ANALYSIS OF INTER-SEGMENT SPINE KINEMATICS DURING TRUNK MOTION

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INTRODUCTION

The purpose of this study is to develop a technique that models the spine as a multi-segment system and determines kinematic patterns in multiple planes. Past studies have used motion analysis systems to examine the lumbar spine with respect to the pelvis [1,2,3] and total spinal segment range of motion in scoliosis [4,5]. However, these studies did not report kinematics of the spine segments while moving in all three planes. The method described here has the potential to document changes in dynamic spine motions following therapeutic interventions for spinal pathologies.

METHODS

Eight reflective skin markers were placed over the following anatomical landmarks: sternum, the spinous processes of 3 thoracic vertebrae (T1, T8, T12), 1 lumbar vertebra (L3), sacrum (Vs), and both anterior superior iliac spines (L.ASIS, R.ASIS). Each participant performed four trunk motion tasks while standing: flexion/extension, lateral bending, axial twist, and a cone (moving trunk through a continuous maximum circular motion, starting with flexion, then lateral bending, extension, opposite lateral bending, and ending with flexion). Using custom software, seven segments were created for analyses of the trunk motions: thorax (T1, T8, Sternum), pelvis (L.ASIS, R.ASIS, Vs), total spine (Vs-T1), and 4 spine segments: (Vs-L3), (L3-T12), (T12-T8), and (T8-T1).

For the first three movement tasks, a transformation matrix was determined from the pelvis coordinate system. Spine segment angles were calculated in the frontal and sagittal planes based on the pelvis coordinate system. Inter-segmental angles were calculated between adjacent spine segments and angular data were normalized based on the position of the T1 marker at four events within each motion: 0% = onset of motion; 25% = change in direction of motion (i.e. end flexion); 75% = change in opposite direction of motion (i.e. end extension); and 100% = end of motion.

For the multi-planar cone motion, segment angles (Z-angles) were found with respect to the vertical axis, which was defined by the pelvis coordinate system. Data were normalized based on the angular location of the T1-Vs segment as a 360° arc was created in space during the motion.

RESULTS AND DISCUSSION

Figure 1 shows sagittal plane flexion/extension angles for one person. Motion of the L3-T12 segment with respect to the Vs-L3 segment contributed to over half of the thorax flexion motion, but this segment had little contribution in extension. For this person, minimal motion occurred in the frontal plane during flexion/extension (data not shown). Figure 2 shows the Z-angle of the pelvis with respect to the room and the lumbar segments with respect to the pelvis. Circular gridlines

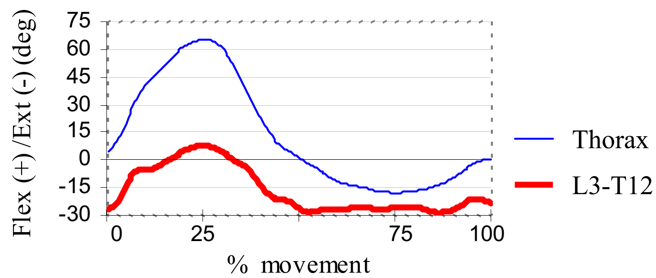

Figure 1: Sagittal plane angles for the Thorax segment with respect to Pelvis and the L3-T12 segment with respect to Vs-L3 during trunk flexion-extension (mean of 3 trials).

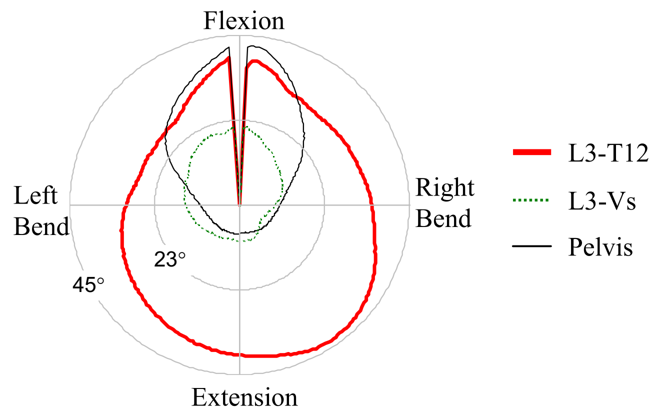

Figure 2: Z-angles during cone movement for the Pelvis with respect to room vertical and L3-Vs and L3-T12 segments with respect to Pelvis vertical (mean of 3 trials).

represent the angular value. For this participant, flexion at the beginning of the cone movement occurred almost equally with tilting of the pelvis and bending of the L3-T12 segment. However, as the person rotated the trunk towards the right and extension, most of the motion of the trunk occurred in the lumbar region with the L3-T12 segment.

CONCLUSIONS

One advantage of this technique is that the contributions of different spine segments to total motion are quantified. Trunk motion can be compared within a subject or between subjects to determine differences in flexibility at certain spinal segments. Limitations of the model include marker obstruction and/or coalescence during extreme motions and skin motion artifact. A database for comparison of normal and pathological spine kinematics is under development.

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