

Review Article

Lower limb muscle strength in patients with low back pain: a systematic review and meta-analysis

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Abstract

Objective: To systematically review the published studies that compare lower limb muscle strength in patients with low back pain to matched healthy controls. **Methods:** We searched Medline, SciELO, Cumulative Index to Nursing and Allied Health (CINAHL), and Scopus up until December 2017. Studies comparing lower limb muscle strength in people diagnosed with low back pain to healthy control participants were included in the systematic review. **Results:** 14 studies, which included 951 healthy controls and 919 patients with low back pain, fulfilled the inclusion criteria. Meta-analysis revealed a lower muscle strength of hip abductor/extensors and knee extensors in patients with low back pain in comparison to healthy controls. The average strength of hip abductors (Five studies, SMD=0.7 95% CI: 0.49 to 0.9) and hip extensors (Two studies, SMD=0.93, 95% CI: 0.62 to 1.23) was significantly lower in patients with low back pain compared to that of healthy controls. Knee extensor muscle strength was significantly lower in patients with low back pain compared to healthy controls (Three studies, WMD=0.31 Nm/kg, 95% CI: 0.1 to 0.5). The meta-analysis indicated a no significant difference in knee flexor muscle strength in patients with low back pain compared to healthy controls. **Conclusions:** Lower limb muscle is impaired in patients with low back pain.

Keywords: Low Back Pain, Meta-Analysis, Muscle Strength

Introduction

Stability is a key component of any mechanical system. Lumbar and pelvic instability may be associated with dysfunctions in the lumbar spine, hip, and knee regions¹. Weakness, shortening, and/or muscle stiffness of muscles of the lumbar and pelvic regions can contribute to dysfunction manifested as low back pain (LBP)^{2,3}. Lumbar instability and

inefficient lumbopelvic motor control appear to be related to the amount of pain and disability present in nonspecific LBP⁴.

Since the proposed stability model of Panjabi², the muscles of the lumbar region have been the subject of studies in patients with chronic LBP. Hodges and Richardson⁵ evaluated patients with and without LBP and showed that patients with pain demonstrate delayed activation of the transverse muscle of the abdomen. However, other biomechanical factors such as the pelvic tilt during functional activities, altered motor control of the lumbopelvic region, and the lack of coordination between the mobility of the pelvis and trunk may also be associated with the presence of LBP^{6,7}.

Lumbopelvic imbalance due to inefficiency of muscles of the hip has been explained as a factor associated with the presence of LBP^{8,9}. Lower limb muscles, especially the hip muscles, have an important role in lumbar spine stability¹⁰. Strength and proper activation of the lower limb muscles can contribute to the coordination between the hip and trunk, aiding in the transfer of forces between the lower limbs and the lumbopelvic region^{11,12}.

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Although studies establish the relationship of the coordination of forces generated between the hip and lumbar spine during functional activities^{12,13}, there are controversies in the literature about the role of lower limb muscles in lumbar stability and the inefficiency of these muscles in people with chronic LBP. In addition, a complete understanding of motor impairments associated with LBP would optimize exercise interventions for patients with LBP. Moreover, as far as we know, there is no meta-analysis of lower limb muscle strength in patients with low back pain. Thus, the aims of this study were to systematically review the published studies that compare lower limb muscle strength in patients with LBP to that of matched healthy controls.

Methods

This meta-analysis was completed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹⁴.

Eligibility criteria

This systematic review included articles that evaluated lower limb muscle strength in patients with LBP. Studies were eligible for this systematic review if they met the following criteria: 1) included patients with chronic, nonspecific LBP were included in this systematic review. For this study, chronic, nonspecific LBP was defined as LBP of longer than 3 months' duration without leg pain; 2) only studies comparing lower limb muscle strength in patients with LBP to that of a healthy control group. No restriction was made in terms of number of participants, gender, publication status or language. Studies that enrolled patients with acute LBP or LBP in association with neurologic diseases were excluded from this systematic review.

Search methods for identification of studies

We searched for references using Medline, SciELO, Cumulative Index to Nursing and Allied Health (CINAHL), and Scopus up until December 2017, without language restrictions. A standard protocol for this search was developed and controlled vocabulary Medical Subject Headings [MeSH] terms for Medline) was used. Key words and their synonyms were used to sensitize the search ("pain"; "low back pain"; "leg"; "lower limb"; "strength"; "torque"; "force"). For the preparation of the search strategy, two groups of keywords were used: participants and outcomes.

We checked the references used in the articles included in this systematic review to identify other potentially eligible studies. For ongoing studies, authors were contacted by e-mail to obtain confirmation of any data or additional information.

Data collection and analysis

The aforementioned search strategy was used to obtain titles and abstracts relevant to this review. Each identified

abstract was independently evaluated by two reviewers. If at least one of the researchers considered a reference eligible, the full text was obtained for complete assessment. Two reviewers independently assessed the full text of selected articles to verify their conformity to the eligibility criteria.

Two reviewers independently extracted data from the published studies using standard data extraction forms adapted from Higgins and Green¹⁵. Aspects of the study population, devices and instruments used to assess muscle strength outcomes, muscle strength data, and results were reviewed. Any further information required from the original author was requested by e-mail. A flow diagram of the study selection process based on PRISMA recommendations is seen in Figure 1.

Data extraction

Two authors, independently blinded, extracted descriptive and outcome data from the included studies using a standardized form developed by the authors and adapted from the Cochrane Collaboration's model for data extraction¹⁵. We considered the following data: 1) aspects of the study population, such as the diagnosis, disease duration, average age, and sex; 2) aspects of the measures performed (sample size, instruments, muscles, joints, movements, positions, strength, dynamometer device, total time); and 3) study results.

Assessment of risk of bias

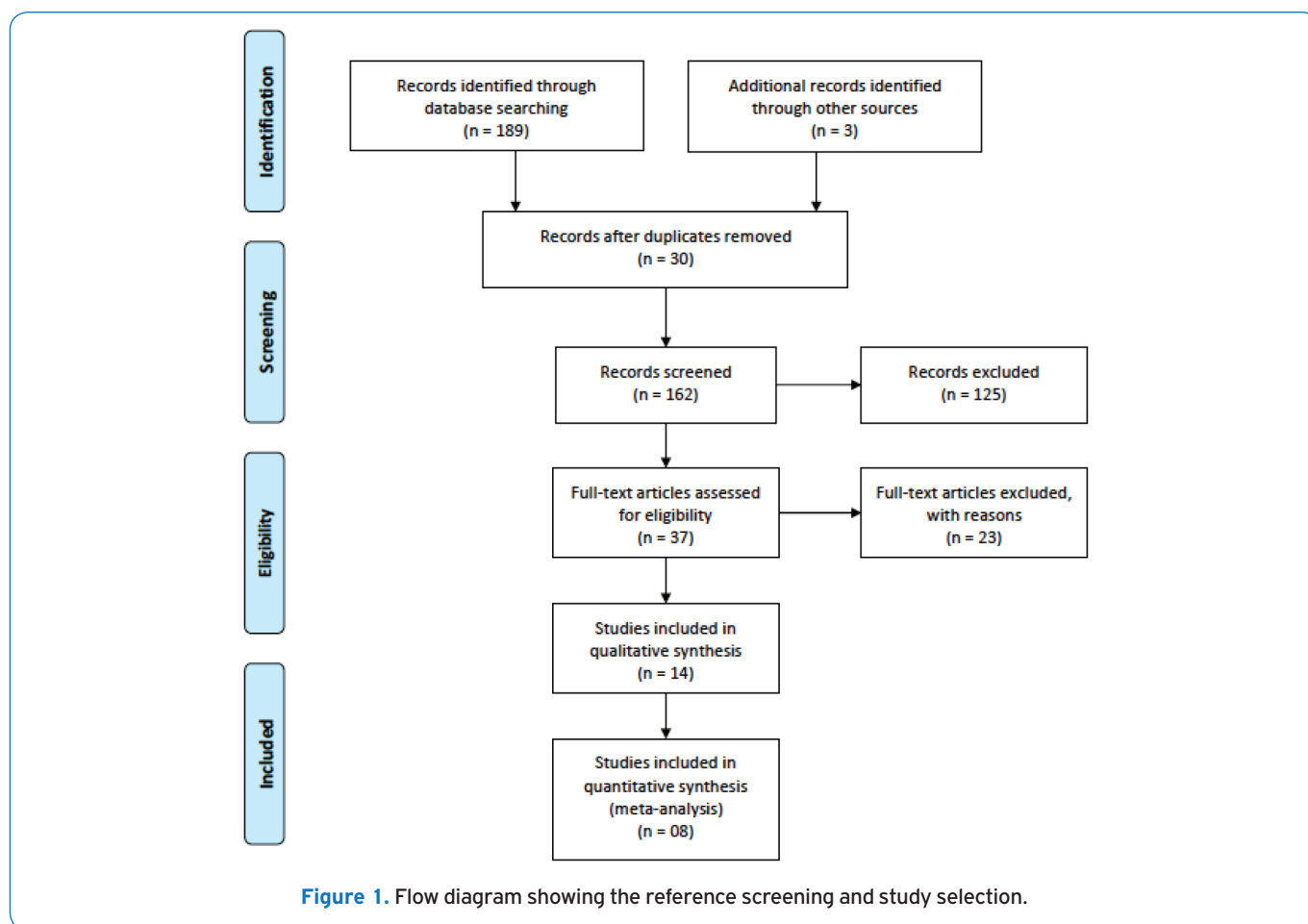
The methodological quality was assessed across four domains (sample, study design, analysis of outcomes, and presentation of information), culminating in a total of 14 items. This tool was based on the list of items developed by Lankhorst et al.¹⁶, which used the Cochrane criteria¹⁵, the Newcastle-Ottawa Scale, and studies conducted by van Rijn et al.¹⁷ and Tulder et al.¹⁸.

Statistical assessment

Means and standard deviations of lower limb muscle strength were extracted for the purpose of calculating differences between groups. In studies reporting absolute values of muscle strength (Newtons [N] or Newton-meters [Nm]) and/or explosive muscle strength (N/s or Nm/s), these values were subsequently normalized to the body mass reported by the respective studies. If body mass was not reported, the corresponding author of the study was contacted to obtain the data. When necessary, standard deviation was extracted or calculated using available data (e.g., confidence intervals [CIs]) or information presented in graphical format¹⁵.

Data analysis

Standardized mean differences (SMDs) were calculated from means and standard deviations of muscle strength data. The SMDs of 0.2, 0.5, and 0.8 were considered



small, moderate, and large, respectively.¹⁹ The percentage difference in muscle strength was also calculated to provide a further indication of the relative difference in strength between patients with LBP and control participants [(LBP strength – control strength)/control strength × 100]. Results were grouped according to the type of strength measurement (e.g., isometric or isokinetic) or joint action performed. Data were pooled for multiple studies in a meta-analysis within each group using a random-effects model.

An α value <0.05 was considered statistically significant. Statistical heterogeneity of the treatment effect among studies was assessed using Cochran's Q test and the I^2 inconsistency test, for which values between 25% and 50% were considered indicative of moderate heterogeneity, and values greater than 50% were considered indicative of high heterogeneity¹⁸. All analyses were conducted using Review Manager Version 5.3 (Cochrane Collaboration)²⁰.

Results

As presented in the PRISMA flowchart (Figure 1), after screening 37 full texts for eligibility, a total of 14 published studies²¹⁻³⁴ were included in the systematic review. A

supplementary table with results of the assessment of the methodological quality can be found in Electronic Supplementary File 1.

Study characteristics

The number of participants included in this systematic review ranged from 951 healthy controls to 919 patients with LBP. The mean age of participants ranged from 20.0 to 47.9 years old for healthy controls and 19.3 to 48.6 years old for patients with LBP. 10 studies included patients of both genders, 2 studies included only male patients, 1 study included only female patients, and 1 study did not specify gender.

Isokinetic strength testing was used to quantify lower limb muscle strength in 7 studies^{23,24,26,29-31,34}, and isometric dynamometry was used in 3 studies^{21,25,28}. Isokinetic strength was expressed as peak torque (Nm) in 2 studies^{26,34}, and as body weight-normalized peak torque (Newton-meters per kilogram [Nm/kg]) in 5 studies^{23,24,29-31}. Isometric muscle strength was measured as body weight-normalized peak torque. Two studies^{27,33} measured the muscle strength by manual pressure meter. Sample size, strength measure, joints, and movements of included studies are summarized in Table 1.

Table 1. Characteristics of the studies Included in the Review.

Study	LBP group (N analyzed, age, % F)	Control group (N analyzed, age, % F)	Strength Measure	Testing device	Joints	Movements	Methodological Quality
Bussey et al, 2016	N= 14 19.3 yr, 100% F	N= 25 20.04 yr, 100% F	Isometric strength (Nm/ kg)	Manual dynamometer	Hip	Abduction	11
Cooper et al, 2015	N= 150 41.4 yr, 64.7% F	N= 75 40.7 yr, 65.3	Manual muscle testing (0-5)	Manual resistance	Hip	Abduction	11
Cai & Kong, 2015	N= 18 26.0 yr, 50% F	N= 18 23.6 yr, 50% F	Isokinetic strength (Nm/ kg)	Isokinetic dynamometry	Hip Knee	Abduction Extension Flexion Extension	9
Sutherland & Hart, 2015	N= 12 24 yr; 58% F	N= 12 22 yr 75% F	Isokinetic strength (Nm/ kg)	Isokinetic dynamometry	Hip	Abduction	11
Penney T et al, 2014	N=21 46 yr 43% F	N=22 44 yr 36% F	Isometric strength (Nm/ kg)	Manual dynamometer	Hip	Abduction	11
Yahia et al, 2011	N= 30 41.1 yr 80% F	N=30 39.1 yr 80% F	Isokinetic strength (Nm)	Isokinetic dynamometry	Knee	Flexion Extension	12
Arab et al, 2010	N= 200 100 GL with ITBI 44.2 yr 100 GL without ITBI 42.5yr	N= 100 43.3yr	Manual pressure meter (kPa)	Mechanical device	Hip	Abduction	11
Kendall et al, 2010	N= 10 32 yr; 80% F	N= 10 26 yr, 20% F	Isometric strength (Nm/ kg)	Manual dynamometer	Hip	Abduction	10
Marshall et al, 2010	N=15 42.1 yr M 39.4 yr F NI	N=15 39.6 yr M 40.7 yr F NI	Isokinetic strength (Nm/ kg)	Isokinetic dynamometry	Knee	Flexion	12
Tsai et al, 2010	N= 16 48.6 yr 100%M	N= 16 47.9 yr 87 100%M	Isokinetic strength (%BW)	Isokinetic dynamometry	Hip	Abduction Adduction Flexion Extension	11
Marshall et al, 2009	N=21 40.7 yr 48% F	N=15 40.1 yr 48% F	Isokinetic strength (Nm/ kg)	Isokinetic dynamometry	Knee	Flexion	10
Bernard et al, 2008	N= 51 15.0 yr 78.4% F	N= 276 14.7 yr 44.2% F	Muscle Test (Hip extensor test & Killy's test) min, seg	Table	Hip Knee	Extension Flexion	12
Nourbakhsh & Arab., 2002	N= 300 43 ±13 yr 50% F 43 ±14 yr 50% M	N= 300 43±13 yr 50% F 43±15 yr; 50% M	Manual pressure meter (kPa)	Mechanical device	Hip	Abduction Adduction Flexion Extension	11
Lee et al, 1995	N= 61 32.3±9.4 yr 100%M	N=37 27.1±6.6 yr 100% M	Isokinetic strength (Nm)	Isokinetic dynamometry	Knee	Flexion Extension	14

Ht, height; Wt, Weight; F, females; M, males; yr, years; Nm, Newton metros; Nm/kg, Newton metros por kilograma; %BW= percentual do peso do corpo (pico de torque [Nm]/Bw [kg] x 100).

The muscle strength data of studies included in the systematic review are provided in Table 2. Eight studies^{23-27,31,33,34} contained sufficient information to be pooled in a meta-analysis to compare lower limb muscle strength in patients with LBP to that of healthy control groups. Four studies^{23,26,31,34} were able to be pooled to compare isokinetic strength. All studies reported muscle strength data as mean and SD. Thus, there was no need to transform data.

Five studies^{23-25,27,33} assessed hip abductor muscle strength. A total of 1,003 participants (551 patients with LBP

and 452 healthy controls) were included in these 5 studies. Due to the difference between the instruments used in the assessment of hip abductor muscle strength, we performed a meta-analysis using SMD. A significant difference in isokinetic muscle strength of the hip abductors of 0.7 (95% CI: 0.49 to 0.9) was found between participants in the healthy control group and the LBP group. (Figure 2A)

Two studies^{23,33} assessed hip extensor muscle strength. A total of 636 participants (318 patients with LBP and 318 healthy controls) were included in these 2 studies. Due to the difference between the instruments used in the assessment

Table 2. Data muscle strength of the studies Included in the Review.

Study	Units	Muscle strength ABDTHip LBP vs Control	Muscle strength ADTHip LBP vs Control	Muscle strength EXHip LBP vs Control	Muscle strength FXHip LBP vs Control	Muscle strength EXTKnee LBP vs Control	Muscle strength FLXKnee LBP vs Control	Results
Bussey et al, 2016	Nm/kg	R (1.6 vs 1.7) L (1.5 vs 1.6)	NA	NA	NA	NA	NA	There is no difference in hip-abduction strength between LBP patients compared with healthy controls. (p=.843).
Cooper et al, 2015	MMT O-5	AS (3.4 vs 4.5) US (4.6 vs 4.5)	NA	NA	AS (4.8 vs 4.5) US (4.9 vs 4.5)	NA	NA	Hip-abduction strength in affected side was significantly lower in LBP patients compared with healthy controls p<.001).
Cai & Kong, 2015	Nm/kg	M (1.5 vs 1.5) F (1.1 vs 1.2)	NA	M (1.3 vs 1.5) F (1.3 vs 1.2)		M (2.1 vs 2.6) F (2.0 vs 2.3)	NA	Knee extensor strength was significantly lower in LBP patients compared with healthy controls (p=.016).
Sutherland & Hart, 2015	Nm/kg	(1.6 vs 1.6)	NA	NA	NA	NA	NA	There is no difference in hip-abduction strength between LBP patients compared with healthy controls. (p=.944).
Penney et al, 2014	N/Kg	R (1.0 vs 1.4) L (1.0 vs 1.2)	NA	NA	NA	NA	NA	Hip-abduction strength in right and left side were significantly lower in LBP patients compared with healthy controls (p<.05)
Yahia et al, 2011	Nm	NA	NA	NA	NA	60° (54.4 vs 103.7) 120° (48.5 vs 67.4)	60° (87.7 vs 124.6) 120° (71.1 vs 98.5)	Knee flexors and extensors strength at speeds 60 to 120°s were significantly lower in LBP patients compared with healthy controls (p<.05).
Arab et al, 2010	Kpa	(27.5 vs 33.5)	NA	NA	NA	NA	NA	Hip-abduction strength in was significantly lower in LBP patients compared with healthy controls p<.001).
Kendall et al, 2010	N/kg ²	(6.6 vs 9.5)	NA	NA	NA	NA	NA	Hip-abduction strength in was significantly lower in LBP patients compared with healthy controls p<.05).
Marshal et al, 2010	Nm/kg	NA	NA	NA	NA	NA	C ₃₀ (0.9 vs 1.0) C ₁₂₀ (0.7 vs 0.8) E ₃₀ (1.2 vs 1.1) E ₁₂₀ (1.1 vs 1.1)	There is no difference in hamstring concentric and eccentric strength at speeds 30 to 120°s between LBP patients compared with healthy controls. (p>.05).
Tsai et al, 2010	Nm/kg	R (1.4 vs 1.5) L (1.3 vs 1.6)	R (1.2 vs 1.5) L (1.2 vs 1.6)	R (2.6 vs 3.3) L (2.7 vs 3.3)	R (0.6 vs 0.9) L (0.6 vs 0.8)	NA	NA	Left hip-abduction and adduction strength in were significantly lower in LBP patients compared with healthy controls p<.05)
Marshal et al, 2009	Nm/kg	NA	NA	NA	NA	NA	C ₃₀ (0.9 vs 1.0) C ₁₂₀ (0.7 vs 0.8) E ₃₀ (1.2 vs 1.1) E ₁₂₀ (1.1 vs 1.1)	There is no difference in hamstring absolute strength between LBP patients compared with healthy controls. (p=.843).
Bernard et al, 2008	min, seg	NA	NA	(1min e 24 seg vs 2min e 20seg)	NA	(1min e 20seg vs 2min e 39seg)	NA	It was observed a statistically significantly difference in the endurance in hip extensors and quadriceps, which were weaker in the LBP group than their controls. The teenagers with LBP obtained 40% hip extensors' values and 50% Killy' values lower than in their control group.
Nourbakhsh & Arab, 2002	Kpa	(26 vs 32)	(23 vs 31)	(22 vs 29)	(36 vs 43)			Hip- (abduction, flexion and extension) strength was significantly lower in LBP patients compared with healthy controls p<.05).
Lee et al, 1995	Nm	NA	NA	NA	NA	(191.4 vs 264.7)	(109.1 vs 176.3)	Total knee strength was significantly lower in LBP patients compared with healthy controls (p=.016).

NA, Not assessed; R, right; L, left; M, male; F, female; . AS, affected side; US, unaffected side; GMED, gluteus medius; TFL, tensor fascia lata; GMAX, gluteus maximus; ITBI, Iliotibial Band Tightness; MMT, manual muscle test; C, concentric; E, Eccentric; C30 concentric at 30%; C60 concentric at 60%; C120 concentric at 120%; E30 Eccentric at 30%; E60 Eccentric at 60%; E120 Eccentric at 120%.

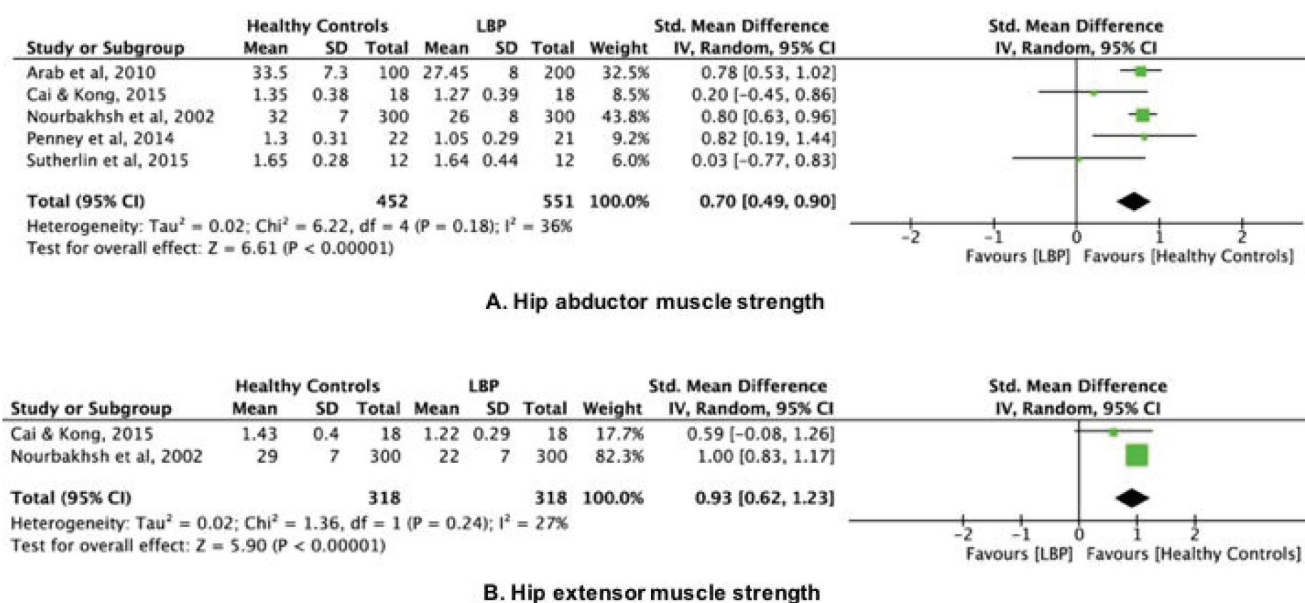


Figure 2. Hip strength-LBP vs Healthy controls.

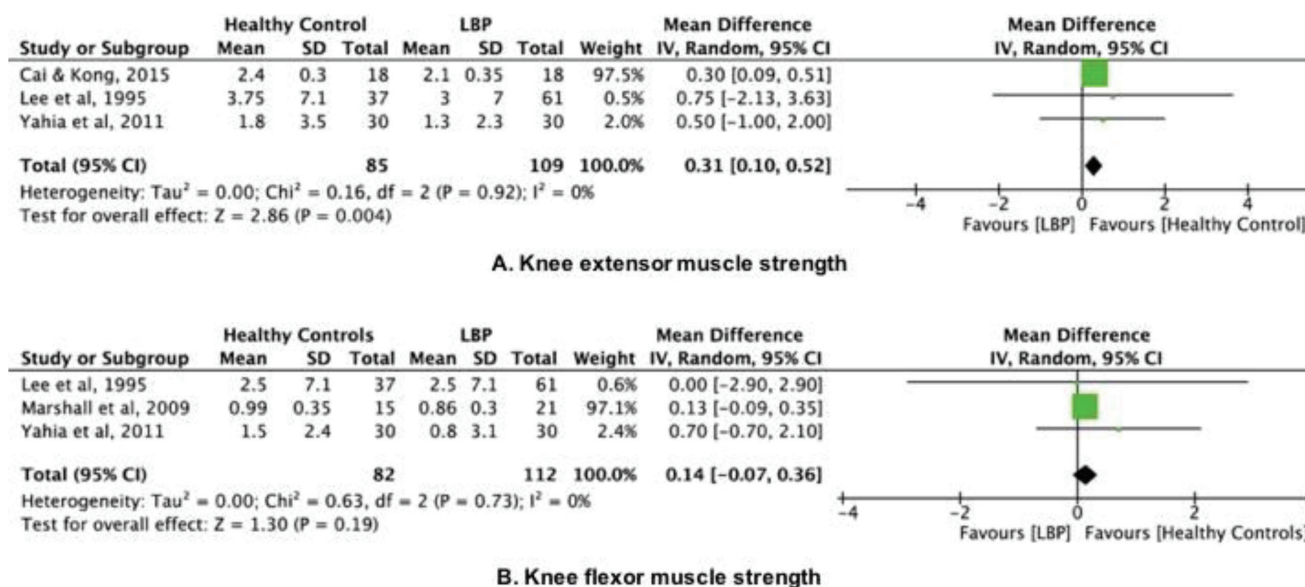


Figure 3. Knee strength-LBP vs Healthy controls.

of hip extensor muscle strength, we performed a meta-analysis using SMD. A significant difference in isokinetic muscle strength of the hip extensor of 0.93 (95% CI: 0.62 to 1.23) was found between participants in the healthy control group and the LBP group. (Figure 2B)

Three studies^{23,26,34} assessed isokinetic muscle strength of the knee extensors. A total of 194 participants (109 patients

with LBP and 85 healthy controls) were included in these 3 studies. A significant difference in isokinetic muscle strength of the knee extensors of 0.31 Nm/kg (95% CI: 0.1 to 0.5) was found between participants in the healthy control group and the LBP group. (Figure 3A)

Three studies^{26,31,34} assessed isokinetic muscle strength of the knee flexors. A total of 194 participants (112 patients

with LBP and 82 healthy controls) were included in these 3 studies. A no significant difference in isokinetic muscle strength of the knee flexors of 0.1 Nm/kg (95% CI: -0.07 to 0.4) was found between participants in the healthy control group and the LBP group (Figure 3B).

Discussion

The main finding of the current systematic review was that lower limb muscle strength was significantly lower in patients with LBP compared with that of healthy controls. In terms of hip strength, there was moderate-quality evidence that patients with LBP have weaker hip abduction/extension strength when compared with that of healthy controls. When considering isokinetic knee strength, there was moderate-quality evidence that patients with LBP have weaker knee extension when compared with that of healthy controls.

The results of this systematic review have significant clinical implications. Muscle strength is a strong predictor of health. In a recent study, Li et al.³⁵ concluded that low muscle strength is independently associated with elevated risk of all-cause mortality. In another recent study, Roshanravan et al.³⁶ reported that low isometric muscle strength was associated with persistent severe lower extremity limitation.

Lower limb weakness also has been associated with a range of lower-limb chronic diseases^{37,38}. In addition, muscle strength is a critical aspect of human movement that can influence tissue stress³⁹. The hip muscles are tightly coupled with lumbar paraspinal muscles via the thoracolumbar fascia, which allows the load transfer from the lumbar spine to the lower extremities³⁹. In addition, the hip muscles help to control rotational alignment of the lower limbs and maintain pelvic stability during single-leg stance⁴⁰. Thus, hip muscle weakness may also contribute to LBP due to abnormal segmental movement of the lumbar spine if the pelvis is not stable during gait or standing⁴¹. However, the contribution of hip weakness to LBP development is unknown. Moreover, although our findings indicate that hip muscle strength was significantly lower in the LBP group (vs. the healthy control group), other studies have found no relationship between hip strength and development of back pain^{13,42}.

In a recent systematic review, Steinberg et al.⁴³ assessed whether hip muscle performance was associated with leg, ankle, and foot injuries. They concluded that there is limited evidence that hip muscle performance variables are related to leg, ankle, and foot injuries, and that emerging evidence indicates that poor hip muscle performance might be a result of the injury rather than a contributor to the injury.

Knee strength deficits in patients with LBP are less conclusive. There is very moderate evidence that knee extensor strength was significantly lower in patients with LBP compared with that of healthy controls; however, patients with LBP have isokinetic muscle strength of knee flexors comparable to that of healthy controls.

Because LBP is one of the leading causes of pain and disability in adults, it is important to find pragmatic treatments that not only treat the pain, but also decrease disability. Moreover, it is well understood that movement is altered in the presence of pain⁴⁴. Our findings are important for the physiotherapist responsible for reviewing exercise protocols for patients with LBP. The results may provide evidence for innovative interventions that target lower limb muscle strength and motor control in patients with LBP. In addition, while this review identified patients with LBP who also had lower limb weakness, it is not possible to present a single muscle strength value that identifies those in the clinic who are weak versus those who are not.

Exercise is effective in reducing the severity of chronic pain, as well as providing more general benefits associated with improved overall physical and mental health⁴⁵. The medical literature suggests that the exercise programs prescribed for patients with LBP have been primarily focused on activation of the deep trunk muscles^{46,47}. However, patients with LBP also require targeted training in muscle endurance and strength; this provides a theoretical basis for prevention of disability and rehabilitation of these patients⁴⁸.

The results of this study should be interpreted with caution because muscle strength differences observed between groups were small. Limitations in the present study need attention. Results were limited by heterogeneity between studies, insufficient standardization, and absence of control for confounders in individual studies. This heterogeneity may be associated with the different methods and protocols used to measure muscle strength in the studies and the small number of studies included in the meta-analysis. Furthermore, the small number of studies included in the meta-analysis reduces the I²'s power to adequately detect heterogeneity between studies. In terms of measuring maximal strength, the isokinetic dynamometer muscle strength test is considered the gold standard test; however, studies included in the review assessed muscle strength using other instruments. In addition, the inclusion of studies with both medicated and non-medicated patients could pose significant challenges, with emerging lines of evidence indicating that nonsteroidal anti-inflammatory drugs could improve muscle strength in patients with chronic LBP^{49,50}.

The current systematic review highlights the importance of conducting future studies with larger samples to determine the magnitude of the relationship between lower limb muscle strength and the development of LBP.

Conclusion

When compared to that of healthy controls, lower limb muscle strength may be lower in patients with LBP. Clinical trials are required to analyze the inclusion of lower limb muscle strengthening in the rehabilitation protocols used to manage the treatment of patients with LBP.

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Electronic Supplementary File 1

Quality assessment results.

Study	Selection bias						Measurement and outcome bias								Data presentation			Total Score
Author, date)	Q1	Q2	Q3	Q4	Q5	Selection bias (Maximum=5)	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Measurement and outcome bias (maximum = 7)	Q13	Q14	Data presentation (maximum = 2)	
1. Bussey et al, 2016	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
2. Cooper et al, 2016	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
3. Cai et al, 2015	N	N	N	Y	Y	2	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	9
4. Sutherland et al, 2015	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
5. Penney et al, 2014	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
6. Yahia et al, 2011	Y	Y	Y	Y	Y	5	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	12
7. Arab et al, 2010	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
8. Kendall et al, 2010	N	N	Y	Y	Y	3	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	10
9. Marshall et al, 2010	Y	Y	Y	Y	Y	5	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	12
10. Tsai et al, 2010	Y	N	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
11. Marshall et al, 2009	Y	N	N	Y	Y	3	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	10
12. Bernard et al, 2008	Y	Y	Y	Y	Y	5	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	12
13. Lee et al, 1995	N	Y	Y	Y	Y	4	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	11
14. Nourbakhsh et al, 2002	Y	Y	Y	Y	Y	5	Y	Y	Y	N	Y	N	Y	5	Y	Y	2	14
TOTAL Score & Percentage Yes	79	36	86	100	100		100	100	100	0	100	0	100		100	100		

- Q1. Was the study population clearly specified, defined and adequately described?
 Q2. Were both groups drawn from the same population (selected from similar populations and including the same time period)?
 Q3. Were both groups comparable for age, sex, BMI/weight?
 Q4. Was muscle strength described for LBP group?
 Q5. Was an attempt made to define LBP and control group characteristics?
 Q6. Did the method description enable accurate replication of the measurement procedures?
 Q7. Was the measurement instrument clearly defined, valid, reliable, and adequately described?
 Q8. Was a system for standardizing movement instructions reported?
 Q9. Were assessors trained in standardized measurement procedure?
 Q10. Did the same assessors test those with and without LBP?
 Q11. Were assessors blinded as to which group subjects were in?
 Q12. Was the same assessment procedure applied to those with and without LBP?
 Q13. The results of between-group statistical comparisons are reported for at least one key outcome"?
 Q14. Point estimates and measures of variability are provided for at least one key outcome for those with and without LBP?