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Does the Evidence Support the Existence of Lumbar Spine Coupled Motion? A Critical Review of the Literature

Low back pain is prevalent in industrial societies.[25] It is a primary cause of disability and results in annual medical expenditures exceeding billions of dollars.[44,46] Common noninvasive interventions for low back pain include manual therapy techniques such as muscle energy, joint mobilization, and thrust joint manipulation, all of which for the purpose of this literature review will be referred to as mobilization/manipulation. One reason for performing mobilization/manipulation techniques is to normalize joint accessory motion, with the belief that by doing so, physiological spinal movement also will be normalized. Typically, the goals of manual therapy procedures are to decrease pain, improve function, decrease disability, and prevent reoccurrence.

There are numerous approaches to performing joint mobilization/manipulation. These techniques are diverse, in part because they are derived from dissimilar theoretical bases. Some of the approaches to mobilization/manipulation used by physical therapists, including those proposed by Kaltenborn,[20] Saunders,[36] Dutton,[8] and Mafosky,[24] are based on the concept of coupled motion, or coupling, which has been defined as "a phenomenon of consistent association of one motion (translation or rotation) about an axis with another motion about a second axis."[2] In effect, one motion cannot be produced without the other.

In a recent survey of 369 physical therapists in the United States, more than 85% of respondents stated that lumbar coupling biomechanics were important or very important in treatment decision making, and more than 93% reported that they frequently or consistently used lumbar coupling biomechanics when performing manual therapy techniques.[6] Based on these high percentages, there is a clear need to evaluate the validity of the assertion that a specific coupled pattern of motion exists in the lumbar spine.

Three authors commonly referenced in discussions of the specific characteristics of coupled motion are Lovett, Fryette, and Kapandji. In the early 1900s, Lovett[1,19] reported that lumbar spinal segments that are moved into side bending from a neutral or flexed position rotate in a direction opposite the direction of the side bending. If side bending is induced when the segments are in an extended position, then the segments will rotate in the same direction as the side-bending motion. Lovett performed additional observations of motion in a spine with the posterior elements removed and found that rotation always occurred in the direction opposite the direction of side bending. He concluded from these observations that the facet joints are responsible for motion when the spine is extended; however, when the spine is

● **STUDY DESIGN:** Literature review.

● **OBJECTIVES:** To synthesize the current literature addressing coupled motion between side bending and rotation in the lumbar spine to determine if a consistent pattern exists across articles.

● **BACKGROUND:** Low back pain is one of the most common conditions seen in outpatient physical therapy clinics. This condition is often treated with manual therapy techniques. Many approaches to manual therapy incorporate the concept of coupled motion.

● **METHODS AND MEASURES:** Using OVID databases, we reviewed and categorized articles published between 1982 and 2006 that addressed coupled motion between side bending and rotation in the lumbar spine. We identified 24 articles in which 32 analyses addressed our clinical question.

● **RESULTS:** Seventeen of the 24 articles identified concluded that some form of coupled motion exists; however, there was little agreement across articles as to the specific characteristics of coupled motion.

● **CONCLUSIONS:** The inconsistency in reported patterns of coupled motion suggests that physical therapists should use caution when applying concepts of coupled motion to the evaluation and treatment of patients with low back pain. *J Orthop Sports Phys Ther 2007;37(4):169-178. doi:10.2519/jospt.2007.2300*

● **KEY WORDS:** coupled movements, lumbar biomechanics, lumbar motion

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in flexion or neutral, the facet joints no longer articulate with one another and coupled motion no longer is determined by the orientation of the facet joints.

Fryette,[19,36] an osteopathic physician, expanded on Lovett's observations in a text published in 1954. Fryette concurred with Lovett's observations, but added that in end range flexion when side bending is initiated rotation is coupled to the same side. He attributed this phenomenon to ligamentous tension.

In 1974, Kapandji[21] published a commonly used text in which he described current theories related to spinal kinesiology. Kapandji concurred with Lovett and Fryette regarding coupled motion in the neutral position, but did not mention any changes with positioning in flexion or extension.

Many of the principles of osteopathic manipulative medicine are based on Fryette's laws.[13,19,27] Several books on spinal manual therapy geared toward physical therapists have also based some of their evaluation and intervention procedures on Fryette's observations regarding coupled motion,[24,36] suggesting that coupled-motion concepts are used by many physical therapists in the clinical setting.

Several physical therapists have expressed a different opinion regarding the characteristics of coupled motion. Kaltenborn[20] stated that when the spine is in neutral and in extension, side bending is coupled with rotation to the opposite side, whereas only in flexion are side bending and rotation coupled to the same side. Dutton[8] concurs with Fryette, with the exception that at L5/S1 coupling varies among individuals. Conversely, Cook[7] stated that there is little evidence to support the use of coupled motion in the evaluation and treatment of low back pain, especially if it is not used in conjunction with clinical tests in which symptoms are reproduced.

Despite differences in the pattern of coupled motion reported by various authors, concepts of coupled motion are the basis for a number of decisions that are commonly made in determining evaluation and intervention mobilization/manipulation procedures for patients with spinal pain. These concepts were developed primarily by osteopaths and chiropractors. Nevertheless, they influenced the development of many of the mobilization/manipulation techniques used by physical therapists. Some of the more common of these considerations are described below.

Evaluation

Much of osteopathic manipulative medicine is based on the premise that spinal impairments often are caused by vertebral motion restrictions or positional changes.[13,19,27,36] The identification of these impairments is based on Fryette's laws of coupled motion. Motion restrictions and positional changes are identified by the combination of movement that is restricted. Patients with a neutral or type I lesion demonstrate restrictions in either flexion or extension, and in side bending and rotation to the opposite side, whereas patients with a nonneutral or type II lesion demonstrate restrictions in either flexion or extension, and in side bending and rotation to the same side. When evaluating for restrictions or positional changes, rotation and side bending in neutral, or rotation and side bending in flexion or extension are often evaluated simultaneously.

A number of chiropractors utilize a classification system that differs from the osteopaths. This classification system was first reported by Cassidy[15,16] and later modified by Grice.[15,16] Cassidy categorized lumbar motion into 3 different groups. Patients with type I motion demonstrate movement such that, when side bending is initiated, rotation occurs to the opposite side. This motion is considered normal. Those with type II motion demonstrate rotation to the same side when side bending is initiated. When patients with type III motions actively side bend toward one side, the motion segment side bends and rotates to the opposite side of the active motion. Cassidy stated that these type II and III movement patterns represent a progressive increase in spinal impairment and are accompanied by a loss of function. Grice expanded this categorization system by including a type IV movement pattern. In this movement pattern, when the patient actively side bends toward one side, the motion segment side bends towards the opposite side and rotates towards the same side as active motion.

Both osteopathic and chiropractic disciplines are based on the belief that in the presence of spinal impairment, the normal coupling pattern is altered.[14-16] Individuals in these disciplines, therefore, use their understanding of the pattern of coupling at each spinal motion segment to guide them in determining whether that segment is impaired. For example, if the clinician believes that side bending left is normally coupled with rotation to the right at L4, and a patient demonstrates a movement pattern at L4 such that side bending left is accompanied by rotation left, the clinician might conclude that there is a movement impairment at L4. Hypomobility into coupled motions also indicates that there is impairment at that segment.

Physical therapists do not adhere to any one specific belief system. Mobilization/manipulation interventions are often based on one or a combination of evaluation findings, including pain location, pain provocation, and joint mobility tests. Recent evidence supports the use of a specific combination of examination results to determine the appropriateness of spinal manipulation.[3]

Intervention

From both an osteopathic and a chiropractic perspective, accessory motion restrictions are treated by performing mobilization/manipulation techniques that move the joint into the restricted directions.[13,17,19] A patient with a restriction in flexion, side bending left and rotation left, determined by an accessory motion examination,[9] would therefore be treated with techniques designed to restore motion into flexion, side bending left, and/or rotation left. Positional impairments, defined as an alteration of the position of one joint surface in relation to the other,[9] are treated by performing mobilization/manipulation techniques that move the joint in a direction opposite the direction of the positional impairment. A patient with a positional impairment such that the vertebra is fixed in extension, side bending right and rotation right would therefore also be treated with mobilization/manipulation techniques into the direction of flexion, side bending left, and/or rotation left. In both situations, the therapist could simultaneously correct all restrictions by mobilizing/manipulating either into flexion, side bending, or rotation left.

Principles of coupled motion are also used to "lock," or prevent movement at joints above and below the motion segment being treated with mobilization/manipulation techniques.[8] For the purpose of locking, patients are placed such that the vertebra above and/or below the motion segment being treated are positioned in a combination of flexion/extension, side bending, and/or rotation that is opposite that of normal coupling motion.[12] For example, if the goal of treatment is to increase mobility at L5 and motion is coupled to the same side in the lumbar spine, the clinician could position L4 and above into side bending and rotation to the opposite side to minimize motion at these segments when mobilizing/manipulating L5. The exact combination of positions depends on the clinician's belief regarding the pattern of coupled motion at the motion segments being locked.

The purpose of this paper is to categorize and synthesize published studies addressing the validity of the theory that a specific pattern of coupled motion between side bending and rotation exists in the normal lumbar spine. We identified studies that addressed coupling specifically between side bending and rotation because these 2 motions are most commonly referenced in relation to the clinical application of spinal coupled motion.

Three previously published papers have addressed the issue of the validity of coupled motion.[5,11,18] In 2 of these papers, the investigators addressed this issue solely in relation to osteopathic[11] or chiropractic[18] teachings. In our paper, we did not address coupling in light of any one manual therapy approach. Our paper also differs from each of these 3 prior publications in that our literature search resulted in a larger number of articles specifically addressing coupling between side bending and rotation.

METHODS

Literature Search

To search for articles for this systematic literature review, we used the following databases in OVID: Medline (1966-October 2006), all EBM reviews (1982-October 2006), and CINHAL (1982-December 2006). The following key words were searched: *articular*, *axial rotation*, *biomechanics*, *coupled movements*, *lateral*, *lateral bending*, *lateral flexion*, *lumbar*, *lumbar vertebrae*, *movement*, *range of motion*, *rotation*, *side bending*, *spine*, *translation*, *zygapophyseal joint*. The COMBINE toolbar in Ovid was used to merge different combinations of these keywords. Searches were limited to studies using human subjects and written in English.

Three hundred fifty-five articles initially were identified. We scanned titles and abstracts for relevance to our clinical question and subsequently identified 71 articles for retrieval. We searched the bibliographies of each of these articles for additional references. A study was excluded if all of the live subjects or cadavers were described as having significant spinal pathology such as spondylolisthesis or spinal fracture. The articles were then evaluated for the following inclusion criteria:

- The article appeared in a peer-reviewed journal
- Subjects, including both live subjects and cadavers, were aged 18 years or older
- The study specifically addressed coupled angular motion associated with side bending and rotation in the lumbar spine. Studies addressing angular motion into flexion and extension, and translational motion into any direction were therefore excluded
- The study addressed motion between any 2 lumbar vertebra that were adjacent to one another
- The article identified the specific motion that was coupled with the initial motion

For the article to be retained, both authors were required to concur that these criteria were met. When there was a disagreement, we discussed the issue until a consensus was reached

Statistical Analysis

Numerous investigators have suggested that coupled motion varies depending on whether the initial motion was side bending or rotation.[4,5,10,18,29-32,37,41] Separate analyses were therefore performed for studies in which side bending was the motion initiated, and in which the motion initiated was rotation.

For coupled motion principles to be useful in clinical decisions, 1 specific pattern of coupled motion must be established. In reviewing the data from the studies we identified, we therefore compared each specific pattern of coupled motion against a second group of studies that encompassed all other patterns. For example, if side bending was the motion that was initiated, when evaluating whether side bending and rotation are coupled to the opposite side the 6 studies meeting these criteria were compared with the 15 studies that showed different patterns.

When appropriate, we used chi-square goodness-of-fit statistics to determine if there was sufficient evidence to reject the null hypothesis. Because we were interested in determining whether, across studies, 1 specific pattern of coupled motion was reported more frequently than all others combined (a 1-tailed hypothesis), we performed a statistical analysis

TABLE 1 Summary of the Literature (table rows continue on next page)

Study	Sample Size (n)	Age and Sex	Description of Subjects	Position in Which the Subject Was Tested
Lewit (1997)[23]	19	20-75 y, males and females	• Live subjects • All subjects had at least 1 unilateral restricted motion segment into rotation at T10/11, T12/L1, or L1/2	Seated upright in neutral position
Krismer et al (2000)[22]	15	20-92 y, males and females	• Cadavers • Some subjects had degenerated discs	Upright
Ochia et al (2006)[28]	15	Males mean (SD) age, 33.5 (6.5) y; females mean (SD) age, 35.9 (9.2) y	• Live subjects • Subjects were asymptomatic	Supine with the lumbar spine in neutral
Schultz et al (1979)[37]	23	21-60 y, males and females	• Cadavers • Subjects were not chosen based on the condition of the lumbar spine • 1 cadaver had a herniated nucleus pulposus, 1 had Marfans syndrome	Upright
Panjabi (1989)[30]	6	Information not provided	• Cadavers • Description of subjects not provided	Upright in full flexion, neutral, and full extension
Oxland (1992)[29]	9	35-62 y, males	• Cadavers • Description of subjects not provided	Upright
Panjabi et al (1994)[31]	9	35-62 y, males	• Cadavers • Subjects not chosen on the basis of low back pain; some cadavers had degenerative changes in the low back	Upright
Cholewicki et al (1996)[4]	9	35-62 y, males	• Cadavers • No gross abnormalities on radiographs	Information not provided
Pearcy (1985)[32]	20: 10 positioned in rotation, 10 positioned in side bending	21-37 y, males	• Live Subjects • Subjects never had low back pain requiring time off from work and were pain free for 12 mo prior to entering the study; 1 subject in the rotation group had spina bifida occulta	Standing in neutral position
Steffen et al (1997)[41]	16	19-51 y, males	• Live subjects • Subjects had no current or history of low back pain	Standing upright with hands on head
Feipel et al (2001)[10]	22	15-57 y, males and females	• Live subjects • Subjects were healthy volunteers	Standing upright
Arkin (1950)[1]	5	26-27 y, information not provided	• Live subjects • Subjects had no scoliosis	Standing, sitting and supine, in flexion, extension and neutral
Miles et al (1961)[26]	54	19-45 y, males and females	• Live subjects • Description of subjects not provided	Standing in neutral position with hands on head
Haas et al (1992)[16]	249	>18 y, information not provided	• Live subjects: 144 subjects with current low back pain, 106 subjects asymptomatic with a history of low back pain, and 29 subjects asymptomatic with no history of low back pain	Standing upright
Speiser et al (1990)[40]	2	Information not provided	• Live subjects • Subjects had low back pain when they entered the study; 1 subject was status post discectomy	Upright
Soni et al (1982)[39]	10	Information not provided	• Cadavers • Description of subjects not provided	Upright, from a position of full extension to full flexion in small increments

Active or First Motion Performed (Rotation and/or Side Bending)	Coupled Motion	Spinal Levels	2-D or 3-D Technology	How Coupled Motion was Determined
Rotation	• Side bending coupled to the opposite side in unrestricted motion segments • Side bending coupled to the same side in restricted motion segments	T10/11-L5/S1	2-D	Uniplanar radiography
Rotation	• Coupled motion into side bending inconsistent and not dependent on the presence of disc degeneration	T12/L1-L5/S1	3-D	Biplanar radiography
Rotation	• L1/2-L4/5: side bending coupled to the opposite side • L5/S1: side bending coupled to the same side	L1/2-L5/S1	3-D	CT scan
Rotation, side bending	• Rotation: coupled motion into side bending inconsistent • Side bending: coupled motion into rotation inconsistent	T12/L1-L5/S1	3-D	Computerized motion analysis using displacement dial gage indicators
Rotation, side bending	• Rotation, L1/2-L2/3: side bending coupled to the opposite side • Rotation, L3/4: coupled motion into side bending inconsistent • Rotation, L4/5-L5/S1: side bending coupled to the same side • Side bending, L1/2: coupled motion into rotation inconsistent • Side bending, L2/3-L5/S1: rotation coupled to the opposite side	L1/2-L5/S1	3-D	Stereophotogrammetry
Rotation, side bending	• Rotation: side bending coupled to the same side • Side bending: rotation coupled to the opposite side	L5/S1	3-D	Sterephotography
Rotation, side bending	• Rotation, L1/2-L3/4: side bending coupled to the opposite side • Rotation, L4/5-L5/S1: side bending coupled to the same side • Side bending, L1/2-L3/4: rotation coupled to the same side • Side bending, L4/5-L5/S1: rotation coupled to the opposite side	L1/2-L5/S1	3-D	Biplanar radiography
Rotation, side bending	• Rotation, L1/2-L3/4: side bending coupled to the same side • Rotation, L4/5-L5/S1: side bending coupled to the opposite side • Side bending, L1/2-L3/4, L5/S1: rotation coupled to the same side • Side bending, L4/5: rotation coupled to the opposite side	L1/2-L5/S1	3-D	Stereophotogrammetry
Rotation, side bending	• Rotation, L1/2-L3/4: side bending coupled to the opposite side • Rotation, L4/5: coupled motion into side bending inconsistent • Rotation, L5/S1: side bending coupled to the same side • Side bending, L1/2-L4/5: rotation coupled to the opposite side • Side bending, L5/S1: rotation coupled to the same side	L1/2-L5/S1	3-D	Biplanar stereoradiography
Rotation, side bending	• Rotation: coupled motion into side bending inconsistent • Side bending: rotation coupled to the opposite side in unrestricted motion segments	L3/4	3-D	Biplanar radiography with videography and indwelling sensors
Rotation, side bending	• Rotation: coupled motion into side bending inconsistent • Side bending: coupled motion into rotation inconsistent	T12/L1-L5/S1	3-D	Electrogoniometry
Side bending	• Rotation coupled to the opposite side	L1/2-L3/4	2-D	Uniplanar anterior-posterior radiography
Side bending	• For most subjects, rotation coupled to the opposite side	L1/2-L5/S1	2-D	Uniplanar anterior-posterior radiography
Side bending	• L1/2, L2/3 and L3/4: coupled motion was inconsistent • L4/5: rotation coupled to the same side	L1/2-L4/L5	2-D	Uniplanar radiography
Side bending	• Rotation coupled to the opposite side	L3/4-L5/S1	2-D	Uniplanar radiography
Side bending	• Rotation coupled to the same side	L1/2-L4/L5	3-D	Computerized analysis using a linkage transducer

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TABLE 1 Summary of the Literature
(continued from pages 172-173)

Study	Sample Size (n)	Age and Sex	Description of Subjects	Position in Which the Subject Was Tested
Vicenzino et al (1993)[45]	4	23-42 y, males	• Cadavers • Description of subjects not provided	Upright in flexion and extension
Shirazi-Adl (1994)[38]	1	65 y, male	• Cadaver • Description of subjects not provided	Upright
Rohlmann et al (2001)[35]	10	18-74 y, males and females	• Cadavers • Subjects had radiographically normal spines	Upright
Stokes et al (1981)[42]	77	19-71 y, males and females	• Live subjects • Subjects with and without low back pain included; some subjects with low back pain had undergone a fusion or discectomy, or had signs or symptoms of a herniated disc	Standing upright in neutral
Plamondon et al (1988)[33]	16	Mean age (SD), 25 (7) y; males and females	• Live subjects • Subjects never had low back pain	Standing upright
Gregory et al (1998)[14]	27	20-50 y, information not provided	• Live subjects • Subjects had low back pain; some subjects had joint "fixations"	Standing upright with hands on head
Pope et al (1977)[34]	29: 20 cadavers, 9 live subjects	Cadavers: 18-40 y, males; live subjects: 18-35 y, males	• Cadavers and live subjects • Cadavers not chosen based on the condition of the lumbar spine • Subjects "normal"	Normal resting supine posture
Tanz (1953)[43]	45	35-77 males and females	• Live subjects • Subjects had no current low back pain, but some subjects had a history of low back pain, and some subjects had abnormal radiographs	Recumbent

on the data only when over 50% of studies showed 1 specific pattern of coupled motion compared with all other patterns combined. We set our alpha level at .10. Because there was wide variability in the number of subjects across the studies we retained for analyses (range, 1-249), we also analyzed categories of coupled motion patterns by the number of subjects in studies using the same criteria that were used to evaluate differences among study results.

Several conditions that might affect the determination of coupled motion have been identified. These conditions include the age of the subject,[22] position in the sagittal plane (flexion versus extension versus neutral positioning),[1,4-6,11,30,37,39,45] spinal level tested,[4,6,11,28,30-32,38,45] method for determining coupled motion,[5,18,28,31-34,41] whether subjects had back pain or pathology,[5,6,11,14-16,22,23,42] whether the testing was performed on live subjects or cadavers,[4,6,31,32,34] and sex. For each article, we therefore collected data on these conditions. Because cell counts in these subcategories were small, we visually evaluated these data to determine whether any trends emerged that might explain the reported pattern of coupled motion.

RESULTS

A total of 24 articles were retained. Information on the conclusions of each study in relation to coupled motion reported in these 24 articles is provided in **TABLE 1**. Twenty-one articles reported on coupled motion patterns in which side bending was the first motion performed, whereas 11 articles reported results for rotation-initiated conditions. Eight of the 24 articles reported on both conditions, thus the number of conditions totals 32 (**TABLE 2**). We used this information to categorize study results into 5 discreet groupings: side bending and rotation are coupled to the same side; side bending and rotation are coupled to the opposite side; coupling varies depending on the spinal level; coupling between side bending and rotation is inconsistent; and coupling between side bending and rotation is nonexistent. Within the category "coupling varies depending on the spinal level" there was no agreement across studies as to which motions were coupled at a particular spinal level (**TABLES 1-4**).

Active or First Motion Performed (Rotation and/or Side Bending)	Coupled Motion	Spinal Levels	2-D or 3-D Technology	How Coupled Motion was Determined
Side bending	In flexion: • L1/2 in side bending right: rotation coupled to the same side • L1/2 in side bending left: rotation coupled to the opposite side • L2/3, L4/5: rotation coupled to the opposite side • L3/4, L5/S1: rotation coupled to the same side In extension: • L1/2, L3/4: rotation coupled to the opposite side • L2/3, L4/5, L5/S1: rotation coupled to the same side	L1/2-L5/S1	3-D	Observation markers in combination with photographic slides, protractor and goniometry measurements, and graphing techniques
Side bending	• In the upper segments, rotation coupled to the opposite side • In the lower segments, rotation coupled to the same side	L1/2-L5/S1	3-D	CT scan
Side bending	• No coupled motion	L1/2-L5/S1	3-D	Triplanar radiography
Side bending	• Rotation coupled to the opposite side	L1/2-L5/S1	3-D	Biplanar radiography with computer analysis
Side bending	• Coupled motion into rotation minimal and inconsistent	L1/2-L4/5	3-D	Biplanar radiography
Side bending	• Coupled motion into rotation inconsistent	L4/5	3-D	Biplanar radiography
Side bending	• Rotation coupled to the same side	L1/2-L4/5 or L5/S1	3-D	Biplanar radiography
Side bending	• For most subjects no coupled motion into rotation	L1/2-L5/S1	3-D	Biplanar radiography

The conclusions of 17 of 24 articles[1,4,16,23,26,28-32,34,38-42,45] indicate that some specific form of coupled motion pattern between rotation and side bending does exist in the lumbar spine. However, in 7 articles, no pattern was identified.[10,14,22,33,35,37,43] Furthermore, among the 17 articles in which some pattern was reported, there was little agreement across articles as to the direction of the coupled motion, either when rotation or side bending was initiated (**TABLES 1-4**). Only 1 condition met our criteria for requiring statistical analysis: the condition in which the number of subjects (versus the number of studies) was analyzed, rotation was the motion initiated, and coupling into side bending was inconsistent. The *P* value associated with this analysis was greater than .10.

Although small cell counts preclude definitive conclusions, there does not appear to be a relation between any of the reported patterns of coupled motion and whether the study was performed on live subjects or cadavers, or whether the instrumentation used to determine coupled motion entailed 2-dimensional or 3-dimensional technology (**TABLES 3** and **4**). Eight studies restricted their sample to males.[4,29,31,32,34,38,41,45] Of these, 5 studies[4,31,32,38,45] reported that coupled motion varies depending on spinal level, whereas the other 3 studies[29,34,41] reported different results. There is insufficient data to draw any conclusions regarding the effect on the determination of coupled motion by spinal pathology, or position while testing for coupled motion patterns (**TABLE 1**).

DISCUSSION

We were not able to find evidence of a consistent pattern of coupled motion between side bending and rotation in the lumbar spine across articles. This was the case even when considering such conditions as the age and sex of the subject, position in the sagittal plane, or method of detecting coupled motion. These findings have implications for the application of theories regarding coupled motion to manual therapy practice, as there is no evidence to support the use of coupled motion principles to evaluate or treat patients with low back pain.

In 2 previously published reviews,[11,18] investigators addressed the validity of coupled motion. Gibbons and Tehan[11]

TABLE 2 Number (Percent) of All Studies and Subjects in Each of the 5 Coupled-Motion Categories

Type of Coupled Motion	Studies (n = 32)	Subjects (n = 786)
For most subjects, side bending and rotation is coupled to the opposite side	6 (19%)[1,26,29,40-42]	163 (21%)
For most subjects, side bending and rotation is coupled to the same side	3 (9%)[29,34,39]	48 (6%)
For most subjects, coupling varies depending on the spinal level	12 (37%)[4,16,28,30-32,38,45]	337 (43%)
Coupling between side bending and rotation is inconsistent	9 (28%)[10,14,22,23,33,37,41]	183 (23%)
For most subjects, coupling between side bending and rotation is nonexistent	2 (6%)[35,43]	55 (7%)

stated that while coupled motion does occur in the lumbar spine, it varies in amount and direction. Harrison et al[18] concluded that a specific and complex pattern of coupled motion does exist in the lumbar spine; but this pattern has not been adequately identified with the current methods used to evaluate coupled motion, and more research is needed to fully understand the characteristics of these coupled patterns.

Our findings regarding the inconsistency of coupling in the lumbar spine do not necessarily contradict the conclusions drawn in both of these papers. However, our identification of 2 articles that concluded that coupling is nonexistent in the lumbar spine[35,43] does not support the findings of Gibbons and Tehan. In relation to the conclusions drawn by Harrison et al that a not-yet-completely-understood pattern of coupled motion exists, the authors do not provide evidence to support this contention. It is also important to recognize that even if a complex pattern of coupled motion does exist it is less likely to be detectable in the clinical setting than the more simple patterns that have been proposed and investigated thus far.

In the final review article, Cook[5] found inconsistency in coupling when side bending was initiated, but suggests that coupled motion might occur when rotation is initiated and that this concept should be investigated in future studies. We identified 11 studies[4,10,22,23,28-32,37,41] in which rotation was initiated and believe that this is a sufficient number to draw a conclusion about the consistency of rotation-initiated coupled motion. In our analysis, we could not find a consistent coupled pattern when either side bending or rotation was initiated.

Most investigators reported within their respective publications that a specific pattern of coupled motion does exist.[1,4,16,23,26,28-32,34,38-42,45] Why, then was there inconsistency in the specific pattern of coupled motion reported across studies? Only a few investigators performed any statistical analyses on their data,[16,45] thus there is a possibility that those studies that reported specific coupled patterns might have done so in error. This is supported by the observation that in the few studies in which standard deviations for the amount of coupled motion were reported, these standard deviations were large.[29,32,33,45] With a large variability in the amount of coupled motion among subjects within studies, the results of statistical analyses would less likely show that a specific coupled pattern exists. Study conclusions might have differed had the researchers tested their hypotheses using statistical approaches.

Most investigators did not address the accuracy of the coupled motion measurement being studied, despite the fact that the amount of coupled motion has been reported to be 2.5° or less.[18,29,31-33,41,45] In 1 study reporting on the accuracy of the coupled motion, the measurement error was less than 1° when using stereophotography.[4] This high level of precision suggests that measurement error does not account for the variability in conclusions across studies. Nevertheless, the technologically advanced instrumentation used in many of these studies is not available

TABLE 3 Number (Percent) of Studies and Subjects, Type of Subject and Instrumentation Used in the Study, for Studies in Which Rotation Was the First Motion Performed in Each of the 5 Coupled-Motion Categories

			Type of Subject		Instrumentation	
Type of Coupled Motion	Studies (n = 11)	Subjects (n = 153)	Cadavers (n = 6)	Live Subjects (n = 5)	2-D (n = 1)	3-D (n = 10)
For most subjects, side bending and rotation is coupled to the opposite side	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
For most subjects, side bending and rotation is coupled to the same side	1 (9%)[29]	9 (6%)	1 (17%)[29]	0 (0%)	0 (0%)	1 (10%)[29]
For most subjects, coupling varies depending on the spinal level	5 (45%)[4,28,30-32]	49 (32%)	3 (50%)[4,30,31]	2 (40%)[28,32]	0 (0%)	5 (50%)[4,28,30-32]
Coupling between side bending and rotation is inconsistent	5 (45%)[10,22,23,37,41]	95 (62%)	2 (33%)[22,37]	3 (60%)[10,23,41]	1 (100%)[23]	4 (40%)[10,22,37,41]
For most subjects, coupling between side bending and rotation is nonexistent	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

TABLE 4 Number (Percent) of Studies and Subjects, Type of Subject, and Instrumentation Used in the Study, for Studies in Which Side Bending Was the First Motion Performed in Each of the 5 Coupled-Motion Categories

			Type of Subject		Instrumentation	
Type of Coupled Motion	Studies (n = 21)	Subjects (n = 633)	Cadavers (n = 10)	Live Subjects (n = 12)	2-D (n = 4)	3-D (n = 17)
For most subjects, side bending and rotation is coupled to the opposite side	6 (29%)[1,26,29,40-42]	163 (26%)	1 (10%)[29]	5 (42%)[1,26,40-42]	3 (75%)[1,26,40]	3 (18%)[29,41,42]
For most subjects, side bending and rotation is coupled to the same side	2 (10%)[34,39]	39 (6%)	2 (20%)[34,39]*	1 (8%)[34]*	0 (0%)	2 (12%)[34,39]
For most subjects, coupling varies depending on the spinal level	7 (33%)[4,16,30-32,38,45]	288 (45%)	5 (50%)[4,30,31,38,45]	2 (17%)[16,32]	1 (25%)[16]	6 (35%)[4,30-32,38,45]
Coupling between side bending and rotation is inconsistent	4 (19%)[10,14,33,37]	88 (14%)	1 (10%)[37]	3 (25%)[10,14,33]	0 (0%)	4 (24%)[10,14,33,37]
For most subjects, coupling between side bending and rotation is nonexistent	2 (10%)[35,43]	55 (9%)	1 (10%)[35]	1 (8%)[43]	0 (0%)	2 (12%)[35,43]

** 1 study was performed on live subjects and cadavers.*

in most clinics and many of the techniques associated with these instruments have related health risks from radiation or invasive procedures. More advanced methods of determining the presence and direction of coupled motion, therefore, are not feasible in the clinical setting. The 2 most common methods of assessing coupled motion in the clinical setting are palpation and uniplanar radiography. It is highly unlikely that coupled motions of 2° or less are detectable with these more simple diagnostic methods. The determination of a patient's coupled motion pattern is, therefore, in all likelihood, not a realistic clinical examination tool. Even if it were feasible, the clinical relevance of a 1° or 2° impairment in coupled range of motion is questionable.

There are several concerns with our analysis of the research on coupled motion. One issue is the possibility that we incorrectly interpreted the results of some studies due to the lack of consistency across articles in describing coupled motion. For example, in many studies, the authors used terminology related to *x*, *y*, and *z* axes[4,11,18,22,28-34,40]; however, there was inconsistency regarding the direction that was represented by a particular axis across the papers we reviewed. One early article even used ambivalent terms such as *to and fro*, presumably to describe flexion and extension, respectively.[43] There is, therefore, the possibility that we could have misinterpreted the direction of motion described in some papers; however, both authors independently extracted information from each article, and when there was a discrepancy, we discussed the issue until a consensus was reached. Finally, there might have been an insufficient number of articles from which to draw concrete conclusions about the conditions that might affect coupled motion. For example, it is possible that the pattern of coupled motion was dependent on the subject's age or the method in which coupled motion was determined, but there were an insufficient number of studies within categories of age or method of determining coupled motion to identify a clear trend. This issue is further compounded by heterogeneity among subjects within studies.

CONCLUSION

The concept of coupled motion has been studied extensively with little consensus as to its presence and direction. These findings have implications for determining appropriate manual therapy evaluation and intervention techniques, as there does not appear to be a sound rationale for applying any of the principles of coupled motion to these procedures. Clinicians should, therefore, consider eliminating the use of the concept of coupled motion patterns in their evaluation and intervention for patients with lumbar spine conditions. Rather, clinical decisions regarding the determination of physical therapy interventions for patients with low back pain should focus on more validated examination procedures. Similarly, intervention components, such as positioning for low back mobilization/manipulation procedures, should not be based on a presumed pattern of joint coupling. ◉

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