before surgery for a spinal disorder. However, overall, the mean values for the cervical and thoracic spine parameters investigated were very similar to those found in a large cohort of Japanese volunteers.[20] The possibility of a shoulder disorder was excluded as far as possible by not including patients with a history of surgery, osteoarthritis, or marked differences in shoulder measurements between sides.

We plan to research the relation between postural abnormalities and functioning of the shoulder joint in the future. In shoulder joint surgery, there is a possibility that the results of the

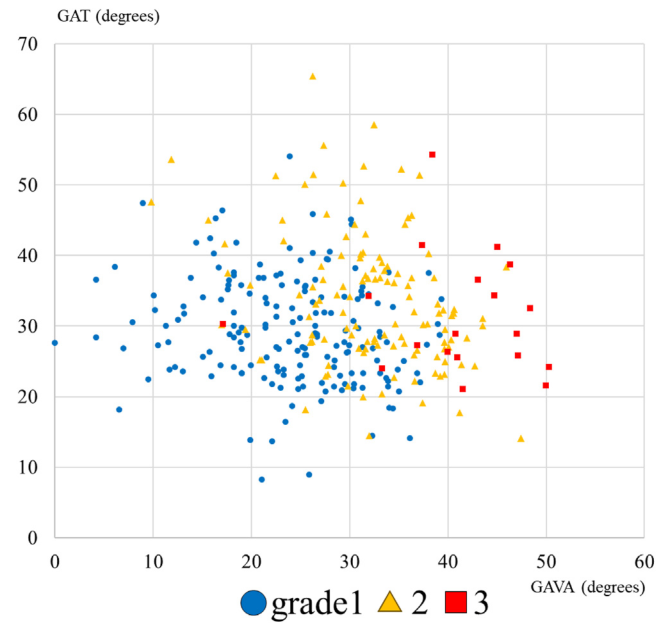

Figure 6 Distribution of cases according to grade. The *blue circles* represent grade 1 cases, the *yellow triangles* represent grade 2 cases, and the *red square* represent grade 3 cases. Each case shows a higher grade with increasing degrees of glenoid anterior tilt and glenoid anteversion angle. *GAT*, glenoid anterior tilt; *GAVA*, glenoid anteversion angle.

same surgical procedure for the same disease differ because of malpositioning of the scapula. Our classification system would be useful as a simple index for determining the position of the scapula, particularly in patients undergoing reverse shoulder arthroplasty. It may also be possible to elucidate the relation between postural abnormalities and shoulder joint function further by measuring the muscle volume of the paraspinal muscles and muscles around the shoulder joint. Furthermore, surface electromyography investigations could be useful for identifying muscles that become overactive and those that become less active in response to changes in posture. We believe that it would be possible to establish a rehabilitation program that focuses on the identified muscles as a fundamental treatment for shoulder joint disease or as an adjuvant therapy in the perioperative period in patients undergoing shoulder joint surgery.

Conclusion

In this study, we investigated the relation between SPAPs and scapular position, identified independent influencing factors, and demonstrated that the scapular position can be estimated by grading using simple plain radiographs. In the future, we plan to investigate the relation between the clinical findings at the shoulder joint and the position of the scapula using this classification system to help elucidate the pathology of shoulder joint diseases, including SPAPs.

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References

1. Başkurt Z, Başkurt F, Gelecek N, Özkan MH. The effectiveness of € scapular stabilization exercise in the patients with subacromial impingement syndrome. J Back Musculoskelet Rehabil 2011;24:173-9. https://doi.org/10.3233/BMR-2011-0291.
2. Berthonnaud E, Dimnet J, Roussouly P, Labelle H. Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. J Spinal Disord Tech 2005;18:40-7. https://doi.org/10.1097/01.bsd.0000117542.88865.77.
3. Boulay C, Tardieu C, Hecquet J, Benaim C, Mouilleseaux B, Marty C, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. Eur Spine J 2006;15:415-22. https://doi.org/10.1007/s00586-005-0984-5.
4. Boyle JJW, Milne N, Singer KP. Influence of age on cervicothoracic curvature: an ex vivo radiographic survey. Clin Biomech 2001;17:361-7.
5. Boyles RE, Ritland BM, Miracle BM, Barclay DM, Faul MS, Moore JH, et al. The short-term effects of thoracic spine thrust manipulation on patients with shoulder impingement syndrome. Man Ther 2009;14:375-80. https://doi.org/10.1016/j.math.2008.05.005.
6. Deutsch A, Altchek DW, Schwartz E, Otis JC, Warren RF. Radiologic measurement of superior displacement of the humeral head in the impingement syndrome. J Shoulder Elbow Surg 1996;5:186-93.
7. Donatelli R. Physical therapy of the shoulder. 4th ed. New York: Churchill-Livingstone; 2004.
8. Duval-Beaupère G, Schmidt C, Cosson P. A barycentremetric study of the sagittal shape of spine and pelvis: the conditions required for an economic standing position. Ann Biomed Eng 1992;20:451-62.
9. Endo K, Ikata T, Katoh S, Takeda Y. Radiographic assessment of scapular rotational tilt in chronic shoulder impingement syndrome. J Orthop Sci 2001;6:3-10.
10. Fayad F, Roby-Brami A, Yazbeck C, Hanneton S, Lefevre-Colau MM, Gautheron V, et al. Three-dimensional scapular kinematics and scapulohumeral rhythm in patients with glenohumeral osteoarthritis or frozen shoulder. J Biomech 2008;41:326-32. https://doi.org/10.1016/j.jbiomech.2007.09.004.
11. Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. Spine (Phila Pa 1976) 2005;30:682-8. https://doi.org/10.1097/01.brs.0000155425.04536.f7.
12. Grimsby O, Gray JC. Interrelationship of the spine to the shoulder girdle. In: Donatelli RA, editor. Clinics in physical therapy: physical therapy of the shoulder. 3rd ed. New York: Churchill Livingstone; 1997. p. 95-129.
13. Hebert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. Arch Phys Med Rehabil 2002;83:60-9. https://doi.org/10.1053/apmr.2002.27471.
14. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. Arch Phys Med Rehabil 1999;80:945-50.
15. Lee SH, Son ES, Seo EM, Suk KS, Kim KT. Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment. Spine J 2015;15:705-12. https://doi.org/10.1016/j.spinee.2013.06.059.
16. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. J Orthop Sports Phys Ther 2005;35:72-87. https://doi.org/10.2519/jospt.2005.35.2.72.
17. Lin JJ, Hanten WP, Olson SL, Roddey TS, Sotoquijano DA, Lim HK, et al. Functional activity characteristics of individuals with shoulder dysfunctions. J Electromyogr Kinesiol 2005;15:576-86. https://doi.org/10.1016/j.jelekin.2005.01.006.
18. Lin JJ, Lim HK, Yang JL. Effect of shoulder tightness on glenohumeral translation, scapular kinematics, and scapulohumeral rhythm in subjects with stiff shoulders. J Orthop Res 2006;24:1044-51. https://doi.org/10.1002/jor.20126.
19. Mell AG, LaScalza S, Guffey P, Ray J, Maciejewski M, Carpenter JE, et al. Effect of rotator cuff pathology on shoulder rhythm. J Shoulder Elbow Surg 2005;14:58S-64S. https://doi.org/10.1016/j.jse.2004.09.018.
20. Oe S, Togawa D, Nakai K, Yamada T, Arima H, Banno T, et al. The influence of age and sex on cervical spinal alignment among volunteers aged over 50. Spine (Phila Pa 1976) 2015;40:1487-94. https://doi.org/10.1097/BRS.0000000000001071.
21. Offierski CM, MacNab I. Hip-spine syndrome. Spine (Phila Pa 1976) 1983;8:316-21.
22. Ogston JB, Ludewig PM. Differences in 3-dimensional shoulder kinematics between persons with multidirectional instability and asymptomatic controls. Am J Sports Med 2007;35:1361-70. https://doi.org/10.1177/0363546507300820.
23. Otoshi K, Takegami M, Sekiguchi M, Onishi Y, Yamazaki S, Otani K, et al. Association between kyphosis and subacromial impingement syndrome: LOHAS

study. J Shoulder Elb Surg 2014;23:e300-7. https://doi.org/10.1016/j.jse.2014.04.010.
24. Ozaki J. Glenohumeral movements of the involuntary inferior and multidirectional instability. Clin Orthop Relat Res 1989;289:107-11.
25. Paletta GA Jr, Warner JJ, Warren RF, Deutsch A, Altchek DW. Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tearing. J Shoulder Elbow Surg 1997;6:516-27.
26. Piazzolla A, Solarino G, Bizzoca D, Montemurro V, Berjano P, Lamartina C, et al. Spinopelvic parameter changes and low back pain improvement due to femoral neck anteversion in patients with severe unilateral primary hip osteoarthritis undergoing total hip replacement. Eur Spine J 2018;27:125-34. https://doi.org/10.1007/s00586-017-5033-7.
27. Sahrmann SA. Diagnosis and treatment of movement impairment syndromes. London: Mosby; 2002.
28. Schwab F, Lafage V, Patel A, Farcy JPP. Sagittal plane considerations and the pelvis in the adult patient. Spine (Phila Pa 1976) 2009;34:1828-33. https://doi.org/10.1097/BRS.0b013e3181a13c08.
29. Struyf F, Nijs J, Mollekens S, Jeurissen I, Truijen S, Mottram S, et al. Scapular-focused treatment in patients with shoulder impingement syndrome: a randomized clinical trial. Clin Rheumatol 2013;32:73-85. https://doi.org/10.1007/s10067-012-2093-2.
30. Wang CH, McClure P, Pratt NE, Nobilini R. Stretching and strengthening exercises: their effect on three-dimensional scapular kinematics. Arch Phys Med Rehabil 1999;80:923-9.
31. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using Moire topographic analysis. Clin Orthop Relat Res 1992;285:191-9.