JAOA ORIGINAL CONTRIBUTION

Cervical Spine Bending: A Factor Confounding Whole Trunk and Lumbar Forward Bending Range of Motion

William J. Brooks, DO; Michael M. Patterson, PhD; Ethan Wagner, DO; and Patrick Hardigan, PhD

Context: Knee bending during tests of lumbar forward bending (FB) may introduce confounding variability. Precluding bending at the knees has, therefore, long been standard protocol to produce valid and reproducible results. However, there is limited research on cervical spine bending as a confounding variable in whole trunk and lumbar FB.

Objective: To examine the role of cervical spine bending on the range of whole trunk and lumbar FB.

Methods: Participants were recruited from the faculty, staff, and student population of Nova Southeastern University's Health Professions Division. Each participant underwent 4 FB tests with varying cervical starting positions. Range of motion was measured for whole trunk FB and lumbar FB by using the fingertip-to-floor and double digital inclinometer techniques, respectively.

Results: Two hundred thirty-six participants met the study criteria. Statistically significant differences were found in both whole trunk (6.96 cm) and lumbar (3.95°) FB range of motion when the cervical spine was backward bent after full spine FB ($P<.05$). Statistically significant differences were also found in both whole trunk (15.72 cm) and lumbar (7.38°) FB when the cervical spine was backward bent before thoracolumbar spine FB ($P<.05$).

Conclusion: Cervical spine bending influences the ability of the trunk and lumbar spine to bend forward and is, therefore, a confounding variable during tests of whole trunk and lumbar spine FB.

J Am Osteopath Assoc. 2012;112(7):429-436

Low back pain is well recognized as an enormous cost to society both in direct health care expense and in being the most frequent cause of disability in working-age adults. Manipulative medicine has been recognized as an effective treatment for patients with low back pain.[1,2] Osteopathic manipulative medicine is understood, in part, as a means to restore available range of motion at a joint. Thus, at least 1 benefit of manipulative medicine for low back pain has been hypothesized to be the restoration of spinal mobility.[3,4] However, published studies[5-20] continue to reveal confusing evidence about what relationships exist between lumbar motion and low back pain syndromes.

An array of techniques for measuring spinal motion continues to be explored with reference to validity, reliability, safety, and practicality.[17,21-31] An unrecognized confounding variable would undermine these efforts. Indeed, the results of these efforts have been sufficiently problematic—especially with regard to interexaminer reliability—such that spinal range of motion is no longer recognized as a criterion for impairment ratings by the American Medical Association (AMA).[32] In spite of these limitations, lumbar range of motion continues to be used as a fundamental indicator of function for clinical evaluation.[33-36]

In the present study, we focused specifically on forward bending (FB) of the spine in the standing context. Interexaminer reliability has been difficult to establish for standing lumbar FB.[22,37-41] Research on potential confounding variables has focused on the influence of age, sex, time of day, warm-up or no warm-up, motion at the hips, and, recently, motion at the knees and ankles.[12,42-45]

Until the 1980s, lumbar FB range of motion was commonly measured with the fingertip-to-floor test. However, the fingertip-to-floor test came to be appreciated as an invalid (construct) measure for *between-subjects comparison* of lumbar motion because anatomic variations of the cephalad extremities and thoracic region as well as motion throughout the

From the Restorative Care Foundation in Kansas City, Missouri (Drs Brooks and Patterson), the Kansas City University of Medicine and Biology in Missouri (Drs Brooks and Wagner), and the Nova Southeastern University College of Osteopathic Medicine (NSU-COM) in Ft Lauderdale, Florida (Drs Patterson [retired] and Hardigan). All research was conducted at NSU-COM.

Financial Disclosures: This work was supported by a Wallace Research Foundation grant to the Restorative Care Foundation to Drs Brooks and Patterson and by NSU-COM.

Address correspondence to William J. Brooks, DO, Restorative Care Foundation, 9204 NW 80th Terr, Kansas City, MO 64152-1616.

E-mail: wjbdo@wjbrooksdo.com

Submitted August 31, 2011; revision received March 4, 2012; accepted March 21, 2012.

thoracic region and at the hips are confounding variables. The fingertip-to-floor test is, therefore, also an invalid test of lumbar FB range of motion for *within-subject comparison* because of motion at the hips and of the thoracic spine. The current AMA-sanctioned standard for measuring spinal region motion is the dual inclinometer technique.[46] For measurement of lumbar motion, the method subtracts motion at the hips, allowing for appreciation of lumbar motion specifically. The sacral inclinometer reading—which is presumed to represent FB at the hips—is subtracted from the inclinometer reading at L1. Although dual inclinometer technique isolates measurement between specific loci, full FB of the lumbar spine includes FB of the thoracic spine and at the hips. To appreciate this total motion, the fingertip-to-floor test remains a construct valid method for within-subject comparisons of whole-trunk FB.

There are conflicting indirect data on the influence at the knee and ankle bending during tests of lumbar FB range of motion.[6,23,45,47-50] Standard AMA protocol requires the standing patient to maintain extension at the knees to control for the possibility that flexion at the knees introduces confounding variability.[46] Our literature search did not uncover a single exception to this requirement in all experimental protocols of standing FB. Notably, however, the literature search also did not uncover any study that specifically investigated the confounding influence of knee bending.

The possible influence of knee bending on FB range of motion led the primary investigator (W.J.B.) to question whether neck bending influences range of motion in whole trunk FB and lumbar FB. Clinical observations did suggest an influence, which is consistent with the osteopathic tenet that the body is a unit.[51] We found 2 reports[52,53] that focused on the contribution of structures cephalad to the lumbar spine during FB. One reported that in baboon cadavers there was slight displacement of the spinal cord when the cervical spine and/or the thigh with extension at the knee was forward bent.[52] The study did not address lumbar or trunk range of motion. Another study concluded that the human caudal thoracic spine forms a functional unit with the lumbar spine during whole trunk FB.[53] We found only 1 experimental protocol in which each participant was asked to maintain a specific position of the neck (forward bent) during measurement of lumbar FB range of motion. Notably, cervical FB was not monitored in that study.[29]

The goal of the present study was to examine the role of cervical spine bending on the range of whole trunk and lumbar FB. Two null hypotheses were formulated: (1) with extension at the knees, cervical spine bending would have no effect on lumbar FB range of motion, and (2) with extension at the knees, cervical spine bending would have no effect on whole trunk FB range of motion.

To test these null hypotheses, 3 tests of FB were designed, including unspecified FB (test A), specified sequential cephalic to caudal FB (test B_1), sustained whole trunk FB with specified cervical backward bending (BB) followed by further whole trunk FB (test B_2), and specified sequential cephalic to caudal FB with cervical BB throughout the movement (test C).

We predicted that test A would result in greater FB range of motion than test B_1. We also predicted that test B_2 would allow for additional range of motion in lumbar FB and whole trunk FB. Finally, we predicted that test A and test B_2 would produce similar findings. As we had no clinical experience with test C, we had no expectations regarding test C.

Methods

Participants

Participants were recruited from personnel of the Nova Southeastern University Health Professions Division in February and March 2002. Recruitment took place on each day of testing by asking passing students, faculty, and staff to participate. There were a total of 3 days of testing (2 in February and 1 in March). Participants gave written informed consent to participate in the study, which was approved by the Nova Southeastern University Institutional Review Board. Inclusion criteria were ages 18 to 65 years, ability to stand and bend forward, no current severe illness, and no recent surgery. Patients were excluded if they could touch past the floor while bending forward.

Method

Three tests (A, B_1, B_2, and C) were developed to measure FB. A video of these tests is available online at http://www.jaoa.org/content/112/7/429/suppl/DC1. Before formal data collection was performed, all examiners underwent training the day prior to testing, during which they practiced on participants who gave informed consent and were blind to the hypotheses. Training data were collected, and subsequent debriefing and further practice were supervised by W.J.B.

All tests took place mid-morning through afternoon. Participants were blind to the hypotheses and expectations of the study. Sex, height, age, current neck or back pain, history of spinal surgery, and medical intervention for neck or back pain were recorded for each participant. Before performing the tests, each participant removed his or her shoes, stood erect on a 4-inch raised platform, and looked straight ahead. A dual digital inclinometer (Saunders Digital Inclinometer; The Saunders Group, Inc; Chaska, Minnesota) was placed before testing. Examiner 3 found the S2 vertebra by palpating medially from the posterior superior iliac spines, marked that point with black marker, and placed 1 digital inclinometer below the point. Examiner 4 located the iliac crests, palpated medially to the L4 spinous process and then cephalad to the L1 spinous process, and marked and then placed an inclinometer over L1. Each inclinometer was held at the same location throughout all tests and was zeroed

Table 1.
Descriptive Statistics of Participants in a Study on Cervical Spine Bending and Forward Bending

Variable	Mean (SD)	Range
Age, y[a]	33.4 (12.6)	21.0-75.0
Height, in[b]	67.2 (4.4)	59.0-83.0
Weight, lb[c]	162.6(35.5)	90.0-260.0
Sex[d]		
Male	123 (52.6)	NA
Female	111 (47.4)	NA
Pain[d]		
Y	59 (25.2)	NA
N	175 (74.8)	NA

[a] n=236
[b] n=235
[c] n=236
[d] Data presented as No. (%)

Abbreviations: NA, not applicable; SD, standard deviation

before each test with the participant standing erect.

Test A was performed first. Test B_1 or C was performed after test A, with the order alternated randomly between participants. Test B_2 was performed immediately after test B_1. Unlike test A, tests B_1, B_2, and C were guided with the direction and sequencing of neck bending specified and carefully maintained by tactile monitoring. In all tests, extension was maintained at the knees. Examiner 5 (W.J.B.) provided verbal and tactile instruction from each participant's right side. Examiner 1 monitored the participant's knees and any effort to bend at the knees during all 3 tests. For each test, examiner 2 measured the fingertip-to-floor distance with a modified skirt ruler to assess whole trunk FB. Dual digital inclinometer method was used to measure lumbar region FB. The inclinometer at L1 measured FB at L1. The sacral inclinometer measured FB at the hip. Lumbar region FB was calculated by subtracting FB at the hips from FB at L1.

Test A—The first test always consisted of nonspecified FB, similar to current AMA protocol. Examiner 5 instructed each participant to "please bend forward as far as you can in whatever way is natural, letting your arms dangle in front of you and keeping your fingers straight."

Test B_1—For test B_1, or progressive segmental FB, examiner 5 instructed each participant as follows: "Following my guidance, please bend sequentially forward, beginning with your head." Examiner 5 placed his right hand on the participant's occiput and monitored the head position throughout the test. With his left hand, he provided tactile cues to the participant by running his fingertips from the head sequentially caudad along the spinous processes to the sacrum. As cervical FB progressed, he added, "Keep your chin tucked. Let your arms dangle in front of you, keeping your fingers straight." If the participant did not maintain FB of the head and neck, the instructions and the test were repeated once.

Test B_2—Test B_2, or progressive segmental FB followed by specified cervical backward bending (BB), followed by further trunk FB, invariably began from the position of the participant at the conclusion of test B_1. Examiner 5's left hand was placed on the participant's right cephalic thoracic region and his right hand on the participant's forehead. Examiner 5 instructed the participant to "please remain forward bent, except allow your head and neck to bend backward." Examiner 5 tactilely guided the participant's neck into complete and sustained BB and monitored the head position throughout the test. The cephalic thoracic region was monitored by the instructor's left hand to ensure that there was no BB of the thoracic spine. He then asked the participant to "please bend further forward as far as you are able."

Test C—For test C, or "specified cervical BB followed by whole trunk FB," examiner 5's left hand was placed on the participant's right cephalic thoracic region and the fingertips of his right hand were placed on the forehead of the participant, who was asked to "please bend just your neck backward." Examiner 5 guided the participant's neck into complete BB and monitored the forehead throughout the remainder of the test. Backward bending of the thoracic spine was monitored with his left hand. If BB progressed into the thoracic or lumbar spine regions, the participant was returned to the starting position and the process was repeated once. The participant was then instructed, "Now please bend the rest of your spine forward as far as you can, beginning here (T1) and progressing down your spine. Let your arms dangle in front of you, keeping your fingers straight." Simultaneously, examiner 5 ran the fingertips of his left hand sequentially caudad along the spinous processes from T1 to the sacrum.

Each test was considered complete when FB ceased or when the participant could no longer maintain the specified position of the neck or knees.

Data Recording

The fingertip-to-floor distance and inclinometer readings for each test were recorded on a numbered data sheet that also contained each participant's sex, height, weight, age, current neck or back pain, history of spinal surgery, and medical intervention for neck or back pain.

Statistical Analysis

Generalized estimating equations were used to assess the differences in FB while controlling for the covariates gender, age, height, weight, and current pain (neck or back). The generalized estimating equations model used the Gaussian distribution with an independent correlation structure. Generalized estimating equations are methods of parameter estimation for correlated data. If these correlations are not taken into account, the standard errors of the parameter estimates will be invalid and hypothesis-testing results nonreplicable. Descriptive statistics were calculated for the covariates. An α level of .05 was set for all statistical significance testing.

Results

Two hundred ninety-six participants were recruited (219 in February 2002; 77 in March 2002). Sixty participants who did not report for data collection, had undergone spinal surgery, bent past touching the floor, or had data input errors were excluded. Two hundred thirty-six participants were consequently included in the data analysis. A complete data set, which was used for the generalized estimating equations model, was available for 232 participants. Participants' mean (standard deviation [SD]) age was 33.4 (12.6) years. One hundred seventy-five (75%) participants were not experiencing pain at the time of the experiment (*Table 1*). Descriptive statistics are presented in *Table 1*. To increase study power, we analyzed participant demographic variables between the February and March trials (data from the 2 February trials were combined for this analysis). Results of the χ^2 analysis and the independent *t* tests indicated no statistically significant differences between the 2 groups. Therefore, we pooled the data for the generalized estimating equations.

Table 2. Forward Bending Range of Motion With Cervical Spine Bending (N=232)

Test	Mean (SD) FB Range of Motion	95% CI
Whole-Trunk FB, cm		
A	36.63 (2.57)	35.32-37.94
B_1	41.45 (2.66)	40.14-42.76
B_2	34.43 (2.65)	33.13-35.74
C	50.18 (2.58)	48.87-51.48
Sacrum FB, °		
A	46.9 (0.7)	45.3-48.6
B_1	41.3 (0.6)	39.7-42.9
B_2	47.5 (0.6)	45.9-49.2
C	41.3 (0.6)	39.7-43.0
L1 FB, °		
A	94.4 (4.0)	92.1-96.8
B_1	87.3 (4.2)	84.9-89.7
B_2	97.5 (4.4)	95.1-99.9
C	83.9 (4.4)	81.5-86.3
Lumbar FB, °		
A	47.5 (0.9)	45.6-49.4
B_1	46.0 (0.8)	44.1-47.9
B_2	50.0 (0.8)	48.0-51.9
C	42.6 (0.8)	40.7-44.5

Abbreviations: CI, confidence interval; FB, forward bending; SD, standard deviation.

Fingertip to Floor (Whole Trunk FB)

Controlling for sex, age, height, weight, and current pain (neck or back), statistically significant differences ($P<.05$) were found between tests C and B_2, between tests C and A, between tests C and B_1, between tests B_1 and B_2, and between tests B_1 and A. Test C resulted in the least FB range of motion, with a mean (SD) fingertip-to-floor distance of 50.18 (2.58) cm (95% confidence interval [CI], 48.87-51.48). Test B_2 resulted in the greatest FB range of motion with a mean (SD) fingertip-to-floor distance of 34.43 (2.65) cm (95% CI, 33.13-35.74) (*Table 2* and *Table 3*).

Sacrum Inclinometer (FB of the Trunk at the Hip)

Controlling for sex, age, height, weight, and current pain (neck/back), statistically significant differences ($P<.05$) were found between tests B_2 and B_1, between tests B_2 and C, between tests A and B_1, and between tests A and C. Test B_2 resulted in the greatest FB range of motion with a mean (SD) range of 47.5° (0.6°) (95% CI, 45.9-49.2), while test B_1 resulted in the least range of motion with a mean (SD) range of 41.3° (0.6°) (95% CI, 39.7-42.9) (*Table 2* and *Table 3*).

Lumbar Inclinometer (FB at L1)

Controlling for sex, age, height, weight, and current pain (neck/back), statistically significant differences ($P<.05$) were found between tests B_2 and C, between tests A and C, between tests B_2 and B_1, and between tests A and B_1. Test B_2 resulted in the greatest FB range of motion with a mean (SD) range of 97.5° (4.4°) (95% CI, 95.1-99.9), while test C resulted in the least range of motion with a mean (SD) range of 83.9° (4.4°) (95% CI, 81.5-86.3) (*Table 2* and *Table 3*).

Lumbar Region Forward Bending

Controlling for sex, age, height, weight, and current pain (neck/back), statistical differences ($P<.05$) were found between tests B_2 and C, between tests A and C, as well as between tests B_2 and B_1. Test B_2 resulted in the greatest FB range of motion with a mean (SD) range of 50.0° (0.8°) (95% CI, 48.0-51.9) while test C resulted in the least range of motion with a range of 42.6° (0.8°) (95% CI, 40.7-44.5) (*Table 2* and *Table 3*).

Comment

The results of the present study reject our null hypotheses that cervical spine position does not affect whole trunk FB and lumbar FB. The results confirm, for both whole trunk FB and lumbar FB, our expectations that test B_2 (ie, progressive segmental FB, followed by specified cervical BB, followed by whole trunk FB) would result in greater FB range of

Table 3.
Cervical Spine Bending and Forward Bending (FB): Generalized Estimating Equations Model With Covariates (N=232)

Test	Mean Difference Between Tests (95% Confidence Interval)		
Lumber FB Test	B_1	B_2	C
A	1.5 (-2.1-5.1)	2.5 (-1.1-6.0)	4.93 (1.4-8.5)[a]
B_1	…	4.0 (0.4-7.5)[a]	3.4 (-0.1-7.0)
B_2	…	…	7.4 (3.8-11)[a]
Sacrum FB Test			
A	5.7 (2.8-8.6)[a]	0.5 (-2.4-3.4)	5.5 (2.6-8.4)[a]
B_1	…	6.2 (3.3-9.1)[a]	0.1 (-2.8-3.0)
B_2	…	…	6.1 (3.2-9.0)[a]
L1 FB			
A	7.1 (2.7-11.6)[a]	3.1 (-1.4-7.5)	10.5 (6.1-15.00)[a]
B_1	-10.2 (5.8-14.6)[a]	3.4 (-1.0-7.8)	
B_2	…	…	13.6 (9.2-18.0)[a]
Whole-Trunk FB			
A	4.82 (2.39-7.26)[a]	2.13 (-0.30-4.57)	13.59 (11.15-16.03)[a]
B_1	…	6.96 (4.52-9.40)[a]	8.76 (6.33-11.20)[a]
B_2	…	…	15.72 (13.29-18.16)[a]

[a] Difference was statistically significant ($P<.05$).

motion than test B_1 (progressive segmental FB) and that test B_2 would produce results similar to those of test A (ie, nonspecified FB). The results confirm, for whole trunk FB but not for lumbar FB, our expectation that test A would result in greater FB range of motion than test B_1 would. We had no expectation regarding test C (ie, specified cervical BB followed by whole trunk FB). These results also demonstrate that FB at the hips did not occur in isolation from bending of the cervical spine, as evidenced by the statistically significant mean differences of sacral inclinometer readings between test B_1 and test B_2.

For a clinical test to be meaningful, it must satisfy 3 criteria. First, it must be construct valid; that is, it must potentially measure what it is purported to measure, not something else. When a factor has potential causal impact on the measure, it is a confounding variable. Experiments must control or account for confounding variables, lest the experiment be rendered nongeneralizable and, thus, meaningless. For example, if temperature, pressure, volume, container, and duration influence a chemical reaction, all of which are controlled except for temperature' then the utility of the experimental results must be called into question, as the experiment is unlikely to produce consistent results across locations and experimenters. A clinical test must similarly control for confounding variables.

Second, a clinical test must be reliable. For the meaningful care of a specific patient by a single caretaker, intraexaminer reliability is requisite to make interpretable comparisons within the patient, as well as about that individual over time. For any purpose potentially involving more than 1 examiner in the care of a specific patient or a population, interexaminer reliability is necessary.[54]

Third, a clinical test must have predictive validity. That is, a clinical test must contribute to establishing causal relationships. Predictive validity can be addressed only by controlled experimentation. Recognizing causal factors creates the opportunity for rational exploration of the efficacy of treatments. The present study was not a test of predictive validity; rather, it was a test of construct validity—a necessary prerequisite for meaningful tests of predictive validity.

Additionally, a test must be safe, practical, and cost effective. Concurrent validity is established when a test produces results similar to those of another valid test. Establishing concurrent validity is often useful for exploring questions of safety, practicality, and cost.[41,58,56]

In order for a clinical test of a specific question to be construct valid, it must be capable of answering that specific question. Failure to control for a confounding variable therefore invalidates a test, as the specific question is no longer being addressed. Current AMA protocol (ie, test A) seeks to specifically test lumbar FB by controlling motions at the knees and by subtracting FB at the hips from lumbo-pelvic FB. To further ensure that lumbar FB and whole trunk FB range of motion were specifically tested, tests B_1 and B_2 were designed to reveal any influence of cervical spine bending on lumbar FB and whole trunk FB range of motion by controlling cervical spine bending direction and sequence. Test B_1 specifically asks, "What is the participant's capacity for range of motion during whole trunk FB and lumbar FB while FB sequentially cephalad to caudad the entire spine and pelvis?" Test B_2 asks, "What is the participant's capacity for further whole trunk FB and lumbar FB range of motion after progressive segmental FB followed by cervical BB?"

The statistically significant differences between tests B_1 and B_2 show that the direction and sequencing of neck bending does indeed influence the total amount of both whole trunk FB and lumbar FB range of motion. Therefore, direction and sequencing of neck bending is a confounding variable when measuring whole trunk FB and lumbar FB range of motion. Current AMA protocol does not control for direction and sequencing of neck bending and, consequently, is invalid to ascertain specific lumbar FB and whole trunk FB range of motion within and between subjects. The statistically significant difference between test B_2 and test C further demonstrates that the sequencing of whole spine bending is confounding.

For the present study to be meaningful, it must be construct valid. Studies have found warm-up,[46,56,57] sex,[43] age,[37,43] height, and time of day[42,44,58] to be confounding effects of lumbar motion. The question of whether FB was submaximal because pain inhibition must also be addressed.[18] As the present study was a within-subject design, the influence of pain limitation was either constant between tests or, if limiting in 1 test and not another, would only lend credence to the basic conclusion that the direction and sequencing of cervical bending may influence FB, the mechanisms by which remain to be determined. The use of adjusted means accounts for sex, age, height, and weight. Others have controlled for time-of-day effect by waiting at least 2 hours after arising, as the differences in hydration of intervertebral disks are thought to be negligible after 2 hours of weight bearing.[58] The current AMA protocol includes a warm-up exercise.[46,57,60] The present study did not include warm-up. We believe that our study design, our active study population (ie, students and staff during a normal business day), and the mid-morning through afternoon times of data collection mitigate any distortion due to lack of formal warm-up and time of day. Additionally, test A provided some warm-up for tests B_1, B_2, and C, and the alternating sequence of tests B and C likely further mitigated any effect of the absence of formal warm-up. Similarly, another potential confound is test/retest phenomena, in that participants might have, as a result of learning or other psychological factors, consciously altered FB behavior if the tests were repeated. So, to ensure that test A was performed in the most unconscious, "everyday" manner possible, we did not measure test/retest phenomena. Further, we believe that our design of 4 repetitions of FB, alternating test C with test B, mitigated the possibility of error from test/retest.

The present study must also be reliable to be meaningful. The fingertip-to-floor test has been shown to be highly reliable.[22] The largest source of error when using inclinometers appears to be the insufficient training of test administrators, resulting in diminished ability to specify bony landmarks and to steadily hold instruments. However, the intraexaminer reliability of trained administrators is considered satisfactory.[40,41] Our measuring protocols were clearly demonstrated, practiced, and reviewed prior to the study. In addition, the same examiners tested a given participant (promoting uniform measuring technique within a participant), and the data analysis was within subject.

Statistically significant differences and clinically meaningful differences are not equivalent concepts. This study was conducted with a largely asymptomatic population—the population from which normative data are gleaned. The first question, then, is whether specifying the direction and sequencing of cervical bending would materially influence currently accepted norms. The mean difference in lumbar FB range of motion between test A and test B_1 was less than 2°, and the difference between test A and test B_2, less than 3°; neither of these differences was statistically significant at $P<.05$. In other words, the construct invalid current AMA protocol produced results on average not statistically dissimilar to the construct valid tests B_1 and B_2. Thus, this study yielded no compelling impetus to renew research into lumbar FB norms.

The present study does, however, raise the question of clinical significance for an individual patient. Although the mean differences between tests B_1 and B_2 were marginally meaningful (a bit less than 4°) in more than 15% of the participants, lumbar FB range of motion in test B_2 was 7° or greater than in test B_1, and in 7 participants it was greater than 14°, with 1 participant demonstrating a 30° difference. Similarly, 15 participants exhibited 15 cm (approximately 7 inches) or more of increased whole trunk FB range of motion in test B_2 than in test B_1. Thus, for a given participant, the magnitude of difference in either whole trunk FB or lumbar FB as a result of direction and sequencing of the cervical spine may be substantial. These observations raise the question of whether that difference represents inefficient musculoskeletal function (ie, somatic dysfunction), with consequent cervical BB serving as compensatory behavior during FB. The clinical significance of the requirement for compensatory motion may be relative overuse of cervical structures and consequent premature musculoskeletal wear, pain, and eventual damage. This reasoning points to the need for further research discriminating asymptomatic and symptomatic populations—especially patients with chronic axial pain.

These findings and arguments lend support to core tenets of the osteopathic profession—that the "body is a unit" and that function or dysfunction of 1 area of the body may influence function or dysfunction in "remote" areas.[59] The current study examined a subsegment of the body—the spine—and demonstrated that the cervical spine, although historically classified and often clinically viewed as being disjunct from the trunk and lumbar spine, is indeed functionally linked. The possible mechanisms of that linkage can be broadly classified into the following 2 categories: (1) passive contracture or elongation of 1 or more structures (eg, fascia, muscles, tendons, ligaments, disks, dura mater)[60-62] and (2) differences in active muscular behavior including tone and patterns of activation. Further research will be necessary to discriminate those possibilities.

Finally, prior studies[6,15,25,26,28,30,31,39,40,57] have shown poor interexaminer reliability for the AMA-sanctioned method for measuring thoracolumbar motions. Repeating those studies while controlling direction and sequencing of cervical bending may reveal improved reliability. Additionally, controlling for cervical bending may help future investigations clarify the relationships between lumbar motion and low back pain.

Interpretation of these results is limited by an insufficient platform to ensure that no participant could touch the floor during any test, by absence of measured examiner reliability, and by nonspecific characterization of pain.

Conclusion

Whole trunk FB, lumbar FB, and FB at the hips do not occur in isolation from direction and sequencing of cervical bending, as well as from whole spine bending sequence, highlighting—heretofore unaccounted for—sources of error in lumbar and trunk FB studies. Tests to determine lumbar and trunk FB range of motion must control for direction and sequencing of cervical and whole spine bending to be construct valid. The present study supports the osteopathic tenet that "the body is a unit" and raises several additional questions worthy of further research. It also strongly suggests that, in clinical practice, direction and sequencing of cervical bending, as well as whole spine bending sequence, should be controlled when measuring lumbar and trunk FB range of motion.

Acknowledgments

We gratefully acknowledge the Nova Southeastern University College of Osteopathic Medicine 2002 Osteopathic Principles and Practice Undergraduate Fellows for their assistance in data collection; Khalil Carter, MD, a visiting fellow of the college, for his assistance in data collection and organization; and John Schousboe, MD, PhD, of Park Nicollet Medical Center in St Louis Park, Minnesota, for his assistance in manuscript preparation.

Editor's Note: A supplemental video that depicts the study procedure for the present article is available online at http://www.jaoa.org/content/112/7/429/suppl/DC1.

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