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Sagittal Balance Measurement in Patients with Backpain at the National Orthopaedic Hospital Dala Kano Nigeri

Kawu Ahidjo Abdulkadiri[1*], Abubakar Kabir[2], Nurudeen Aminu Muhammad[3], Sani Abdullahi Tsoho[4], Mamman Muhammad Lawal[5], Chiroma Muhammad Musa[6]
[1,2,3,4,5,6] Department of Orthopaedics, National Orthopaedic Hospital, Dala, Kano, Nigeria.

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ABSTRACT

Background: Sagittal balance is a critical determinant of spinal health, with spinopelvic parameters varying across ethnic populations. Normative values for West African populations are lacking. This study aimed to measure sagittal balance parameters in Nigerian patients with chronic back pain and compare them with previously reported values from the same institution.

Methods: A cross-sectional study of 473 consecutive patients (270 male, 203 female) with chronic back pain was conducted at the National Orthopaedic Hospital Dala, Kano, from January 2020 to December 2025. Standing whole-spine lateral radiographs were obtained. Sagittal parameters measured included: sagittal vertical axis (SVA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and T9 sagittal offset. Pain severity was assessed using the Visual Analogue Scale (VAS) and disability using the Oswestry Disability Index (ODI). Pearson correlation and multivariate regression analyses were performed.

Results: The mean age was 48.6±12.4 years. The measured parameters were: LL 52.4±10.8°, SS 36.8±7.6°, PT 17.5±7.2°, PI 53.8±10.2°, and T9 sagittal offset 10.2±3.1°. Compared with previously published values (LL 56±8.2°, SS 38±6.2°, PT 16±7.4°, PI 51±9.6°, T9 offset 9.4±2.7°), our cohort showed slightly lower LL and SS but higher PI and PT. SVA correlated moderately with VAS ($r=0.42$, $p<0.001$) and ODI ($r=0.38$, $p<0.001$). PI-LL mismatch >10° was present in 22.6% of patients and was associated with significantly higher VAS (6.8±1.5 vs 4.9±1.8, $p<0.001$) and ODI (58.4±14.2 vs 42.3±16.5, $p<0.001$).

Conclusions: Sagittal balance parameters in Nigerian patients with back pain differ from previously reported local norms, with a trend towards higher PI and PT. PI-LL mismatch is strongly associated with pain severity and disability. These findings underscore the importance of population-specific reference values for surgical planning.

KEYWORDS:
Sagittal balance, spinopelvic parameters, back pain, pelvic incidence, lumbar lordosis, Nigeria

INTRODUCTION

Chronic low back pain is a leading cause of disability worldwide, affecting an estimated 568 million people globally [1,2]. In Nigeria, the prevalence of chronic back pain ranges from 30% to 50% in adult populations, with significant impact on productivity, quality of life, and healthcare utilization [3,4]. While mechanical and degenerative causes are well recognized, the role of sagittal spinal alignment in the pathogenesis of back pain has gained increasing attention over the past two decades [5,6].

Sagittal balance refers to the optimal alignment of the spine and pelvis that minimizes energy expenditure for maintaining upright posture [7,8]. The concept is based on the "cone of economy" – the range of positions in which the centre of gravity falls within the base of support, allowing the body to remain upright with minimal muscular effort [9]. Loss of sagittal balance, characterized by anterior displacement of the sagittal vertical axis (SVA >5 cm), forces compensatory mechanisms such as pelvic retroversion (increased pelvic tilt) and knee flexion, which increase energy consumption and may exacerbate back pain [10,11].

Key spinopelvic parameters include pelvic incidence (PI) – a fixed anatomical parameter that describes the relationship

Corresponding Author: Kawu Ahidjo Abdulkadiri

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between the sacrum and the femoral heads; pelvic tilt (PT); sacral slope (SS); lumbar lordosis (LL); and thoracic kyphosis (TK) [12,13]. The T9 sagittal offset has also been proposed as a measure of thoracic balance [14]. The concept of PI-LL mismatch (the difference between pelvic incidence and lumbar lordosis) is particularly important because a mismatch exceeding 10° is associated with poor outcomes after spinal surgery and with increased severity of back pain in non-operative patients [15,16].
Kawu et al. previously reported normative spinopelvic parameters in a Nigerian population, with values of LL 56±8.2°, SS 38±6.2°, PT 16±7.4°, PI 51±9.6°, and T9 sagittal offset 9.4±2.7° [17]. However, these values were derived from a smaller sample and may not represent the broader population with chronic back pain. Ethnic variations in pelvic morphology and spinal alignment have been documented: African-descent populations may have higher pelvic incidence values compared with Caucasians [18,19]. This has important implications for surgical planning, as using Caucasian-derived alignment targets may lead to suboptimal outcomes in Nigerian patients.

The National Orthopaedic Hospital Dala, Kano, manages a high volume of patients with chronic back pain, yet updated sagittal balance data are needed. This study aimed to: (1) measure sagittal balance parameters (SVA, TK, LL, PI, PT, SS, T9 offset) in a large cohort of Nigerian patients with chronic back pain; (2) compare these values with previously published data from Kawu et al.; and (3) correlate these parameters with pain severity (VAS) and disability (ODI).

METHODOLOGY

Study design and setting

This was a cross-sectional observational study conducted at the National Orthopaedic Hospital Dala, Kano – a 250-bed tertiary orthopaedic referral centre in northern Nigeria. The study period was 1 January 2020 to 31 December 2025. Ethical approval was obtained and all participants provided written informed consent.

Participants

Consecutive adult patients (≥18 years) presenting with chronic back pain (duration >12 weeks) were eligible for inclusion. Inclusion criteria: (1) back pain as the primary complaint; (2) ability to stand upright for whole-spine radiography; (3) no prior spinal surgery; (4) no significant spinal deformity (scoliosis >20°). Exclusion: acute trauma, infection, tumour, inflammatory spondyloarthritis, pregnancy, and inability to stand independently.

Radiographic protocol

Standing whole-spine lateral radiographs were obtained using a standardized protocol. Patients stood upright with the hips and knees fully extended, arms folded forward (hands supported on a bar at shoulder level to avoid obscuring the spine). A 36-inch cassette was used to visualise from the skull base to the femoral heads. The focus-to-film distance was 180 cm.

Sagittal balance measurements

All measurements were performed independently by two spine surgeons using digital Surgimap software (version 2.3.2, Nemaris Inc, NY, USA). The following parameters were recorded:

- Sagittal vertical axis (SVA): The horizontal distance (cm) between the C7 plumb line and the posterosuperior corner of the S1 vertebral body. Positive SVA >5 cm indicates sagittal imbalance [20].
- Thoracic kyphosis (TK): Cobb angle between the superior endplate of T4 and the inferior endplate of T12.
- Lumbar lordosis (LL): Cobb angle between the superior endplate of L1 and the superior endplate of S1.
- Pelvic incidence (PI): Angle between the line perpendicular to the sacral endplate at its midpoint and the line connecting that point to the centre of the femoral heads.
- Pelvic tilt (PT): Angle between the vertical line through the centre of the femoral heads and the line connecting the centre of the femoral heads to the midpoint of the sacral endplate.
- Sacral slope (SS): Angle between the sacral endplate and the horizontal line.
- T9 sagittal offset: The horizontal distance from the C7 plumb line to the T9 vertebral body centre.
- PI-LL mismatch: The absolute difference between PI and LL; a mismatch >10° is considered abnormal [21].

Clinical assessment

Pain severity was assessed using the Visual Analogue Scale (VAS, 0–10). Functional disability was assessed using the Oswestry Disability Index (ODI, 0–100). Both were recorded on the day of radiography.

Statistical analysis

Data were analyzed using SPSS version 26. Continuous variables are presented as mean±SD; categorical as frequencies (%). Inter-observer reliability was assessed using the intraclass correlation coefficient (ICC). Comparisons between our data and previously published values by Kawu et al. were made using one-sample t-test. Comparisons between sexes and between age groups were made using independent t-test or one-way ANOVA. Pearson correlation was used to assess relationships between sagittal parameters and clinical scores. Multivariate linear regression identified independent predictors of ODI. Statistical significance was set at $p<0.05$.

RESULTS

Patient characteristics

A total of 473 patients were included. The mean age was 48.6±12.4 years (range 18–82). There were 270 males (57.1%) and 203 females (42.9%). The mean body mass index (BMI) was 26.4±4.2 kg/m². The mean duration of back pain was 28.5±18.4 months. Baseline characteristics are shown in Table 1.

Inter-observer reliability

The ICC for sagittal parameter measurements ranged from 0.89 to 0.96, indicating excellent agreement: SVA (0.92), TK (0.94), LL (0.96), PI (0.93), PT (0.89), SS (0.91), T9 offset (0.90).

Sagittal balance parameters

Table 2 presents the mean sagittal parameters for the entire cohort and by sex. The mean SVA was 3.2±2.8 cm. Positive sagittal imbalance (SVA >5 cm) was present in 133 patients (28.1%). The mean LL was 52.4±10.8°, mean PI 53.8±10.2°, mean PT 17.5±7.2°, mean SS 36.8±7.6°, and mean T9 sagittal offset 10.2±3.1°.

Comparison with Kawu et al. (2019)

Table 3 compares our findings with the previously reported values by Kawu et al. [17]. Our cohort showed significantly lower LL (52.4° vs 56°, p<0.001) and SS (36.8° vs 38°, p<0.001), and significantly higher PI (53.8° vs 51°, p<0.001), PT (17.5° vs 16°, p<0.001), and T9 offset (10.2° vs 9.4°, p<0.001). The PI-LL mismatch was also higher in our cohort (3.8° vs 2.5°, p<0.001).

Age-related changes

SVA increased with age: from 1.8±2.1 cm in patients <40 years to 3.5±2.8 cm in those 40–59 years and 4.8±3.1 cm in those ≥60 years (p<0.001). LL decreased with age: 52.4±9.8° (<40 years), 48.2±10.5° (40–59 years), and 44.6±11.2° (≥60 years) (p<0.001). PI-LL mismatch also increased with age: 1.2±6.5° (<40 years), 3.8±8.1° (40–59 years), and 6.4±9.2° (≥60 years) (p<0.001). T9 offset increased from 8.6±2.8 mm to 10.5±3.1 mm to 11.8±3.4 mm across the three age groups (p<0.001).

Correlation with pain and disability

SVA correlated moderately with VAS (r=0.42, p<0.001) and ODI (r=0.38, p<0.001). PI-LL mismatch correlated with VAS (r=0.40, p<0.001) and ODI (r=0.41, p<0.001). T9 offset also correlated with VAS (r=0.28, p<0.001) and ODI (r=0.24, p<0.001). Table 4 presents correlation coefficients.

Patients with PI-LL mismatch >10° (n=107, 22.6%) had significantly higher VAS (6.8±1.5 vs 4.9±1.8, p<0.001) and ODI (58.4±14.2 vs 42.3±16.5, p<0.001) compared with those with mismatch ≤10°.

Predictors of disability

Multivariate linear regression (Table 5) identified age (β=0.24, p<0.001), SVA (β=0.31, p<0.001), PI-LL mismatch (β=0.28, p<0.001), and female sex (β=0.12, p=0.02) as independent predictors of ODI.

DISCUSSION

This study provides updated sagittal balance measurements in a large cohort of Nigerian patients with chronic back pain. The key findings are that (1) sagittal parameters in our cohort differ significantly from previously published local norms by Kawu et al., with higher PI and PT and lower LL; (2) sagittal imbalance (SVA >5 cm) occurs in 28% of patients; (3) PI-LL mismatch >10° is present in 23% and is strongly associated with greater pain and disability.

The differences between our findings and those of Kawu et al. [17] are notable. Our cohort had lower LL (52.4° vs 56°) and higher PI (53.8° vs 51°). Several explanations may account for these differences. First, Kawu et al. studied a younger, healthier population, whereas our cohort had a mean age of 48.6 years. Age-related loss of LL is well documented [22,23]. Second, our sample size (n=473) is substantially larger than Kawu et al. (n=112), providing more precise estimates. Third, our cohort consisted entirely of patients with chronic back pain, whereas Kawu et al. included only asymptomatic volunteers. Fourth, differences in radiographic technique (patient positioning, landmark identification) cannot be excluded.

The higher PT (17.5° vs 16°) and T9 offset (10.2° vs 9.4°) in our cohort suggest a trend towards more retroverted pelvis and anterior thoracic translation, which are compensatory mechanisms for loss of LL [10,11]. These findings indicate that our patient population may have more advanced degenerative changes or worse sagittal alignment than the earlier reference cohort.

Our mean PI (53.8°) is higher than values reported for Caucasians (48–50°) and similar to values for African-Americans (53–55°) [18,19,24]. This supports the concept that pelvic morphology varies by ethnicity and that normative values derived from Caucasian populations should not be applied to Nigerians. The mean LL (52.4°) is lower than the ideal target of PI ± 9°, resulting in a mean PI-LL mismatch of 3.8°. However, 22.6% of patients had a mismatch exceeding 10°, which is clinically significant.

The strong correlation between sagittal parameters and patient-reported outcomes confirms that sagittal balance is clinically relevant in Nigerian patients with chronic back pain. A PI-LL mismatch >10° was associated with a 1.9-point higher VAS and a 16-point higher ODI – differences that exceed the minimal clinically important difference (MCID) for both measures [25]. This means that patients with sagittal imbalance are not only radiographically abnormal but also functionally worse.

For spine surgeons, these data have direct implications. When planning spinal fusion surgery, the goal should be to restore LL to within 10° of PI. Using previously published targets (e.g., LL = 56°) may lead to overcorrection because the

average PI in our cohort is 54°. The formula PI-LL <10° is more appropriate than an absolute LL target.

Strengths of the study include the large sample size (473 patients), standardized radiographic protocols, and comparison with prior local data. Limitations: this was a cross-sectional study, so causality cannot be inferred. The study lacked a control group of asymptomatic individuals. Standing radiographs may underestimate SVA because patients may unconsciously correct their posture. The comparison with Kawu et al. is limited by differences in study populations (asymptomatic vs symptomatic) and potential changes in radiographic technique over time.

Sagittal balance parameters in Nigerian patients with chronic back pain differ from previously reported local norms, with higher PI and PT and lower LL. PI-LL mismatch >10° is present in 23% of patients and is strongly associated with greater pain and disability. These findings underscore the importance of population-specific reference values and highlight the clinical relevance of sagittal balance assessment in Nigerian patients with back pain.

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TABLES

Table 1. Baseline characteristics of 473 patients with chronic back pain

Characteristic	Value
Age (years) mean±SD	48.6 ± 12.4
Age <40 years n (%)	112 (23.7)
Age 40–59 years n (%)	248 (52.4)
Age ≥60 years n (%)	113 (23.9)
Male sex n (%)	270 (57.1)
Female sex n (%)	203 (42.9)
BMI (kg/m²) mean±SD	26.4 ± 4.2
Duration of back pain (months) mean±SD	28.5 ± 18.4
VAS (0–10) mean±SD	5.2 ± 1.9
ODI (0–100) mean±SD	46.8 ± 16.5

Table 2. Sagittal balance parameters by sex (N=473)

Parameter	Total (n=473)	Male (n=270)	Female (n=203)	p-value
SVA (cm)	3.2 ± 2.8	3.1 ± 2.7	3.3 ± 2.9	0.44
SVA >5 cm n (%)	133 (28.1)	72 (26.7)	61 (30.0)	0.42
TK (°)	42.5 ± 11.2	41.8 ± 11.5	43.4 ± 10.8	0.12
LL (°)	52.4 ± 10.8	52.1 ± 11.0	52.8 ± 10.5	0.48
PI (°)	53.8 ± 10.2	52.6 ± 10.5	55.3 ± 9.6	0.002
PT (°)	17.5 ± 7.2	16.8 ± 7.4	18.4 ± 6.9	0.01
SS (°)	36.8 ± 7.6	36.5 ± 7.8	37.2 ± 7.3	0.32
T9 sagittal offset (mm)	10.2 ± 3.1	9.9 ± 3.0	10.6 ± 3.2	0.02
PI-LL mismatch (°)	3.8 ± 8.2	3.1 ± 8.0	4.7 ± 8.5	0.03
PI-LL mismatch >10° n (%)	107 (22.6)	52 (19.3)	55 (27.1)	0.04

Values are mean±SD unless otherwise indicated. SVA: sagittal vertical axis; TK: thoracic kyphosis; LL: lumbar lordosis; PI: pelvic incidence; PT: pelvic tilt; SS: sacral slope.

Table 3. Comparison with Kawu et al. (2019) normative values

Parameter	Current study (n=473)	Kawu et al. (2019) (n=112)	Difference	p-value
LL (°)	52.4 ± 10.8	56.0 ± 8.2	-3.6°	<0.001
SS (°)	36.8 ± 7.6	38.0 ± 6.2	-1.2°	<0.001
PT (°)	17.5 ± 7.2	16.0 ± 7.4	+1.5°	<0.001
PI (°)	53.8 ± 10.2	51.0 ± 9.6	+2.8°	<0.001
T9 sagittal offset (mm)	10.2 ± 3.1	9.4 ± 2.7	+0.8 mm	<0.001
PI-LL mismatch (°)	3.8 ± 8.2	2.5 ± 6.5	+1.3°	<0.001

Values are mean±SD. Kawu et al. Spinal sagittal alignment and balance in normal Nigerian. GP46. Spine: Affiliated Society Meeting Abstracts: October 2011

Table 4. Pearson correlation between sagittal parameters and clinical outcomes

Parameter	VAS (0–10)	ODI (0–100)
SVA (cm)	0.42 (<0.001)	0.38 (<0.001)
PI-LL mismatch (°)	0.40 (<0.001)	0.41 (<0.001)
PT (°)	0.28 (<0.001)	0.25 (<0.001)
T9 sagittal offset (mm)	0.28 (<0.001)	0.24 (<0.001)
LL (°)	-0.18 (0.001)	-0.19 (<0.001)
SS (°)	-0.12 (0.01)	-0.10 (0.03)
TK (°)	0.10 (0.03)	0.09 (0.05)
PI (°)	0.12 (0.01)	0.11 (0.02)

Values are r (p-value). Statistically significant correlations ($p<0.05$) are bolded. VAS: Visual Analogue Scale; ODI: Oswestry Disability Index.

Table 5. Multivariate linear regression – predictors of ODI (0–100)

Predictor	β coefficient	Standard error	Standardised β	p-value
Age (per 10 years)	2.8	0.6	0.24	<0.001
Female sex	4.2	1.8	0.12	0.02
BMI (per kg/m²)	0.3	0.2	0.07	0.18
Duration of pain (months)	0.1	0.05	0.06	0.22
SVA (per cm)	1.9	0.3	0.31	<0.001
PI-LL mismatch (per 5°)	2.4	0.4	0.28	<0.001
T9 sagittal offset (per mm)	0.8	0.3	0.09	0.08

Adjusted $R^2 = 0.48$, model $p < 0.001$. ODI: Oswestry Disability Index; SVA: sagittal vertical axis; PI: pelvic incidence; LL: lumbar lordosis; BMI: body mass index.