Ranges of Dynamic Spinal Alignment During Gait in Patients with Mild and Severe Adult Spinal Deformities

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INTRODUCTION

Coronal and sagittal surgical correction strategies for adult spinal deformity (ASD) rely heavily on radiographic alignment goals. There is a deficit in understanding how static alignment translates to physical ability in daily life. Kinematic gait analysis provides comprehensive quantification of physical function in spinal deformity patients, however outcome measures are often reported as segmental ranges-of-motion (ROM) which inhibits direct relation to radiographic alignment. Kinematic evaluations including standing and walking can be used to fill this gap. Kinematic analysis has the potential to improve the concept of ideal spinal alignment by providing clinically-meaningful measures of dynamic changes in spinal alignment.

METHODS

Non-randomized, retrospective review of 48 ASD patient's radiographic and functional data and 56 healthy subject's range-of-motion (ROM) data. Spinal alignment was assessed radiographically and during a standing and an over-ground walking test. Dynamic alignment was initialized by linking radiographic alignment to kinematic alignment during the standing test and then to initial-heel contact alignment during gait. Dynamic maximum and minimum changes in alignment during gait were made relative to initial heel contact for each gait cycle. Total gait cycle range-of-motion (ROM) was also included for both ASD patients and healthy controls. Dynamic alignment measures included Coronal vertical axis (CVA), sagittal vertical axis (SVA), T1 Pelvic Angle (TPA), lumbar lordosis (LL), and pelvic tilt (PT). Comparisons were made between healthy and ADS subjects ROM and mild to severe SRS-Schwab deformity classifications. We hypothes that ASD patients will exhibit greater dynamic ranges of spinal alignment during gait compared to healthy controls. Additionally, ASD patients with greater deformity will show similarly greater dynamic ranges of spinal alignment during gait compared to patients with lesser deformity.

RESULTS AND DISCUSSION

Spinal alignment results are summarized in Table 1. Severe deformity patients exhibited significantly worse radiographic deformity than mild deformity patients with greater global malalignment (CVA and SVA), lower LL, and greater PT. There was a consistent trend found across nearly all dynamic alignment measures of significantly greater anterior truncal inclination (greater SVA + greater TPA + reduced LL + reduced PT) at IHC and at dynamic maximums and minimums. The only significant difference found in dynamic ROM between healthy and ASD subjects was for greater PT ROM among ASD patients (Mild p=0.019, Severe p<0.001). No significant differences in dynamic ROM were found between mild and severe ASD groups, however a marginally higher PT was seen for severe compared to mild deformity patients. In this study, the dynamic characteristics of spinal alignment were well indicated by the severity of the baseline deformity: greater baseline deformity was reflected in similarly greater dynamic deformity, however there wasn't an equal dependency on dynamic ROM. This lack of change of dynamic RoM suggests that dynamic compensation mechanisms incorporating the pelvis and lower limbs may be driving more of the "within-ROM" changes.

Table 1. Summary of radiographic and dynamic spinal alignment during gait for mild and severe adult spinal deformities as well as baseline range-of-motion data for healthy adults. Values are reported as mean ± one standard deviation.

Alignment Measure	Measure Type	Healthy (n=46)	Mild (n=22)	Severe (n=29)	Mild to Severe p value
SVA (mm)	Radiographic	-	6.9±29.5	74.3±54.2	<0.001**
	Dynamic @IHC	-	47.1±45.5	122.7±55.7	<0.001**
	Dynamic Max	-	59.9±47.8	136.6±58.0	<0.001**
	Dynamic Min	-	32.2±46.4	106.8±56.5	<0.001**
	Dynamic ROM	27.7±6.0	27.7±8.1	29.8±12.2	0.497
TPA (°)	Radiographic	-	20.0±7.8	25.9±12.4	0.056
	Dynamic @IHC	-	23.3±8.8	29.8±12.8	0.047*
	Dynamic Max	-	24.8±9.2	31.6±12.7	0.038*
	Dynamic Min	-	21.4±8.9	27.7±12.8	0.051
	Dynamic ROM	3.4±0.7	3.4±0.9	3.9±1.8	0.304
LL (°)	Radiographic	-	49.8±16.0	37.7±20.0	0.024*
	Dynamic @IHC	-	44.3±15.6	34.0±19.7	0.049*
	Dynamic Max	-	42.0±15.6	31.3±20.0	0.042*
	Dynamic Min	-	46.2±15.3	39.6±21.5	0.038*
	Dynamic ROM	3.7±1.0	4.2±1.3	4.5±2.9	0.736
PT (°)	Radiographic	-	15.6±7.2	26.7±10.0	<0.001**
	Dynamic @IHC	-	14.8±7.2	23.7±9.6	0.001*
	Dynamic Max	-	13.4±7.0	22.1±9.9	0.001*
	Dynamic Min	-	17.2±7.2	26.8±9.8	<0.001**
	Dynamic ROM	3.3±0.6	3.7±1.0†	4.7±2.5††	0.093

SVA: Sagittal Vertical Axis, TPA: T1 Pelvic Angle, LL: Lumbar Lordosis, PT: Pelvic Tilt, IHC: Initial Heel Contact, ROM: Range-of-Motion, * Indicates significance at p<0.05, ** Indicates significance at p<0.001, † indicates significant difference compared to healthy at p<0.05, †† indicates significant difference compared to healthy at p<0.001.

SIGNIFICANCE

Consideration of dynamic ranges of spinal alignment during daily activities like gait can provide improved guidance for surgical planning and to refine patient-specific realignment goals.