INTRODUCTION

Motivation

- Adult degenerative scoliosis (ADS) patients frequently suffer from impairments in mobility.
- Surgical intervention for ADS can improve gait, balance and other health related “quality of life” scores.
- ADS patients have a variety of postural changes in the spine, pelvis and lower extremities.
- Spinal alignment surgery may have potentials to improve balance and the overall functions.
- However, it’s not known if the surgical alignment can enhance the postural sway.

Objectives

- To investigate the effect of surgical alignment on postural sway in ADS patients both before and 3 months after surgery.

Hypotheses

- We hypothesize that ADS patients will have enhanced postural sway post surgery.

METHODS

Subjects

- Eighteen ADS patients participated in this study with the written consents.

Procedures

- Each patient was instructed to maintain a quiet, upright posture throughout the trials one week prior (PRE) and 3 months post-surgery (POST).
- Subjects stood on a forceplate in a self-selected posture with eyes open for a minute.

Data Collection

- Forceplate data were recorded to compute the center of pressure (COP) measures in both anterior-posterior (AP) and medial-lateral (ML) directions.

Analysis

- Two postural sway assessment techniques were used for analysis: (i) traditional summary COP descriptive measures [1] and (ii) invariant density analysis which describes the dynamic COP distribution over time [2].
- Traditional COP measures include Range, and Mean Velocity.
- Invariant density analysis (IDA) examines the stochastic structure of the postural sway using a reduced-order finite Markov-chain model.
- IDA models the distribution of COP over the state space and estimates the uniquely converging steady state distribution $\pi$.
- Investigating the IDA will provide the information on the long-term postural sway behavior.
- Five IDA parameters were computed. $P_{peak}$: the largest probability of $\pi$ MeanDist: the average location of the COP
$D95$: the largest state at which 95% of COP is contained $EV2$: the 2nd largest eigenvalue of the transition matrix, which is describing the convergence rate of the system to $\pi$
Entropy: the measure of randomness and uncertainty

In addition to the existing IDA parameters, a new metric that provides insight into the structure and control mechanisms of the postural control system was introduced. It is the eigenvector corresponding to the second largest eigenvalue [3]. $ZeroCross$ is the zero crossing point of the second eigenvector and measure how much the central nervous system is actively involved in the control of the standing balance.

A paired t-test was used to compare the surgery effect ($a=0.05$).

RESULTS

- Surgical alignment revealed a significant decrease in the $ZeroCross$ from the IDA (Pre: 10.43±5.82mm vs. Post: 8.49±3.78mm, $p$-value: 0.05) (Table 1, Fig. 1).

Fig. 1: A representative plot of the second eigenvector of the transition matrix for both pre-surgery (dashed) and 3 month post surgery (solid). The ZeroCross point happens earlier when subjects received surgery (3 Month Post)

DISCUSSION and CONCLUSION

- The smaller $ZeroCross$ from IDA post-surgery indicates that the surgical intervention and re-alignment allows the human postural control system to provide more active and robust balance.
- In other words, the CNS became more actively involved in the control of standing balance and thus the patients regain more efficient standing balance after the surgical re-alignment.
- The only significant change in $ZeroCross$ and the insignificances from all the other measures suggest that 3 months after surgery may not be sufficient for ADS patients to fully recover the balance.
- Future work will investigate the effect of the surgical alignment with one year follow-up.

Table 1: Postural sway parameters pre and post surgery (Mean±SD)

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>$p$-value</th>
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<tbody>
<tr>
<td>Range</td>
<td>42.51±18.89</td>
<td>39.45±15.06</td>
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<tr>
<td>Mean Vel</td>
<td>8.97±4.02</td>
<td>9.62±4.29</td>
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<td>$P_{peak}$</td>
<td>0.038±0.038</td>
<td>0.04±0.026</td>
<td>0.82</td>
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<tr>
<td>MeanDist</td>
<td>6.70±3.41</td>
<td>5.93±2.60</td>
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<tr>
<td>$D95$</td>
<td>16.69±8.60</td>
<td>14.80±6.34</td>
<td>0.29</td>
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<tr>
<td>$EV2$</td>
<td>0.985±0.025</td>
<td>0.986±0.021</td>
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<tr>
<td>Entropy</td>
<td>3.93±0.84</td>
<td>3.71±10.33</td>
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<tr>
<td>$ZeroCross$</td>
<td>10.43±5.82</td>
<td>8.49±3.78</td>
<td>0.05</td>
</tr>
</tbody>
</table>

References

3. Hur, Ph.D. dissertation, University of Illinois at Urbana-Champaign, 2010