Biomechancial Quantification of Pathologic Manipulable Spinal Lesions: An In Vivo Ovine Model of Spondylolysis and Intervertebral Disc Degeneration

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Abstract

Objective: The purposes of this study were to quantify the biomechanical and pathologic consequences of surgically induced spinal lesions and to determine their response to spinal manipulation (SMT) in an in vivo ovine model.
Methods: Of 24 Merino sheep, 6 received L5 spondylolytic defects, 6 received L1 annular lesions, and 12 served as respective controls. Dorsoventral (DV) stiffness was assessed using oscillatory loads (2-12 Hz). Two SMT force-time profiles were administered in each of the groups using a randomized and repeated-measures design. Stiffness and the effect of SMT on the DV motions and multifidus needle electromyographic responses were assessed using a repeated-measures analysis of variance ($\alpha = .05$). Postmortem histologic analysis and computed tomography validated the presence of lesions.
Results: L5 DV stiffness was significantly increased (40.2%) in the spondylolysis (6.28 N/mm) compared with the L5 control group (4.48 N/mm) ($P < 03$). Spinal manipulations delivered to the spondylolysis group resulted in less DV vertebral displacement ($P < .01$) compared with controls. Dorsoventral stiffness of the disc degeneration group was 5.66 N/mm, 94.5% greater than in the L1 control group (2.91 N/mm) ($P < .01$). One hundred–millisecond SMTs resulted in significantly reduced DV displacements in the disc degeneration group compared with the L1 control group ($P < .01$). Animals in the disc degeneration group showed a consistent 25% to 30% reduction in needle electromyographic responses to all SMTs.
Conclusions: Quantifiable objective evidence of spinal lesions and their response to SMT were confirmed in this study. Neuromechanical alterations provide novel insights into quantifying manipulable spinal lesions and a means to biomechanically assess SMT outcomes. (J Manipulative Physiol Ther 2012;35:354-366)
Key Indexing Terms: *Biomechanics; Manipulation, Spinal; Spondylolysis; Intervertebral Disc Degeneration; Chiropractic*

Spinal disorders represent a broad range of conditions for which patients with musculoskeletal pain seek treatment at an enormous cost to society and governments alike.[1,2] Abnormal mechanics of the spine have been hypothesized as a precursor to musculoskeletal pain via nociceptive afferents in the innervated spinal tissues.[3] The association between abnormal spinal mechanics and nociceptive stimulation includes consider-

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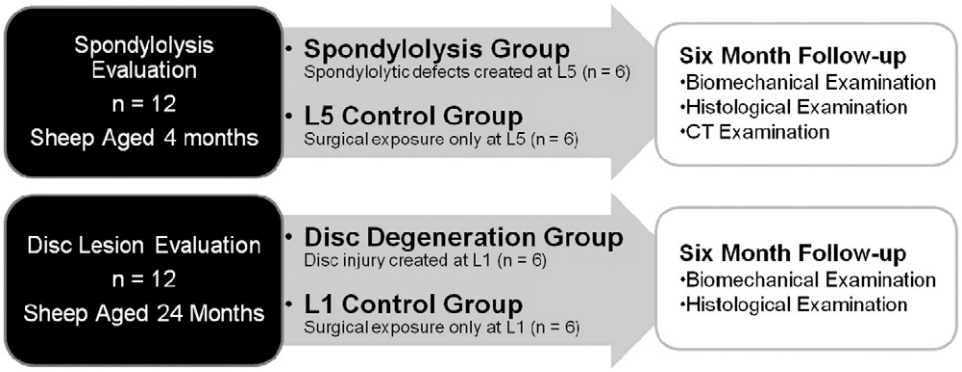

Fig 1. *Grouping and subgroup division is shown for the experimental study design. Twelve 4-month-old sheep were randomized to an active spondylolysis group and L5 control group. An additional twelve 24-month-old sheep were randomly assigned to a disc degeneration group and L1 control group. Six months after the survival surgeries in vivo, biomechanical testing of the spine was conducted followed by postmortem histologic and CT examinations.*

ations of inflammation,[4] biomechanical and nutritional challenges,[5] immunologic factors,[6] changes in the structure and material of the vertebral end plates, and discs such as neoneuralization.[7,8]

Abnormal spinal mechanics may be due to degenerative changes in the spinal column[9,10] and/or injury of the ligaments.[11] Most likely, the initiating event is some kind of trauma involving the spine.[12] It may be a single trauma due to an accident or a microtrauma caused by repetitive motion over a long time.[13] It is also possible that spinal muscles will fire in an uncoordinated way in response to sudden fear of injury, such as when one misjudges the depth of a step.[14] Any or all these events may cause spinal ligament injury. Adverse psychosocial factors may also play an important role in transforming the musculoskeletal pain into disability.[15]

The intervertebral disc (IVD) is a known pain generator among low back pain patients, and the IVD is therefore a primary target of intervention for clinicians applying spinal manipulation (SM).[16] Progressive degenerative changes of the IVD are associated with increased age, trauma, and abnormal postural loading.[17] Indeed, a large proportion of the population undergoing SM has some degree of disc disease.[16] To influence the peripheral pain generator, patients with discogenic disease commonly undergo spinal manipulative therapy (SMT) with the primary goal of normalizing loads and improving spinal mobility.[18] Although not as common a spinal entity undergoing SM treatment, spondylolysis is another common spinal disorder that results from pars defects acquired from trauma, fatigue failure, or nonunion.[19]

In the treatment of spinal disorders, many conservative treatment modalities have been proposed, yet quantification of lesions to better mold the therapeutic response remains elusive. Recent reviews of the limited basic science research in chiropractic noted that nearly all of the theories of the effects and mechanisms of action of SM still lack adequate research and that no definitive anatomic or biomechanical studies have yet identified the lesion manipulated.[20,21]

In vivo animal studies require the validation of adequate models. For disc degeneration, Osti et al[22] developed an ovine model that has been universally accepted and used. A stab wound in the disc, reaching into the nucleus, is followed by accelerated disc degeneration as early as 3 months postsurgery.[23] Only recently has this ovine model been used to study spinal manipulaton.[24,25] For pars defect or spondylolysis, no such model has been validated. The search for the quantifiable detection of spinal lesions has been identified as a major need in spinal research aimed toward defining their biomechanical consequences and clinical relevance. The purpose of this experimental study was to quantify the biomechanical and prospective pathologic consequences of surgically induced spinal lesions of pars fracture (spondylolysis) and IVD degeneration and determine their response to SM in an in vivo ovine model.

Methods

Subjects

Twenty-four Merino sheep in total were examined in this study with approval of the Institutional Animal Ethics Committee of the Arizona State University, Tempe, Arizona, to undergo survival surgical procedures to investigate the effects of induced spinal lesions at 6 of months follow-up. Two animal age groups were selected to be examined. Twelve skeletally immature sheep aged 4 months were chosen to study surgically induced L5 spondylolytic lesions at 6 months follow-up. An additional 12 adolescent sheep aged 24 months were used to examine the histopathologic and biomechanical effects of surgically induced L1 intervertebral lesion on disc degeneration followed at 6 months using a previously validated animal model.[22] In each of these 2 experiments, 6 animals were