An Advanced Biomechanical Model to Assess How Spinal Motion Contributes to Gait: Preliminary Data

R. Konz[1], R. Stine[2], S. Fatone[1], S. Gard[1,2], D. Childress[1,2], A. Ganju[3], S. Ondra[3]
[1]Northwestern University Prosthetics Research Laboratory and Rehabilitation Engineering Research Program; [2]VA Chicago Health Care System, Lakeside Division; [3]Feinberg School of Medicine, Department of Neurological Surgery, Chicago, IL USA

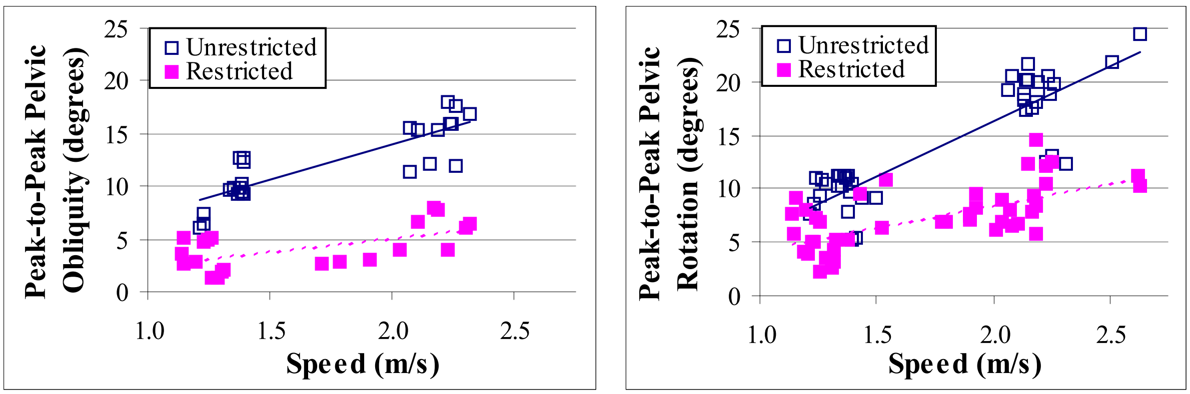
Introduction: The spine has been regarded as a “passenger unit”, implying little direct contribution to gait [1]. However, spinal motion plays a significant role in maintaining an upright posture and balance during ambulation [2-4]. The spine has also been implicated as a shock absorber during gait [5]. Yet, how spinal motion contributes to walking characteristics is not yet clearly understood. Typical gait analysis models either disregard the upper body entirely or, if the spine is included, it is often regarded as a *single* rigid structure. Hence, data on segmental spinal movements associated with walking is scarce [2-4,6-8]. The goal of this study is to develop a multi-segment spinal model, based on spinal regions, to analyze spinal motion during walking and evaluate the effects of restricted spinal motion on gait.

Statement of Clinical Significance: Walking is affected to varying degrees by spinal disorders, such as mild curvatures, and more severe spinal pathologies requiring surgical instrumentation. Trunk imbalance may occur when deformities hamper the spine’s ability to compensate for postural changes, in many cases exhibiting clinically observable gait deviations. If a deformity exceeds the spine’s compensatory abilities the use of orthoses or surgical intervention and fusion may become necessary. While these methods may correct the deformity and balance the head over the sacrum, they alter the normal flexibility of the spine. It is unclear what effect this may have on an individual’s gait. By increasing our understanding of the effects of spinal motion during able-bodied ambulation, we may be able to assist in the pre-surgical decision making process so that normal alignment and balance are restored with minimal negative effects on gait.

Methodology: Ten able-bodied persons will be studied for a bilateral gait assessment using a modified Helen Hayes marker set. These same individuals will then undergo a gait analysis after being fitted with a customized fiberglass body jacket, similar to a TLSO (Thoraco-Lumbo-Sacral Orthosis), to restrict spinal motion. To date, three subjects have been tested. Data were collected in the VA Chicago Motion Analysis Research Laboratory (VACMARL), which is equipped with an eight camera, Eagle Digital Real-Time motion measurement system from Motion Analysis Corporation (MAC). Ground reaction forces (GRF) were measured with six AMTI force platforms as subjects walked along the walkway. OrthoTrak software (MAC) was utilized to process the lower extremity data.

KinTrak software (MAC) was utilized to create an advanced biomechanical model, which will be used to analyze three-dimensional regional spinal movements. Retro-reflective triad markers were placed on the skin at the C5, T7 and L3 spinous processes to determine the location of the cervical, thoracic, and lumbar regions during gait. Additionally, three markers each were placed on the head and pelvis. Angular measurements are calculated based on transverse rotation as the primary axis of motion, obliquity or lateral tilt as the second rotation, and flexion/extension or forward tilt as the third rotation.

Results: So far, preliminary data were analyzed for unrestricted and TLSO restricted walking in three able-bodied subjects. The most striking differences between these two conditions were the reduced pelvic obliquity, believed to be a shock absorbing mechanism of the body [1,9], and decreased pelvic rotation when the subjects' spines were restricted with the TLSO (Figures 1 & 2). No major differences were observed in sagittal plane hip, knee, and ankle joint angles. However, the magnitude of the first peak in the vertical GRF appeared to be slightly greater in subjects with the TLSO restriction than when unrestricted. Furthermore, step lengths were shorter and cadence was greater when subjects walked with the TLSO restriction compared to walking unrestricted.



Figures 1 & 2: Peak-to-peak pelvic obliquity [left] and pelvic rotation [right] for normal and fast walking of three able-bodied subjects unrestricted and restricted using a TLSO.

Discussion: Pelvic obliquity and pelvic rotation are diminished when spinal motion is restricted by the TLSO. The slight increase in vertical ground reaction force magnitude combined with decreased pelvic obliquity could indicate a reduction in the shock absorbing capabilities of a restricted spine. The reduction in pelvic rotation may explain the shorter step lengths taken by individuals restricted with the TLSO. To achieve faster walking speeds with restricted spinal motion, cadence was increased. Additionally, data are being processed and analyzed to quantify the motion of spinal regions during gait and to validate the effectiveness of constraining the spine with a TLSO.

References:

1. Perry J. (1992). Gait analysis: normal and pathological function.
2. Feipel V. *et al.* (2001). *European Spine Journal* 10(1):16-22.
3. Syczewska M. *et al.* (1999). *Clinical Biomechanics* 14:384-88.
4. Thorstensson A. *et al.* (1984). *Acta Physiol Scand* 121:9-22.
5. Smeathers JE. (1998). *Eng Med* 203(48):11-6.
6. Callaghan J.P. *et al.* (1999). *Clinical Biomechanics* 14:203-16.
7. Crosbie J. *et al.* (1997). *Gait & Posture* 5:13-20.
8. Rowe P.J., White M. (1996). *Gait & Posture* 4:242-51.
9. Gard S.A., Childress D.S. (1997). *Gait & Posture* 5:233-8.