Identifying Fall Risk in Spine Patients: The Impact of Sensory Conditions and Postural Adaptation Across Cervical, Lumbar, and Deformity Pathologies

Ram Haddas, Haseeb E. Goheer, Paul T Rubery, Cindy Xindi Wang, Varun Puvanesarajah, Yasmine Ghattas, Ashley Rogerson

INTRODUCTION: Falls represent the leading cause of morbidity and mortality among elderly patients, accounting for over 2 million serious injuries and exceeding $20 billion in annual healthcare costs. Patients with degenerative spine conditions are at particularly high risk due to functional impairments and gait abnormalities resulting from cord compression and pain-related disability. Postural stability is a multifactorial construct involving spinal alignment, sensory integration, muscle conditioning, and neuromuscular responses to external perturbations. Accurate assessment of the patient's balance within the Cone of Economy (CoE) is essential for fall risk evaluation. Traditionally, CoE dimensions are measured using clinical or laboratory-based Romberg testing. Recently, Computerized Dynamic Posturography (CDP) has emerged as a sophisticated tool to evaluate balance by simulating stable and experimentally unstable environments. CDP quantitatively assesses the contributions of visual, vestibular, and somatosensory systems, key components that are often compromised in spine pathology. By identifying the predominant sensory deficit underlying balance impairment, CDP enables tailored, patient-specific interventions aimed at reducing fall risk. This study aims to evaluate the influence of vision, support surface conditions, and adaptive responses, as measured by CDP, on the CoE and fall risk among patients with degenerative cervical, lumbar, and spinal deformity disorders.

METHODS:

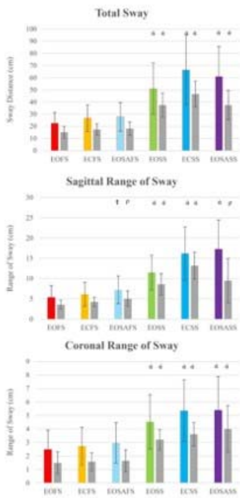
In a prospective, single-center, concurrent cohort study, seventy-one lumbar degenerative (LD), 28 cervical myelopathy (CM), 18 adult spinal deformity (ASD) surgical candidates, and 35 healthy controls (H). Patients completed fall risk assessment, including the Sensory Organization Tests (SOT), which include standard and perturbed stability, both with and without visual cues using CDP (Figure 1). As the patient performs this test, the CDP measures whether the patient is using their ankles or hips to stay balanced, as well as whether their center of gravity is correct. In addition, patients were also fitted with a set of external reflective markers, which measures traditional CoE using human motion capture. All tests are performed with a harnessed up and attached to the machine to ensure safety, where it is impossible to fall. Outcome Measures included the CoE, Center of Pressure (CoP), and Patient-Reported Outcomes Measurement Information System (PROMIS). Repeated-measure Mann-Whitney U tests were used in order to inability of verifying normality due to small sample size. These tests compared the results of the spine patients among themselves and to the healthy control group and between each subset conditions. Moreover, Pearson was used to look for correlation between the CoE and CoP outcomes to the PROMIS.

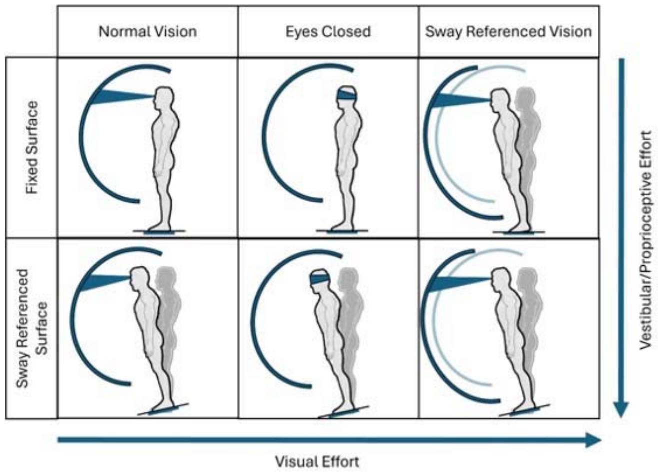
RESULTS:

CoE dimensions were found to be larger in LD, CM, and ASD patients compared to controls across all subtests except EOSASS (coronal RoS: LD: 5.40 vs H: 4.00 cm, $p>0.05$; Figure 2). However, only some of the CoP dimensions were found to be larger in LD patients compared to controls, including EOFS (sagittal RoS: LD: 2.87 vs H: 2.15 cm, $p<0.05$), ECFS (sagittal RoS: LD: 3.63 vs H: 2.62 cm, $p<0.05$; coronal RoS: LD: 1.89 vs H: 1.13 cm, $p<0.05$), EOSS (coronal RoS: LD: 3.22 vs H: 2.28 cm, $p<0.05$), ECSS (coronal RoS: LD: 3.92 vs H: 2.72 cm, $p<0.05$), and EOSASS (sagittal RoS: LD: 11.91 vs H: 8.67 cm; total sway: LD: 34.48 vs H: 28.50 cm, $p<0.05$; Figure 2). Furthermore, the SOT total score was significantly lower in CM and LD patients compared to control (CM: 49.12, LD: 65.74 vs H: 75.08, $p<0.01$). In comparison to baseline measurements (EOFS), CoE and CoP dimensions were significantly larger for all subtests with surround and/or support sway across LD, CM, and ASD patients. The dimension scores also increased in significance with increasing difficulty of subtest, with the exception of CoP total sway for the control patients. In spine patients, PROMIS Physical Function was positively correlated with CoE (coronal RoS: $r=0.45$, $p<0.050$; total sway: $r=0.58$, $p<0.001$) while PROMIS Pain Interference was negatively correlated with CoE (total sway: $r=-0.52$, $p<0.001$) and CoP (total sway: $r=-0.67$, $p<0.001$) measurements.

DISCUSSION AND CONCLUSION:

Falls among elderly patients with degenerative spine disease are a significant cause of morbidity and mortality. Although multiple clinical tools exist to assess fall risk, they may not fully capture patients' true balance capabilities. This prospective study employed CDP, a computer-controlled balance assessment system, to evaluate the influence of vision, support surface, and adaptive responses on fall risk in spine patients. Our findings indicate that patients with degenerative spine disease exhibit increased CoE dimensions, demonstrated by greater sagittal, coronal, and total head sway, as well as expanded CoP excursions, compared to healthy controls. These impairments are exacerbated under conditions requiring heightened visual and proprioceptive input, underscoring the critical role of these sensory systems in maintaining balance. Accurate quantification of fall risk, balance capacity, and the underlying causes of balance dysfunction is essential in this population. By replicating fall-provoking movements in a controlled, safe environment, clinicians can better understand balance impairments and develop targeted interventions to improve patient outcomes.


Total Sway
Sway Distance (cm)
EOFS
ECFS
EOSAFS
EOSS
ECSS
EOSASS
Sagittal Range of Sway
Range of Sway (cm)
Coronal Range of Sway


Normal Vision
Eyes Closed
Sway Referenced Vision
Fixed Surface
Sway Referenced Surface
Vestibular/Proprioceptive Effort
Visual Effort