



Differences in lumbar and pelvic parameters among African American, Caucasian and Asian populations

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Abstract

Purpose Ethnic differences in spino-pelvic parameters among a healthy population are poorly defined in the literature. The purpose of this study was to document sagittal spino-pelvic parameters in a sample of African Americans and to compare them with previously reported data for Caucasians and Asians.

Methods African American individuals without spine pathology who had standing lateral radiographs were identified. Radiographs were measured to determine the following parameters: lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). Data of adult subjects were compared with those previously published for Caucasians ($n = 709$) and Asians ($n = 312$).

Results These measurements (LL, PI, PT, and SS) obtained for the 36 African American subjects aged 18 years or older [15 men and 21 women; mean age 26.6 ± 8.7 range (18–53)] The mean LL, PI, PT and SS values were 57.2° , 57.7° , 15.9° and 41.4° , respectively. A comparative analysis showed the means values for PI was greater in the African American than in Caucasian (57.7° vs. 52.6° , $p = 0.007$), and than in Asian (57.7° vs. 48.7° , $p < 0.001$). The linear regression model for the LL as a function of PI were “predict $LL = 0.41 \times PI + 33.7$ ” in African American, “predict $LL = 0.58 \times PI + 24.3$ ” in Caucasian, and “predict $LL = 0.54 \times PI + 22.0$ ” in Asian, respectively.

Conclusion Significant differences in sagittal spino-pelvic parameters among races were seen. These differences should be considered when planning surgical reconstruction for spinal surgery.

Graphical abstract These slides can be retrieved under Electronic Supplementary Material.

Spine Journal

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Key points

1. spino-pelvic parameters

2. ethnic difference

3. African American

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Spino-pelvic parameters	African American (n = 36)	Caucasian (n = 709)	Asian (n = 312)	p value ^a	AA vs. Cas p value ^b	AA vs. Asian p value ^c	Cas vs. Asian p value ^d
Age (range) (yr)	26.6 ± 8.7 (18–53)	36.8 ± 14.3 (18–81)	37.2 ± 11.7 (18–69)	<0.001	<0.001	<0.001	0.005
Lumbar lordosis (°)	57.2 ± 13.2	54.8 ± 10.5	48.6 ± 9.9	<0.001	0.032	<0.001	<0.001
Pelvic incidence (°)	57.7 ± 11.5	52.6 ± 10.4	48.7 ± 9.7	<0.001	0.007	<0.001	<0.001
Pelvic tilt (°)	15.9 ± 7.0	12.0 ± 6.8	13.3 ± 7.8	0.027			
Sacral slope (°)	41.4 ± 9.2	39.6 ± 7.9	35.3 ± 7.5	<0.001	0.308	<0.001	<0.001

AA, African American; Cas, Caucasian ^aBold type indicates statistical significance. ^bComparison among these cohorts. ^cPost hoc comparison between African American and Caucasian. ^dPost hoc comparison between African American and Asian. ^ePost hoc comparison between Caucasian and Asian. ^fp < 0.05 was considered as significant.

Spine Journal

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Take Home Messages

1. A comparison of the values for sagittal plane lumbar spine and pelvic parameters across the different racial/ethnic population samples aged 18 years or more revealed statistically significant differences.

2. The pelvic incidence of African Americans was 5.1° greater than Caucasian population.

3. The pelvic incidence of African Americans was 9.0° greater than Asian population.

Keywords Pelvic parameters · Pelvic tilt · Pelvic incidence · Ethnic groups · African American

Introduction

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Extended author information available on the last page of the article

In recent years, several studies have established the importance of sagittal pelvic morphology in maintaining efficient upright balance and gait [1–3]. Pelvic morphology affects

not only alignment of the lumbar and thoracic spine but also global spine alignment [2]. Understanding pelvic morphology in asymptomatic individuals provides important information that is useful in the surgical treatment of spinal malalignment seen in patients with spinal deformity.

Pelvic parameters in the sagittal plane are assessed using three well-defined angular measurements: pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) [4]. Since PI remains constant, and does not change with position [5], it is a key parameter during surgical planning for the treatment of spinal deformity [6–8]. Values of pelvic parameters have been reported in healthy volunteers from Caucasian and Asian populations [6, 9–11]. In adolescent idiopathic scoliosis patients, the PI is found to be significantly higher in Africans when compared with Caucasians [12]. However, there is no study comparing differences in pelvic morphology among Caucasian, African American and Asian populations without spine pathology. The aims of the present study were to document sagittal alignment of the lumbar spine and pelvis in a sample of African Americans without spine pathology and to compare them with previously reported data for Caucasians and Asians.

Materials and methods

Sample population

After receiving Institutional Review Board (IRB) approval, a cohort of 141 patients without spinal pathology was identified from two spine specialty clinics seen between May 1, 2012, and May 31, 2016. These study participants were referred by their pediatrician or family physician to rule out scoliosis or other spine pathology. Additional inclusion criteria were: (1) age of 11 years or older at the time of evaluation; (2) standing coronal Cobb angle less than 20°; (3) absence of spinal pathology as confirmed by evaluation from a spine surgeon or radiologist; (4) and no history of spine, hip, or pelvic disorder. All subjects were African American, and the following items were also collected: age, sex, height, weight, and body mass index (BMI).

Radiological evaluation

Each subject had a standing lateral radiograph of the lumbosacral region that included the L1 vertebral body and both femoral heads. Standing posture was standardized. Patients were instructed to stand with their knees locked and their feet been shoulder width apart, looking straight ahead with their elbows bent and placing their fists on the supraclavicular fossa bilaterally. This will place the patient's arms at approximately a 45° angle to the vertical axis of the body [4]. Radiograph was taken in a standardized manner by certified

radiology technicians at the radiology departments of the authors' institutions. The spino-pelvic parameters [lumbar lordosis (LL; Cobb angle between the superior endplate of L1 and the superior endplate of S1), PI, PT, and SS] were measured by two orthopedic surgeons using standard techniques [4, 13]. Comparison on the basis of gender and age were performed. With respect to age, we divided all subjects into two different age groups; Age 11–17 years, and 18 years or older, and compared lumbar spine and pelvic parameter between two groups. The intra-observer reliability was calculated by determining the intra-class correlation coefficient (ICC) for LL, PI, PT, and SS of 40 randomly selected subjects performed two measurement on different days.

Comparison among three racial/ethnic cohorts

The measurements (LL, PI, PT, and SS) obtained for the African American subjects aged 18 years or older were then compared to patient level data from previously published cohorts of 709 asymptomatic Caucasian subjects [14] and 312 asymptomatic Asian subjects [11].

Statistical analysis

All values are expressed as mean \pm standard deviation (SD). The normal distribution of the data was demonstrated with the Shapiro–Wilk test. Differences between two groups were evaluated using the *t* test or Mann–Whitney test. Differences between three groups were assessed using one-way ANOVA, or Kruskal–Wallis test. Post hoc comparisons were made using the Tukey test, or Dunn's multiple comparisons test. Correlations between quantitative parameters were explored using the Pearson or Spearman correlation coefficient test. Linear regression analysis was performed to predict LL, PT, and SS value from the PI value. The R^2 was used to assess the ability of the model to estimate these values. A multivariate linear regression analysis model was built with LL value as the dependent variable. PI value and age were independent variables for this model. An analysis of covariance (ANCOVA) was performed to evaluate the difference in linear regressions. $p < 0.05$ was considered as significant. Statistical analyses were performed using IBM SPSS statistics software (version 24.0; IBM, Chicago, IL, USA).

Results

The 83% of all subjects had a standing lateral whole spine radiograph using 36-inch film and remaining 17% had a standing lateral radiograph of the lumbosacral region that included the L1 vertebral body and both femoral heads. All parameters were measured with good reproducibility. The intra-observer ICCs for LL, PI, PT and SS were 0.989,

Table 1 Lumbar and pelvic parameters in a sample of 141 African American subjects without spine pathology and sex difference

Parameters	All (<i>n</i> = 141) Mean ± SD	Male (<i>n</i> = 49) Mean ± SD	Female (<i>n</i> = 92) Mean ± SD	<i>p</i> value [†]
Age (years)	17.2 ± 7.2	17.6 ± 6.0	17.0 ± 7.7	0.463
Lumbar lordosis (°)	57.9 ± 12.0	58.0 ± 10.6	57.8 ± 12.8	0.938
Pelvic incidence (°)	54.3 ± 10.2	54.3 ± 10.8	54.2 ± 9.9	0.792
Pelvic tilt (°)	13.2 ± 7.4	13.8 ± 6.5	12.8 ± 7.7	0.422
Sacral slope (°)	41.0 ± 7.8	40.7 ± 8.0	41.1 ± 7.7	0.569

[†]Comparison between male and female. *p* < 0.05 was considered as significant

Table 2 Age-related changes in lumbar and pelvic parameters in 141 subjects

Parameters	11–17 years	18–53 years	<i>p</i> value [†]
Number	105	36	
Age (years)	14.0 ± 1.7	26.6 ± 8.7	< 0.001
Lumbar lordosis (°)	58.1 ± 11.6	57.2 ± 13.2	0.534
Pelvic incidence (°)	53.1 ± 9.5	57.7 ± 11.5	0.017
Pelvic tilt (°)	12.2 ± 7.3	15.9 ± 7.0	0.008
Sacral slope (°)	40.8 ± 7.3	41.4 ± 9.2	0.713

*Bold type indicates statistical significance. [†]Comparison between 11–17 and 18–53 years. *p* < 0.05 was considered as significant

0.984, 0.975, and 0.980, respectively. In total, 141 African American subjects were included in the study.

There were 49 men and 92 women who ranged in age from 10 to 53 years (mean 17.2 ± 7.2 years). The mean height, weight and BMI were 64.6 ± 3.9 in., 145.1 ± 43.3 lbs., and 24.3 ± 6.5 kg/m², respectively. Height, weight and BMI were higher among male, although there were no sex differences for age. The mean values for the spino-pelvic parameters were as follows: LL, 57.9° ± 12.0°; PI, 54.3° ± 10.2°; PT, 13.2° ± 7.4°; SS, 41.0° ± 7.8°, respectively (Table 1). There was no sex difference for all parameters.

To investigate the parameters related to age, we examined the correlation between the radiographic parameters (LL, PI, PT, and SS) and age. Only PT was statistically significant correlated with age (*r* = 0.271, *p* = 0.001), while statistically significant differences were not noted for the other parameters; LL, PI and SS. Next, we divided all subjects into two different age groups; Age 11–17 years, and 18 years or older (Table 2) as the previous study has shown that pelvic parameters do not stabilize until individuals reach maturity [15]. There were statistically significant differences between the two age groups for PI and PT (*p* = 0.017 and *p* = 0.008, respectively) (Table 2). PI was not statistically correlated with height, weight, or BMI (*p* = 0.767, *p* = 0.302, *p* = 0.062, respectively) (Table 3).

These measurements (LL, PI, PT, and SS) obtained for the 36 African American subjects aged 18 years or older [15 men and 21 women; mean age 26.6 ± 8.7 range (18–53)]

Table 3 Correlation between pelvic incidence and anthropometric data

Parameters	Correlation coefficient	<i>p</i> value [†]
Height	−0.027	0.767
Weight	0.089	0.302
Body mass index	0.167	0.062

*Bold type indicates statistical significance. [†]Correlation analysis between pelvic incidence and anthropometric data. *p* < 0.05 was considered as significant

were compared with those for the Caucasian population, comprising of 709 healthy French individuals [354 men and 355 women; mean age 36.8 range (18–81)] [14] and those for the Asian population, comprising of 312 healthy Japanese volunteers [45 men and 267 women; mean age 37.2 range (18–69)] [11]. Either ANOVA or Kruskal–Wallis test showed that there were statistically significant differences among three racial/ethnic cohorts with respect LL, PI, and SS (*p* < 0.001, *p* < 0.001, and *p* < 0.001, respectively) (Table 4). In post hoc analysis, the means values for PI (57.7° vs. 52.6°) was greater in the African American group than in Caucasian cohort (*p* = 0.007), whereas the values for LL (57.2° vs. 54.8°, *P* = 0.512), and SS (41.4° vs. 39.6°, *p* = 0.208) were not significantly different between these two cohorts. The means values for LL (57.2° vs. 48.6°), PI (57.7° vs. 48.7°), and SS (41.4° vs. 35.3°) were greater in the African American cohort than in the Asian cohort (*p* < 0.001, *p* < 0.001, and *p* < 0.001, respectively). Also, the means values for LL (54.8° vs. 48.6°), PI (52.6° vs. 48.7°), and SS (39.6° vs. 35.3°) were greater in the Caucasian cohort than in the Asian cohort (*p* < 0.001, *p* < 0.001, and *p* < 0.001, respectively) (Table 4).

There were statistically significant correlations between LL and PI in African American cohort (*r* = 0.354, *p* = 0.034), Caucasian cohort (*r* = 0.557, *p* < 0.001) and Asian cohort (*r* = 0.534, *p* < 0.001). The linear regression model for the LL as a function of PI was “predict LL = 0.41 × PI + 33.7” in African American (*r* = 0.354), “predict LL = 0.58 × PI + 24.3” in Caucasian (*r* = 0.557), and “predict LL = 0.54 × PI + 22.0” in Asian (*r* = 0.534), respectively (Table 5). These models had an *R*² of 0.125, 0.335,

and 0.285, respectively. Using these models in a subject with PI of 50°, the predicted LL in African American, Caucasian, and Asian subject were 54.2°, 53.3°, and 49.0°, respectively. There was statistically significant difference between Caucasian and Asian cohort for these models ($p < 0.001$).

There were also statistically significant correlations between PT and PI as well in African American cohort ($r = 0.564$, $p < 0.001$), Caucasian cohort ($r = 0.636$, $p < 0.001$) and Asian cohort ($r = 0.658$, $p < 0.001$). The linear regression model for the PT as a function of PI were “predict PT = $0.35 \times \text{PI} - 4.0$ ” in African American ($r = 0.564$), “predict PT = $0.43 \times \text{PI} - 9.3$ ” in Caucasian ($r = 0.636$), and “predict PT = $0.52 \times \text{PI} - 12.2$ ” in Asian ($r = 0.658$), respectively (Table 6). These models had an R^2 of 0.318, 0.425, and 0.433, respectively. Using these models in a subject with

PI of 50°, the predicted PT in African American, Caucasian, and Asian subject were 13.5°, 12.2°, and 13.8°, respectively. There was statistically significant difference between Caucasian and Asian cohort for these models ($p < 0.001$).

There were statistically significant correlations between SS and PI in African American cohort ($r = 0.740$, $p < 0.001$), Caucasian cohort ($r = 0.757$, $p < 0.001$) and Asian cohort ($r = 0.552$, $p < 0.001$). The linear regression model for the SS as a function of PI were “predict SS = $0.59 \times \text{PI} + 7.3$ ” in African American ($r = 0.740$), “predict SS = $0.58 \times \text{PI} + 9.3$ ” in Caucasian ($r = 0.757$), and “predict SS = $0.44 \times \text{PI} + 13.8$ ” in Asian ($r = 0.552$), respectively (Table 7). These models had an R^2 of 0.547, 0.574, and 0.304, respectively. Using these models in a subject with PI of 50°, the predicted SS in African

Table 4 Lumbar and pelvic parameters among the different demographic groups

Spino-pelvic parameters	African American ($n = 36$)	Caucasian ($n = 709$)	Asian ($n = 312$)	p value [†]	AA versus Cau p value [‡]	AA versus Asian p value [§]	Cau versus Asian p value [¶]
Age (range) (yrs)	26.6 ± 8.7 (18–53)	36.8 ± 14.3 (18–81)	37.2 ± 11.7 (18–69)	< 0.001	< 0.001	< 0.001	0.005
Lumbar lordosis (°)	57.2 ± 13.2	54.8 ± 10.5	48.6 ± 9.9	< 0.001	0.512	< 0.001	< 0.001
Pelvic incidence (°)	57.7 ± 11.5	52.6 ± 10.4	48.7 ± 9.7	< 0.001	0.007	< 0.001	< 0.001
Pelvic tilt (°)	15.9 ± 7.0	13.0 ± 6.8	13.3 ± 7.8	0.057			
Sacral slope (°)	41.4 ± 9.2	39.6 ± 7.9	35.3 ± 7.5	< 0.001	0.208	< 0.001	< 0.001

AA, African American; Cau, Caucasian; *Bold type indicates statistical significance. [†]Comparison among three cohorts. [‡]Post hoc comparison between African American and Caucasian. [§]Post hoc comparison between African American and Asian. [¶]Post hoc comparison between Caucasian and Asian. $p < 0.05$ was considered as significant

Table 5 The linear regression model for the lumbar lordosis as a function of pelvic incidence

	R^2	Slope of liner regression	p value	Intercept of the regression	p value
African American	0.125	0.41	0.034	33.7	0.004
Caucasian	0.335	0.58	< 0.001	24.3	< 0.001
Asian	0.285	0.54	< 0.001	22.0	< 0.001
African American versus Caucasian p value			1.000		
African American versus Asian p value			0.059		
Caucasian versus Asian p value			< 0.001		

$p < 0.05$ was considered as significant

Table 6 The linear regression model for the pelvic tilt as a function of pelvic incidence

	R^2	Slope of liner regression	p value	Intercept of the regression	p value
African American	0.318	0.35	< 0.001	− 4.0	0.436
Caucasian	0.425	0.43	< 0.001	− 9.3	< 0.001
Asian	0.433	0.52	< 0.001	− 12.2	< 0.001
African American versus Caucasian p value			1.000		
African American versus Asian p value			0.460		
Caucasian versus Asian p value			< 0.001		

$p < 0.05$ was considered as significant

Table 7 The linear regression model for the sacral slope as a function of pelvic incidence

	R^2	Slope of liner regression	p value	Intercept of the regression	p value
African American	0.547	0.59	<0.001	7.3	0.188
Caucasian	0.574	0.58	<0.001	9.3	<0.001
Asian	0.304	0.44	<0.001	13.8	<0.001
African American versus Caucasian p value			0.984		
African American versus Asian p value			0.499		
Caucasian versus Asian p value			<0.001		

$p < 0.05$ was considered as significant

American, Caucasian, and Asian subject were 36.8° , 38.3° , and 35.8° , respectively. There was statistically significant difference between Caucasian and Asian cohort for these models ($p < 0.001$).

There were statistically significant correlations between SS and LL in African American cohort ($r = 0.716$, $p < 0.001$), Caucasian cohort ($r = 0.778$, $p < 0.001$) and Asian cohort ($r = 0.692$, $p < 0.001$). The linear regression model for the SS as a function of LL were “predict $SS = 0.50 \times LL + 13.0$ ” in African American ($r = 0.716$), “predict $SS = 0.59 \times LL + 7.3$ ” in Caucasian ($r = 0.757$), and “predict $SS = 0.54 \times LL + 9.2$ ” in Asian ($r = 0.692$), respectively (Table 8). These models had an R^2 of 0.512, 0.606, and 0.479, respectively. Using these models in a subject with LL of 50° , the predicted SS in African American, Caucasian, and Asian subject were 38.0° , 36.8° , and 36.2° , respectively. There was no statistically significant difference among three cohorts for these models ($p < 0.001$).

In order to adjust the influence of age, multiple regression analysis was performed using LL value as a dependent variable, and PI value and age as independent variables. The results showed that age was excluded from significant factors in either cohort.

Discussion

The PI value of African American cohort

Many clinicians now recognize that assessment of spino-pelvic balance and morphology is important in the evaluation and treatment of spinal and hip disorders. Previous studies have reported on normal sagittal parameters of spine and pelvis [1, 9, 14–18]. Several studies have also underscored the importance of sagittal pelvic morphology in the standing balance of normal adults and children [1, 15, 19]. Among these pelvic parameters, PI is a key factor to evaluate sagittal balance of the spino-pelvic-hip complex [3]. PI is independent of posture, incorporates the orientation of the spine, sacrum, pelvis, and hips, enhancing the understanding of overall sagittal alignment [20]. This current review of 141 subjects is, to our knowledge, the largest single cohort of spino-pelvic radiographic measurement among then African American population without spine pathology available in the literature. The value for PI found in the current study for the African American subjects ($54.3^\circ \pm 10.2^\circ$) was smaller than the value (56.0°) obtained by Lonner et al. in his study of African American adolescent idiopathic scoliosis patients ($p = 0.044$), whereas it was greater than the value ($48.9^\circ \pm 11.0^\circ$) obtained in African American cadaveric specimens reported by Weinberg ($p < 0.001$) [20].

Table 8 The linear regression model for the sacral slope as a function of lumbar lordosis

	R^2	Slope of liner regression	p value	Intercept of the regression	p value
African American	0.512	0.50	<0.001	13.0	0.012
Caucasian	0.606	0.59	<0.001	7.3	<0.001
Asian	0.479	0.54	<0.001	9.2	<0.001
African American versus Caucasian p value			1.000		
African American versus Asian p value			0.563		
Caucasian versus Asian p value			0.135		

$p < 0.05$ was considered as significant

The racial/ethnic difference of pelvic parameters

Because this study included young African American subjects aged 17 years or younger, these measurements (LL, PI, PT, and SS) obtained for the 36 African American subjects aged 18 years or older [15 men and 21 women; mean age 26.6 ± 8.7 range (18–53)] were compared with those for the Caucasian population, which comprised 709 healthy French individuals [354 men and 355 women; mean age 36.8 range (18–81)] [14] and those for the Asians population, which comprised 312 healthy Japanese volunteers [45 men and 267 women; mean age 37.2 range (18–69)] [11] to ensure an accurate comparison. This study showed that PI in African American is 5.1° greater than in Caucasian and 9.0° greater than in Asian (Table 4). There are no previous studies comparing African American, Caucasian and Asian populations available in the previous literature. Other researchers have shown differences in sacro-pelvic parameters among between racial/ethnic groups. Zarate-Kalfopulos et al. [21] found that SS were found to be significantly greater in the Mexican Mestizo compared with the Caucasian, and the LL, PI, and SS were found to be significantly greater in the Mexican Mestizo compared with the Asian. The value for PI found in the current study for African American subjects aged 18 years or older ($57.7^\circ \pm 11.5^\circ$) was not statistically difference to the value (55.6°) for PI of Mexican Mestizo subjects aged 18 years or older ($p=0.271$) [21]. Hanson et al. found significantly greater lumbosacral curvature in blacks than in whites, but they did not refer to PI [22]. These authors concluded that racial/ethnic differences might influence the individual spino-pelvic alignment. The result of this current radiographic measurements' study complements these findings of racial/ethnic differences. Moreover, LL and SS were also found to be significantly greater in the African American compared with our Asian cohort.

The relationship PI with LL, PT and SS among difference racial/ethnic cohort

We also investigated the relationship of PI with LL, PT and SS on the basis of the individuals aged 18 years or older. In this study, the linear regression model for the LL as a function of PI were “predict $LL=0.41 \times PI + 33.7$ ” in African American ($r=0.354$), “predict $LL=0.58 \times PI + 24.3$ ” in Caucasian ($r=0.557$), and “predict $LL=0.54 \times PI + 22.0$ ” in Asian ($r=0.534$), respectively. Interestingly, the relationship between PI and LL in African Americans ($r=0.354$) is lower than in the Caucasian ($r=0.557$) or Asian cohort ($r=0.534$). The African American cohort probably represents a more heterogeneous group than the Caucasian or Asian cohort used in this study because they are African individuals of descent with some Caucasian admixing [23].

And, the linear regression model for the PT as a function of PI were “predict $PT=0.35 \times PI - 4.0$ ” in African American, “predict $PT=0.43 \times PI - 9.3$ ” in Caucasian, and “predict $PT=0.52 \times PI - 12.2$ ” in Asian, respectively. R^2 of these models were not so high. Especially, R^2 value was low in African Americans. This is thought to be due to the heterogeneity of the African American and lack of sample number in the African American cohort. Therefore, further examination is necessary, in order to apply the equation derived from these statistical data to clinical practice. However, these study results may suggest that the relationships of PI with LL, PT and SS were different among racial/ethnic populations.

Pelvic parameters and gender

Similar to previous reports [14, 20, 24, 25, 27], the results of this study showed there was no statistically significant difference in any of the pelvic parameters between male and female. However, there is one study reporting that PI was greater in females than in male among 300 asymptomatic volunteers [26], and another study reporting that PT was greater in female than in male and SS was smaller in female than in male among elderly volunteers [17]. In these two reports, they investigated among subjects, which are consisted of relatively elderly population. Because this study included younger African American subjects aged from 11 to 53, this suggests that there was no significant difference in any of the pelvic parameters between male and female among young African American cohort.

Pelvic parameters and age

PI has been known to increase until the age of ten and then stabilize [15, 27–29]. Although a correlation between PI and age was not seen in the current study, PI in subjects aged 18 years or older is greater than in subjects aged 17 years or younger. The results of this study also demonstrate that PT tended to increase with age. A larger study reported that both PT and LL among normal children and adolescents tend to increase with age to maintain an adequate sagittal balance during growth, and the SS is not significantly influenced by age after acquisition of walking [15]. The results of this current study partially support this previous evidence. However, in our study, there was no statistically significant relationship between age and LL or SS.

Pelvic parameters and anthropometric data

This current study also did not show any statistically significant correlation between anthropometric data (height, weight, and BMI) and PI. These results are different from those reported by Boulay et al. [24], who found that there

was a strong correlation between BMI and PI ($r=0.40601$, $p=0.005$). They discussed that the correlation between BMI and PI might be attributed to the late ossification of the sacrum even after the age of 20 years [24].

This study constitutes the largest single cohort of lumbar spine and pelvic radiographic measurement among African American subjects without spine pathology, and it reveals racial/ethnic differences in the values for the spino-pelvic parameters (LL, PI, and SS) and relationship between LL and PI. Therefore, when planning surgical reconstruction for spinal malalignment or other spine pathologies, the study suggest that surgeons address these racial/ethnic differences of pelvic morphology. These results presented here also serve as a reference data for clinical practice in our field.

There are several important limitations to this work. First, the recruited subjects were all discharged after their consultant spine surgeon or radiologist ruled out spine pathology. Since no follow-up visits were planned, it is possible that some of these patients will developed a spinal disorder in the future. It may affect spinal alignment, which is considered as a major limitation of this study. Second, the participants aged 18 years or older in the present study constituted only 26% of the sample. The PI is reported to tend to increase from 4 to 18 years of age in larger sample size study [15]. Therefore, when we compare the value for these parameters among different racial/ethnic cohorts, we did sub-analysis by enrolling only 36 subjects aged 18 years or older from our sample population. The statistical differences seen in a more balances sample group would have been greater, as the current study design is biased toward a type II error. Third, the values of PI and LL are reported to change with age due to degeneration of the intervertebral disk and the sacroiliac joint. In this study [17, 30], we could not adjust age among populations. Theses age difference may also have an effect on the results, which is the limitation of this study. Fourth, it is difficult to identify the geographic origin of the African American cohort in this study. This may also create a selection bias. Fifth, although we investigated ethnic/racial differences of pelvic morphology in static upright posture, we could not investigate ethnic/racial differences of dynamic change in this study. Further investigation is necessary.

Conclusion

A comparison of the values for sagittal pelvic parameters across the different racial/ethnic population samples revealed significant differences. These results presented here serve as a reference data when planning surgical reconstruction for spinal surgery.

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Compliance with ethical standards

Conflict of interest Relevant financial activities outside the submitted work: board membership, consultancy, employment, grants, payment for lectures, travel/accommodations/meeting expenses, patents, royalties, and stocks. HA has nothing to disclose. JRD, SDG and LYC are employees of Norton Healthcare. Nuvasive provided funds directly to database company. No funds are paid directly to Individual or Individual's Institution 06/2012-04/2015. JRD receives consulting fees, holds patents and receives royalties from Medtronic; is on the editorial review board of JBJS Highlights, Spine, Spine Deformity, JAAOS and Global Spine; is a member of the SRS Board. SDG received research grants from Norton Healthcare; receives consulting fees, holds patents from and receives royalties from Medtronic. YY, YM, JM and PR have nothing to disclose. LYC is a Member, Editorial Advisory Board, Spine and Spine Journal, University of Louisville Institutional Review Board, Scoliosis Research Society Research Committee; receives research funds from Orthopedic Research and Educational Fund, Norton Healthcare, Scoliosis Research Society; received funds for travel from Association for Collaborative Spine Research, University of Southern Denmark, University of Louisville; consulting fees from Washington University at St. Louis.

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