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Do spinopelvic parameters affect the severity of thoracolumbar trauma differently between in-vehicle traffic accidents and falling from a height?

Spinopelvik parametreler torakolomber travmanın şiddetini araç içi trafik kazası ve yüksekten düşme arasında farklı şekilde etkiler mi?

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Abstract

Purpose: Although there is a comprehensive characterization of the impact of spinopelvic parameters on outcomes after degenerative spine surgery, the impact of spinopelvic parameters on thoracolumbar trauma has not yet been defined. In the present study, it was aimed to reveal the correlation between the severity of vertebral fractures developing after trauma according to the mechanism of occurrence and sagittal spinopelvic parameters.

Materials and methods: Patients with thoracolumbar vertebra fractures were evaluated retrospectively. The patients were divided into two groups: in-vehicle traffic accident (sitting group) and fall from height (standing group). The pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS) and vertebral Hounsfield unit (HU) values were measured on computed tomography (CT) scans.

Results: The results of the multivariate logistic regression analysis performed in the study revealed that a one-unit increase in PI reduced the risk of more comminuted fractures (A2 and above) by 0.90 times in sitting position trauma (Odds ratio (OR): 0.90; 95% CI: 0.84-0.96; *p*=0.002) and by 0.96 times in standing position trauma (OR: 0.96; 95% CI: 0.93-0.99; *p*=0.040).

Conclusions: It was observed that in vertebral fractures developed after trauma, the fact that the vertebral column of patients with low PI is more rigid increased the severity of the fracture.

Keywords: Vertebral fracture, Hounsfield unit, pelvic parameters, AO Spine thoracolumbar classification.

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Öz

Amaç: Spinopelvik parametrelerin dejeneratif omurga cerrahisi sonrası sonuçlar üzerindeki kapsamlı bir etkisinin karakterizasyonu olmasına rağmen, spinopelvik parametrelerin torakolomber travma üzerindeki etkisi henüz tanımlanmamıştır. Bu çalışmada travma sonrası gelişen vertebra kırıklarının oluşma mekanizması ve tipine göre sagittal spinopelvik parametreler ile arasındaki ilişkinin ortaya konulması amaçlandı.

Gereç ve yöntem: Torakolomber vertebra kırığı olan hastalar retrospektif olarak değerlendirildi. Hastalar araç içi trafik kazası (oturarak travmaya maruz kalan grup) ve yüksekten düşme (ayakta travmaya maruz kalan grup) olmak üzere iki gruba ayrıldı. Bilgisayarlı tomografi görüntülerinde pelvik insidans, pelvik tilt, sakral slop ve vertebral Hounsfield ünitesi değerleri ölçüldü.

Bulgular: Çalışmada yapılan çok değişkenli lojistik regresyon analizi sonuçları, PI'deki bir birimlik artışın, oturan grup travmalarında daha fazla parçalı kırık (A2 ve üzeri) riskini 0,90 kat azalttığını ortaya koydu (Risk oranı: 0,90; %95 GA: 0,84-0,96; *p*=0,002) ve ayakta durma pozisyonu travmasında 0,96 kat (Risk oranı: 0,96; %95 GA: 0,93-0,99; *p*=0,040).

Sonuç: Travma sonrası gelişen vertebra kırıklarında düşük PI'li hastaların vertebral kolonunun daha rijit olmasının kırığın şiddetini arttırdığı görüldü.

Anahtar kelimeler: Vertebral kırık, Hounsfield ünitesi, pelvik parametreler, AO Spine torakolomber sınıflandırması.

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Introduction

Vertebral fractures usually take place in the thoracolumbar and lower lumbar regions and have adverse effects on the patient's quality of life [1]. Vertebral fractures occur in conditions affecting the bone such as inappropriate axial or rotational loading during trauma, osteoporosis, metastasis and infection [2, 3]. A successful classification system both facilitates the communication between physicians and guides prognosis and treatment by determining the severity of injury [4].

The AO Spine classification, a commonly used system for the classification of thoracolumbar injuries, attempts to facilitate fracture classification and guide treatment, establishing hierarchical and morphological criteria [4]. A type injuries indicate compression; B type injuries indicate distraction, and C type injuries indicate translation [5]. The AO Spine classification system is descriptive rather than determining the treatment and holds more options to describe the fracture morphology. The major mechanisms in the occurrence of the vertebral fracture are mostly unknown. Vertebral fractures vary according to the trauma type, forces that the spine and pelvis are exposed to, and anatomical and biological characteristics of the patient [6]. Lumbosacral sagittal balance and pelvic parameters play a significant role in maintaining the physiological function of the spine and compensatory mechanisms [7-9].

Spinopelvic parameters and sagittal balance are hot topics in spine surgery. Being one of the sagittal spinopelvic parameters, pelvic incidence (PI), independent of the position of the pelvis, is a constant value [10]. Although PI falls short to indicate pelvis width and whole spine balance, it helps us to get an idea about the pelvis to encounter in case the balance between the pelvis and the spine is disturbed [11-13]. Abnormal spinopelvic values take a part in the occurrence of pathologies such as low back pain, lumbar disc herniation, degenerative disc disease, degenerative and isthmic spondylolisthesis, and hip osteoarthrosis [14-17]. Among vertebral fractures, osteoporotic fractures hold a significant place. Quantitative computed tomography (QCT) and dual energy X-ray absorptiometry (DXA) are used in detecting bone mineral density (BMD). Spatial and volumetric BMD (sBMD and vBMD) measured with DXA and QCT are generally utilized to estimate the risks of vertebral fracture [18, 19]. However, due to high cost of equipment and personnel in BMD measurements, for osteoporosis, vertebral bone attenuation in HU value, which is measured from CT images, has been suggested to be used instead of these examinations [18]. The results of vertebral HU values have been shown to be affirmative in the detection of osteoporosis [18-21].

Objective

The literature has not elucidated the relationship between PI and severity of spinal fracture. The objective of the current study is to establish the correlation between the sagittal spinopelvic parameters and the severity of vertebral fractures assessed by the AO Spine classification and to identify possible risk factors in patients with vertebral fracture occurred after trauma.

Material and method

Study design

Permission was obtained from Tokat Gaziosmanpasa University Clinical Research Ethics Committee for the study (date: 18.04.2022 and number: 83116987). The patients who were admitted to the emergency department of our hospital between 01/01/2016 and 12/31/2020 after trauma and were diagnosed with thoracolumbar and lower lumbar vertebral fractures were retrospectively reviewed. Since the study was retrospective in nature, informed consent was waived. Age, gender, height, weight and BMI of the patients were collected. The diagnosis was made with clinical examination and radiographic assessment, whereas the study data were retrieved from the medical files of the patients with the help of the electronic health record system (ENLIL hospital information management system, version v2.19.46 20191118). The patients were separated into two groups as in-vehicle traffic accidents (IVTA) and falling from height. Our aim in dividing patients into standing and sitting groups; to evaluate the effect of changing and unchanging spinopelvic parameters on the type of fracture by changing the way the force that causes the fracture is applied. Vertebral fracture was considered to occur in standing position in patients who fall from height and in sitting position in those injured in IVTA. All measurements were performed on preoperative CT scans of the patients using the patient archiving computer system (PACS) software (Sectra Workstation IDS7, Version 21.2.11.6289, ©2019 Sectra AB).

Patients aged over 18 years with acute thoracolumbar and lower lumbar vertebral fractures occurred due to trauma were included in the study. Fractures were judged as acute when the patient had been detected to have a fracture with spine BT in our hospital within 7 days of fracture occurrence. Patients whose thoracolumbar and lower lumbar spine can be clearly evaluated in PACS, those with CT scans allowing multi-plane reconstruction (MPR) imaging, those with a clear evaluation of the femoral head and pelvis for the measurement of sagittal spinal parameters and those without anatomical changes in the pelvis detected on CT scans were included into the study.

Patients having a past history of spine or pelvis surgery or fractures, those with pathological, chronic or multiple vertebral fractures, those having congenital spinal deformity and those who had a hip anomaly disrupting the proximal femoral anatomy such as developmental hip dysplasia and prosthesis or who underwent hip surgery were left out from the study.

The patients' medical records were reviewed by an orthopedist and a neurosurgeon, both with at least 5 years of experience. All measurements were made separately by the two observers, and the average of their results was calculated to minimize measurement errors. The neurosurgeon performed the measurements again to assess the intra-observer variability one month after the first measurement.

For all patients, the CT scan that includes the pelvis acquired while the patient lies in the supine position with hip and knee joints extended was examined. The patients received no additional radiation as the CT scans had been taken during routine treatment.

Measurement of vertebral HU

As defined in previous studies, the L1 vertebra were mostly selected in measuring HU, since the HU value of L1 provides better results in the detection of osteoporosis compared to other vertebrae [20]. However, if L1 was fractured, the HU value of T12 or L2 was used as stated by the literature [19]. All data were manually evaluated after performing MPR of the CT data images by using the PACS software [18]. The oval region of interest (ROI) was placed in the axial section of the trabecular part of the vertebral body [22].

Vertebral fracture classification

The vertebral fractures between T12 and L5 were graded according to the commonly used "the AO Spine classification of thoracolumbar injuries". The types of fractures according to the AO Spine classification are shown in Figures 1A-1E.

Measurement of spinal and pelvic parameters

PI, PT and sacral slope(SS) angle were measured to evaluate the sacropelvic balance. For the measurement of PI, in MPR images of the CT, the angle formed by the intersection of the two lines was calculated; the first line was drawn, if the femoral heads overlap, from the midpoint of the femoral head, if not, from the middle of the line connecting the midpoint of both femoral heads to the midpoint of the upper endplate of S1; and the second line was drawn at a 90-degree angle from the midpoint of the upper endplate of S1 to the bottom.

SS is the angle between the line drawn from the upper endplate of S1 and the horizontal line extending from the midpoint of the upper sacral endplate.

PT is described as the measurement in degrees of the angle between a line connecting the midpoint of sacral endplate to the center of the femoral heads and the vertical axis (Figure 2).

Figure 1A. A0: No fracture or clinically insignificant fracture of the spinous or transverse processes

Figure 1B. A1: Wedge compression or impaction fracture, which involves a single endplate of the vertebral body without involvement of the posterior vertebral Wall

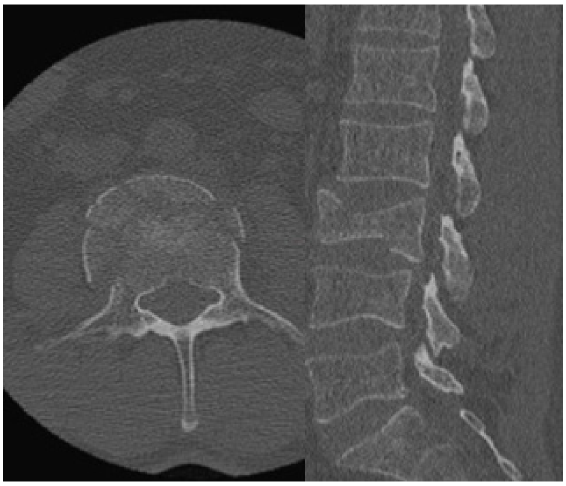

Figure 1C. A2: Split or pincer type fracture, which involves both endplates without the involvement of the posterior Wall

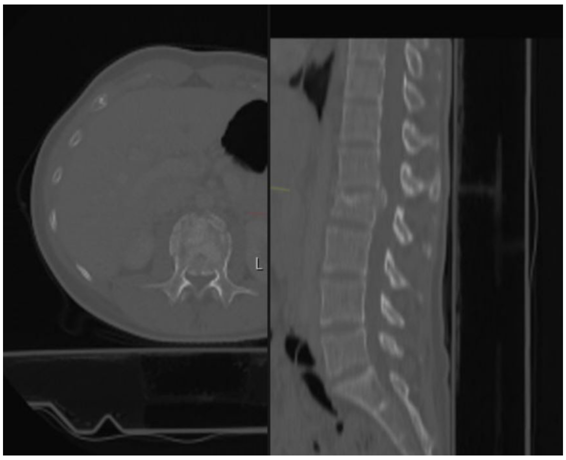

Figure 1D. A3: Incomplete burst fracture, which involves a single endplate along with the posterior vertebral Wall

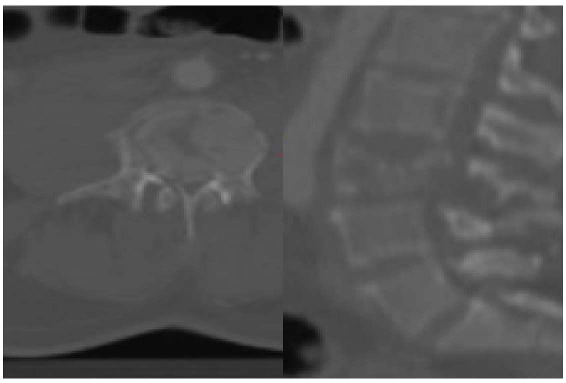

Figure 1E. A4: Complete burst fracture, which involves both endplates along with the posterior vertebral wall: Split fractures that involve the posterior vertebral wall are also included

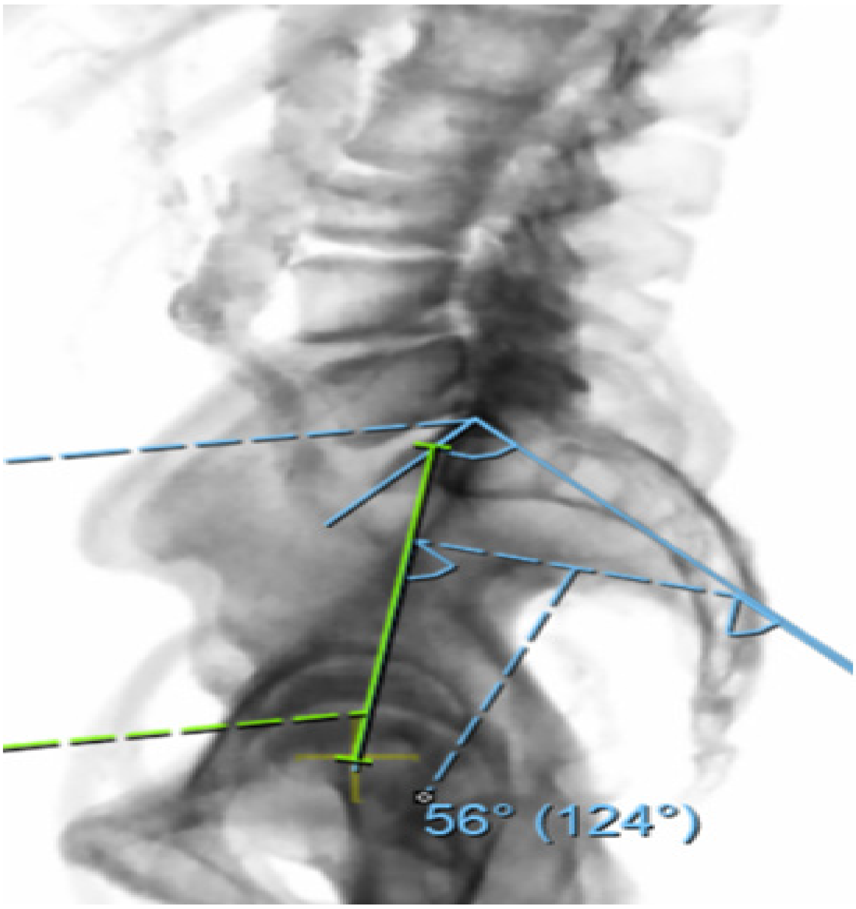

Figure 2. Pelvic incidence measurement

Statistical analysis

In the study, the quantitative variables were reported in mean and standard deviation, whereas frequency and percentage were used to express the qualitative variables. The differences between groups in terms of the means of quantitative variables were determined using the *independent samples t test* and one-way analysis of variance, when there were two groups in which the normality assumption was met. Tukey HSD was used for multiple comparisons. In the qualitative variables, the chi-square test was employed in assessing the relationships between related variables by creating contingency tables. The *p*-values less than 0.05 was regarded as statistically significant. The Pearson correlation coefficient was utilized to find the relationship between quantitative variables. Univariate and Multivariate logistic regression analysis was used to examine the effect of more than one independent variable on the dependent variable. All statistical calculations were conducted using a commercially available statistical software (IBM SPSS Statistics 19, SPSS inc., an IBM Co., Somers, NY).

Results

There were 82 (33.6%) female and 162 (66.4%) male patients in the study, and the mean age was 51.52±15.99 (20–88) in the study. The female patients in the study were older than males (55.22±17.3, 49.6±14.97, respectively; t=2.605; *p*=0.010). The male patients were taller (*p*≤0.001). The female vertebrae were more osteoporotic. The vertebral HU value was significantly higher in males (178.06±55.9) than in females (158.4±65.29) (*p*=0.015). The difference between males and females was not statistically significant in terms of PI, PT, SS, weight and BMI (t=0.519; *p*=0.604, t=0.947; *p*=0.344, t=1.661; *p*=0.098, t=0.824; *p*=0.411, t=1.683; *p*=0.094, respectively, Table 1).

Table 1. Distribution of quantitative variables by gender

	Gender		t	p
	Female	Male		
	Mean	Mean		
Age (years)	55.22±17.33	49.64±14.97	2.605	0.010*
HU level (hounsfield Units) (up)	158.48±65.29	178.06±55.94	2.439	0.015*
SS	34.57±9.76	37.03±11.46	1.661	0.098
PI	50.45±9.9	51.19±10.77	0.519	0.604
Pelvik Tilt	15.87±12.45	14.16±13.65	0.947	0.344
Weight (kg)	72.94±3.97	73.64±7.12	0.824	0.411
Height (m)	1.66±0.03	1.69±0.05	3.992	<0.001*
BMI (kg/m²)	26.41±1.66	25.91±2.41	1.683	0.094

HU: Hounsfield Units, SS: Sacral Slope, PI: Pelvic incidence, BMI: Body mass index, The independent samples t test used, *: *p*<0.05

According to the AO Spine thoracolumbar classification system, there were 231 patients with type A compression injury and 13 patients with Type B tension band injury. Of the patients, 89 (36.5%) had been exposed to trauma in sitting position and 155 (63.5%) in standing position. The patients injured in sitting positions had a lower mean age (*p*=0.009). There was no statistically significant difference observed between the sitting and standing groups regarding HU, SS, PI, PT, weight, height and BMI results (t=0.958; *p*=0.339, t=0.924; *p*=0.356, t=0.914; *p*=0.057, t=1.564; *p*=0.119, t=0.372; *p*=0.710, t=1.577; *p*=0.116, t=0.739; *p*=0.461, t=0.986; *p*=0.325, respectively, Table 2). The female/male ratio was similar with respect to injury position (χ^2=0.094; *p*=0.759) (Table 3). Distribution of quantitative variables according to the AO Spine classification sitting and standing group in Table 4 and 5.

Among the patients, 44.3% had fractures in L1, 18.0% in L2 and 16.8% in T12 vertebrae. In terms of the AO Spine classification, of the fractures, 26.6% was A1, 24.2% was A2, 20.9% was A0 and 23.4% was A4. No statistically significant correlation was detected between the AO Spine classification fracture types in terms of weight, height, and BMI (F=1.411; *p*=0.231, F=2.063; *p*=0.087, F=0.833; *p*=0.505, respectively).The AO group had a significantly higher PI value compared to the other groups (A0=59.05±10.47, A1=49.86±10.08, A2=48.64±9.13, A4:47.95±7.92; F=11.705;_ *p*≤0.001) (Figure 3).

Table 2. Distribution of quantitative variables by injury position

Variables	Total Mean±SD	Position		t	p
		Sitting (IVTA)	Standing (Falling from height)		
		Mean±SD	Mean±SD		
Age (years)	51.52±15.99	47.99±15.79	53.54±15.8	2.644	0.009*
HU level (hounsfield Units) (up)	171.48±59.83	176.32±62.11	168.7±58.51	0.958	0.339
HU level(down)	163.44±65.08	168.52±66.17	160.52±64.48	0.924	0.356
Sacral Slope	36.21±10.96	34.44±9.65	37.22±11.56	1.914	0.057
Pelvic incidence	50.94±10.47	49.56±9.88	51.73±10.74	1.564	0.119
Pelvic tilt	14.74±13.26	15.15±13.65	14.5±13.07	0.372	0.710
Weight (kg)	73.4±6.24	72.57±5.91	73.88±6.39	1.577	0.116
Height (m)	1.68±0.05	1.68±0.04	1.68±0.05	0.739	0.461
BMI (kg/m²)	26.07±2.2	25.89±2.41	26.18±2.06	0.986	0.325

IVTA: in-vehicle traffic accidents, BMI: body mass index, The independent samples t test used, *: *p*<0.05

Table 3. Distribution of qualitative variables by injury position

Variables		Position		X^2	*p*
		Sitting (1)	Standing (2)		
		n (%)	n (%)		
Gender	**Female**	31 (34.8)	51 (32.9)	0.094	0.759
	Male	58 (65.2)	104 (67.1)		
Type	**1**	80 (89.9)[a]	151 (97.4)[b]	6.358	0.012*
	2	9 (10.1)[a]	4 (2.6)[b]		
Segment	**L1**	36 (40.4)	72 (46.5)	9.546	0.089
	L2	16 (18)	28 (18.1)		
	L3	9 (10.1)	22 (14.2)		
	L4	8 (9)	2 (1.3)		
	L5	4 (4.5)	6 (3.9)		
	T12	16 (18)	25 (16.1)		
AO Spine Classification	**A0**	22 (24.7)	29 (18.7)	5.561	0.230
	A1	21 (23.6)	44 (28.4)		
	A2	19 (21.3)	40 (25.8)		
	A4	19 (21.3)	37 (23.9)		
	B2	8 (9)	5 (3.2)		

Pearson chi-square test was used, [a-b]: means with the different letter in the rows indicates statistical significance, *: *p*<0.05

Table 4. Distribution of quantitative variables according to the AO Spine classification (sitting)

Variables	AO Spine Classification (sitting)					*F*	*p*
	A0	A1	A2	A4	B2		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD		
Age (years)	49.18±14.19[ab]	50.05±14.78[ab]	58.21±16.72[b]	37.63±12.68[a]	39.63±10.13[a]	5.728	<0.001*
HU level	213±59.61[a]	178.91±73.19[ab]	137.44±58.26[b]	168.37±37.61[ab]	179.88±40.28[ab]	4.488	0.002*
Sacral Slope	33.02±9.03[abc]	31.81±10.34[ab]	39.26±10.36[ac]	30.68±7.11[b]	42.75±2.55[c]	4.525	0.002*
Pelvic incidence	54.8±9.13[a]	51.62±10.52[ab]	47.71±9.88[ab]	44.58±7.95[b]	46.01±7.63[ab]	3.844	0.006*
Pelvic Tilt	21.77±13.42[a]	19.81±12.92[a]	8.6±10.34[b]	13.89±14.29[ab]	3.26±6.3[b]	5.490	0.001*
Weight (kg)	74.27±5.92[a]	69.81±6.36[b]	73.37±5.84[ab]	74.16±5.3[ab]	69.5±2.67[ab]	2.777	0.032*
Height (m)	1.68±0.04	1.68±0.03	1.69±0.05	1.66±0.03	1.67±0.04	1.015	0.405
BMI (kg/m²)	26.29±2.09	24.91±2.66	25.92±2.71	26.88±2.21	24.98±1.2	2.219	0.074

HU: hounsfield unit, One-way analysis of variance was used, [a-d]: the same letter in the rows indicates statistical insignificance
*: *p*<0.05, BMI: body mass index

Table 5. Distribution of quantitative variables according to the AO Spine classification (standing)

Variables	AO Spine Classification (standing)					*F*	*p*
	A0	A1	A2	A4	B2		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD		
Age (years)	51.62±19[a]	53.39±15.16[ab]	61.9±12.09[b]	44.92±13.29[a]	63±8.25[ab]	7.079	<0.001*
HU level	200.25±58.84[ac]	154.51±68.06[b]	126.87±58.71[c]	170.15±54.77[ab]	181±29.53[abc]	2.694	<0.001*
Sacral Slope	36±10.24	37.19±11.45	39.99±13.78	34.2±8.94	44.7±13.67	1.850	0.122
Pelvic incidence	62.27±10.41)[a]	49.01±9.88[b]	49.09±8.85[b]	49.69±7.42[b]	50.84±19.39[ab]	10.848	<0.001*
Pelvic Tilt	26.27±14.16[a]	11.8±9.16[b]	9.13±12.47[b]	15.41±11.28[b]	6.14±11.88[b]	10.783	<0.001*
Weight (kg)	72.21±5.4	73.32±6.05	75.3±7.25	73.78±6.46	77.8±4.6	1.573	0.184
Height (m)	1.68±0.04	1.67±0.04	1.69±0.06	1.68±0.04	1.66±0.04	1.418	0.231
BMI (kg/m²)	25.56±1.92	26.22±2.14	26.25±2.09	26.25±1.97	28.31±1.58	2.073	0.087

HU: hounsfield unit, One-way analysis of variance was used, [a-d]: the same letter in the rows indicates statistical insignificance
*: *p*<0.05, BMI: body mass index

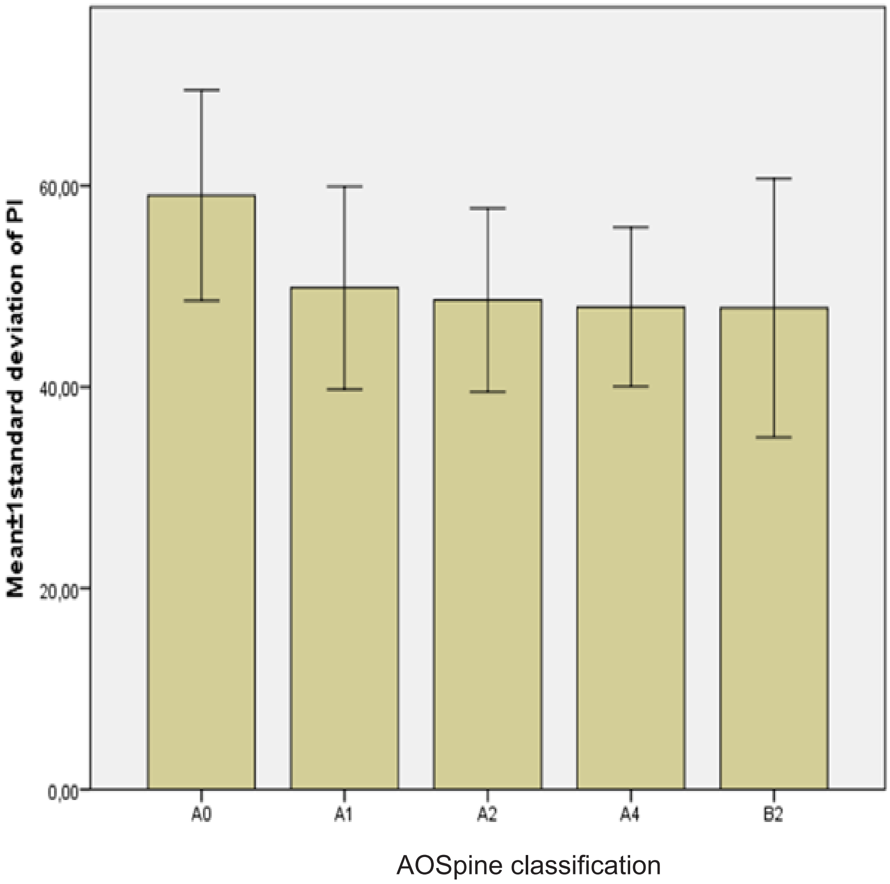

Figure 3. Bar graph of pelvic incidence values according to the AO Spine classification (Mean±1 SD)

Between the age of the patients and their HU values, there was a negative correlation considering all patients as well as in the sitting group (Table 6) and in the standing group (Table 7).

The univariate logistic regression analysis results revealed that for every one-unit increase in the PI value, the risk of more comminuted fractures (A2 and above) decreased by 0.919 times in sitting position trauma (OR:0.919; 95% CI:0.87-0.96; *p*=0.001) and by 0.957 times in standing position trauma (OR:0.957; 95% CI:0.92-0.98; *p*=0.006) (Table 8).

The univariate logistic regression analysis conducted in the study indicated that a one-unit increase in the HU value decreased the risk of more comminuted fractures (A2 and above) by 0.994 times in standing position trauma (OR:0.994; 95% CI:0.989-0.999; *p*=0.028) and by 0.989 times in sitting position trauma (OR:0.989; 95% CI:0.981-0.997; *p*=0.005) (Table 9).

As a result of the multivariate logistic regression analysis performed in the study, it was observed that for every one-unit increase in PI, the risk of more comminuted fractures (A2 and above) decreased by 0.901 times in sitting position trauma (OR:0.901; 95% CI:0.843-0.963; *p*=0.002) (Table 8) and by 0.965 times in standing position trauma (OR:0.965; 95% CI:0.933-0.998; *p*=0.040) (Table 9).

Table 6. Pairwise correlation between quantitative variables (sitting n=89)

Variables		**HU level (up)**	**HU level (down)**	**Sacral Slope**	**Pelvic incidence**	**Pelvic Tilt**	**Weight (kg)**	**Height (m)**	**BMI (kg/m²)**
Age (years)	**r**	-0.576*	-0.607*	0.082	0.092	0.011	-0.067	0.219*	-0.160
	p	<0.001	<0.001	0.442	0.393	0.915	0.533	0.040	0.135
HU level(up)	**r**	1	0.850*	-0.012	0.021	0.020	0.049	-0.022	0.047
	p		<0.001	0.909	0.844	0.855	0.646	0.841	0.659
HU level (down)	**r**		1	0.019	0.103	0.058	0.079	-0.078	0.099
	p			0.862	0.335	0.587	0.462	0.470	0.355
Sacral Slope	**r**			1	0.025	-0.688*	-0.025	0.107	-0.078
	p				0.813	<0.001	0.817	0.319	0.467
Pelvic incidence	**r**				1	0.708*	0.157	-0.066	0.164
	p					<0.001	0.143	0.536	0.126
Pelvic Tilt	**r**					1	0.133	-0.123	0.175
	p						0.216	0.251	0.102
Weight (kg)	**r**						1	-0.024	0.874*
	p							0.826	<0.001
Height (m)	**r**							1	-0.502*
	p								<0.001

* Correlation is significant at the 0.05 level (2-tailed)

Table 7. Pairwise correlation between quantitative variables (standing n=155)

Variables		HU level (up)	HU level (down)	Sacral Slope	Pelvic incidence	Pelvic Tilt	Weight (kg)	Height (m)	BMI (kg/m²)
Age (years)	**r**	-0.669*	-0.677*	-0.075	-0.014	0.051	0.236*	0.135	0.159*
	p	<0.001	<0.001	0.357	0.866	0.528	0.003	0.093	0.049
HU level(up)	**r**	1	0.902*	0.075	0.127	0.040	-0.190*	-0.103	-0.135
	p		<0.001	0.354	0.116	0.623	0.018	0.201	0.093
HU level(down)	**r**		1	0.099	0.212*	0.089	-0.229*	-0.117	-0.165*
	p			0.220	0.008	0.271	0.004	0.146	0.040
Sacral Slope	**r**			1	0.311*	-0.625*	-0.031	-0.038	-0.005
	p				<0.001	<0.001	0.699	0.640	0.952
Pelvic incidence	**r**				1	0.547*	-0.049	0.063	-0.096
	p					<0.001	0.541	0.435	0.237
Pelvic Tilt	**r**					1	-0.008	0.092	-0.074
	p						0.921	0.254	0.361
Weight (kg)	**r**						1	0.454*	0.763*
	p							<0.001	<0.001
Height (m)	**r**							1	-0.227*
	p								0.004

** Correlation is significant at the 0.05 level (2-tailed)*

Table 8. Univariate and Multivariate logistic regression results (Sitting)

Variables	Univariate				Multivariate			
	p	**Odds Ratio**	**95% C.I.for Odds Ratio**		***p***	**Odds Ratio**	**95% C.I.for Odds Ratio**	
			Lower	**Upper**			**Lower**	**Upper**
Gender	0.649	1.225	0.511	2.932	0.690	1.246	0.423	3.668
PI	0.001*	0.919	0.873	0.968	0.002*	0.901	0.843	0.963
Age	0.349	0.987	0.961	1.014	0.009*	0.941	0.899	0.985
ÜSH	0.005*	0.989	0.981	0.997	0.018*	0.975	0.955	0.996
ASH	0.026*	0.992	0.985	0.999	0.974	1.000	0.980	1.021

Reference category for Gender: Female

Table 9. Univariate and Multivariate logistic regression results (Standing)

Variables	Univariate				Multivariate			
	p	**Odds Ratio**	**95% C.I.for Odds Ratio**		***p***	**Odds Ratio**	**95% C.I.for Odds Ratio**	
			Lower	**Upper**			**Lower**	**Upper**
Gender	0.174	1.596	0.813	3.133	0.066	1.985	0.957	4.118
PI	0.006*	0.957	0.927	0.988	0.040*	0.965	0.933	0.998
Age	0.523	1.007	0.987	1.027	0.543	0.991	0.961	1.021
HU level(up)	0.219	0.997	0.991	1.002	0.169	1.010	0.996	1.025
HU level(down)	0.028*	0.994	0.989	0.999	0.026*	0.985	0.971	0.998

Reference category for Gender: Female

Discussion

Lumbosacral sagittal balance has a significant role in maintaining the normal physiological function of the spine [7, 23]. Independent factors such as spinal curvature and spinal loading contribute the risk of vertebral fracture [24, 25]. Very little is known about how spinopelvic balance and spinal malalignment affect spinal load distribution. Once a vertebral fracture occurs, the risk of subsequent fracture substantially increases within the first year [26, 27]. To be able to prevent vertebral fractures, there is a need to elucidate the mechanical, morphological and biological mechanisms underlying fracture occurrence [6]. The present study demonstrated that in patients with acute vertebral fracture, the cases with more severe fracture according to the AO Spine classification are characterized by lower vertebral HU and PI values, and that HU and PI values can be utilized to identify the risk of high-grade fractures. So far as we are aware, this study is the first in the literature to show that PI is an important determinant of fracture severity in acute vertebral fractures due to trauma. Because of the relationship between spinal sagittal parameters and vertebral fracture risk, which we detected in our study in trauma patients, taking these variations in the spinal sagittal parameter into account will help better understand vertebral fracture types. To understand fully the types of vertebral fractures will make a contribution to resolve a number of question marks in the classification and treatment of thoracolumbar vertebral fractures. Our study will guide clinical and biomechanical studies to be conducted in the future to better understand vertebral fracture types.

PI is an important link between the pelvis and mobile spinal vertebral structures that determines the ability of the pelvis to rotate around the axis of the femoral head, which is the optimal compensation for sagittal alignment [28]. Because the compensatory characteristic of the pelvic incidence on the sagittal alignment, we hypothiesed that pelvic parameters may effect the vertebral fracture severity.

It is known that pelvic incidence is an individual fixed feature and does not change with body positions. An increase in the PI causes a horizontal sacrum, while a decrease in the PI causes a vertical sacrum [29, 30]. A vertical sacrum transmits the load more directly to the vertebrae. In the literature, we could not find any other study examining the relation between the PI and vertebral fracture severity. However, studies examining the relationship between degenerative spine diseases and PI have previously shown the relationship between low PI and disease severity [31, 32]. For example, Imagama et al. [31] and Strube et al. [32] showed the relationship between low PI and increased disc degeneration. Kobayashi et al. [33] reported that while high PI was associated with flexible vertebrae, low PI was associated with a more rigid spine. The presence of rigidity that is related to the decreased PI and/or the more vertical sacrum seen at decreased pelvic incidence that is related to the more direct load transfer to the vertebrae may cause a more severe fracture in response to trauma.

Relevant studies in the literature indicate that spinopelvic parameters are generally evaluated in terms of compensations and complications occurring in elderly osteoporotic vertebral fractures or after treatment. It has been stated that sagittal spinal alignment takes a significant role in the biomechanical adaptation of the spine [34, 35]. The sacrum has been recognized as the first vertebra of the spine by Dubousset [36, 37]. PI, a parameter of the sagittal spine profile, defines the angulation of the sacrum in the pelvis with respect to the hip joints [35]. Bao et al. [38] in their study evaluating osteoporotic vertebral fractures, concluded that spinal malalignment that develops after fracture will cause elevated PI, which in turn will increase the L5–S1 bending moment. In the study on osteoporotic vertebral fractures, Fechtenbaum et al. [8] reached a conclusion that pelvic parameters contribute in the development of the compensatory mechanism. The study in which Kobayashi et al. [33] evaluated the lumbo-pelvic complex showed that patients with physiologically low PI and high anatomical acetabular anteversion (anatomical AA) have a spine that indicates low lumbar lordosis (LL) when standing. They also noted that in daily life activities, low PI is associated with low vertebral sagittal flexibility, which is in turn compensated by using hip joint mobility. The detection of more severe fractures in the patients with low PI also in our study confirms that low PI leads to a more rigid spine.

Albeit it has been reported that changes occur during adolescence in PI and pelvic morphology, PI is regarded to remain anatomically constant throughout an individual's life. The normative value of PI has been stated to be 50°-55° [39]. In our study, the mean PI of the patients was found to be 50.9°, which is in accordance with the literature. No significant correlation between PI and age was found in the present study, however, there existed a close correlation between PI and fracture type.

PI impacts the force transmission and has been associated with spondylolisthesis [13]. A large PI value corresponds a horizontal sacrum located anteriorly, while a low PI value corresponds a vertical sacrum located posteriorly high [9]. Chau et al. [40] showed that spinopelvic parameters such as thoracic kyphosis (TK), PT, and PI increase after vertebral fracture. Ru et al. [41] indicated that sacral anatomical parameters show strong correlations with lumbopelvic parameters and that the specific lumbar shape may be affected by the sacral morphology. Lordosis of the spinal segments adjacent to the fracture, posterior tilting of the pelvis, hip extension, knee flexion and even ankle dorsiflexion may develop to compensate for the kyphosis that may occur in the sagittal plane after vertebral fractures [42]. Previous studies demonstrated that patients with vertebral fracture have higher TK and lower LL [8]. On the contrary, Smorgick et al. [43] found no significant correlation between PI, PT, SS, fracture type, or fracture height loss in their study in which 124 patients were included.

Vertebral HU has been reported to be an effective parameter for the detection of osteoporosis [19, 44]. In elderly patients with osteoporotic fractures, much lower HU values have been detected than in those without fracture [45]. Our study confirms these results.

Our study bears certain limitations. First, there was a limited number of cases in the study, and all of which were from a single center. Second, the study was a retrospective analysis. For this reason, as the tomographies were taken only in the supine position, the variation of sagittal spinal parameters in other positions was not able to be examined. Besides, mechanisms such as knee flexion and ankle extension that may affect the fracture mechanism were not taken into account. Further prospective studies are necessary to better elucidate the association between spinal parameters and fracture.

In conclusion low PI causes a more rigid vertebral column, which indicates that patients with low PI are at increased risk in terms of high degree fractures according to the AO Spine classification, and that pelvic parameters play a role in compensatory mechanisms. The lower the vertebral HU value, the more likely patients are to have a high-grade vertebral fracture.

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V.K. and S.A. reviewed, corrected and approved. In addition, all authors discussed the entire study and approved the final version.

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