Lumbar spine coupled motions: A literature review with clinical implications

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Introduction

Paris and Loubert[1] defined coupled motions as combined motions that are mechanically forced to occur. Kaltenborn et al[2] proposed a more clinically oriented definition describing coupled motions as movement combinations that result in the greatest ease of movement, i.e., producing the greatest range of motion and the softest endfeel. In biomechanical terms, coupled motion is the phenomenon of a consistent association of a motion along or about one axis, whether it be a translation or a rotation, with another motion about or along a second axis; the principal motion cannot be produced without the associated motion occurring as well[3]. Coupled motion can also be defined as the motion that occurs in directions other than the direction of the load applied[4,5].

Coupled motions have obvious implications for manual medicine and, therefore, text books on this topic usually provide descriptions of coupling behavior, e.g., in the lumbar spine[1,2,6-8] (Table 1). However, these text book descriptions are generally not supported by primary references[1,2,7]. If references are provided, they are frequently outdated and of questionable methodology[6,8]. Evidence-based practice (EBP) requires the use of best available research evidence[9]. Recently, Whitmore[10] produced a case report using a limited review of the literature on lumbar motion coupling to provide an evidence-based rationale for a manual medicine approach to the rehabilitation of low back pain (LBP) hypothesized to originate in mechanical dysfunction of L5-S1. A limited review of the literature carries the risk of not uncovering contradictory evidence. This goal of this article is to review the research evidence available on lumbar motion coupling. We will discuss the studies retrieved, review evidence for clinically relevant possible determinants of coupling behavior, and conclude with clinical implications of the evidence presented.

Method

A computerized search of the Medline database and the online contents of Spine were performed with the key words lumbar motion coupling. Further studies were provided from the author's personal library and the references of a recent review of lumbar spine coupling behavior[11]. With the exception of three references[12-14], all studies on three-dimensional motion coupling behavior of the lumbar spine were retrieved for this article[3-5,15-20].

Research studies

The spinal column is generally symmetrical about the sagittal plane[21]. Therefore, we might reasonably expect no or only minimal coupled motion associated with the sagittal plane movements of flexion and extension. Cholewicki et al[4] noted no coupled rotation or sidebending when applying flexion and extension moments to cadaveric lumbosacral spines. Hindle et al[15] found no coupled motion in vivo during flexion and extension in asymptomatic

Authors	Proposed lumbar motion coupling
Paris and Loubert[1]	• Contralateral rotation coupled to sidebending in erect spine
Kaltenborn et al[2]	• Contralateral rotation-sidebending coupling in extension • Ipsilateral rotation-sidebending coupling in flexion
Van der El[6]	• Contralateral rotation coupled to sidebending in spinal neutral and midrange extension • Ipsilateral rotation coupled to sidebending in flexion and end range extension
Greenman[7]	• Contralateral rotation coupled to sidebending in spinal neutral and extension • Ipsilateral rotation coupled to sidebending in flexion
Gatterman and Panzer[8]	• Contralateral rotation coupled to sidebending

Table 1: Coupling motion description in manual medicine text books.

subjects. Schuit and Rheault[16] reported only very small coupled motions in asymptomatic adults. Lund et al[20] reported small coupled motions of rotation and sidebending at (L4) L5-S1 in patients with chronic LBP. Oxland et al[5] found coupled motions of axial rotation and sidebending of less than 0.5° in both flexion and extension at L5-S1 in cadaveric spines. In contrast, Pearcy et al[17] did find coupled motion in asymptomatic individuals; they suggested that we consider coupled segmental rotation and sidebending greater than 4° in flexion and greater than 3° in extension an abnormal finding.

Frequently used manual therapy techniques emphasize non-sagittal plane movements[2,6-8,10]. The studies retrieved have researched the coupled motions occurring during either axial rotation or sidebending as the primary motion[3-5,15-20]. Table 2 reviews the coupled motions found with axial rotation as the primary motion, table 3 summarizes the coupling found during sidebending.

Determinants of lumbar spine coupling behavior

We could hypothesize that coupled motions in the lumbar spine are the possible result of multiple interacting clinically relevant factors, such as lumbar spine sagittal plane posture, age, gender, and pathology. Information on the influence these factors have on motion coupling behavior may facilitate a more appropriate choice of manual interventions.

Oxland et al[5] distinguished between postural and structural motion coupling. Postural coupling refers to the influence of the (degree of) lumbar lordosis and was hypothesized to occur as a result of differences in vertebral orientation throughout the spine. Structural coupling was defined as the result of the physical characteristics of the joints, e.g., articular tropism and intervertebral disk (IVD) degeneration. Panjabi et al[19] studied the effect of five sagittal plane postures on motion coupling in cadaveric lumbosacral spines. The different postures did not affect the

Authors	Method	Subjects	Findings
Cholewicki et al[4]	In vitro Stereophotogrammetry Segmental motion	9 fresh frozen L1-S1 male cadaveric spines No gross radiographic abnormalities (35-62 y.o.)	Ipsilateral SB L1-L4 Contralateral SB L4-L5 (smaller than at L5-S1) Contralateral SB L5-S1 (2° SB to every 1° of ROT) FL L1-S1
Hindle et al[15]	In vivo 3Space Isotrak Regional motion	80 asymptomatic subjects (20-65 y.o.)	Contralateral SB
Schuit and Rheault[16]	In vivo OSI C6000 Spine Motion Analyzer Regional motion	20 asymptomatic subjects (21-52 y.o.)	95% ipsilateral SB 5% contralateral SB Inconsistent FL or EXT
Pearcy and Tibrewal[17]	In vivo Biplanar radiography Segmental motion	10 asymptomatic subjects (21-30 y.o.)	Contralateral SB L1-L4 Ipsi/contralateral SB L4-L5 Ipsilateral SB L5-S1 FL $\leq$ 4° at L1-L4, 9° at L4-L5, 5° at L5-S1
Russell et al[18]	In vivo 3Space Isotrak Regional motion	171 asymptomatic subjects (20-69 y.o.)	Contralateral SB
Panjabi et al[19]	In vitro Stereophotogrammetry Segmental motion	6 fresh frozen L1-S1 cadaveric spines	Contralateral SB L1-L3 No coupling L3-L4 Ipsilateral SB L4-S1 FL L1-S1
Lund et al[20]	In vivo Transpedicular screws Optoelectronic tracking Segmental: (L4) L5-S1	12 patients Chronic LBP (26-62 y.o.)	7/12: right SB with bilateral ROT 3/12: ipsilateral SB with ROT 2/12: no coupled SB 3/12: ROT coupled with FL 6/12: ROT coupled with EXT 3/12: Inconsistent FL/EXT with ROT

Table 2: Coupling motion associated with rotation (ROT) SB=sidebending; FL=flexion; EXT=extension; LBP=low back pain; y.o. years old

direction of coupling between sidebending and rotation. As for associated sagittal plane movements, in four of five postures, the associated sagittal plane motion both during sidebending and rotation was flexion. Only in starting sidebend rotation in a maximal flexion position, was extension the coupled sagital motion associated with sidebending or rotation. Vicenzino and Twomey[3] studied the effects of submaximal flexion and extension combined with left or right sidebending on coupled rotation in cadaveric spines. As reported in Table 3, flexion and extension affected coupling behavior mainly in the mid-lumbar spine (L2-L5). Coupling at L1-L2 was contralateral, except for an ipsilateral coupling in flexion combined with right sidebending. Coupled rotation at L5-S1 was ipsilateral independent of spine position[3]. The influence of sagittal plane posture thus remains inconclusive except possibly at L5-S1, where both studies[3,19] found no influence of posture on coupling behavior. However, direction of coupling reported was opposite at L5-S1 in these studies again not allowing for clear conclusions.

Authors	Method	Subjects	Findings
Vicenzino and Twomey[2]	In vitro Transverse plane photography Segmental motion	4 fresh frozen L1-S1 cadaveric spines Rolander classification IVD degeneration 0-2 Facet tropism 1°-21°	Contralateral ROT at L1-L2 except for ipsilateral coupling in FL-SB right L2-L3 and L4-L5: ipsilateral ROT in EXT, contralateral ROT in FL L3-L4 contralateral ROT in EXT, ipsilateral ROT in FL L5-S1 ipsilateral ROT
Cholewicki et al[4]	In vitro Stereophotogrammetry Segmental motion	9 fresh frozen L1-S1 male cadaveric spines No gross radiographic abnormalities (35-62 y.o.)	Ipsilateral ROT L1-L4 (small) Contralateral ROT L4-L5 (excursion< 10% SB) Ipsilateral ROT L5-S1 (excursion 25% SB) FL L1-S1
Oxland et al[5]	In vitro Stereophotogrammetry Segmental motion: L5-S1	9 fresh frozen L1/2-S1 male cadaveric spines (35-62 y.o.)	Contralateral ROT L5-S1
Hindle et al[15]	In vivo 3Space Isotrak Regional motion	80 asymptomatic subjects (20-65 y.o.)	Contralateral ROT FL
Schuit and Rheault[16]	In vivo OSI C6000 Spine Motion Analyzer Regional motion	20 asymptomatic subjects (21-52 y.o.)	50% contralateral ROT 50% ipsilateral ROT FL
Pearcy and Tibrewal[17]	In vivo Biplanar radiography Segmental motion	10 asymptomatic subjects (22-37 y.o.)	Contralateral ROT L1-L5 Ipsilateral ROT L5-S1 EXT L1-L4 Occasional FL L4-L5 FL L5-S1
Russell et al[18]	In vivo 3Space Isotrak Regional motion	171 asymptomatic subjects (20-69 y.o.)	Contralateral ROT FL
Panjabi et al[19]	In vitro Stereophotogrammetry Segmental motion	6 fresh frozen L1-S1 cadaveric spines	Contralateral ROT L2-S1 No coupling L1-L2 FL L1-S1
Lund et al[20]	In vivo Transpedicular screws Optoelectronic tracking Segmental: (L4) L5-S1	22 patients Chronic LBP (26-62 y.o.)	11/22: ipsilateral ROT 8/22: no coupling 3/22: contralateral ROT 10/22: SB coupled with FL 3/22: SB coupled to EXT 9/22: inconsistent FL/EXT

Table 3: Coupled motion associated with sidebending (SB) ROT=rotation; FL=flexion; EXT=extension; LBP=low back pain; y.o.=years old

Age and gender may also affect motion coupling due to age-related segmental changes and between-gender differences in morphology. Hindle et al[15] studied coupling behavior in 80 asymptomatic subjects divided in four age groups (20-29; 30-39; 40-49; >50); 40 subjects were male, 40 were female. They found no changes in coupling behavior between men and women or related to age. Russell et al[18] studied 103 men and 68 women in five age groups adding a 60-69 year old group to the Hindle et al[15] study. They found that generally coupled motions were significantly smaller when comparing the older to the younger age groups, but noted that this may have been the result of greater effort by the younger age groups during cardinal plane motion tests with resultant associated motions. Conclusions are affected by the fact that both studies[15,18] researched regional lumbar motion, but this research does not seem to support differences in coupling behavior based on age or gender.

Pathology may be another factor responsible for coupling behavior. Coupled motions occur in cadaveric spines devoid of muscles: the role of muscles in producing coupling seems minor[3]. White and Panjabi[21] hypothesized a role for suboptimal muscle control to explain coupled motions during flexion and extension. Pearcy et al[22] reported a decrease in coupled L1-L2 and L4-L5 sidebending during sagittal plane motion in six patients with mechanical LBP after physiotherapy treatment consisting of abdominal strengthening and pelvic tilt exercises in addition to a back school educational program. They hypothesized a possible role for uni- or bilateral muscle contraction determining direction and range of motion of coupling. As for the influence of ligamentous lesions, Oxland et al[5] found no influence of sectioning the dorsal (interspinous, supraspinous, flaval, and capsular) ligaments on L5-S1 motion coupling. They did report that the IVD played a major role in limiting sidebending coupled to L5-S1 axial rotation. Vicenzino and Twomey[3] found no association between conjunct rotation and degree of IVD degeneration, but cautioned against generalization based on their findings due to the small number of specimens used and the low incidence of IVD degeneration in the specimens studied. In an additional study of 36 patients with LBP, Hindle et al[15] found a significant restriction in the amount of sidebending produced as a coupled motion with rotation in patients with diskogenic complaints. Lund et al[20] found no significant differences in motion coupling in patients with IVD degeneration versus patients post-laminectomy or post-diskectomy. Oxland et al[5] also reported that the zygapophyseal joints (ZJ) were mainly responsible for the flexion coupled to axial rotation and the axial rotation coupled to sidebending at L5-S1. Vicenzino and Twomey[3] found no association between facet tropism and coupling despite a mean facet tropism of 100 in their specimens. They also reported no influence of ZJ resection, but they did note that compressive preload might play a role in producing coupled rotation in the presence of facet tropism. Hindle et al[15] noted that in patients with ZJ complaints rotation as a coupled motion to sidebending was restricted. The research reviewed thus provides inconclusive data regarding the effect of muscle hypertonicity or dyscoordination, IVD and ZJ degeneration, and facet tropism on lumbar spine coupling behavior.

Discussion

The studies reviewed in this article used in vitro[2,4,5,19] and in vivo[15-18,20] assessments of lumbar spine motion coupling. It is unclear to which extent results from in vitro studies can be generalized to the patient population commonly seen in physiotherapy clinics. Some studies used asymptomatic subjects[15-18]: external validity to the patient encounter in physiotherapy would again seem limited or at best unclear. Some studies assessed regional[15,16,18] rather than segmental motions[2,4,5,17,19,20]. Regional studies will not provide the information most useful to the manual medicine practitioner interested in segmental motion behavior. Measurement methods included stereophotogrammetry[4,5,19], biplanar radiography[17], externally applied electromagnetic motion analyzers[15,16,18], and percutaneous pins with optoelectronic tracking[20]. Biplanar radiography only allows for end range static measurements possibly less relevant to the manual medicine practitioner interested in midrange mechanical behavior of the patient with joint hypomobility. Soft tissue movements may affect the reliability and validity of measurements made with externally applied motion analyzers. One may wonder what the effect of percutaneous transpedicular pins is on the normal motion behavior of subjects.

The research reviewed in this article indicated no differences based on age or gender with regards to lumbar motion coupling behavior. The evidence presented on the role of sagittal plane posture, muscle hypertonicity or dyscoordination, IVD and ZJ degeneration, and ZJ tropism is inconclusive.

Clinical implications

The research reviewed in this article shows that no consensus exists on the direction and magnitude of segmental coupled motions associated with all three cardinal plane motions in the lumbar spine. In addition, the research available is inconclusive regarding the effects of sagittal plane posture and clinically relevant pathology on motion coupling behavior. Age and gender have not been shown to affect coupling behavior. The research also indicates that coupled motion may differ depending on whether the principal motion used, e.g., as a mobilizing force in manual therapy techniques, is rotation or sidebending.

Obviously, relying on non- or poorly referenced descriptions of motion coupling behavior in manual medicine text books[1,2,6-8] or on conclusions based on a limited review of the available research[10] is not consistent with EBP. Patient pathology, sagittal plane posture during manual techniques, and principal mobilizing motion during these interventions also provide no conclusive information on the coupling behavior to be expected in the lumbar spine. Vicenzino and Twomey[3] suggested that, in the absence of a clear consensus, the therapist should use clinical assessment findings, especially those of passive intervertebral motion (PIVM) tests as the basis for treatment selection. However, inter-rater reliability and validity of these PIVM tests have not shown to be sufficient to establish a diagnosis based on these tests[23,24]. Clinicians need to keep in mind that inter-individual differences in motion coupling behavior will affect choice of especially manual interventions for treatment of mechanical dysfunctions of the lumbar spine. At this time, no evidence-based diagnostic tools in either history or physical examination seem to be available to the primary care manual medicine practitioner to determine the nature of these inter-individual differences.

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