# Global Sagittal Alignment Variations with Body Mass Index in Patients Without Spine Deformity

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INTRODUCTION: The significance of including the head and cervical spine in sagittal alignment evaluations has been increasingly recognized. There is limited research on the impact of body mass index (BMI) on global sagittal alignment. Exploring how BMI affects these global alignment parameters would provide a more comprehensive understanding of spine alignment variations across different body compositions.

METHODS: Consecutive patients at a single institution undergoing full-body spine imaging from November 2022 to February 2024 were included. Patients with spinal deformity, degenerative spine conditions, or prior spine surgeries were excluded. Radiographic parameters of global spinal alignment were measured including cranial sagittal vertical axis to the sacrum (CrSVA-S), to the hip (CrSVA-H), to the knee (CrSVA-K), to the ankle (CrSVA-A), cranium-hip-sacrum angle (CrHS), cranium-knee-sacrum (CrKS), and cranium-ankle-sacrum (CrAS) (Figure 1). The patients were stratified based on age by three categories (<40, 40-59, and ≥60) and sex. Student's t-test was performed to compare differences in obese (≥30 kg/m2) and non-obese (<30 kg/m2) patients for groups defined by age and sex. Continuous variables were reported as the mean ± standard deviation and categorical variables were reported as frequencies. For all analyses, a p-value less than 0.05 in a two-sided test was considered statistically significant. Multivariable regression analysis was performed with age and sex as predictors of the radiographic measurements (CrSVA-S, Cr-SVAH, CrSVA-K, CrSVA-A) and radiographic angles (CrKS, CrAS, CrHS). Beta coefficients for age and sex as predictors of the radiographic parameters were reported for each model with 95% confidence intervals. P-values less than 0.05 were considered statistically significant.

RESULTS:

392 patients without spinal deformity, degenerative spine conditions, or prior spine surgeries were included. The average BMI was 26.22, with 21.2% of eligible patients classified as obese (Table 1). For females, significant differences were found in CrSVA-S for the 40-59 age group (higher in obese: 4.13±2.66 cm vs. non-obese: 2.01±2.69 cm), CrSVA-H for the 40-59 age group (higher in obese: -0.08±1.68 cm vs. non-obese: -2.05±2.65 cm), CrKS for the <40 (higher in obese: 2.22±4.08° vs. non-obese: 0.027±2.55°) and 40-59 age groups (higher in obese: 3.16±2.62° vs. non-obese: 0.98±2.30°), and CrAS for the <40 age group (higher in obese: 1.03±2.23° vs. non-obese: -0.09±1.50°). No significant differences were found in CrSVA-K, CrSVA-A, and CrHS across all age groups (Table 2). For males, significant differences were found in CrSVA-K for the ≥60 age group (higher in non-obese: 1.99±3.60 cm vs. obese: -1.88±6.33 cm), CrSVA-A for the ≥60 age group (higher in non-obese: 4.23±3.29 cm vs. obese: 1.79±4.93 cm), and CrAS for the <40 age group (higher in obese: 1.35±1.25° vs. non-obese: 0.03±1.53°). For males, no significant differences were found in CrSVA-S, CrSVA-H, CrSVA-A (for <40 and 40-59 age groups), CrHS, and CrKS across all age groups (Table 3).

BMI has a statistically significant negative association with CrSVA-S (β = -0.082, p = 0.010) and CrSVA-H (β = -0.067, p = 0.036). BMI shows a significant positive association with CrHS (β = 0.176, p = 0.012), CrKS (β = 0.142, p < 0.001), and CrAS (β = 0.071, p < 0.001). The relationship between BMI and CrSVA-K is not significant (β = 0.058, p = 0.075), and BMI does not significantly affect CrSVA-A (β = 0.011, p = 0.708) (Table 4).

DISCUSSION AND CONCLUSION: The data presented in this study reveals the importance of considering BMI when evaluating global sagittal alignment parameters. These values can help establish normal values for measures of global spinal alignment based on BMI.

**Figure 1. Radiographic Points for Global Sagittal Alignment Parameters**

**Table 1. Demographic and Baseline Characteristics of the Patient Cohort**

| Characteristic | Mean or N (%) |
|---|---|
| **Total N** | 392 |
| **Age (Years)** | 49.11±17.24 |
| **Age Category (Years)** | |
| <40 | 138 (35.2%) |
| 40-59 | 128 (32.7%) |
| ≥60 | 126 (32.1%) |
| **Sex** | |
| Male | 190 (48.5%) |
| Female | 202 (51.5%) |
| **BMI (kg/m²)** | 26.22±5.37 |
| Non-Obese (<30 kg/m²) | 309 (78.8%) |
| Obese (≥30 kg/m²) | 83 (21.2%) |

**Table 2. A Comparison of Radiographic Parameters between Women with Body Mass Index <30 kg/m² and ≥30 kg/m²**

| | Age Category | Females with Body Mass Index <30 kg/m² (n=41) | Females with Body Mass Index ≥30 kg/m² (n=161) | P-value |
|---|---|---|---|---|
| **CrSVA-S (cm)** | <40 | 1.63±2.82 | 2.92±4.28 | 0.220 |
| | 40-59 | 2.01±2.69 | 4.13±2.66 | 0.020 |
| | ≥60 | 3.22±3.44 | 4.41±4.48 | 0.257 |
| **CrSVA-H (cm)** | <40 | -1.92±2.72 | -1.40±4.65 | 0.386 |
| | 40-59 | -2.05±2.65 | -0.08±1.68 | 0.029 |
| | ≥60 | -1.69±3.43 | -0.38±3.86 | 0.167 |
| **CrSVA-K (cm)** | <40 | 2.14±2.98 | 2.21±4.21 | 0.961 |
| | 40-59 | 1.16±3.22 | 1.48±3.22 | 0.629 |
| | ≥60 | -0.14±3.40 | 0.10±3.56 | 0.718 |
| **CrSVA-A (cm)** | <40 | 2.69±2.84 | 2.82±3.99 | 0.829 |
| | 40-59 | 2.11±2.69 | 3.69±2.53 | 0.070 |
| | ≥60 | 1.55±3.28 | 2.14±3.23 | 0.501 |
| **CrHS (°)** | <40 | 16.12±7.81 | 19.51±8.04 | 0.211 |
| | 40-59 | 18.90±6.22 | 21.57±8.91 | 0.246 |
| | ≥60 | 24.11±6.58 | 25.90±10.06 | 0.302 |
| **CrKS (°)** | <40 | 0.027±2.55 | 2.22±4.08 | 0.026 |
| | 40-59 | 0.98±2.30 | 3.16±2.62 | 0.007 |
| | ≥60 | 3.61±3.14 | 4.94±5.21 | 0.116 |
| **CrAS (°)** | <40 | -0.091±1.50 | 1.03±2.23 | 0.047 |
| | 40-59 | 0.28±1.52 | 0.65±2.11 | 0.498 |
| | ≥60 | 1.55±2.07 | 2.49±2.24 | 0.097 |

**Table 3. A Comparison of Radiographic Parameters between Men with Body Mass Index <30 kg/m² and ≥30 kg/m²**

| | Age Category | Males with Body Mass Index <30 kg/m² (n=42) | Males with Body Mass Index ≥30 kg/m² (n=148) | P-value |
|---|---|---|---|---|
| **CrSVA-S (cm)** | <40 | 2.37±3.19 | 3.72±2.17 | 0.186 |
| | 40-59 | 3.28±2.72 | 2.90±3.72 | 0.656 |
| | ≥60 | 5.85±3.85 | 4.64±5.05 | 0.370 |
| **CrSVA-H (cm)** | <40 | -1.33±2.95 | 0.11±1.99 | 0.082 |
| | 40-59 | -0.80±2.76 | -1.46±3.69 | 0.438 |
| | ≥60 | 1.42±3.86 | -0.54±6.30 | 0.184 |
| **CrSVA-K (cm)** | <40 | 1.56±3.59 | 2.11±2.32 | 0.580 |
| | 40-59 | 1.95±2.53 | 0.52±3.50 | 0.071 |
| | ≥60 | 1.99±3.60 | -1.88±6.33 | 0.008 |
| **CrSVA-A (cm)** | <40 | 3.40±3.34 | 3.50±2.48 | 0.927 |
| | 40-59 | 4.03±2.91 | 2.71±3.16 | 0.112 |
| | ≥60 | 4.23±3.29 | 1.79±4.93 | 0.046 |
| **CrHS (°)** | <40 | 18.40±7.15 | 18.03±4.82 | 0.870 |
| | 40-59 | 20.09±7.92 | 20.90±7.50 | 0.707 |
| | ≥60 | 24.19±7.78 | 26.76±6.92 | 0.303 |
| **CrKS (°)** | <40 | 1.39±2.31 | 2.10±2.32 | 0.352 |
| | 40-59 | 2.04±2.52 | 2.57±2.82 | 0.466 |
| | ≥60 | 4.92±3.23 | 5.88±3.81 | 0.386 |
| **CrAS (°)** | <40 | 0.031±1.53 | 1.35±1.25 | 0.009 |
| | 40-59 | 0.33±1.69 | 0.12±2.18 | 0.681 |
| | ≥60 | 1.90±2.63 | 1.94±3.04 | 0.962 |

**Table 4. Linear Regression Models for Radiographic Parameters with Male Sex, Age, and BMI as Predictors**

| | | Beta Coefficient (95% CI) | Variable P-value |
|---|---|---|---|
| **CrSVA-S** | Age | 0.053 (0.034, 0.073) | <0.001 |
| | Male Sex | 1.125 (0.466, 1.784) | <0.001 |
| | Body Mass Index | 0.082 (0.020, 0.145) | 0.010 |
| **CrSVA-H** | Age | 0.026 (0.007, 0.046) | 0.008 |
| | Male Sex | 1.093 (0.429, 1.757) | 0.001 |
| | Body Mass Index | 0.067 (0.004, 0.130) | 0.036 |
| **CrSVA-K** | Age | -0.028 (-0.048, -0.008) | 0.006 |
| | Male Sex | 0.390 (-0.283, 1.063) | 0.208 |
| | Body Mass Index | -0.058 (-0.121, 0.006) | 0.075 |
| **CrSVA-A** | Age | -0.005 (-0.024, 0.014) | 0.599 |
| | Male Sex | 1.340 (0.707, 1.974) | <0.001 |
| | Body Mass Index | -0.011 (-0.071, 0.048) | 0.708 |
| **CrHS** | Age | 0.180 (0.138, 0.223) | <0.001 |
| | Male Sex | 0.907 (-0.541, 2.354) | 0.219 |
| | Body Mass Index | 0.176 (0.039, 0.313) | 0.012 |
| **CrKS** | Age | 0.081 (0.065, 0.097) | <0.001 |
| | Male Sex | 0.892 (0.349, 1.435) | 0.001 |
| | Body Mass Index | 0.142 (0.090, 0.193) | <0.001 |
| **CrAS** | Age | 0.036 (0.025, 0.048) | <0.001 |
| | Male Sex | -0.022 (-0.407, 0.362) | 0.908 |
| | Body Mass Index | 0.071 (0.034, 0.107) | <0.001 |