THE EFFECT OF SURGICAL ALIGNMENT ON GAIT COMPLEXITY IN ADULT DEFORMITY PATIENTS - A NEUROMUSCULAR SYNERGY APPROACH

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INTRODUCTION

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. Previous literature demonstrates that the central nervous system (CNS) might use an organization of muscle synergies to control a wide range of activities, e.g. walking [1]. The muscle synergy hypothesis claims that the CNS may use a single control input to activate a large group of muscles instead of controlling each muscle individually [2]. Hence, neuromuscular synergies may verify the ability of the CNS in generating independent control signals [3]. A lower number of muscle synergies during gait would imply inability of the CNS to generate independent control signals [3]. A greater number of muscle synergies represent more substantial gait complexity since more control inputs are required to achieve the same task [4].

Objective of this study is to compare number of muscle group synergies in ADS patients during gait both before and 3 months after surgery to detect significant differences.

METHODS

Clinical gait analysis was performed on thirteen ADS patients, one week prior and 3 months post-surgery. Five walking trials were performed at self-selected speed of the patients. Surface electromyography (EMG) electrodes were placed and recorded bilaterally from 16 trunk and lower extremity muscles: External Oblique, Gluteus Maximus, Multifidus, Erector Spinae, Rectus Femoris, Semitendinosus, Tibialis Anterior, Medial Gastrocnemius. EMG data was collected at 2000 Hz, high-pass filtered at 20 Hz, low-passed at 450 Hz, then rectified and low-passed at 35 Hz [5]. The data was then normalized to the maximum activity observed among all trials of each subject. The processed EMG was then fed into a non-negative matrix factorizer to extract synergies and their activation coefficients [2]. Mathematically, a higher number of synergies would always reduce the residual error between the reconstructed EMG and the original EMG [2]. The required number of synergies were defined as the minimum number of synergies that could reconstruct EMG signals with a VAF higher than 95%:

$$VAF = 1 - \frac{EMG_{processed} - EMG_{reconstructed}}{EMG_{processed}}$$

Equation 1: VAF definition.

After deciding the number of walking synergies required for each patient both pre- and post-surgery, a paired t-test was used to test the hypothesis (α=0.05) using SPSS.

RESULTS AND DISCUSSION

The results of the paired t-test revealed that surgical alignment cause a significant increase in number of walking synergies. The information regarding the number of synergies can be found in Table. 1 and Fig. 1.

The significant increase in number of walking muscle synergies post-surgery substantiates the improvements in gait quality and complexity for ADS patients following surgical interventions. More synergies can potentially show the ability of the CNS in generating independent control signals. An alternative interpretation of this result is that pain, as a crucial sensory input, has the potential to affect motor control and its complexity. Hence, it sounds cogent to assume surgery can potentially affect the motor control by reducing the pain experienced by subjects throughout walking.

The greater number of muscle group synergies post-surgery will result in a more elaborate gait pattern since more muscle group synergies (that can be considered as the basis vectors of a n-dimensional space) are present to rebuild the EMG signals (Eq. 1).
As an example, the inability of post-stroke patients to generate independent control signals for gait forces their CNS to activate numerous muscles with a single signal (at the same time), causing unwanted co-contractions that hinders their normal gait [3].

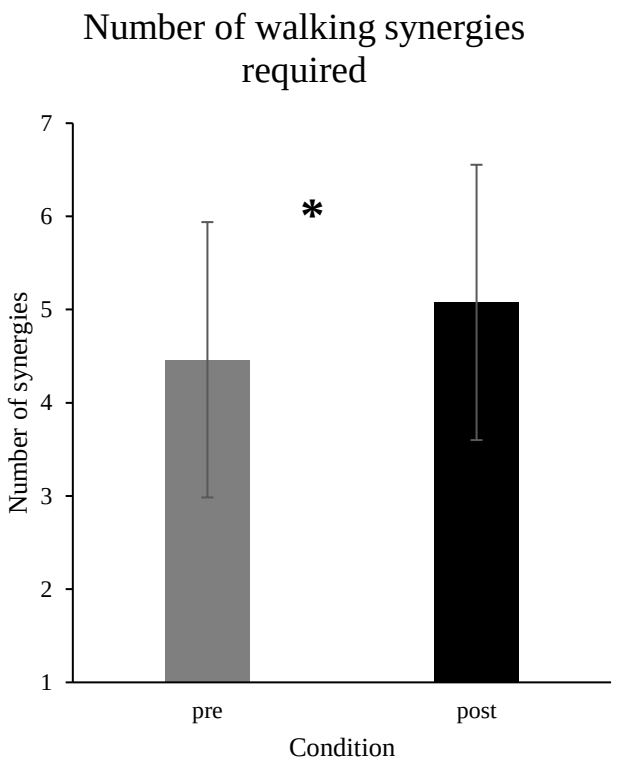

Figure 1: Number of synergies required for patients before and after surgery.

CONCLUSIONS

This study demonstrated an increase in gait complexity by virtue of the increased number of muscle group synergies following surgical intervention in ADS patients. The higher number of synergies observed in ADS patients following a surgery verifies the efficacy of this method in improving subjects' walking patterns/quality.

We recommend that spine care providers use gait analysis as part of their clinical evaluation to provide an objective measure of function and to better understand the effects of the disease and its treatment on their patients' gait, function, and, ultimately, quality of life.

REFERENCES

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Table 1: Required number of walking synergies pre- and post-surgery, and t-test results.

	Pre-surgery	**Post-Surgery**	***p*-value**
Number of synergies (Mean ± SD)	4.54 ± 1.45	5.15 ± 1.46	0.04