Principal Component Analysis Identifies Unique Hip Flexion Gait Characteristics Not Found by Range-of-Motion Analyses Among Adult Spinal Deformity Patients

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INTRODUCTION

Adult Spinal Deformity (ASD) is often associated with pain, disability, and reduced physical function in daily life. Previous studies have found symptomatic ASD patients to exhibit slow, guarded gait driven by global malalignment, dynamic instability, neurological deficits, and kinesiophobia. Although basic patterns of dynamic compensation are well understood, there is a growing need for refined understanding of gait abnormalities unique to deformity types to improve patient-specific treatment strategies. Principal component analysis (PCA) is a useful technique for dimensional reduction of complex data sets and is increasingly being used in the evaluation of gait characteristics among orthopedic patients. The purpose of this study was to determine whether PCA could provide additional insight beyond comparisons of standard peak values typically used for kinematic analysis of gait. We hypothesized that PCA would be able to generate principal components (PCs) which provide improved insight into characteristics of ASD patients gait which traditional measures of peak and range-of-motion (ROM) values would not identify.

METHODS

This study was an institutional review board-approved retrospective cross-sectional review of kinematic gait data from ASD patients and healthy controls at a single private practice institution. Subjects completed a series of over-ground walking trials at a self-selected speed. Three-Dimensional motion capture was used to record full-body kinematics during each test. Normalized gait cycle waveforms were generated for the following measures: sagittal vertical axis (SVA), lumbar lordosis (LL), pelvic tilt (PT), hip flexion (HFE), knee flexion (KFE), and ankle dorsiflexion (AFE). Analysis included determination of individual waveform maximums, minimums, and cycle ROM as well as PCA to determine PCs which accounted for more than 90% of the total variation within the entire study population. Single PC reconstruction using representative 5th and 95th percentiles were done to aid in interpretation of underlying feature characteristics for each retained PC. ASD patients were subgrouped as mild or severe by Scoliosis Research Society (SRS)-Schwab deformity classification modifiers. Independent sample t-tests were used to compare baseline differences in peak and ROM measures as well as individual PCs between groups with an α of 0.05 for statistical significance.

RESULTS AND DISCUSSION

This study included 57 ASD patients (Age: 59±15yr, Gender: 42F/15M, BMI: 27±5kg/m^2) and 53 healthy adult controls (Age: 44±13yr, Gender: 27F/26M, BMI: 25±3kg/m^2). Independent sample comparisons of baseline peak data found significant differences among ASD and healthy groups for SVA, LL, PT, KFE, and AFE, however no differences for HFE. Idepedent sample comparisons of PCs were able to identify significant differences between ASD and healthy groups across all measures including HFE. PC2 for HFE, which accounted for 5.3% of the total PC variation, was found to represent a unique feature which was able to discern a delayed phase response during swing among ASD subjects.

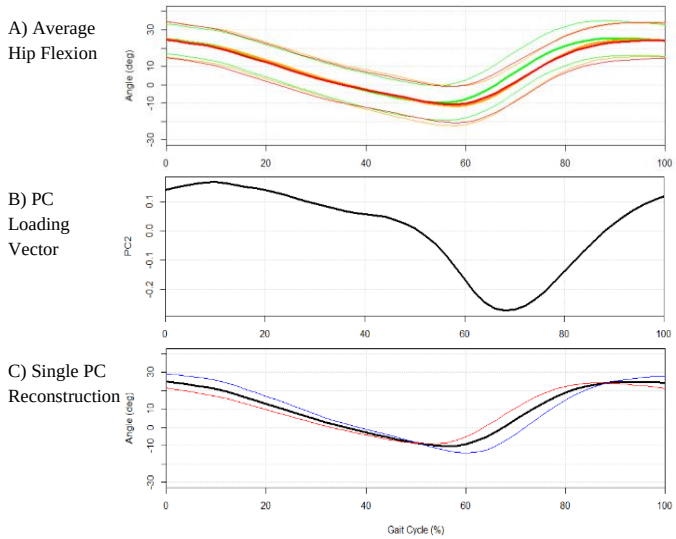

Figure A: Average hip flexion (HFE) waveforms for healthy controls (green) and adult spinal deformity (ASD) patients (orange and red for mild and severe deformity respectively). Figure B: PC2 loading vector for HFE. Figure C: Representations of 5th and 95th percentiles (red and blue respecively) for PC2 HFE reconstruction about mean HFE (black).

CONCLUSIONS

Waveform PCA was able to identify significant differences in HFE among ASD and healthy controls which standard peak analysis was not able to identify. Improved understanding of unique gait characteristics of ASD patients may help spine surgeons develop new patient-specific treatment strategies and outcome assessments.

DISCLOSURE STATEMENT

None