Site of SMT Application Alters Spinal Tissue Loads

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ABSTRACT

INTRODUCTION: Previous studies found that the intervertebral disc (IVD) experiences the greatest loads during spinal manipulation therapy (SMT). Based on that, this study aimed to determine if loads experienced by spinal tissues are significantly altered when the application site of SMT is changed.

METHODS: This is a biomechanical robotic series dissection study. Sample includes thirteen porcine cadaveric motion segments. Outcome measures are forces experienced by lumbar spinal tissues. A servo-controlled linear actuator provided standardized 300 N SMT simulations to six different cutaneous locations of the porcine lumbar spine: L2-L3 and L3-L4 facet joints (FJ), L3 and L4 transverse processes (TVP), and the space between the FJs and the TVPs (BTW). Vertebral kinematics were tracked optically using indwelling bone pins; the motion segment was removed and mounted in a parallel robot equipped with a six-axis load cell. Movements of each SMT application at each site were replayed by the robot with the intact specimen and following the sequential removal of spinal ligaments, FJs and IVD. Forces induced by SMT were recorded, and specific axes were analyzed using linear mixed models.

RESULTS: Analyses yielded a significant difference (p<.05) in spinal structures loads as a function of the application site. Spinal manipulation therapy application at the L3 vertebra caused vertebral movements and forces between L3 and L4 spinal segment in the opposite direction to when SMT was applied at L4 vertebra. Additionally, SMT applications over the soft tissue between adjacent vertebrae significantly decreased spinal structure loads.

CONCLUSION: Applying SMT with a constant force at different spinal levels creates different relative kinetics of the spinal segments and load spinal tissues in significantly different magnitudes.
ANALYSIS
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Background Information

When studying the clinical effects of spinal manipulative therapy (SMT), it is possible that the parameters of the treatment application may impact the outcome for the patient. With respect to the site of application specifically, studies have suggested that manual therapists may be limited in their ability to identify the site of application (1-3) and that the location may actually shift during delivery of the specific treatment (4). The importance of the site of application has been demonstrated through studying the electromyographic responses of the erector spinae muscles, muscle spindle sensory input and spinal stiffness (5-7).

While it appears that the application site can significantly affect the outcomes of SMT, understanding the load distribution of SMT when applied at different sites could allow us to preferentially load particular spinal structures in an attempt to modulate clinical responses for individual patients.

The objective of this laboratory study conducted on porcine (pig) cadaveric motion segments was to describe the effect of a standardized SMT application on load distribution within spinal tissues. It specifically aimed to describe if the application of SMT with a standardized force at different application sites influenced the loads experienced by spinal structures.

Pertinent Results:

The analysis of the intact porcine cadaver specimen revealed significant differences in experienced forces when SMT was applied at different application sites:

- Significant differences in forces were observed when SMT was applied to the L3 vertebra compared to the L4.

- Applying SMT at the L3 vertebral body, between the facet joints and between the TVPs created peak lateral and anteroposterior forces in the opposite direction to those created during SMT to the L4 vertebra.
The loads experienced by the ligamentous structures were smaller than the loads experienced by other spinal structures. Additionally, significantly greater peak superior-inferior forces were experienced by the supraspinous and interspinous ligaments when SMT was applied at L2-3 compared to L4. The application of SMT at the L2-3 facet created rotation in extension, which brings the L3 and L4 spinous processes together (therefore compressing the ligamentous structures). This caudal force experienced by the interspinous ligament could have been created to resist compression during extension.

When SMT was applied to the L3 vertebra, the forces experienced by the facet joints were opposite in direction to when it was applied at the L4 vertebra. The forces experienced by the facet joints were smaller when SMT was applied between the TVPs compared to other structures. Specifically to the facet joints, a significantly greater change in peak lateral force was observed when SMT was applied at and between the L2-3 facet joints than at other sites (likely because of tension in the ligamentum flavum).

The forces experienced by the intervertebral discs (IVD) was greater than the other spinal structures. A greater change in mean lateral force was observed when the SMT was applied at the TVP and this may be due to the role of the IVD in resisting anteroposterior and lateral vertebral motions. The changes in forces experienced by the IVD were significantly smaller when SMT was applied between facet joints (compared to all other sites). The greatest superior-inferior forces were experienced by the IVD when SMT was applied at the L2-3 facet joints and L4 TVP.

**CLINICAL APPLICATION & CONCLUSIONS**

This laboratory study described the loading characteristics of spinal tissues when SMT was applied to different spinal sites, suggesting that the effects of SMT are influenced by application site. The findings of this study also suggest that when SMT is provided to the skin overlying soft tissue (versus the bony structures themselves), the SMT forces are dissipated through the tissues and the vertebral segment will experience smaller loads.

(EDITOR’S NOTE: recall prior work from Bereznick et al. [10] about skin slack and the essentially frictionless skin-fascia interface?).

It is important to note that while this study identified the biomechanical implications of the application site for SMT, the clinical importance in human patient outcomes has not yet been identified and requires further study. This was certainly an enlightening early step in this line of work and we’ll look to future projects to clarify the applicability in our offices!
STUDY METHODS

- Based on previous research (8), a sample size of nine porcine cadavers was calculated, and five additional models were included in order to mitigate any loss of data.

- The 14 fresh porcine cadavers underwent ultrasound imaging to identify the L3 and L4 vertebrae, the left L3-4 facet joint and the left L4 transverse process (TVP). Bone pins were drilled into the vertebral bodies and a rectangular flag with four infrared light-emitting diode markers was attached to each bone pin.

- SMT was applied to the intact cadavers using a servo-controlled linear actuator motor to reduce force-time profile variance and the resulting motion of each bone pin and sensor flag was recorded in three dimensions by an optical tracking system.

- After SMT, the L3-4 segment was cleaned (of non-ligamentous tissue), sealed and refrigerated for less than 5 hours until potting and testing (9).

- To test the segments, the cranial end was fixed to a stationary beam and the caudal end of the L4 potted segment was fixed to a six-axis load cell. The marker movements caused by SMT were transformed into robot trajectories that replicated the relative motion between L3 and L4, and were recorded by the optical tracking system.

- Following the application of all robotic trajectories, spinal structures were then removed or transected and the same robotic trajectories were repeated to quantify the loading distribution within specific spinal tissues. The tissues were removed in the following order: supraspinous and interspinous ligaments; bilateral facet capsules, posterior facet joints and ligamentum flavum; intervertebral disc and anterior and posterior longitudinal ligaments.

- The forces of each specimen were plotted against time to identify peak and mean forces. The values of L4 rotations relative to L3 where peak loads occurred were taken from the rotations of the robotic platform for each trajectory.

STUDY STRENGTHS/WEAKNESSES

Strengths:

- This study presented a controlled, in vitro setting.

- The use of serial dissections allowed for the measurement of forces and movement experienced in spinal structures during the application of SMT.
• Given the well described methodology, this work provides a framework and justification to explore the role of site application in human trials to examine clinical outcomes.

Weaknesses:

• This study used a porcine lumbar spine to model the human spine. While it is an alternative to the human spine, the results must be interpreted with caution when extrapolating this data to humans (particularly in a living human!).

• To apply forces, a linear actuator motor was used to apply forces. While this allows for consistency in vitro, it may not replicate the force-time profile and area of pressure distribution of the forces applied in manual SMT.

• The effect of site application on clinical outcomes cannot be elucidated from this study.

Additional References: