Journal of
*Functional Morphology and Kinesiology*

MDPI

*Review*

# Do Muscle Strength Imbalances and Low Flexibility Levels Lead to Low Back Pain? A Brief Review

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Received: 15 July 2017; Accepted: 3 August 2017; Published: 4 August 2017

**Abstract:** Chronic low back pain (CLBP) has been related to hips, trunk and spine strength imbalances and/or low flexibility levels. However, it is not clear if the assessment and normalization of these variables are effective for prevention of low back pain (LBP) episodes and rehabilitation of patients with CLBP. This brief review explored studies that have associated hip, trunk and spine strength imbalances and/or low flexibility levels to LBP episodes or CLBP condition. Fourteen studies were selected by accessing PubMed and Google Scholar databases. Collectively, the selected studies demonstrate that trunk eccentric/concentric and flexion/extension strength imbalances may be associated with CLBP or LBP episodes. However, the literature fails to demonstrate any clear relationship between hip strength imbalances or low levels of spine flexibility with CLBP or LBP episodes. In addition, there is no direct evidence to support the idea that the normalization of these variables due to resistance and flexibility training leads to pain reduction and functionality improvements in subjects with CLBP. Although further investigation is needed, the lack of a clear direct association between hip strength imbalances or spine low flexibility levels to CLBP or LBP episodes may demonstrate that these variables may have very low effect within the complexity of these conditions.

**Keywords:** chronic low back pain; low back pain episodes; strength ratios; side-to-side asymmetry; flexibility levels

## 1. Introduction

Chronic low back pain (CLBP) is considered one of the main health care problems of the modern day society [1]. Up to 80% of the population report having low back pain (LBP) at some point of their lives, and after a first LBP episode, 44–78% have relapses of pain, leading 26–37% of people to be absent from work after an initial episode [2]. If the problem persists within approximately 12 weeks it may become chronic [3]. The prevalence of nonspecific CLBP is approximately 23%, and 11–12% of people may become disabled by this condition [2]. However, since CLBP is considered a multi-factorial problem, which consists of patho-anatomical, psychological, social, neuro-physiological and physical aspects, the treatment of this condition may be difficult, representing a major cost health problem for society [3–6].

Although most cases of LBP are considered to be non-specific, previous studies have related these conditions to compressive and repetitive muscle strength performance [7], as well as to bilateral and/or unilateral strength imbalances, especially of trunk and hips, which ensure mechanical stability of the spine [1,4,7–12]. For instance, antagonist/agonist, eccentric/concentric, and right/left muscle strength imbalances have been associated to LBP occurrence [11–14]. In addition, low levels of flexibility and muscle activation have been reported in patients with CLBP, having been pointed out as possible causes of this condition [1,15,16].

The knowledge of the effect of unilateral and bilateral strength imbalances and low flexibility levels on the cause of LBP episodes is critical for the prescription of exercises to reduce the symptoms of this condition. However, it is not clear if the assessment and normalization of these variables are effective for the prevention of LBP episodes and rehabilitation of patients with CLBP. Therefore, the aim of this study was to explore studies that have investigated associations between strength imbalances and/or low flexibility levels of trunk, spine and hips and LBP episodes or CLBP conditions.

## 2. Materials and Methods

This review was based on 14 studies [1,4,7–18], published between 1983 and 2016. The articles were found by accessing the databases PubMed and Google Scholar using the following search terms: “Spine” or “Hips” or “Trunk” and “Muscle” and/or “Strength” and/or “Flexibility” and “Levels” or “Imbalance” and “Chronic low back pain” or “Low back pain” (e.g., “Hips muscle strength imbalance and low back pain”). Articles that did not match these terms were excluded, and only studies in the English language were considered. Fifteen additional articles [2,3,5,6,19–29] were used to support the variables investigated in the introduction and discussion of this review. In the present review, the term “spine” refers to the spinal column, while the term “trunk” refers to the anterior and posterior muscles of the trunk.

## 3. Results

Details of the main aims, samples, outcome measures and main results of the 14 selected studies found through our search terms are described on Table 1. Based on the results of the selected studies, three main topics were considered for discussion of LBP episodes and chronic prevalence: strength and/or flexibility of trunk, spine and hips; unilateral trunk flexion/extension strength imbalances; and hip and trunk side-to-side strength asymmetries.

**Table 1.** Summary of studies.

| Topic | Authors | Main Aims | Sample | Outcome Measures | Main Results |
|---|---|---|---|---|---|
| Strength and/or Flexibility levels of Trunk, Spine and Hips | Bayramoglu et al. 2001 * | To compare women with and without CLBP on obesity, spine flexibility, levels of pain, and trunk strength. In addition, to test the association between these variables, and to investigate the effect of a follow-up strength training on the CLBP group. | 45 women (25 with CLBP and 20 without CLBP). | - BMI.<br>- Isokinetic trunk flexion-extension PT. | Women with CLBP had lower flexor and extensor trunk muscle peak torques, greater BMI and lower spine ROM. Strength training resulted in greater flexor and extensor trunk muscle strength, and reduced trunk flexor/extensor ratio (60°/sec only). No correlation between levels of pain and trunk muscle strength or spinal ROM. |
| | Renkawitz et al. 2006 | To examine the relationship between LBP, clinical symptoms, neuromuscular imbalance and trunk strength extension before and after exercise program. | 82 amateur tennis players with (19 females and 27 males) and without (12 females and 24 males) LBP. | - Trunk extension isometric MVC<br>- Spine mobility and flexibility. | Although there was a significant correlation between LBP and neuromuscular imbalance of erector spinae, no clear associations between LBP, trunk extension strength, and clinical testings were found before and after the exercise program. |
| | Grosdent et al. 2015 ** | To compare tennis players with and without LBP on trunk strength and flexibility. | 60 male elite tennis players with (38) and without (22) LBP. | - Trunk extension, rotation, flexion and lateral-flexion isometric MVC<br>- Pelvic and lumbar flexion mobility. | No significant difference between tennis players with and without LBP on trunk strength and spine flexibility. |
| | Nadler et al. 1998 | To investigate if leg length discrepancy, lower extremity laxity and hip flexor tightness were predictors of LBP. | 257 college athletes (170 males and 87 females). | - Hip flexors flexibility.<br>- Leg length discrepancy.<br>- Ligamentous stability.<br>- Overuse syndrome. | Although ligamentous laxity or overuse were found to be potential predictors of LBP, leg length discrepancy and hip inflexibility were not associated to future LBP episodes. |
| | Lee et al. 1999 * | To evaluate trunk strength weakness as a risk factor of LBP in a 5-year prospective study. | 30 male and 37 female young adults with no history of LBP. | - Isokinetic trunk flexion-extension and rotation PT. | Participants with history of LBP in the following 5 years (8 male and 10 female) did not differ from the non-LBP incidence group on trunk flexion-extension and rotation PT. However, women with LBP had lower extension/flexion ratio compared to women without LBP. |
| | Arab et al. 2010 | To investigate hip abductors strength and ITB tightness in subjects with LBP. | 300 (100 with LBP + ITB; 100 with LBP only; 100 without LBP). | - Hip abduction isometric MVC<br>- Length of ITB test. | No significant difference in hip strength levels between LBP individuals with and without ITB. However, subjects without LBP had greater hip abductor strength compared to subjects with LBP. |
| | Carpes et al. 2008 | To evaluate the effects of a short training program on trunk strength and stability of subjects with CLBP. | 6 subjects with one year of nonspecific LBP. | - Qualitative pain grade test.<br>- Low back stabilization tests<br>- Low back and pelvis kinematics.<br>- Body balance<br>- Strength and stability of low back and pelvis complex. | Participants with CLBP improved 3-D kinematics, body balance, pelvis inclination, and low back flexion ROM. Qualitative pain grade test indicated pain decreased and pelvic strength increased. |

**Table 1.** *Cont.*

| Topic | Authors | Main Aims | Sample | Outcome Measures | Main Results |
|---|---|---|---|---|---|
| Unilateral Trunk Flexion/Extension strength Imbalances | Shirado et al. 1995 | To compare trunk extensors and flexors strength between different assessment positions of the isokinetic dynamometer, and flexor/extensor strength ratios between subjects with and without CLBP. | 50 healthy subjects (25 males and 25 females) and 48 patients with CLBP (26 males and 22 females). | - Isokinetic concentric and eccentric trunk flexion-extension PT. | Trunk flexion-extension PT was greater in the siting posture with feet against the floor. Flexion/extension and eccentric/concentric strength ratios were greater in subjects with CLBP at almost all isokinetic speeds compared to non-CLBP. |
| | Oddsson et al. 2003 | To compare lumbar muscle strength, neuromuscular fatigue, and muscle imbalances between subjects with and without CLBP. | 34 male adults (20 healthy and 14 CLBP patients). | - Trunk extension isometric MVC.<br>- EMG over L1, L2 and L5 levels of lower back<br>- Subjective pain tests. | CLBP patients showed less fatigue and did not produce a "true" maximal torque. Muscle imbalances were present in both groups, although greater in CLBP when averaged. Patients with CLBP had altered lumbar back EMG. |
| | Correia et al. 2016 | To compare trunk endurance time, muscle activation and fatigue in tennis players with and without low back pain. | 35 (28 males and 7 females) national level tennis players. | - Trunk flexion, extension and side bridge isometric endurance strength.<br>- History of LBP incidence EMG of rectus abdominis, external oblique, iliocostalis lumborum and longuissimus thoracis. | Players with LBP had lower muscle activation of trunk extensor muscles, less abdominal endurance, and less trunk extensor co-contraction patterns. |
| | Suzuki et al. 1983 | To determine if trunk levels of strength and fatigue are related to low-back-pain syndrome, and the association between trunk muscle strength and lumbar lordosis. | 140 (90 patients with persistent LBP and 40 healthy free pain adults) participants. | - Isokinetic trunk flexion-extension PT. | Patients with CLBP had lower muscle strength and greater muscle fatigue of trunk flexors than extensors. In addition, trunk strength and fatigue were negatively associated to lumbar lordosis. |
| Hip and Trunk side-to-side strength asymmetries | Nadler et al. 2000 | To investigate the association between LBP and previous LE on hip abduction and extension side-to-side strength asymmetries of Division I collegiate athletes. | 210 (140 males and 70 females) Division I collegiate athletes. | - Hip abduction and extension isometric mean MVC.<br>- History of LBP incidence. | Only female athletes with LBP or LE presented greater side-to-side hip extensors asymmetry compared to athletes without LBP or LE. There was no side-to-side asymmetry difference between male tennis players with and without LBP or LE. |
| | Nadler et al. 2001 | To investigate if athletes with hip side-to-side strength asymmetry would be more likely to need treatment of LBP over the subsequent year on Division I collegiate athletes. | 163 (100 males and 63 females) Division I collegiate athletes. | - Hip abduction and extension isometric MVC<br>- History of LBP incidence. | Side to side hip extensor strength asymmetry was predictive of LBP treatment over the ensuing year for female athletes. No association was found between hip abductor side-to-side asymmetry in women or hip abductor and hip extensor side-to-side asymmetries and prediction of LBP in male athletes. |
| | Nadler et al. 2002 | To investigate the effects of core-strengthening training on LBP incidence on Division I collegiate athletes. | 1st year: 166 (101 males and 63 females); 2nd year: 236 (162 males and 74 females); 3rd year: 225 (170 males and 55 females) Division I collegiate athletes. | - Hip extension isometric mean MVC.<br>- Monitoring of LBP incidence. | Although core strengthening training reduced hip extensor side-to-side asymmetry, there was no effect of on LBP incidence reduction. |

* Articles were also discussed in topic: Unilateral Trunk Flexion/Extension Strength Imbalances; ** Article was also discussed in topic: Hip and Trunk Side-to-Side Strength Asymmetries. Abbreviations: CLBP = Chronic Low Back Pain; LBP = Low Back Pain; LE = Lower Extremity Injury; EMG = Electromyography; PT = Peak Torque; MVC = Maximum Voluntary Contraction; ITB = Iliotibial Band; ROM = Range of Motion; BMI = Body Mass Index.

## 4. Discussion

### 4.1. Strength and/or Flexibility of Trunk, Spine and Hips

Low levels of strength and/or flexibility of trunk, spine and hips have been pointed out as either causes, consequences or influencing factors for the prevalence of the CLBP condition [1,4,7–10]. Bayramoglu et al. [1] compared women with and without CLBP on obesity, spine flexibility and trunk strength. Obesity was calculated by body mass index (BMI), flexibility and strength by using an isokinetic dynamometer. Levels of pain and functionality were assessed by the Oswestry Disability Questionnaire. Results demonstrated that women with CLBP had lower flexor (60°/sec = 42.8 ± 12.8%; 120°/sec = 56.8 ± 35.0%; 120°/sec = 46.9 ± 33.3%) and extensor (60°/sec = 57.7 ± 30.3%; 120°/sec = 73.7 ± 19.8%; 180°/sec = 46.4 ± 51.7%) trunk muscle peak torques, as well as greater BMI (9.9 ± 0.5%) and a lower spine range of motion (ROM) (11.6 ± 42.6%). In addition, a 15-day follow-up strength training program was performed by the CLBP group after testing, which included double straight leg-lowers, sit-ups, and prone trunk extensions. Training resulted in significantly greater flexor and extensor trunk muscle strength. However, although the authors concluded that strength and flexibility training associated with weight reduction could potentially improve the CLBP condition by improving trunk strength and spinal ROM, they were unable to find significant correlations between functionality and pain with low levels of trunk strength or spine ROM. In addition, the initial (38.64) and end (38.01) mean scores obtained by the Oswestry Disability Questionnaire did not present a statistical difference.

This is in agreement with Renkawitz et al. [8], who did not find a direct association between LBP and trunk extensor maximal isometric strength in tennis athletes after an intervention program including exercises for strength, coordination, and mobility, as well as trunk and lumbar stretching exercises. In addition, Grosdent et al. [7] failed to find differences between tennis players with or without current LBP in terms of trunk isometric torque and spine ROM, which may also demonstrate a low relationship between levels of strength and flexibility as cause or prevalence of CLBP condition. In agreement with these studies, Nadler et al. [4] did not find any significant relationship between low levels of hip flexibility and rate of collegiate athletes requiring treatment for LBP; Arab et al. [17] did not find any significant difference in hip strength levels between LBP individuals with and without iliotibial tightness, which is associated and common during CLBP, and Lee et al. [10] did not find significant differences between young adults with and without LBP in trunk flexor and extensor isokinetic peak torque.

In contrast, Carpes et al. [9], in a pilot study, found that 20 sessions of training including trunk strength and stability exercises led to low back pain reduction, improvements of limbo-pelvic strength, spine and pelvis flexibility, reduction of lumbar lordosis, as well as improvements in postural stability of a sample of 6 female participants. However, the authors concluded that the small sample size and lack of control group for comparison of the effects of training on the investigated variables could lead to misinterpretations, and required future studies addressing these methodological issues for confirmation of their results.

### 4.2. Unilateral Trunk Flexion/Extension Strength Imbalances

Muscle strength ratios are commonly tested to describe unilateral antagonist to agonist strength properties, functionality and imbalances [19,20,24–26,29]. An increased antagonist/agonist imbalance may demonstrate failure of the antagonist muscles to produce enough strength to decelerate agonist maximal torque actions during a required movement, increasing the likelihood of muscle and ligament injuries during sports performance and functional activities [21,22,25,26,29]. Therefore, unilateral imbalances have also been investigated as possible causes leading to a CLBP condition [1,12,18].

Shirado et al. [12] compared trunk extensor and flexor strength between different assessment positions of the isokinetic dynamometer, as well as trunk flexor/extensor strength ratios in men and women with and without CLBP. They found that concentric and eccentric flexion/extension strength ratios were greater in subjects with CLBP at almost all isokinetic speeds tested compared to non-CLBP. This demonstrates that a CLBP condition may result in greater than normal trunk flexion strength than extension when trunk extension movements are performed, resulting in a trunk strength imbalance. Interestingly, Bayramoglu et al. [1] found that a short strength training program in which two trunk flexion (double straight leg-lowers, sit-ups) and one trunk extension (prone trunk extensions) exercises were included lead to a significant decrease on concentric flexion/extension ratio at a slow isokinetic speed (60°/sec = 32.2 ± 29.3%), but did not significantly change the ratio at intermediate (120°/sec = 14.9 ± 37.1%) and high isokinetic speeds (180°/sec = 4.5 ± 36.1%) in participants with CLBP. This may show that subjects with CLBP may need to greatly activate trunk flexor (antagonists) strength to decelerate trunk extensors (agonists) during trunk extension actions. However, Lee et al. [10] demonstrated that subjects with LBP had lower trunk extension/flexion ratio at 60°/sec compared to subjects without LBP (men = 22.0 ± 3.6%; women = 23.0 ± 15.8%), which shows that trunk extension strength is reduced when trunk flexion movements are performed. Contrary to these findings, Suzuki et al. [18] did not find any difference in trunk flexion/extension strength ratio between patients with persistent LBP compared to healthy participants, but the fatigability of trunk flexors was significantly greater (18.3 ± 1.4%) for the group with LBP. Therefore, these results show that subjects with LBP may use different strategies and distinct strength patterns to perform trunk extension and flexion movements due to increased pain or caution.

Shirado et al. [12] also found that subjects with CLBP had approximately 2 to 4 times greater unilateral eccentric/concentric ratios of trunk flexors and extensors through all slow-fast tested isokinetic velocities compared to non-CLBP. The authors assumed that this ratio would be an important muscle strength balance measurement in CLBP patients as trunk extensors and flexors are activated either concentrically or eccentrically in several daily life tasks. Since eccentric strength is used to decelerate and control movements [24–28], this may demonstrate that subjects with CLBP constantly perform extreme and unnecessary levels of eccentric strength when performing trunk extension and flexion daily tasks such as picking up an object from the floor or returning it to its original place [12]. However, in this study, some subjects reported back pain and discomfort when performing strength tests, which may have increased their muscle inhibition and decreased performance.

Furthermore, Oddsson et al. [15] showed that subjects with the presence of CLBP could not perform maximal effort during trunk extensors isometric strength tests, and had reduced control of lumbar muscle activation. Correia et al. [16] also found that tennis players with symptoms of LBP had significantly reduced iliocostalis lumborum and longuissimus thoracis muscle activation patterns during trunk extension isometric test compared to players without LBP. Although Shirado et al. [12] were not specific as to whether pain was aggravated during eccentric strength tests, this may call into question whether or not the subjects with CLBP accurately performed maximal trunk flexion and extension eccentric strength, which may have adversely affected their results. However, since patients with CLBP report pain when performing several strength tasks, the fact that they felt pain and discomfort may also approximate results in functional situations of their daily life, especially when performing tasks that involve eccentric strength.

### 4.3. Hip and Trunk Side-to-side Strength Asymmetries

Screening for side-to-side strength asymmetry has become a common practice for identifying muscle strength differences between right and left or dominant and non-dominant sides of the body [27,28]. High levels of side-to-side asymmetry have been associated with an increased risk of injuries [23], postural problems and rate of LBP episodes [11,14].

Nadler et al. [11] investigated the relationship between LBP episodes and hip side-to-side asymmetries in 210 male and female Division I collegiate athletes. Both right-to-left hip extensors and abductors were assessed on a dynamometer attached to a specially designed anchoring station. The history of lower extremity or LBP was recorded through interviews and previous injury records, when available. Results demonstrated that hip extensors of female athletes with LBP had 9.6%

significantly greater side-to-side asymmetry compared to female athletes without LBP. Therefore, the authors concluded that screening for side-to-side asymmetry may be an important tool on the prevention of LBP. However, there are potential limitations to fully supporting the assumption in this study, such as: (1) There were no significant differences between hip abductor or extensor side-to-side asymmetries in male athletes; (2) There were no significant differences between hip abductor side-to-side asymmetries in female athletes; an (3) LBP was screened through interview and previous injury records, but no other common research methods for recording levels of pain and functionality were used, such as the Oswestry Disability Questionnaire.

Nevertheless, although these results are in agreement with their subsequent cohort study with 163 Division I collegiate athletes [14], where a greater concentric strength side-to-side asymmetry of hip extensors was predictive ($p = 0.05$) of LBP treatment over the ensuing year for women only, in a third study, Nadler et al. [13] did not find any effect of a core resistance training protocol (focused on normalizing hip side-to-side asymmetries by strengthening abdominal, paraspinal, and hip extensors) on LBP episodes reduction in college athletes. Similarly, although Grosdent et al. [7] demonstrated that tennis players had greater nondominant than dominant lateral-flexors and rotator strength compared to sedentary participants, there was no significant difference in trunk strength imbalances when tennis players with and without current LBP were compared.

## 5. Conclusions

This brief review explored studies that investigated potential associations between CLBP or LBP episodes with strength imbalances and/or flexibility levels of the trunk, spine and hips. Collectively, the selected studies demonstrate that trunk eccentric/concentric and flexion/extension strength imbalances may be associated to episodes or chronic prevalence of LBP. However, the literature fails to demonstrate any clear relationship between hip strength imbalances or spine flexibility levels with this condition. In addition, there is no direct evidence to support that the normalization of these variables through resistance and flexibility training leads to pain reduction and functionality improvements in subjects with CLBP. Most studies to date demonstrate methodological limitations on the assessment of LBP episodes, difficulty of testing the strength and flexibility of participants with CLBP who are constantly in pain and have functional limitations, or small sample sizes for inferences of results for the general population. In addition, the different sample sizes from the selected studies of this review also limit great generalizations of the investigated topics. Therefore, future acute and chronic longitudinal studies are needed to further understand how effective screening and training are for decreasing strength imbalances and increasing flexibility levels on the cause and effect of CLBP. However, since LBP episodes leading to CLBP can be related to multi-factorial problems, which rely heavily on psychosocial aspects, it is possible that these variables may have very low effect within the complexity of this condition.

**Conflicts of Interest:** The authors declare no conflict of interest.

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