Journal of Manipulative and Physiological Therapeutics 531
Volume 23 • Number 8 • October 2000
0161-4754/2000/$12.00 + 0 **76/1/109679** © 2000 JMPT

Highlighting of Intervertebral Movements and Variations of Intradiskal Pressure During Lumbar Spine Manipulation: A Feasibility Study

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ABSTRACT

Objectives: To demonstrate relative movement of the vertebrae and variations in intradiskal pressure during 2 different lumbar spinal manipulations, in flexion or extension, in 2 unembalmed cadavers.

Design: A pressure sensor was inserted into the L3-4 disk in cadaver 1 and into the L1-2 to L4-5 disks in cadaver 2. Two adjacent vertebrae (L3 and L4 in cadaver 1, and L4 and L5 in cadaver 2) were each equipped with 2 monoaxial accelerometers to record acceleration in the caudocranial axis and a biaxial accelerometer to record acceleration in the "horizontal" anatomic plane.

Setting: Laboratory study.

Results: During the thrust, relative intervertebral movements were demonstrated; movements differed with the type of manipulation (in flexion or extension). Intradiskal pressure initially increased, then decreased.

Conclusions: Lumbar spinal manipulations have a biomechanical effect on the intervertebral disks, producing a brief but marked change in intradiskal pressure. This effect, which differs slightly with the different types of manipulation studied, is the consequence of movements of the adjacent vertebrae. (J Manipulative Physiol Ther 2000;23:531-5)

Key Indexing Terms: Intradiskal Pressure; Low Back Pain

INTRODUCTION

Spinal manipulation is a widely used modality for the treatment of back pain. Recently published work has shown manipulation to be beneficial in low back pain.[1] However, the mechanism by which the beneficial results are achieved remains unknown. Shekelle[2] identified 4 effects: (1) the release of entrapped synovial folds, (2) the relaxation of hypertonic muscle by sudden stretching, (3) the disruption of articular or periarticular adhesions, and (4) the unbuckling of motion segments that have undergone disproportionate displacement. Because the intervertebral disk is the main constituent of the motion segment, the modifications of intradiskal pressure and the movements of the adjacent vertebrae at the time of the manipulative thrust are important aspects. It was shown in cadavers (with the use of bone pins threaded into the spinous processes of T10, T11, and T12) that the thrust was accompanied by a relative movement of the vertebrae.[3] The logical conclusion would be that this movement may affect the intradiskal pressure. However, to our knowledge, this effect has not been studied. Some authors have, however, suggested that a pressure drop in the disks may play a role in the manipulation of the lumbar[4] or the cervical[5] spine.

The goal of our work was to study the feasibility of measuring intradiskal pressure and movements of the 2 adjacent vertebrae during a lumbar manipulative thrust.

METHODS

Two unembalmed cadavers of male subjects who had died fewer than 7 days previously and who had left their bodies to scientific research were used in this study (Table 1). The bodies had been stored at 4°C and were installed in the laboratory at least 2 hours in advance at room temperature. Before the tests, lateral radiographs of the lumbar spine were obtained, to ensure that there was no major narrowing of the lumbar disk space. The disks studied in the test were removed at the end of the experiment to check for absence of degeneration and were found to be Nachemson[6] group 1 and group 2.

Set-up. The lumbar spine was accessed through a laparotomy. Cadaver 1 was instrumented in the following way: an intradiskal pressure sensor (EPI-127*-14-SC; Entran, Paris, France) was inserted into the L3-4 disk.

Its sealed effective range was 14 bars; its resonance frequency went up to 1.7 MHz, and it had thermal compensation. According to the manufacturer, the errors of nonlinearity and hysteresis were about ±1% of the scale. The sensing surface, of approximately 1.3 mm^2, was exposed at the end of a 40-mm long needle of 1.6-mm outside diameter.

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Paper submitted July 15, 1999; in revised form October 7, 1999.
doi:10.1067/mmt.2000.109679

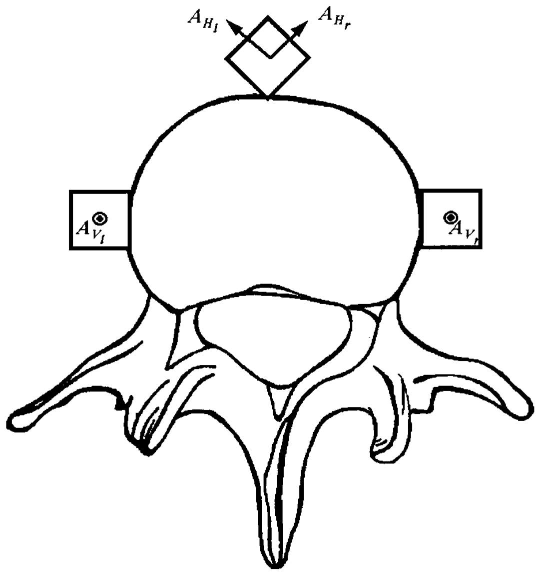

Fig 1. *The accelerometer assembly.*

Table 1. *Subject characteristics*

Subject	Age (y)	Height (cm)	Mass (kg)	Cause of death	Postmortem days before test (n)
1	49	167	61.5	Carcinoma of the esophagus	6
2	71	171	73	Stroke	6

The sensor was guided into the center of the nucleus under fluoroscopic control, through an outer needle of 2-mm outside diameter. The sensor was held by this outer needle, which was supported by the vertebra below the targeted disk. The 2 vertebrae adjacent to the targeted disk (L3 and L4) were each equipped with 3 accelerometers (EGA 87-*F-5-DM; Entran).

They were ±5 g damped accelerometers with a bandwidth of ±5% from 0 to 60 Hz and a resonance frequency greater than 250 Hz. The errors caused by nonlinearity and hysteresis were approximately ±1% of the scale.

The accelerometers were fixed to a metal support that was rigidly mounted on the vertebral body. Two monoaxial accelerometers were placed on the lateral aspects of the vertebral body, one on the right and one on the left. They measured accelerations along the "vertical" caudocranial axis ($\overrightarrow{A_{VR}}$ and $\overrightarrow{A_{VL}}$ respectively, for the right-side and the left-side accelerometer). A biaxial accelerometer was placed on the anterior aspect of the vertebral body. It measured dorsoventral accelerations in the "horizontal" anatomic plane, in orthogonal axes. One measure was directed to the right ($\overrightarrow{A_{HR}}$), and 1 measure was directed to the left ($\overrightarrow{A_{HL}}$; Fig 1). This equipment recorded linear accelerations of each of the 2 vertebrae in 3 orthogonal directions; however, it did not allow the calculation of their angular accelerations and therefore ruled out the calculation of the 3-dimensional motion of the vertebrae.

Fig 2. *Manipulation in lumbar flexion used in this study.*

Table 2. *Number of tests (lumbar spinal manipulations) that yielded analyzable data*

Cadaver	Manipulations in flexion (n)	Manipulations in extension (n)
1	1	1
2	2	1

Cadaver 2 was instrumented in the same way, but all the lumbar intervertebral disks from L1-2 to L4-5 were equipped with pressure sensors, and the accelerometers were fixed on the vertebral bodies of L4 and L5.

Spinal manipulations. The cadavers were dressed in body suits and placed on a rigid table. The 2 manipulations studied were osteopathic lumbar thrust maneuvers, which were performed in the following manner: For the first manipulation (manipulation in flexion; Fig 2), the cadaver was placed on its right side, with the downside (right) hip in very slight flexion. The lumbar spine was flexed. The operator's right forearm and hand were applied to the pelvis of the cadaver, parallel to the left thigh, while the left hand reached under the arm of the cadaver to steady the shoulder and the thorax. The thrust came from the operator's right hand, rotating the pelvis downward and indirectly applying axial torque and traction to the lumbar spine. This manipulation corresponds to what is called the "spinous push-pull" by Bergmann et al[7] and the "basic lateral decubitus technique in flexion" by Maigne.[8] In the current study, the term *manipulation in flexion* was used.

For the second manipulation (manipulation in extension; Fig 3), the cadaver was placed on its right side, but with the downside (right) hip in full extension and with the back extended. The operator's forearm was perpendicular to the plane of the back. The thrust was applied by the operator's hand, at right angles to the axis of the spine. The goal was to produce rotation of the lumbosacral spine and to force the extension.[8]

These 2 maneuvers are frequently used in manual medicine, in the treatment of low-back pain.[7,8] Two manipulations in flexion and 2 manipulations in extension were performed on each cadaver; the total number of tests was 8.

Data analysis. The analysis was limited to the thrust, which required resetting to 0 after taking up the slack and before each thrust, to compensate for the effects of the preparatory phase of taking up the slack. Recorded measurements thus

Fig 3. *Manipulation in lumbar extension used in this study.*

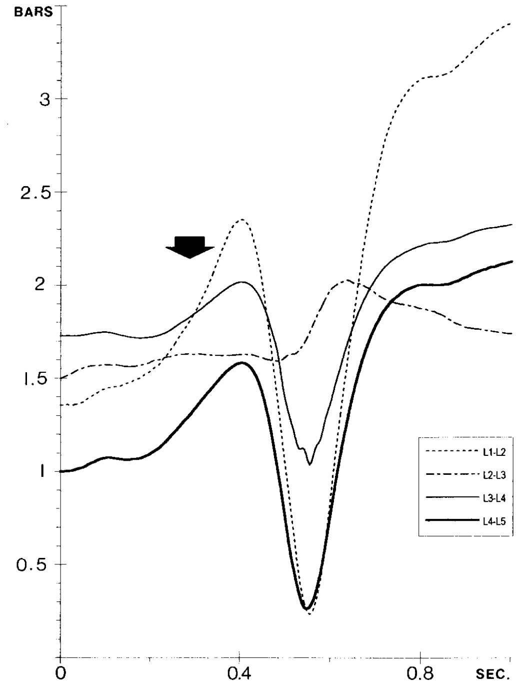

Fig 4. *Intradiskal pressure variation during a manipulative thrust (maneuver in flexion, cadaver 2). The black arrow indicates the start of the thrust, as shown by accelerometer data. The curves show variations and not absolute values.*

corresponded to relative, and not to absolute, variations. The signals were conditioned (low-pass filtered at 50 Hz) and digitized at a sampling rate of 250 Hz. Data analysis was performed on the variations of the intradiskal pressure and the modulus of the resultants of vertebral vertical accelerations in the caudocranial direction ($\vec{R_V}$) and in the "horizontal" plane ($\vec{R_H}$)

$\vec{R_V} = (\vec{A_{VR}} + \vec{A_{VL}})/2$

$\vec{R_V} = (\vec{A_{VR}} + \vec{A_{VL}})/2 \rightarrow \vec{R_H} = (A_{VR} + A_{VL})/2$ and

$\vec{R_H} = A^2_{HR} + A^2_{HL} \rightarrow \vec{R_H} = \sqrt{\vec{A_{HR}} + \vec{A_{HR}}}$

The difference between the modulus of the acceleration resultants in the vertical caudocranial direction (D_V) and the horizontal plane (D_H), between the vertebrae above (a) and below (b) the targeted disk, informed about the intervertebral relative movement:

$$D_V = R_{Va} - R_{Vb} \text{ and } D_H = R_{Ha} - R_{Hb}$$

RESULTS

Only 5 of the 8 tests that were performed yielded analyzable data from all pressure and acceleration channels (Table 2). In the other 3 tests, recordings on one or more channels were sometimes saturated by the extent of the movement.

An increase followed by a decrease in intradiskal pressure was observed and was preceded by variations in the accelerations indicative of a relative movement of the adjacent vertebrae. This lag between the start of the relative movement and the increase in pressure, measured for 2 manipulations in flexion, was 12 msec and 28 msec, respectively.

Intradiskal pressure. The onset of intradiskal pressure variations was fast (less than 200 msec) with manipulations in flexion and slower (400-700 msec) with manipulations in extension. A pressure rise was observed during the first phase of the thrust (mean value, 0.5 ± 0.17 bar), followed by a pressure drop during the late phase (mean value, 0.65 ± 0.2 bar; Figs 4 and 5).

Relative vertebral movements. The calculation of the difference between the modulus of the acceleration resultants of each vertebra showed variations for the vertical and horizontal axes indicative of a relative movement of the adjacent vertebrae (Table 3; Fig 5). For manipulation in flexion, the difference of the modulus of the vertical and horizontal acceleration resultants showed similar variations. For manipulation in extension, the difference of the modulus of the horizontal acceleration resultant was greater than the vertical one, which shows vertebral movements in the horizontal plane to be predominantly involved.

The estimate of the relative movement between L4 and L5 (cadaver 2) during the thrust of a manipulation in flexion was performed by double integration of the difference of the modulus of the caudocranial acceleration resultants (D_V). The results showed that L4 and L5 moved towards each other (approximated) during the rise in pressure and moved apart (separated) as the pressure decreased. The maximum value of vertebral approximation (between the beginning and the end of the thrust) was 1.1 mm.

DISCUSSION

Our study shows that it is possible to identify variations in intradiskal pressure and relative movement of the adjacent vertebrae during manipulative thrust in cadavers.

The absence of muscle tone was not considered to be a major problem. Spinal manipulations are performed in vivo on relaxed patients. Triano and Schultz[9,10] noted the absence of myoelectric response during various lumbar manipulations in healthy volunteers and concluded that the biomechanical effect of manipulation could be considered to be completed before any protective muscular response that might develop. Lee et al[11] arrived at similar conclusions. Furthermore, the physical sensation felt by the operator in

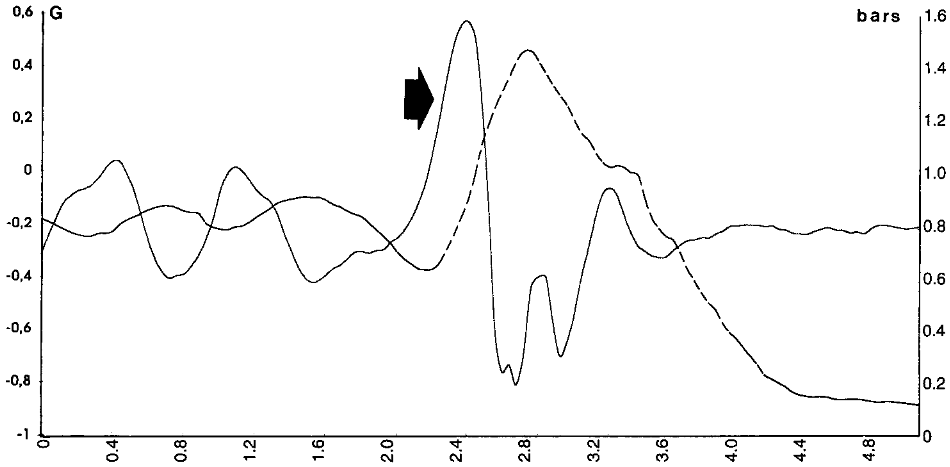

Fig 5. *Accelerations (between L3 and L4) and intradiskal pressure (L3-4 disk) variation during a manipulative thrust (maneuver in flexion, cadaver 1).* Solid line: *accelerations in the horizontal plane. The peak* (arrow) *indicates the start of the thrust.* Dotted line: *intradiskal pressure. Vertical axis, left: acceleration (in g); right: intradiskal pressure. Horizontal axis: time (in seconds).*

Table 3. *Relative accelerations (meters per second squared) between L3 and L4 (cadaver 1) and L4 and L5 (cadaver 2), in the horizontal plane and along the vertical axis, during the manipulations in extension or flexion**First test.

	Cadaver 1 extension*	Cadaver 1 extension†	Cadaver 2 flexion*	Cadaver 2 flexion†	Cadaver 2 extension*
Relative accelerations in the horizontal plane	8.73	2.45	3.53	3.43	2.45
Relative accelerations along the vertical (caudocranial) axis	0.29	0.69	2.45	1.86	0.88

*First test.
†Second test.

our study was similar to that perceived in a living patient when he or she is relaxed.

Dehydration of the nucleus could affect the pressure values measured. We obviated this problem by working on whole cadavers, rather than on isolated spine specimens. Furthermore, it has been shown[12] that 24 to 36 hours after death, a fluid redistribution within the disk can be observed; as a result of the altered vertebral loading pattern, the fluid content of the nucleus increases. This phenomenon could partially compensate for the dehydration that occurs in the days after death.

The recording and calculating techniques used in this study were not able to give entirely accurate acceleration values (because acceleration varied very rapidly) or vertebral movement data (which had to be calculated from the accelerations measured). However, we are confident that the pressure signal was recorded accurately and precisely because the pressure varied more slowly.

Our study was conducted in 2 cadavers, with complete sets of recordings in only 5 manipulations. As a result, we were unable to undertake a statistical analysis of repeatability. Although this is certainly a weak point of our study, it should be noted that the results obtained were consistent.

Intradiskal pressures. To our knowledge, there are no data in the literature on intradiskal pressure during manipulation. Nachemson and Morris[13] showed that the pressure within the nucleus was directly related to the axial compression load applied to the disk. This was confirmed in dynamic studies in cadavers.[14,15] The initial pressure rise seen in our study may be due to the rotation that is characteristic of the manipulative thrust. Rotation may make the adjacent vertebral bodies move towards each other, because of the orientation of the fibers at 30 degrees to the disk plane,[16] thereby increasing the pressure within the disk. The ensuing pressure drop is greater in terms of absolute value. It follows that simple recoil after the thrust does not adequately explain the phenomenon. It would appear that what happens is caused by traction on the lumbar spine[17] by the operator, whose arms work in different directions, with 1 arm steadying the shoulder and the other pulling on the pelvis. This traction is enhanced by the fact that the operator uses his/her weight, by jerking his/her thorax downwards towards the patient, to provide momentary further distraction.

In our view, this brief decrease in pressure could produce therapeutic benefit in 2 mechanisms. The first mechanism relates to the concept proposed by Cyriax and Cyriax[4] that a protrusion may be sucked back into the center of the joint by the reduction in the intradiskal pressure that is created during traction. From our study, it would appear that the drop in intradiskal pressure during manipulation should suffice to reduce a nucleus that is herniated into a weakened annulus. The second mechanism relates to an observation made by Adams et al,[18] who found that, if posture loading the lumbar disk in slight kyphosis is maintained for a prolonged period of time, there will be localized peaks of compressive stress within the disk, even though at the beginning, the pressure was uniform throughout the nucleus. These stress concentrations are thought to stress the end plates and, in vivo, may give rise to pain. We think that the pressure drop within the disk during manipulation may produce a more uniform pattern of compressive stress and, hence, provide pain relief.

Relative vertebral movements. The study by Gál et al[3] showed relative displacement of the T10, T11, and T12 vertebrae during a posterior-to-anterior thrust. Our study was performed in the lumbar spine and complements the work done by the earlier authors. In our study, the accelerometers that were mounted directly on the vertebrae allowed instantaneous measurement of vertebral body accelerations during manipulation. Unfortunately, our accelerometer assembly could not record angular movement (ie, torsion) in the horizontal plane, whereas Gál et al had been able to measure rotation. The manipulative thrust was accompanied by a relative movement of the adjacent vertebrae, with the vertebrae moving closer together and then moving apart again along the vertical axis. This movement pattern correlated with the pressure changes observed, which consisted in an increase in pressure followed by a decrease, a few milliseconds after the start of the relative vertebral movement. The maximum amount of approximation between L4 and L5 was 1.1 mm.

CONCLUSION

Our data differed with the type of manipulation performed (flexion or extension). With flexion, the variations were fast and brief, and the differences in acceleration in the caudocranial axis were almost as great as those in the horizontal plane. With extension, the variations were slower and more prolonged, and the acceleration differences were greater in the horizontal plane. This would suggest that each type of manipulation works in its own specific way.

ACKNOWLEDGMENTS

This work had the approval and assistance of the Service du Don des Corps of Paris University Medical School (Prof Jean-Pierre Lassau).

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