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Does the application site of spinal manipulative therapy alter spinal tissues loading?

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Abstract

BACKGROUND CONTEXT: Previous studies found that the intervertebral disc (IVD) experiences the greatest loads during spinal manipulation therapy (SMT).

PURPOSE: 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.

STUDY DESIGN: A biomechanical robotic serial dissection study.

SAMPLE: Thirteen porcine cadaveric motion segments.

OUTCOME MEASURES: Forces experienced by lumbar spinal tissues.

METHODS: 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 manipulative 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.

Keywords: biomechanics; forces; lumbar vertebrae; porcine; robotics; spinal manipulation

FDA device/drug status: Not applicable.

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Introduction

Randomized controlled trials investigating the effects of spinal manipulative therapy (SMT) on the spine have reported conflicting evidence. Although some studies observed significant improvement in low back pain following SMT interventions [1–4], other studies reported that SMT was not significantly superior to other types of intervention (e.g., exercise; standard medical care) [5–7]. Although this conflicting evidence can be explained partially in light of recent findings that suggest SMT affects some, but not all, patients with low back pain [8], another explanation is that variability in SMT applications may create varied responses to this popular therapy [9]. Similar to other treatment parameters that have been described to significantly affect the outcome of physical interventions such as dosage and application site [10–12], SMT input parameters likely modulate the physiological outcomes following an SMT application.

Specifically, SMT input parameters have been reported to significantly vary between clinicians and applications [13–15]. With respect to the application site, previous investigations have reported not only the limited ability of manual therapists to accurately identify the site of application [14,16,17], but also that the location in which SMT is actually applied may shift about 10 mm during SMT application [18]. Based on that, basic and clinical research have been conducted to assess the influence of SMT input parameters on both biomechanical and neurophysiological responses to SMT. Specifically, Colloca and Keller [19] observed differences in electromyographic responses of the erector spinae muscle when SMT was delivered at the spinous or transverse processes of different spinal levels. Additionally, although Reed and colleagues [20] demonstrated that the site in which SMT was applied significantly affected muscle spindles sensory input, a biomechanical study conducted by Edgecombe and colleagues [21] showed significant changes in spinal stiffness related to SMT application site.

Although the abovementioned findings indicate that the SMT application site significantly affects the physiological outcomes elicited by SMT, many other SMT parameters have yet to be studied including SMT loading characteristics as they relate to influencing specific spinal tissues. By elucidating the SMT load distribution within spinal tissues when SMT is applied at different application sites, the relation between SMT application site and spinal tissue response could be defined. Importantly, if it can be shown that the SMT application at specific sites preferentially loads particular spinal structures, then SMT could be provided to a specific location tailored to each individual's condition, potentially improving SMT efficacy and safety.

Given the above, the objective of this study was to describe the effect of a standardized SMT application on load distribution within spinal tissues as a function of application sites. Specifically, this study aimed to describe if the application of an SMT with standardized force provided at different application sites (including adjacent spinal segments) influenced loads experienced by spinal structures.

Methods

Sample size calculation

The sample size calculation was conducted based on the data previously reported by Kawchuk and colleagues [22] using the General Power Analysis Program (G*Power 2) (University of Trier, Germany). With a statistical power set to 0.80 (80%), two-tailed tests with level of significance set at α=0.05 (5%) and an effect size of 0.99–1.2, a sample size of nine porcine cadavers was required. Five additional porcine models were included to mitigate any loss of data for a total of 14 cadaveric porcine specimens. All experimental protocols of this study were approved by the Animal Care and Use Committee of the University of Alberta.

Specimen preparation

Fourteen fresh porcine cadavers (Duroc X [large white X Landrace breeds]) of approximately 60–65 kg were included in this study. In each intact cadaver, ultrasound imaging and needle probing were used to identify the L3 and L4 vertebrae, the L3–L4 left facet joint (FJ), and the left L4 transverse process (TVP). Bone pins were drilled into the L3 and L4 vertebral bodies, and a rectangular flag having four infrared light-emitting diode markers was attached to the upper end of each bone pin (Fig. 1).

Following the application of SMT on the intact porcine cadaver (detailed in the following sections), the lumbar spine was removed en bloc [22]. The L3–L4 spinal segment was cleaned of nonligamentous tissues, sealed in a plastic bag, and kept refrigerated at 3°C for less than 5 hours until potting and testing on the following day [23]. The specimen was kept moist with physiological saline throughout preparation, embedding, and testing [24,25]. Because of complications during data collection, one specimen was excluded because of problems in robotic calibration for attaining neutral position alignment. Therefore, data from 13 specimens were analyzed. Given the fragile nature of the intertransverse ligaments and their frequent damage during en bloc spinal removal, all

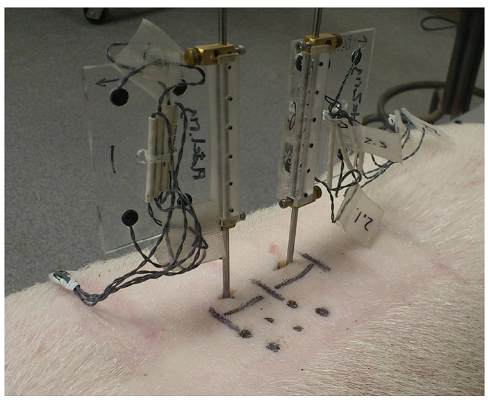

Fig. 1. Rectangular flags with four infrared light-emitting diode markers attached to bone pins drilled into L3 and L4 vertebrae.