Review Article :

Lumbar Segmental Instability Classification: Functional, Structural and Multiple Instability

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Abstract

Low back pain (LBP) is a widespread condition. One of the common cause of LBP is lumbar segmental instability (LSI). The understanding of LSI can be improved by dividing cases into three subcategories: functional instability; if neuromuscular system is dysfunctional, structural instability; if osseoligamentous structure is disrupted, and multiple instability; if both subcategories are existed. Elucidating distinctions between sub-classifications might improve common understanding regarding LSI subcategories among physical therapists, radiologists and spinal physicians. The purpose of this review is to highlight the distinctions among the three LSI subcategories, which includes their definitions, scientific evidence, and clinical tests. This review will help to improve understanding of LSI and guide clinical diagnostic decisions. Additionally, this review might help in future research on LSI into three distinct and clinically meaningful sub-classifications.

Keywords:

Low back pain, Lumbar segmental instability, Classification, Functional instability, Structural instability, Multiple instability.

الملخص

آلام أسفل الظهر (LBP) هي حالة منتشرة. أحد الأسباب الشائعة لـ LBP هو عدم استقرار أو ثبات الفقرات القطنية(LSI) . يمكن تحسين فهم LSI عن طريق تقسيم الحالات المرضية الى ثلاث فئات فرعية: عدم استقرار الفقرات وظيفيا؛ إذا قلّة كفاءة النظام (العصبي-العضلي). عدم استقرار الفقرات بنائيا؛ إذا قلّة كفاءة النظام (الهيكلي-الرباطي). عدم الاستقرار المضاعف؛ إذا تأثر كلا النظامين في آن واحد. قد يؤدي إيضاح الفروق بين التصنيفات الفرعية إلى تحسين الفهم المشترك فيما يتعلق بفئات LSI الفرعية بين أخصائيي العلاج الطبيعي وأطباء الأشعة وأطباء العمود الفقري. الغرض من هذه المراجعة هو تسليط الضوء على الفوارق بين فئات LSI الفرعية الثلاثة، والتي تشمل تعريفاتها، والأدلة العلمية، والاختبارات السريرية. تساعد هذه المراجعة في تحسين فهم LSI وتوجيه قرارات التشخيص السريري. علاوة على ذلك، قد تساعد هذه المراجعة في توجيه الأبحاث المستقبلية حول LSI الى ثلاثة تصنيفات فرعية مميزه وذات مغزى سريري.

الكلمات المفتاحية :

آلام أسفل الظهر، عدم استقرار الفقرات القطنية، التصنيف، عدم الاستقرار الوظيفي، عدم الاستقرار الهيكلي الرباطي، عدم الاستقرار المضاعف.

INTRODUCTION:

Lumbar segmental instability (LSI) is believed to be a main cause of the high recurrence rates of low back pain (LBP)[1]. However, concept of LSI is different among different specialties [2]. For example, spinal surgeons view LSI as segmental movement that exceeds normal segmental range of motion (ROM), especially at end-ROM[2]. In contrast, physiotherapists view LSI as neuromuscular control error across motion segments, especially at mid-ROM[3]. Both types lead to excessive tissue elongation/ compression and thus irritation/injury of the soft tissues of motion segment [4]. Despite unique features, both can exist separately or jointly (multiple instability).

The main aim of this review is to highlight distinctions among LSI sub-classifications: Functional, structural, and multiple instability. Elucidating distinctions between sub-classifications might improve common understanding regarding LSI subcategories among physical therapists, radiologists and spinal physicians [5]. Additionally, this review might help in future research on LSI into three distinct and clinically meaningful sub-classifications.

Lumbar segmental instability:

In normal tasks of daily living, e.g. bending forward, each spinal segment slide forward and rotate [2]. Therefore, if one segment suddenly moves beyond its normal range, spinal structures may sustain overstretch/compression injuries/irritation [3,4]. Instability is defined as loss of segmental stiffness or abnormal response to applied loads characterized by movement of motion segments beyond normal constraints [6]. Panjabi proposed a biomechanical model of spinal stabilization system involving three anatomical subsystems: passive, active and neural control subsystems [4] (Figure-1).

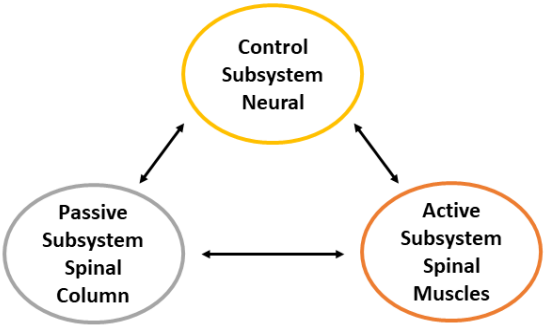


Figure 1. the spinal stability system consists of three subsystems: passive spinal column, active spinal muscles and neural control unit

However, the main function of the neuromuscular control subsystem is to orchestrate adequate and timely orders to ensure appropriate muscular recruitment [7]. This leads LSI classification into: 1)functional instability, if active(neuromuscular) system is dysfunctional; 2)structural instability, if passive (osseoligamentous) system is disrupted; and 3) multiple instability, if both systems are affected (Figure-2).

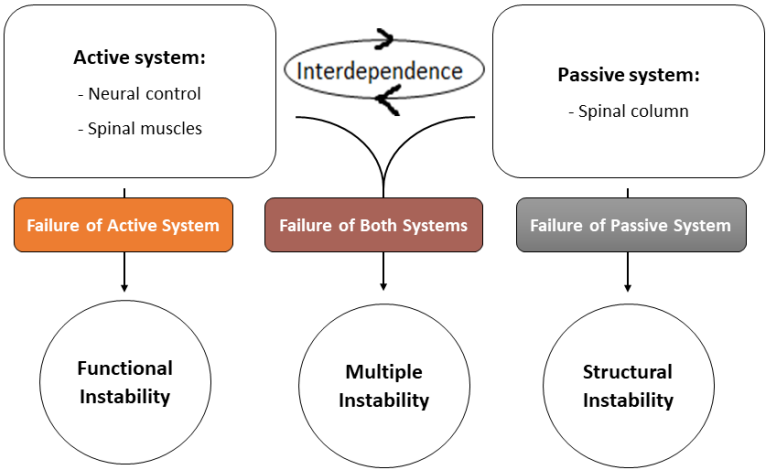


Figure 2. Relationship between the binary stabilization system and the SLI classification

LSI patients have LBP during spinal movement, positioning/sustained postures[8]. The patient report "giving-way"/"slipping" sensation [9]. Symptoms decrease with rest and bracing [10].

Functional (patho-mechanical) instability:

Functional instability refers to "a significant decrease in capacity of active system to maintain the intervertebral neutral zones within physiological limits[expansion of neutral zone] so that there is no neurological dysfunction, no major deformity and no incapacitating pain"[11]. (Figure-3)

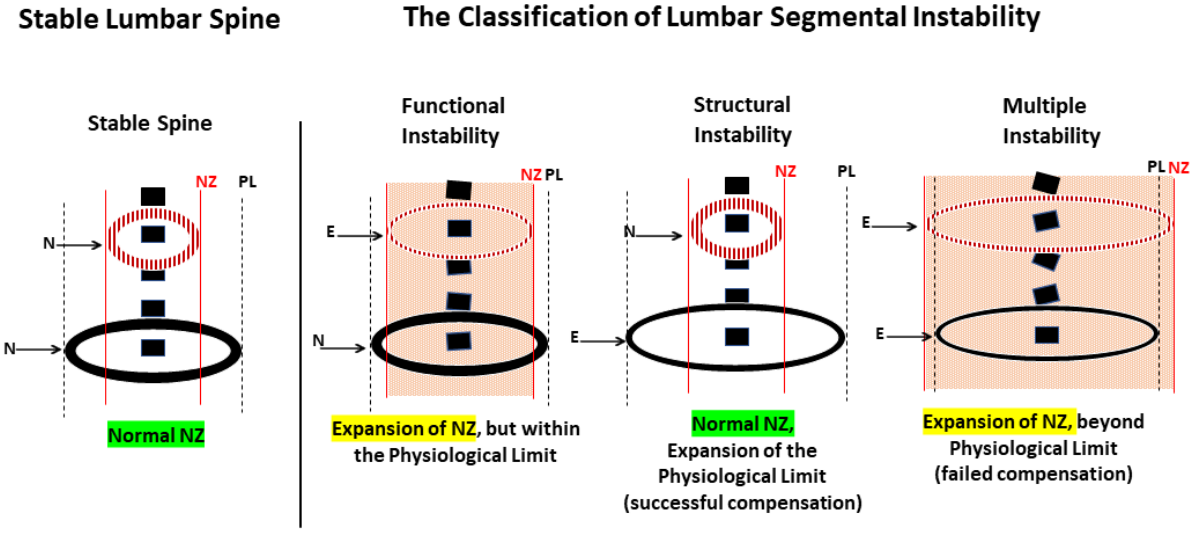


Figure 3: Theoretical interaction between the active system (red circles) and passive system (black circles) and their effects on the size of the neutral zone (NZ) in the stable lumbar spine and instability subcategories. NZ: neutral zone; PL: physiological limit; N: normal; E: expansion.

If spinal segment is unable to support load and maintain a normal pattern of displacement, it is considered unstable, which may generate LBP [12].

Evidence of Functional Instability:

Studies have reported abnormal increase in lumbar segmental translation in patients with recurrent LBP [13,14]. Other studies have reported muscular deficits at pain level or increased fatty tissue infiltration leading to acute [15], chronic and recurrent LBP [16]. Wallwork et al.[17] reported an association in chronic LBP patients between lumbar multifidus muscle(LMM) atrophy and reduced voluntary isometric muscle contraction. Furthermore, Tsao et al. found an association between recurrent LBP and adaptive motor cortex remapping favouring superficial fascicles of the longissimus erector spinae at expense of the deep fibres of the LMM [18]. Lastly, LBP patients demonstrated reduced proprioception, impaired postural control and impaired ability to react to perturbations [19]. All this evidence may indicate a deficit of the active system, which may increase the risk of lumbar spine buckling injuries as a result of delayed and inefficient spinal muscular recruitment.

Functional Instability Tests:

Hicks et al. proposed four predictors that, together, form the clinical prediction rule (CPR) for determining which LBP patients will respond to stabilization exercise[20]. CPR involves four variables [21]: age <40 years, positive result for Prone Instability Test (PIT), presence of aberrant lumbar movement during trunk motion testing and a mean straight leg raise (SLR) >91°. If CPR is positive (three of four variables are present), likelihood of stabilization success increases from 33% to 67%. CPR was validated in two treatment-based classification studies [22,23] and reliability ranges from substantial to excellent [21]. Another CPR validity study, Rabin et al.[24] proposed a modified CPR that involves only two items (the presence of aberrant movement and a positive PIT) and had an improved predictive validity for identifying individuals most likely to succeed with stabilization exercise, but this requires further validation.

Structural (Radiographic/Pathoanatomical) Instability:

Structural/radiographic instability refers to "disruption of passive stabilizers and decreased structural integrity"[25] due to progressive degenerative changes [4]. The main feature of segmental osseoligamentous structures is passive stability at physiological end-ROM. (Figure-3)

Evidence of Structural Instability:

Various imaging techniques such as radi-

ography, CT, and MRI are used to visualize structural abnormalities. Carragee et al. found that about 90% of 200 asymptomatic subjects had radiographic signs of abnormality, despite not having LBP. Among asymptomatic subjects , 36% had a herniated disc, 21% had spinal stenosis and >90% had a degenerated disc [26]. More pertinently, LSI radiographic studies have reported high false-positive rates for individuals without LBP [2].

As the majority of people with static radiographic signs are asymptomatic, it is important to realize that these signs might indicate a previous period of degenerative instability that resulted in re-stabilization [9]. Thus, static radiographic signs of degenerative instability are part of normal aging and their usefulness depends on establishing a cause-and-effect relationship between them and clinical presentation among LSI patients [2].

Structural Instability Tests:

Widely used assessment method is flexion-extension/dynamic radiography, which was first described by Knuttson to identify and quantify abnormal anterior-to-posterior translation of the motion segments at end-ROM [27].Common criteria for structural instability diagnosis is 3 mm or 9% of vertebral body width on flexion-extension radiograph or 9° of sagittal plane rotation between the L1–L5 motion segments. There are a number of clinical tests that are reported to predict dynamic radiograph findings [28] (Table 1).

Table 1: Clinical tests predicting dynamic radiograph findings

Author	Test	Reliability	Sensitivity (95% CI)	Specificity (95% CI)	+LR (95% CI)	–LR (95% CI)
Kasai et al.[29]	PLET	k=0.46 to 0.76	84 (68, 93)	90 (82, 96)	8.8 (4.5, 17.3)	0.2 (0.1, 0.4)
Esmailiejah et al.[30]	PLET	-	78.8	94.7	19.44 (2.80, 135)	0.29 (0.15, 0.55)
Abbott et al[.31]	PPIVM (flexion)	-	5 (1, 22)	99.5 (97, 100)	8.7 (0.6,134.7)	1.0 (0.9, 1.1)
	PPIVM (extension)	-	16 (6, 38)	98 (94, 99)	7.1 (1.7, 29.2)	0.9 (0.7, 1.1)
Fritz et al.[13]	Lack of intervertebral hypomobility	k=-0.2 to 0.3	43 (0.27, 0.61)	95 (0.77, 0.99)	9.0 (1.3, 63.9)	0.60 (0.43, 0.84)

k=kappa coefficients; +LR=positive likelihood ratio; –LR=negative likelihood ratio; PPIVM=Passive Physiological Intervertebral Movements; PLET=Passive lumbar extension test.

Multiple (pathomechanical/ pathoanatomical) Instability:

Multiple instability is defined as "expansion of the neutral region that cannot be held at physiological limits when a problem occurs in subsystems that provide sta-

bility in the spine" [32] (Figure-3).

Clinically, multiple instability can be defined as; an expansion of intervertebral motion of the lumbar spine beyond physiological limits that causes chronic intractable LBP (with or without sciatica) due to suboptimal generation of stiffness by both active and passive systems".

Evidence of Multiple Instability:

Panjabi hypothesized that sub-failure ligament injuries due to single or cumulative micro-traumas generates corrupted signals to the neuromuscular control unit, which in turn produces a corrupted muscular response. The persistently inaccurate muscular response produces higher stresses and strains on the spinal components, leading to further sub-failure [16].

Accumulated evidence links spinal osseoligamentous injuries or degeneration to neuromuscular control impairments that indicate multiple instability. For example, experimentally induced intervertebral disk injury causes focal atrophy, as indicated by decreased LMM cross-sectional area at the relevant level in a porcine [33] model and in patients with disk herniation [34,35]. Furthermore, spinal degeneration conditions are associated with decreased density of the paraspinal muscles [36]. More recent, 22 consecutive patients undergoing surgery due to chronic degenerative lumbar spine pathology were found to have high levels of LMM degeneration [37].This further confirms relationship between degenerative osseoligamentous structures and dysfunction of active subsystem in LBP patients.

Multiple Instability Tests:

To categorize a case of LSI as multiple instability, both functional and radiographic instability tests have to be positive.

Conservative treatment of lumbar segmental instability:

In functional instability, the neutral zone (NZ) expansion can overstretch and/or compress spinal structures beyond their normal NZ limits. However, the expansion does not pass the physiological limits. Therefore, although the flexion-extension radiography results are negative, patient signs and symptoms can indicate functional instability (false-negative). Therefore, historically, functional instability diagnosis has been considered as a diagnosis of exclusion [28]. In contrast, multiple instability affects both the active and passive systems, so the expansion of the NZ passes the physiological limits, which can be observed on flexion-extension radiographs. Contrary, structural instability is a potential rather than an actual instability sub-classification that represents disruption and deterioration of the passive stabilizers, which might be masked (successful com-

pensation) primarily by the active system. However, if the compensation fails, the segmental motions will exceed the physiological limits, causing multiple instability. Based on this model, we can predict that functional and multiple instabilities are reversable (Figure 4).

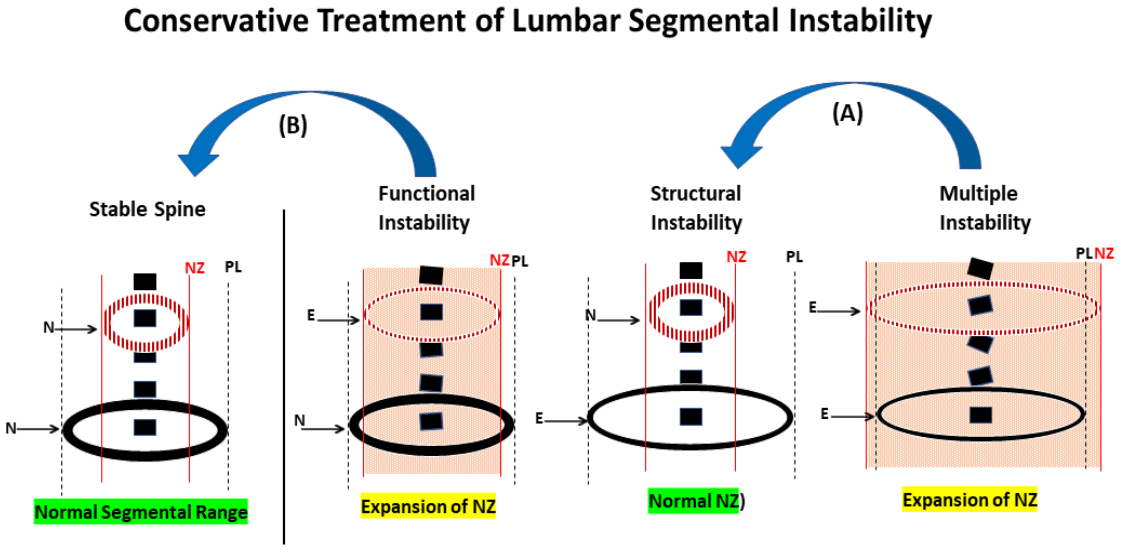


Figure 4: The arrows indicate the translation of patient classification from: (A) the expansion of NZ classifications (multiple instability) to potentially normal NZ classification (structural instability) and (B) the expansion of NZ classifications (functional instability) to normal NZ classification (healthy stable spine).

CONCLUSIONS:

In this review, we proposed clinical LSI classification system involving functional, structural and multiple instability that are based on reformulation of Panjabi's theory. Two clinical instability sub classifications are caused by expansion of NZ: functional and multiple instability, primarily due to active stabilization system dysfunction.

As stabilization exercises can restore functionality of active system, which subsequently restores the normal NZ, multiple instability can be reversed to produce structural instability and functional instability can be reversed to produce a stable spine.

SOURCE OF FUNDING

NIL

CONFLICT OF INTEREST

NIL

KEY POINTS:

- The understanding of clinical concept of LSI can be improved by dividing LSI individuals into three subcategories: functional, structural and multiple instability.
- Active (neuromuscular) system dysfunctionality may cause LBP due to expansion of NZ.

- The improvement of patients' outcome due to stabilization exercises can be attributed to restoration of active system functionality, thus, restoration of normal NZ.
- Because active stabilization system is trainable, multiple instability and functional instability can be reversed to produce structural instability and stable spine, respectively.

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