THE EFFECT OF SURGICAL ALIGNMENT ON STANDING BALANCE IN ADULT DEFORMITY PATIENTS – AN INVARIANT DENSITY APPROACH

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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 π.
- Investigating the IDA will provide the information on the long-term postural sway behavior.
- Five IDA parameters were computed.
  Ppeak: the largest probability of π
  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 π
  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 (α=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).

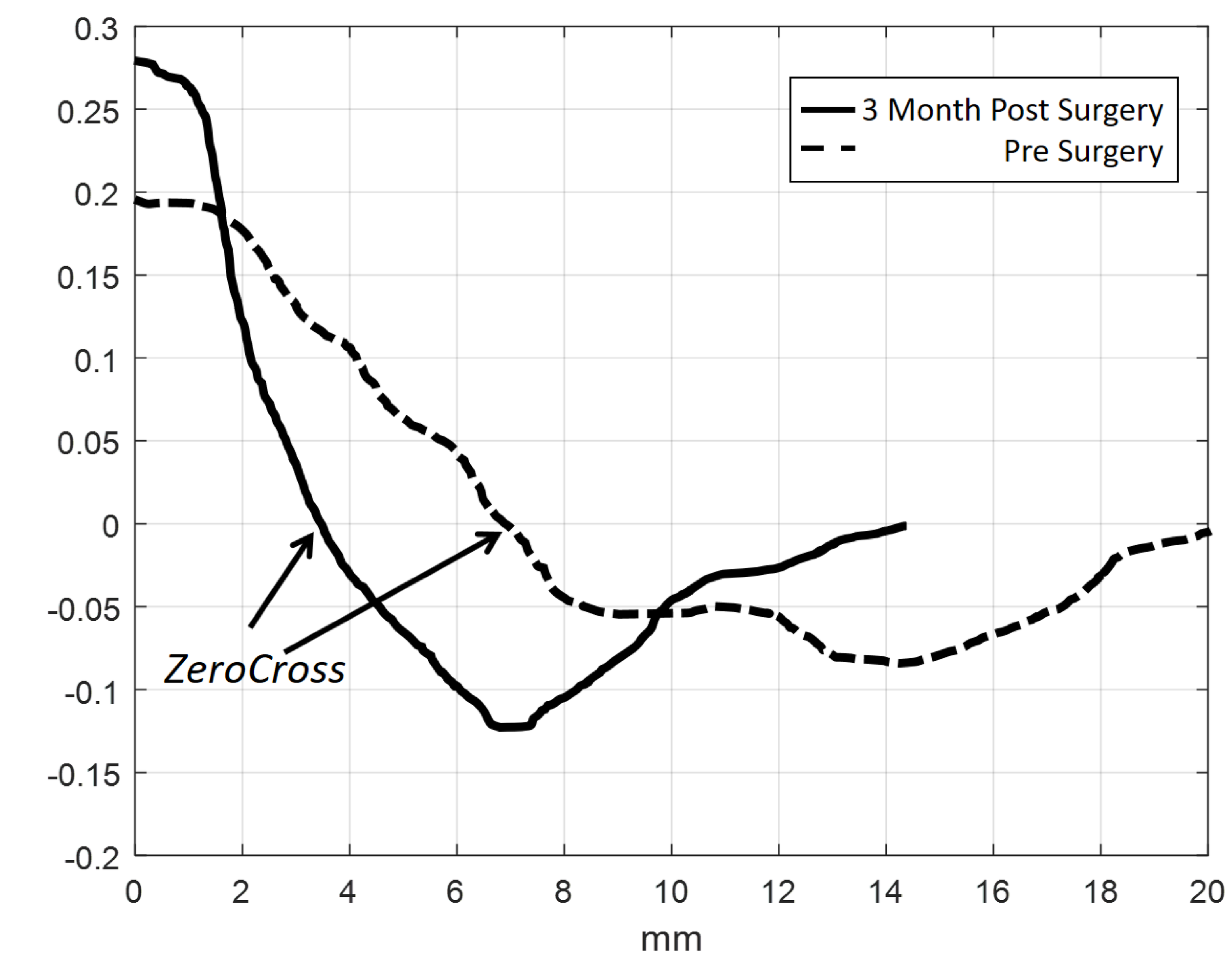

Fig. 1: A representative plot of the second eigenvector of the transition matrix for both pre-surgery (dashed) and 3 month post surgery (solid). The *ZeroCross* point happens earlier when subjects received surgery (3 Month Post)

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

	Pre	Post	p-value
Range	42.51 ± 18.89	39.45 ± 15.06	0.25
Mean Vel	9.97 ± 4.02	9.62 ± 4.28	0.56
Ppeak	0.038 ± 0.038	0.04 ± 0.026	0.82
MeanDist	6.70 ± 3.41	5.93 ± 2.60	0.29
D95	16.69 ± 8.60	14.80 ± 6.34	0.29
EV2	0.985 ± 0.025	0.986 ± 0.021	0.71
Entropy	5.92 ± 0.84	5.71 ±0.83	0.24
ZeroCross	10.43 ± 5.82	8.49 ± 3.78	0.05*

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.

References

1. Prieto et al., IEEE Trans. Biomed. Eng., 43(9), pp956–966, 1996.
2. Hur et al., IEEE Trans Biomed Eng, 59 pp1094 –1100, 2012.
3. Hur, Ph.D. dissertation, University of Illinois at Urbana-Champaign, 2010