ASSOCIATION OF SPINAL DEFORMITY AND PELVIC TILT WITH GAIT ASYMMETRY IN ADOLESCENT IDIOPATHIC SCOLIOSIS PATIENTS: GROUND REACTION FORCE INVESTIGATION

1 Edward Chu,2 Yang-Sun Park,3 Young-Tae Lim,1 Kyung Koh,3 Jong-Moon Kim,1 Hyun-Joon Kwon,1 Ross H. Miller, and1,4 Jae Kun Shim

1University Maryland, College Park, USA
2Hanyang University, Seoul, South Korea
3Konkuk University, Chungju, South Korea
4Kyung Hee University, Yongin, South Korea

email: edchux@umd.edu, web: http://www.sph.umd.edu/neuromechanics

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a prevalent orthopedic problem in children between 10 and 16 years of age [1]. If left untreated, scoliosis can lead to asymmetry of the trunk, which may lead to more serious cardiorespiratory and other orthopaedic problems [2]. Gait asymmetry of ground reaction force (GRF) in AIS has been frequently investigated; however, previous studies have reported conflicting results, with some studies reporting a significant relationship between gait asymmetry in GRF and the severity of the spinal deformity, and some studies reporting no significant relationship [3,4].

The goal of this current study is to provide greater insight into gait asymmetry in AIS patients. This study specifically investigated whether the asymmetry of the GRF magnitude and timing in AIS patients would be associated with spinal deformity and pelvic tilt.

Spinal deformity is the primary orthopaedic characteristic in AIS and the degree of asymmetry ostensibly affects the degree of gait asymmetry. GRF reflect the whole-body motion and are sensitive to individual body segment kinematics. Previous studies have shown that pelvic tilt is correlated with leg-length inequality, and leg length inequality can affect GRF phase times [5,6]. We therefore hypothesized that (i) between-leg asymmetry of GRF magnitude variables would increase with spinal deformity, and (ii) asymmetry of GRF time variables would increase with pelvic tilt (PT).

METHODS

Nine adolescents (3 male and 6 female; ages = 15±1.24 years) with AIS participated and all participants provided written consent. The study was approved by Chungju Konkuk University Hospital.

Frontal plane spinal radiographs were taken. The degree of spinal deformity was quantified using two measures:

- The maximum Cobb angle (MCA; [7]), calculated as the largest angle in the frontal plane among the absolute values of all existing Cobb’s angles greater than 10°.
- A new exploratory measure, the adjusted Cobb angle (ACA), calculated as the sum of Cobb’s angles in the frontal plane considering the direction of the angle, with the ACA being positive if the angle is going counter-clockwise with respect to the perpendicular line of the vertebrae at the bottom of the curve, and negative when the angle is going clockwise.

PT was also quantified and was calculated as the angle between the line connecting the right and left iliac crest and the horizontal line in the frontal plane.
In the gait data collections, participants were instructed to walk naturally, at a self-selected, comfortable speed along a 20-m walkway. GRF were measured from two force platforms embedded in the middle of the walkway. Starting position was adjusted so that subjects stepped consecutively on the platforms with the right and left feet without deliberately targeting the platforms.

To assess the gait asymmetry between legs, the Asymmetry Index (AI) was calculated using the following formula:

$$AI = \frac{R - L}{0.5 \times (R + L)}$$

Where R and L represent the values of a specific GRF component from the right foot and the left foot, respectively [8]. AI was calculated for selected peak and average magnitudes of the vertical and anterior-posterior GRF, as well as the timing of peaks and the braking/propelling phases of stance. Correlations between AIs and the spinal deformity measures were calculated by linear regression ($\alpha = 0.05$).

RESULTS AND DISCUSSION

The average walking speed of the subjects (1.22±0.17 m/s) was similar to previously reported walking speeds for this age group [9].

There were significant correlations between the AI of average vertical GRF over the stance phase ($F_{z\text{AVG}}$) with MCA and ACA, but not with PT (Table 1). The GRF timing results such as AI of the average stance phase contact time ($T_{\text{stance}}$), indicated that there was an association between the asymmetry of $T_{\text{stance}}$ and PT, while there was no significant association of $T_{\text{stance}}$ with ACA or MCA (Table 1).

Our study used a new index, the adjusted Cobb’s angle, which considers multiple directions of scoliosis curvatures in addition to maximum Cobb’s angle. Both the maximum and adjusted Cobb’s angles showed significant correlation coefficients with the asymmetry of GRF magnitude.

CONCLUSIONS

In general, our study shows that the gait asymmetry of both magnitudes and time variables of GRF are associated with the severity of the spinal deformities and pelvic tilt: the spinal deformity is generally associated with the between-leg asymmetry in GRF magnitudes, while the pelvic tilt is associated with the asymmetry of the time variables.

REFERENCES


Table 1: Linear regression results ($\alpha = 0.05$) for AI of average vertical GRF over the stance phase ($F_{z\text{AVG}}$) and AI of stance phase contact time ($T_{\text{stance}}$) with maximum Cobb’s angle (MCA), adjusted Cobb’s angle (ACA), and pelvic tilt (PT). Correlation coefficient (r) and p-values (p) are provided. Statistically significant correlations are bolded.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MCA</th>
<th></th>
<th>ACA</th>
<th></th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p</td>
<td>r</td>
<td>p</td>
<td>r</td>
</tr>
<tr>
<td>$F_{z\text{AVG}}$</td>
<td>0.79</td>
<td>0.011</td>
<td>0.697</td>
<td>0.037</td>
<td>-0.476</td>
</tr>
<tr>
<td>$T_{\text{stance}}$</td>
<td>-0.452</td>
<td>0.172</td>
<td>-0.379</td>
<td>0.315</td>
<td>0.715</td>
</tr>
</tbody>
</table>