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Systematic Review

Is there an association between hip range of motion and nonspecific low back pain? A systematic review

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ABSTRACT

Objective: To systematically review whether there is an association between hip range of motion (ROM) and nonspecific low back pain (NSLBP).
Data sources: MEDLINE, EMBASE, Cochrane library, PsychINFO, CINAHL and AMED databases were searched from year of inception until October 31st, 2018, using a combination of LBP and hip joint search terms. Commonly cited journals were also hand searched within the previous two years.
Study selection: Two reviewers independently screened identified articles, by title and abstract and then by full-text. After first round screening of 2908 identified records, 248 progressed to full-text screening. Due to the heterogeneity of studies identified, post hoc inclusion criteria of English language, studies comparing subjects with NSLBP and healthy controls, cross-sectional design, and clinical measures of hip ROM were applied. Twenty-four records were finally included.
Data extraction: Extracted data included population characteristics, duration and severity of NSLBP, hip movement direction, testing position, measurement tool and between-group difference. The Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was used to assess for study bias.
Data synthesis: Hip flexion ROM was measured in seven studies, extension in 13, internal rotation (IR) in 14, external rotation (ER) in 13, abduction in six, and adduction in only two studies. Among all directions tested, IR ROM was reported in more studies as significantly reduced in NSLBP subjects compared to healthy individuals. Overall the quality of evidence was very low. Common sources of study bias included lack of sample size justification, blinding of outcome assessors, adjusting for key confounders, and poor reporting.
Conclusion: There is very low-quality evidence to support an association between limited hip ROM and NSLBP. Limited hip IR ROM was the only movement impairment found to be significantly associated with NSLBP, however this should be viewed with caution due to the low-quality supportive evidence. Further studies are needed.

Low back pain (LBP) is a disorder affecting approximately 80% of the population at some point in their life, and has been associated with morbidity, functional disability and being a burden on the medical system and society (Zhou et al., 2016; Wong and Lee, 2004; van Middelkoop et al., 2011; Kim et al., 2013; Itz et al., 2013; Haskins et al., 2012). The majority of LBP presentations are of a non-specific nature (i.e., no identifiable pathology such as malignancy, infection, fracture, or inflammatory diseases) (National Collaborating Centre for Primary Care (UK), 2009) (Savigny et al., 2009), and up to 65% of individuals may develop chronic LBP with symptoms persisting for at least a year following the initial onset (Kim et al., 2013; Itz et al., 2013; Slater et al., 2012).

Whilst structures in the lumbo-sacral region are usually implicated in non-specific LBP (NSLBP) (Savigny et al., 2009), movement interaction between the hip joint and the spine has been of increasing interest since the 1990s (Paquet et al., 1994; Mellin, 1988). The anatomical proximity of the hip joint, and its associated contributions to lumbo-pelvic kinematics and function, have been recognized as potential factors contributing to LBP (Offierski and MacNab, 1983). Notably, limitation and asymmetry in hip range of motion (ROM) in different planes has been found to be present in NSLBP subjects both in clinical settings and in common activities of daily living (Mellin, 1986; Cibulka et al., 1998), such as sit-to-stand, forward bending and rotation-related activities (Sung, 2013; Shum et al., 2005; Crosbie Jack et al., 2013).

There is a plethora of evidence supporting the kinematic

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relationship between the hip joint and NSLBP, and in their clinical guidelines for LBP, Delitto et al. (2012) recommend the assessment and treatment of ROM of the hip joint in patients with chronic LBP (Kim et al., 2013; Delitto et al., 2012; Lee and Kim, 2015; Hoffman et al., 2011; Harris-Hayes et al., 2009). Consistent with this recommendation, adequate hip internal rotation (IR) ROM ($> 35^0$) unilaterally, has been found to be a criterion associated with improvement in NSLBP following spinal manipulation, and unilateral average rotation $\geq 25^0$ was found to be a criterion associated with improvement in NSLBP following a Pilates-based exercise program (Stolze et al., 2012; Flynn et al., 2002). Indeed, there is emerging evidence to support conservative treatment for improving hip mobility in NSLBP patients (Lejkowski and Poulsen, 2013; Grimshaw and Burden, 2000; Childers et al., 2002; Boyle and Demske, 2009; Boyle, 2011), as well as substantial evidence documenting the resolution of NSLBP and restoration of low back function following surgical intervention for hip disease (Chimenti et al., 2016; Ben-Galim et al., 2007).

There is also growing evidence indicating an association between altered hip kinematics during functional tasks and NSLBP (Wong and Lee, 2004; Harris-Hayes et al., 2009; Porter and Wilkinson, 1997; Milosavljevic et al., 2005), and with the development of NSLBP in healthy individuals (Nelson-Wong et al., 2009; McGill et al., 2015; Bussey et al., 2016). Two recent systematic reviews investigated the kinematic relationship between the hip and the lumbar spine in individuals with NSLBP or a lumbar spine disorder (Sadeghisani et al., 2015a; Redmond et al., 2014). However, these reviews were either limited to the effect of surgical interventions targeted at the hip for LBP and lacked critical appraisal of the evidence (Redmond et al., 2014), or were limited to the relationship between hip rotation ROM and NSLBP (Sadeghisani et al., 2015a).

This study is part of a larger investigation examining firstly whether there is an association between hip joint kinematics and NSLBP (as measured by ROM (research question (RQ)1[1]) and during movement (RQ1[2])), and secondly whether hip joint treatment is associated with improvement in NSLBP (RQ[2]). The aim of the present study was restricted to determining whether there is an association between hip joint ROM in any plane and NSLBP (RQ1[1]). It is proposed that a more complete understanding of the relationship between the hip joint and LBP may assist clinicians in better assessing and managing the complex clinical presentation of NSLBP.

1. Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009).

1.1. Search strategy

The following databases were systematically searched for studies from year of inception to 31st October 2018, that investigated an association between hip joint kinematics and LBP, including the effect of hip treatment on LBP: Medline, Embase, Cochrane library, PsychINFO, CINAHL and AMED. Following the Cochrane Back Review Group's guidelines (Furlan et al., 2009), the LBP search string included but was not limited to the following key words: dorsalgia, back pain, backache, low back pain, coccydynia, sciatica, lumbago, and back disorder. The hip search string used 'Hip joint' MeSH terms including, but not limited to: hip joint, hip dislocation, hip prosthesis, hip osteoarthritis, hip fractures, arthroplasty, replacement, hip contracture, hip injuries, and femoroacetabular (see Appendix 1 for the detailed search strategy and key words for all databases). In addition, commonly cited journals were also hand searched for relevant papers from 2015 to 31st October 2018.

Upon search completion, two investigators independently reviewed titles and abstracts to identify eligible studies before undertaking full text screening. Identified studies were downloaded into reference management software (EndNote X8 [1], Thomas Reuters, New York, NY) and duplicates were removed. Disagreement regarding inclusion of articles was resolved by discussion between the two investigators, and a third independent reviewer arbitrated when consensus could not be reached.

1.2. Study selection

'LBP' was operationally defined as pain localized below the costal margin and above the inferior gluteal folds (with or without leg pain) of any duration and severity, including any known history of LBP.

Studies reporting 'hip joint kinematics' had to include one or more of the following: measurement of movement or ROM (active or passive, cardinal or non-cardinal planes of movement), movement patterns of the femoroacetabular articulation (e.g., sit-to-stand and other functional tests), or hip joint muscle length (e.g., iliopsoas, piriformis), including the Thomas test and its modified versions given its common use in clinical practice and research to assess hip joint extension. Included studies had to specify that their aim was to measure hip joint ROM and/hip flexor muscle length and did not include measurements not primarily assessing hip joint movement (e.g., straight leg raise test), muscle strength or motor control, and subjective self-reports relating to hip joint movement (e.g., stiffness, locking, catching) or pain. 'Hip joint treatment' referred to any interventional modality (including surgical) that was primarily targeted towards the hip joint.

Articles were not restricted by language, provided the title and abstract were in English at first stage screening. Studies were excluded if the population investigated was under 18 years of age or was diagnosed with a specific LBP pathology (e.g., fracture, osteoporosis, ankylosing spondylitis), and if they involved cadavers, animals, or computer or other models. Reviews, commentaries, letters or editorials were also excluded. Due to the heterogeneity of study designs and populations investigated, we applied post hoc inclusion criteria of studies using only clinical measurements of hip ROM, studies that compared between NSLBP and non-NSLBP subjects, and cross-sectional designs in the English language.

1.3. Data extraction

The lead reviewer (MA) extracted the following data from the reviewed full texts: population type and characteristics, age, gender, duration and severity of NSLBP (e.g., visual analogue scale, Oswestry Disability Index score), hip movement measured for ROM (flexion, extension, IR, external rotation (ER), abduction, adduction), measurement mean value, and clinical measurement tool (active/passive; goniometer, inclinometer, motion tracking device, other).

Results for between-group differences in hip ROM were extracted and, where possible, calculated for mean difference, 95%CI, p value and effect size (Cohen's d).

1.4. Quality appraisal and data synthesis

Risk of bias across studies was assessed using the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (National Heart, Lung, and Blood Institute; National Institutes of Health; U.S. Department of Health and Human Services) (National Institutes of He, 2017). Inapplicable items related to whether exposures were measured prior to outcomes, whether the timeframe was sufficient for establishing an association between exposure and outcome, whether exposures were measured more than once over time, and loss to follow-up.

We used the GRADE approach (Balshem et al., 2011; Guyatt et al., 2011, 2011a, 2011b, 2011c, 2011d, 2011e, 2011f, 2011g, 2011h) to

[1] EndNote X8.2 (Bld 13302). (2018). Clarivate Analytics.

evaluate the quality of the overall body of evidence in answering the study question. Careful consideration was given to common limitations of observational studies as suggested by Guyatt et al. (2011) including failure to develop and apply eligibility criteria, flawed measurements of exposure and outcome, and failure to adequately control confounding. In addition, inconsistencies in findings and high risk of bias in the body of evidence may also impact the quality of the body of evidence (Balshem et al., 2011; Guyatt et al., 2011, 2011a, 2011b, 2011c, 2011d, 2011e, 2011f, 2011g, 2011h).

2. Results

The initial search yielded 3714 results of which 2908 progressed to first round screening (title and abstract) after duplicates were removed, with 248 records progressing to full text screening. Following application of the post hoc inclusion criteria, 24 records remained. Agreement between the two reviewers was 'substantial' for title and abstract screening with κ = 0.70 (95%CI 0.65–0.75), and 'moderate' for full text screening with κ = 0.60 (95%CI 0.50–0.70). Of the 48 episodes of disagreement, 44 were resolved by consensus between the two reviewers (17 included, 27 excluded), with four arbitrated by the third reviewer, and determined to be included (prior to application of post hoc criteria). Post hoc 24 studies were included in this review as they directly addressed this study's research question. See Fig. 1 for the study selection process.

2.1. Quality appraisal synthesis

The overall quality of the body of evidence was very low with inconsistencies in findings and serious study limitations increasing the risk of bias, notably the lack of blinding of outcome assessors and adjustment for potential confounders, inadequate sample size justification and power calculation, and lack of testing for the strength of association between different durations of NSLBP and ROM limitations. Details of the risk of bias for each study, according to the NIH quality assessment tool, are outlined in Table 1.

2.2. Hip ROM measurement

Table 2 outlines the data extracted from each of the included studies. Across the included studies, hip range of movement was tested in all planes. Flexion was tested in seven studies, extension in 13 studies (using the Thomas test in eight), IR in 14 studies, ER in 13 studies, abduction in six studies and adduction in only two studies. Measurement tools used included a goniometer (n = 17), inclinometer (n = 5), motion tracking system (n = 1), and one study did not describe the tool

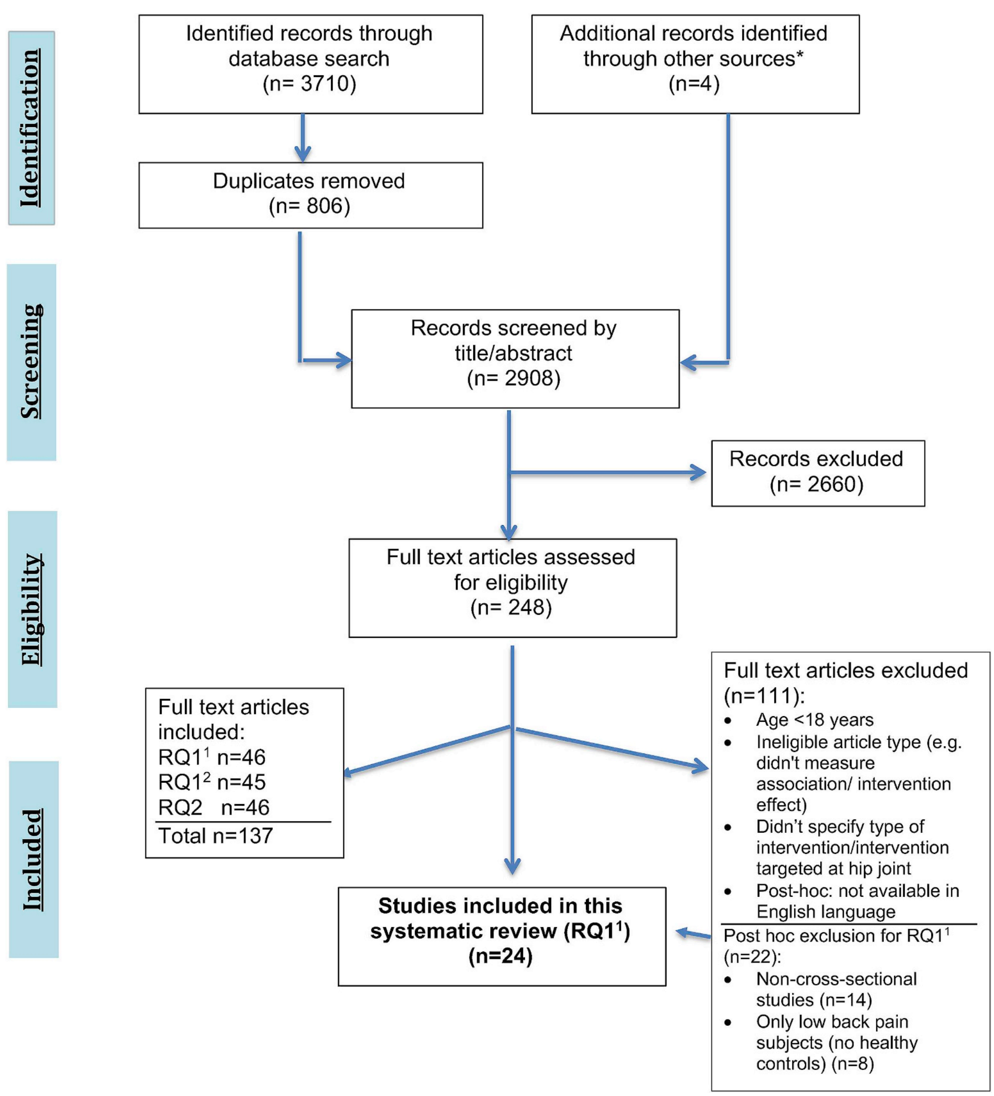

Fig. 1. PRISMA flowchart for the selection of studies. *hand search of commonly cited journals. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses. RQ: research question; RQ1[1]: hip ROM clinical measurements. RQ1[2]: femoroacetabular movement pattern measurements. RQ2: hip interventions in NSLBP.

Table 1
Methodologic quality and risk of bias assessment of included studies.

Study	Research question or objective in the paper clearly stated	Study population clearly specified & defined	Participation rate of eligible persons ≥50%	Subjects selected/ recruited from the same/ similar population (same time period); inclusion and exclusion criteria prespecified and applied uniformly to all participants	Sample size justification, power description/ variance and effect estimates provided	Exposure(s) of interest measured prior to the outcome(s) being provided	Timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if existed	For exposures that can vary in amount/ level, study examined different levels of exposure as related to the outcome	Exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants	Exposure (s) assessed more than once over time	Outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants	Outcome assessors blinded to the exposure status of participants	Loss to follow-up after baseline 20% or less	Key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)
Adegoke & Fapojuwo 2010	✓	✓	✓	✓	✓	NA	NA	x	✓	NA	✓	NR	NA	x
Ashmen et al., 1996	✓	✓	NR	✓	x	NA	NA	x	✓	NA	✓	NR	NA	✓
Bach et al., 1985	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	✓
Chesworth et al., 1994	✓	✓	NR	✓	x	NA	NA	✓	✓	NA	✓	✓	NA	✓
Ellison et al. 190	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	x
French et al., 2015	✓	✓	✓	✓	x	NA	NA	✓	✓	NA	✓	NR	NA	x
Handrakis et al., 2012	✓	✓	✓	✓	x	NA	NA	✓	✓	NA	✓	✓	NA	✓
Kishi et al., 2009	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	x
Lephart et al., 2010	✓	✓	✓	✓	✓	NA	NA	x	✓	NA	x	NR	NA	✓
Mellin, 1990	✓	✓	✓	✓	x	NA	NA	✓	✓	NA	✓	NR	NA	✓
Murray et al., 2009	✓	✓	✓	✓	✓	NA	NA	x	✓	NA	✓	✓	NA	x
Nagai et al., 2015	✓	✓	✓	✓	✓	NA	NA	✓	✓	NA	✓	NR	NA	✓
Nourbakhsh and Arab 2002	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	✓
Nourbakhsh et al., 2006	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	x
Paatelma et al., 2009	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	✓	NA	x
Roach et al., 2015	✓	✓	NR	x	x	NA	NA	x	✓	NA	✓	x	NA	x
Roncarati and McMullen 1988	✓	✓	✓	✓	x	NA	NA	x	✓	NA	x	NR	NA	x
Scholtes et al., 2009	✓	✓	✓	✓	x	NA	NA	x	✓	NA	✓	NR	NA	x
Stuelcken et al., 2008	✓	✓	✓	✓	x	NA	NA	x	✓	NA	x	✓	NA	x

(continued on next page)

Table 1 (*continued*)

Study	Research question or objective in the paper clearly stated	Study population clearly specified & defined	Participation rate of eligible persons ≥50%	Subjects selected/ recruited from the same/ similar population (same time period); inclusion and exclusion criteria prespecified and applied uniformly to all participants	Sample size justification, power description/ variance and effect estimates provided	Exposure(s) of interest measured prior to the outcome(s) being provided	Timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if existed	For exposures that can vary in amount/ level, study examined different levels of exposure as related to the outcome	Exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants	Exposure (s) assessed more than once over time	Outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants	Outcome assessors blinded to the exposure status of participants	Loss to follow-up after baseline 20% or less	Key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)
Tanaka et al., 2015	✓	✓	✓	✓	×	NA	NA	✓	✓	NA	✓	NR	NA	✓
Vad et al., 2003	✓	✓	✓	✓	×	NA	NA	×	✓	NA	✓	NR	NA	×
Vad et al., 2004	✓	✓	✓	✓	×	NA	NA	×	✓	NA	✓	✓	NA	×
Van Dillen et al., 2000	✓	✓	✓	✓	×	NA	NA	✓	✓	NA	×	✓	NA	✓
Van Dillen et al., 2008	✓	✓	✓	✓	×	NA	NA	×	✓	NA	✓	✓	NA	✓

NR: not reported, NA: not applicable.

used. Across the studies, measurements included both active and passive ROM, however in some studies this discrimination was not made.

3. Associations between NSLBP and hip ROM

3.1. Flexion

Seven studies compared hip flexion ROM between healthy individuals and those with NSLBP, of which four tested this in supine lying, and three did not describe how this was measured. Three studies used active ROM testing, one used passive ROM testing, and three did not describe whether they used active or passive testing. Six studies used a goniometer and one study used an inclinometer. The majority (n = 6) of studies showed that individuals with NSLBP tended to have a slight limitation of hip flexion (5^0-10^0), however differences were either marginal or not significant (Fig. 2a). Most studies failing to find a difference had small sample sizes and may have been underpowered to detect a clinically meaningful difference in flexion ROM.

The overall quality of evidence related to hip flexion ROM was very low due to inconsistent findings and risk of bias relating to lack of blinding of outcome assessors, poor reporting of ROM measurement, inadequate adjustment for confounders, and lack of sample size justification.

3.2. Extension

Thirteen studies compared hip extension ROM between individuals with NSLBP and healthy individuals, but eight of these used the Thomas test (or its modified version). Of the remaining five studies, two used active ROM testing, one used passive ROM testing and two did not describe whether they used active or passive testing. Extension ROM testing in these five studies was undertaken in prone lying, except for one study which tested participants in side lying. Of the eight studies which used the Thomas test (or its modified version) to examine for between-group differences in hip flexor (iliopsoas) length, four of these studies intended to measure iliopsoas/other hip flexor muscle length rather than hip joint extension ROM per se. Ten of the 13 studies used a goniometer, two studies used an inclinometer and one study did not describe the measurement tool.

Most studies failed to demonstrate a statistically significant difference between individuals with NSLBP and healthy individuals with only four studies reporting a significant difference between groups of up to approximately 10^0 reduction in hip extension ROM in NSLBP individuals (Fig. 2b). One study (Stuelcken et al., 2008) showed an increase in hip extension ROM in NSLBP individuals; however, this study suffered from flawed measurements of both exposure and outcome, as well as lack of adjustment for confounders. Overall the quality of evidence for changes in hip extension ROM was very low due to inconsistencies in findings, variability in ROM measurement methods (see Fig. 2b), and risk of bias relating to lack of adjustment for confounders and blinding of assessors.

3.3. Internal rotation

Fourteen studies compared hip IR ROM between individuals with NSLBP and healthy individuals. Five studies used active ROM testing, five used passive ROM testing, one used both, and three did not describe whether they used active or passive testing. Nine studies used a goniometer and five studies used an inclinometer. Most studies (n = 8) tested for IR ROM in prone lying, one study measured in supine lying, one study measured in sitting, and four did not describe the test position for this movement. The majority of studies (n = 10) demonstrated a tendency for a limitation of IR ROM in individuals with NSLBP, with five studies reaching significance (Fig. 2c). Significant IR limitations were up to 10^0 and were found either unilaterally (left side (n = 1), lead hip (n = 2)) or bilaterally (n = 2), regardless of whether

Table 2
Summary of 24 included studies.

Authors	POPULATION		Hip ROM measured (AROM/PROM/NR; position)	TOOL	Significant between group differences: MD (°), 95% CI, p value, Cohen's *d*
	NSLBP group	Non-NSLBP group			
Adegoke and Fapojuwo, 2010 [a]	N = 30 males, mean age 47.10 (SD 12.82) years, mechanical LBP referred to/receiving physiotherapy at time of study (LBP duration NR); volunteers from surrounding hospitals	N = 30 males, mean age 47.67 (SD 10.41) years; healthy, no recent (6 months) history of LBP/hip pain, staff members at university hospital. Matched by age (± 2), gender	AROM Flx, Ext, Abd, Add (supine); IR, ER (prone)	Goniometer	**LESS Lt Flx LBP group**: 4.83° (−8.49°, −1.17°), p = 0.01, *d* 0.68
Ashmen et al., 1996 [b]	N = 8 female athletes, age NR; CLBP(≧6 months prior to enrollment in study)	N = 8 females, age NR; healthy. Matched by position and sport	AROM Ext (prone)	Goniometer	**LESS Lt Ext LBP group**: 7.81° (SD-NR), t = 4.01, p 0.005, *d* > 1.48
Bach et al 1985 [c]	only compared between runners and non-runners: Runners: N = 45 (28 male, 17 female); age male (19.4) years, female (25.7) years; Non-runners: N = 46 (18 male, 25 female (3 loss f/u)), age male (26.7) years, female (24.7) years		AROM Ext (TT), Abd (in K/F at edge of bed)	Goniometer (for TT), Specially designed goniometer (for Abd)	No correlation between LBP and hip ROM in runners/non-runners.
Chesworth et al 1994 [d]	N = 20 (14 male, 6 female) LBP, mean age 38.8 (SD 15.3) years; LBP outpatients from physiotherapy department, recruited during initial visit; mean LBP duration 7.5 (SD 9.8) years. Students, light duty occupation, retirees, labor oriented	N = 20 (14 male, 6 female), mean age 39.1 (SD 14.6) years; Healthy (no history of LBP in past 6 months); recruited from hospital &surrounding community. Matched by age (± 5 years), gender, height, weight	AROM ER, IR (prone)	Goniometer	**LESS IR, ER LBP group**: **IR Rt** −18.5°, t = 5.22, **Lt** −14.4°, t = 5.33; **ER Rt** −14.6°, t = 4.95, **Lt** −21.1°, t = 7.16
Ellison et al 1990 [e]	N = 50 (21 male, 29 female), mean age 37.4 (SD 10.9) years; LBP patients referred to physiotherapy at rehabilitation centre, undergoing treatment for LBP at time of study (LBP duration: NR)	N = 100 (25 male, 75 female), mean age 26 (SD 5) years; healthy volunteers students and staff at university surrounding	PROM ER, IR (prone)	Goniometer	**LESS IR LBP group:** **Lt**: 6.40° (−10.26°; −2.53°), p = 0.00, *d* 0.56 **Rt:** 5.50° (−9.72°; −1.27°), P = 0.01, *d* 0.42
French et al 2015 [f]	N = 16 (6 male, 10 female), mean age 62.44 (SD 7.19) years; patients with radiographically confirmed hip OA; LBP duration 89.31(SD 110.51) months, VAS 5.48 (SD 3.61); RMDQ (0–24): 10.26 (SD 5.56)	N = 8 (5 male, 3 female), mean age 70.13 (SD 9.54) years; patients with radiographically confirmed hip OA; No Back pain	AROM Flx, Abd(supine), IR, ER (sitting)	Goniometer	no significant differences for ALL ROM on unaffected side
Handrakis et al 2012 [g]	N = 30 ((males, females NR), Pain (LBP); VAS≧2/10; LBP duration: NR)	N = 54 (males, females NR), min/no LBP	AROM Ext (hip flexor length (TT))	Goniometer	no statistical difference between groups for hip flexors length (Ext ROM)
Kishi et al 2009 [h]	N = 26 males, age NR; university Kendo practitioners; LBP history (N = 16 with LBP at time of survey); kendo training period 11.9 (SD 1.6) years; LBP duration: since high school (N = 10), senior high school days (N = 23), university days (N = 4)	N = 11males, age NR; university Kendo practitioners; No LBP; kendo training period 12.1(1.9) years	PROM Flex, Ext, IR, ER, (position NR)	Goniometer	no diff b/w groups for ALL ROM
Lephart et al 2010 [i]	N = 16 males, mean age 48.6 (SD 7.4) years, amateur golfers with LBP < 2years BUT not at time of testing	N = 16 males, mean age 47.9 (SD 8.3) years, no LBP history. Matched by age & handicap (level)	Flex, Ext, IR, ER, Abd, Add (method- NR)	Goniometer	no diff b/w groups for ALL ROM
Mellin, 1990 [j]	N = 55 (26 male, 29 female), mean age 21.4 (SD 1.9) years, 21.4 (SD 0.9) years respectively; Medical, nursing, physiotherapy, students volunteers with LBP. Duration: 1–3days (N = 15), 4–10days (N = 25), 11–30days (N = 11), > 30days (N = 4)	N = 48 (29 male, 19 female), mean age 21.5 (SD 2.2), 21.5 (SD 1.1) years respectively; Medical, nursing, physiotherapy, students volunteers, no LBP	AROM sum of bilateral hip Flex (supine) Ext, IR, ER (prone)	Inclinometer	**LESS Ext, ER LBP group (females only)**: **Ext**: 8° (−13.8°; −2.20°), p = 0.00, *d* 0.784 **ER**: 9° (−17.32°; −0.68°), p = 0.03, *d* 0.64 **LESS Flx LBP group (males only)**: -8° (−15.85°; −0.15°), p = 0.04, *d* 0.548
Murray et al 2009 [k]	N = 28 (26 male, 2 female), mean age 56.4 (SD 8.4) years; amateur golfers with LBP within past 12 months/currently suffering LBP	N = 36 (32 male, 4 female), mean age 54.3 (SD 14.4) years; amateur golfers, no LBP	PROM + AROM IR, ER (prone)	Inclinometer	**LESS IR LBP lead hip** **Passive IR**: 10° (−14.62°, −5.20°), p (NR); **Active IR**: 7° (−11.14°; −2.03°), p (NR)
Nagai et al 2015 [l]	N = 30 (males, females-NR), mean age 31.6 (SD 5.9) years, active-duty helicopter pilots with LBP within the past 12months, but no LBP at time of study. ODI 18.3 (SD 16.6), pain duration 2.4 (SD 4.1) days, NPRS 5.3 (SD 2.2)	N = 30 (male, female NR) mean age 31.6 (SD 6.0) years, no-LBP history. Matched by age (± 5years), gender, total flight hours (± 500 hrs)	PROM IR, ER, (prone)	Digital inclinometer	No difference b/w groups for ALL ROM but **INCREASED Asymmetry in Total rotation LBP group** side-to-side symmetry: LBP 0.95° (0.03) vs No-LBP 0.97° (0.04), p = 0.03
Nourbakhsh et al 2002 [m]	N = 300 150 male, 150 female, mean age 43.1 (SD 14), 43.3 (SD 13) years respectively. CLBP, 68% (N = 204) had LBP > 6 months and reporting pain and stiffness in low back at time of study. Patients selected from 5 hospitals and from patients in the orthopaedic and PT department; LBP duration > 6weeks, or > 3 intermittent episodes of each > 1week for the previous year.	N = 300 (150 male, 150 female), mean age 43 (SD 15), 43 (SD 13) years respectively; Asymptomatic, accompanies for patients or referred to the hospital for non- musculoskeletal problems. Matched by age and gender.	PROM Abd (Hip Adductors length; average Rt + Lt) (supine)	Goniometer	NO significant difference b/w groups for Abd ROM (Adductors length)

(*continued on next page*)

Table 2 (*continued*)

Authors	POPULATION		Hip ROM measured (AROM/PROM/NR; position)	TOOL	Significant between group differences: MD (°), 95% CI, p value, Cohen's *d*
	NSLBP group	Non-NSLBP group			
Nourbakhsh et al 2006, [n] 2002 [m]	see Nourbakhsh et al., 2002	see Nourbakhsh et al., 2002	AROM Ext (hip flexor length (TT); average sum of bilateral hips)	Goniometer	NO significant difference b/w groups for Ext ROM (hip flex extensibility)
Paatelma et al 2009 [o]	1.CLBP; N = 55 (24 male, 31 female), mean age 42.3 (SD 11.6) years; LBP > 3months; selected from primary-care patients (screened to exclude need for surgery) 2. Subacute LBP (SLBP); N = 47 (29 male, 18 female), mean age 44.6 (SD 10.6) years; subjects employed, with current (new/recurrent) LBP, last episode lasted < 3months; selected from occupational health centres	control; N = 55 (22 male, 33 female), mean age 37.5(8.1) years; No LBP diagnosis/any treatment for LBP in the past 1 year. Recruited from university surrounding	1. Bilateral hip mobility 2. Bilateral IP tightness (method-NR)	Not reported	forward stepwise logistic model: subjects with IP tightness were found to have 2.77 times more chance to have CLBP, and 7.09 to have SLBP compared to those with normal IP length
Roach et al 2015 [p]	N = 30 (14 male, 16 female), mean age 45 (SD 12) years; active volunteers from medical & recreational facilities with CLBP > 3months; participating in recreational sport/regular exercise routine (≥3 days/week)	N = 30 (13 male, 17 female); mean age 34 (SD 13.1) years; volunteers from medical & recreational facilities, no LBP	AROM Ext (MTT); IR, ER (prone)	Digital inclinometer	**LESS Ext LBP group** −10.94° (−15.09°; −6.78°), P = 0.00, *d* 1.41
Roncarati and McMullen 1988 [q]	N= NR, age NR; recruited from physiotherapy, sports medicine, clinics, high- schools & universities' surrounding, with LBP self-induced (trauma)/intrinsic (mechanical); LBP frequency: X10.7 times than non-LBP group	N= NR, age NR; non-LBP	hip muscles flexibility (extensors, ERs, IRs length) (method- NR)	Goniometer	significantly correlated w LBP: limited length of hip extensors (r = 0.095, p = 0.008), external rotators (r = 0.099, p = 0.006), Internal rotators (r = 0.088, p = 0.012)
Scholtes et al., 2009 [r]	N = 50 (32 male, 18 female), mean age 28.2 (SD 8.1) years; CLBP duration 6.5 (SD 5.4) years; participating regularly(≥2/week) in rotation-related sport; modified ODI% 14.6 (SD 7.6); current VAS 2.9 (SD 1.7); number of acute flare ups in the past 12months: 7.1 (SD 3.8)	N = 41 (22 male, 19 females), mean age 27.9 (SD 7.4) years; No LBP and not participating regularly in rotation-related sport	AROM ER (average Rt + Lt) (prone)	Motion capture system (eVaRT)	no significant difference for ER between groups
Stuelcken et al., 2008 [s]	1. N = 14 females; LBP 2. N = 14 females, LBP mean age (for ALL females) 22.5 (SD 4.5) years; cricket elite fast bowlers with LBP history attributed/aggravated by performing cricket related skills (N = 9 at least one episode in the past 12 months; N = 3 LBP at the start of study)	1. N = 8 males, mean age 21.5 (SD 3.0) years, No LBP at time of study 2. N = 12 females cricket elite fast bowlers, no LBP, mean age as reported for ALL females in the study	AROM Ext (hip flexor length; MTT)	Goniometer (spirit level for horizontal reference)	**INCREASED Ext LBP fast bowler Females vs no-LBP Males** **BAS Ext**: +12° (4.60°; 19.39°), p = 0.00, *d* 1.49 **Non-BAS Ext**: +8.90° (0.79°; 17.00°), P = 0.03, *d* 1.04 (No differences between females with or without LBP)
Tanaka et al 2015 [t]	N = 18 (males, females NR), mean age 62.6 (SD 11.0) years; patients with radiographically confirmed hip OA with LBP at time of study; duration: NR	N = 17 (males, females NR), mean age 64.1 (SD 8.4) years; patients with radiographically confirmed hip OA no LBP	Flx, Abd(supine), Ext (prone/sly if did not reach 0°)	Goniometer	No significant difference for ALL ROM on unaffected side
Vad et al 2003 [u]	Symptomatic LBP, N = 40 males, age (NR), professional tennis players with LBP duration > 2 weeks, limiting Tennis performance, screened also for shoulder pain.	N = 60 males, age (NR); professional tennis players, Asymptomatic,	PROM IR (supine 90° hip flx)	Goniometer	**LESS IR (90° hip flx) LBP group**: **Lead hip**: 5.90° (−6.39°; −5.40°), p = 0.00, *d* 4.89 **Non-lead hip**: 1.50° (−2.19°, −0.80°), p = 0.00, *d* 0.88
Vad et al 2004 [v]	N = 14 males, mean age 30.7 (21–38) years; professional golfers Symptomatic; LBP history > 2weeks for the past year, limiting golf performance (no LBP at time of study)	N = 28 males, mean age 31.6 (23–40) years; professional golfers, non-symptomatic; no LBP history	IR (method-NR)	Goniometer	**LESS lead hip IR LBP group**: −5.10° (−5.93°; −4.26°), p = 0.00, *d* 4.07
Van Dillen et al., 2000 [w]	N = 10 (4 male, 6 female), mean age 33.7 (SD 9.31) years; LBP (patients referred to physiotherapy); LBP duration > 7weeks	N = 35 (10 male, 25 female), mean age 31.3 (SD 11.36) years; Back Healthy	AROM Ext in 4 TT positions (average Rt + Lt): HET1:Abd 0°, K/F 80° HET2:Abd 0°, full K/E HET3:max Abd, K/F 80° HET4:max Abd, full K/E	Goniometer	**Ext in HET2 LBP group**: −4.16° (−8.00°; −0.31°), p = 0.03, *d* 0.79 **Ext in HET3 LBP group**: −4.84° (−7.94°; −1.73°), p = 0.00, *d* 1.01

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Table 2 (*continued*)

Authors	POPULATION		Hip ROM measured (AROM/PROM/NR; position)	TOOL	Significant between group differences: MD (°), 95% CI, p value, Cohen's *d*
	NSLBP group	Non-NSLBP group			
Van Dillen et al 2008 [x]	N = 24 (17 male, 7 female), mean age 26.17 (SD 7.27) years, Students participating regularly in rotation related sports with chronic LBP (> half days in past 12months, single/multiple episodes) OR recurrent LBP (< half the days in past 12months, multiple episodes); reported increase of LBP to be associated with participation in their sport. LBP duration 7.02 (SD 5.73) years; number of episodes in past 12 months: 9.29 (SD 2.66); NRS pain in past 1week: 2.77 (SD 1.80); ODI %: 15.9 (SD 8.3)	N = 24 (18 male, 6 female), mean age 26.96 (SD 7.74) years; Students participating regularly in rotation related sports; no LBP (no history of LBP that limited ADL performance > 3 days/did not seek medical intervention); matched for age, gender, BMI, Baecke activity score	PROM ER, IR, (prone)	Inclinometer	No significant difference between groups for unilateral ER, IR

NOTE: Hip range of motion (ROM) measured bilaterally unless otherwise specified.

Abbreviations: Abd (Abduction); Add (Adduction); ADL (activities of daily living); AROM (active ROM); BAS (bowling arm side); C.I (confidence intervals); CLBP (chronic low back pain); ER (external rotation); Ext (extension); Flx (flexion); HET (hip extension test); IP (iliopsoas); IR (internal rotation); K/F (knee flexion); LBP (low back pain); Lt (left); MD (mean difference); MTT (modified TT); N (represents sample size); NPRS (numeric pain rating scale); NR (not reported); OA (osteoarthritis); ODI (Oswestry Disability Index); PROM (passive ROM); PT (physical therapy); RMDQ (Roland Morris Disability Questionnaire); Rt (right); SLBP (subacute LBP); TT (Thomas test); VAS (visual analogue scale).

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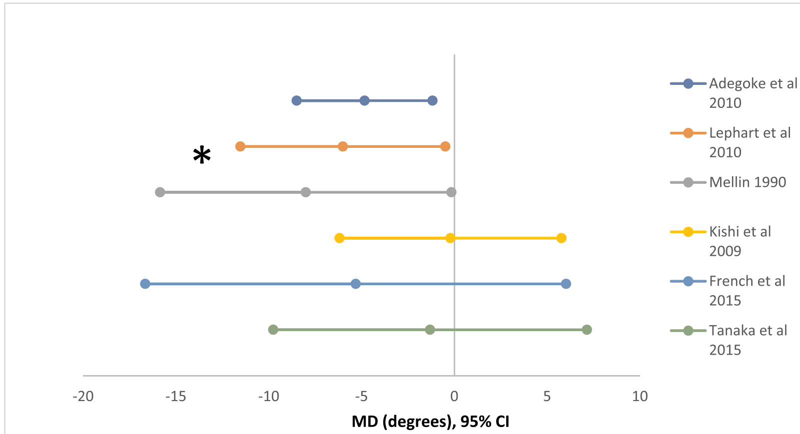

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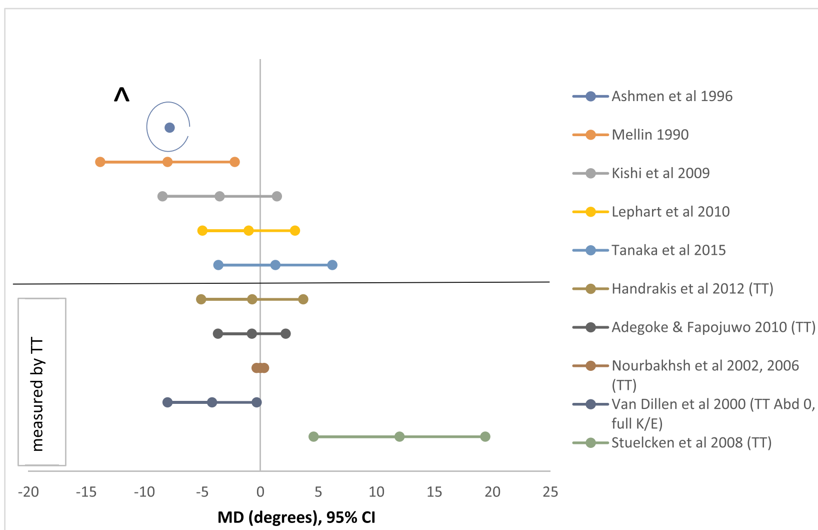

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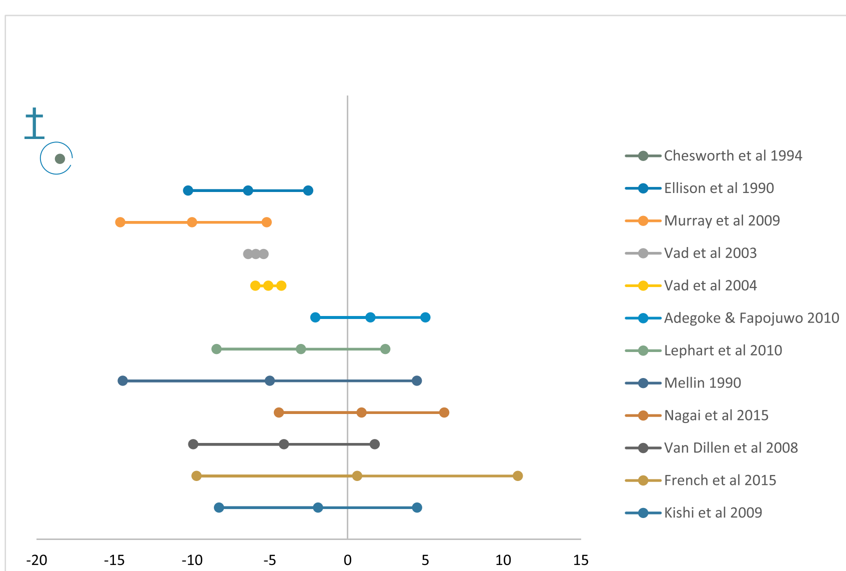

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Fig. 2. Hip ROM differences between NSLBP and healthy individuals. Fig. 2A–F. Mean differences (MD, 95% CI) in hip ROM per movement direction, between NSLBP and healthy individuals for included studies, for which data was available. A. Flexion; B. Extension; C. Internal rotation; D. External rotation; E. Abduction; F. Adduction. * Lephart et al (2010), Van Dillen et al (2008): did not reach a significant difference after a Bonferroni correction, as reported in study. ˆ, †, ‡ single dot represents significant mean difference for which 95% CI not reported/ not able to extract data. ¥ MD not reported.

individuals were participating in rotation-related sports or not.

Again, the overall quality of evidence was very low mainly due to inconsistencies in findings, with a high risk of bias relating to lack of adjusting for confounders, blinding of outcome assesors, and sample size justification.

3.4. External rotation

Thirteen studies compared hip ER ROM between individuals with NSLBP and healthy individuals. Six studies used active ROM testing, four used passive ROM testing, one used both, and two did not indicate whether testing was active or passive. Seven studies used a goniometer, five studies used an inclinometer, and one study used a motion tracking system. Nine studies tested for this movement in prone lying, one study tested in sitting, and three did not describe the position of testing. The majority ($n = 7$) of studies showed a limitation of ER ROM of up to 10^0 in individuals with NSLBP, but only two studies reached statistical significance, of which one included only females in the sample tested (Fig. 2d). The high risk of bias relating to lack of adjusting for confounders, blinding of assesors and sample size justification rendered the quality of the body of evidence for a limitation of ER ROM as very low.

3.5. Abduction and adduction

Six studies compared hip abduction ROM between individuals with NSLBP and healthy individuals. Except for one study which did not describe the position of testing, all studies measured this in supine lying, one of which had the participant's knees flexed and the lower leg hanging off the treatment table. Two studies used active ROM testing, and four did not indicate whether measurement was active or passive. Only two studies tested for a between-group difference in adduction ROM, of which one tested this actively in supine lying, and the other did not describe the position of testing and whether this was measured actively or passively. All studies used a standard goniometer. Differences were minimal, with no studies demonstrating a significant difference, and there was no consistent tendency for a greater or lesser range in individuals with NSLBP for either movement (Fig. 2e and f).

The overall quality of evidence was low with serious limitations due to flawed or poorly reported measurements of ROM, as well as lack of blinding of assessors. In relation to adduction, there is simply not enough evidence to meaningfully comment on its association with NSLBP.

4. Discussion

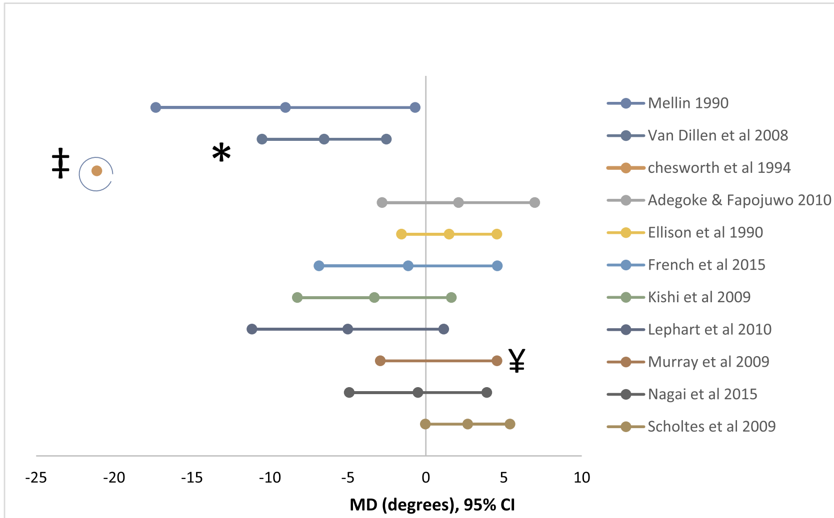
This systematic review provides a comprehensive review of the literature pertaining to the association between triplanar hip ROM and NSLBP. Despite there being relatively few studies demonstrating a statistically significant difference in hip ROM between individuals with NSLBP and healthy individuals, there is a general tendency for a reduction in hip ROM in NSLBP participants in the sagittal and horizontal planes of movement. For studies that reported significant between-group differences, approximately half reported mean differences that were $\geq 5°$, which is greater than the standard error of measurement for commonly used clinical tools such as goniometers and inclinometers (ranging from 3 to 4°). (Cheatham et al., 2017).

The lack of consistent between-group differences in hip ROM between individuals with NSLBP and healthy individuals in the studies in this review may suggest that for certain hip movements, any such difference is minimal or perhaps even non-existent. Alternatively, if only a proportion of patients with NSLBP have hip impairments, it perhaps isn't surprising to find that there is often no significant difference between groups of patients with NSLBP and groups of people without NSLBP. Any difference would be ‘washed out’ by those without any hip impairment.

The variations in findings between studies may also be explained by various differences in the measurement methodologies employed and their reporting. Studies used both active and passive ROM testing, and some did not describe the tools, or the positions used. However, passive and active ROM testing has been shown to differ for a given joint, as the latter may be influenced by muscle strength, motor control, and pain, and may not be sensitive enough to detect a difference in people with NSLBP (Bruno et al., 2014). True intra-articular kinematics has been described as the joint motion regardless of the cause of motion, and passive ROM has commonly been found to be significantly greater than active ROM in healthy individuals (Berryman Reese and Bandy, 2016). On the other hand, passive ROM testing requires adequate handling skills of the clinician. Both of the above considerations may have accounted for some of the differences found between studies and have affected the quality of the evidence due to flawed or poor measurement reporting. As there is still some conjecture in the literature as to the most reliable and valid way to assess joint ROM, researchers should define clearly their objectives in measuring ROM and their methods. In particular, it is of importance to compare between ROM measurements obtained actively and passively, as suggested by the American Medical Association (Berryman Reese and Bandy, 2016). Another possible reason for the inconsistencies found between studies may be differences in samples tested, particularly proportions of male and female participants. This may have also affected the grading of the quality of the body of evidence.

Many studies specifically tested for hip-related muscle length (e.g., hip flexors, adductors) while reporting the results as hip joint ROM, and in other studies it was not clear whether the objective was to measure joint ROM or muscle length. Since a correlation between hip muscle flexibility and joint angle of movement is yet to be established (Vigotsky et al., 2016; Harvey, 1998), caution should be exercised using muscle length measurement to indicate overall joint ROM in a particular direction; especially if the muscles in question cross more than one joint, which has been the case in some studies (e.g., Thomas test for hip flexors including rectus femoris as a proxy for hip extension ROM, adductor muscle length as a proxy for hip abduction ROM). However, despite the possible limitation of measurement of hip muscle length, these studies were included in the current review as impaired hip muscle length may be a factor differentiating individuals with NSLBP and thus may be of importance for clinicians to examine. Noteworthy is the study by Van Dillen et al. (2000), which was the only study to differentiate between the different muscles crossing the hip and knee by using four positions of the Thomas test, with a significant reduction in hip extension (with the knee kept straight) in the NSLBP group.

A common risk of bias across the studies was controlling for confounders, which is of particular importance in cross-sectional study designs (Guyatt et al., 2011). Matching participants with NSLBP to healthy participants regarding potential confounding factors such as age, gender, body mass index and occupation/activity level occurred in eight of the 24 studies included in this review, of which five used independent t-tests or between-group 2x2 ANOVA rather than paired t-tests, or a repeated measure/mixed design ANOVA, with only two studies controlling for Type 1 error. In addition, many studies that compared sides with the various hip movements in NSLBP versus healthy subjects, used multiple simple t-tests without applying a Bonferroni correction rather than using a 2x2 mixed design ANOVA. This



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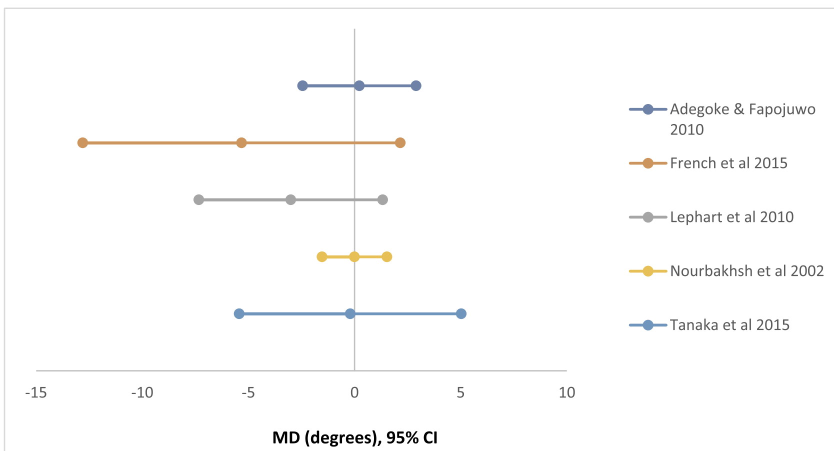

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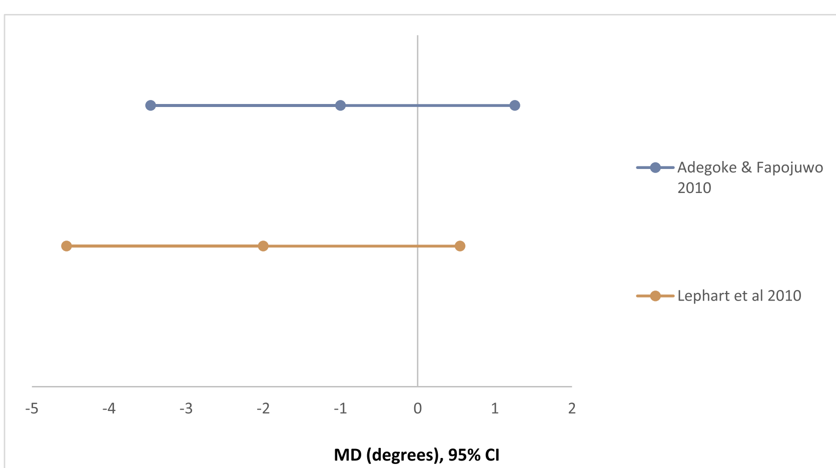

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Fig. 2. (*continued*)

may have affected the strength of any associations, especially in instances where differences did not quite reach significance. Two relevant confounders which were not specifically tested for in any study are joint hypermobility syndrome and anatomical variations of the femoroacetabular joint. Joint hypermobility syndrome is prevalent in up to 30% of the general population and has been found to be positively associated with LBP (Russek, 1999; Corben et al., 2008). In addition, there is emerging evidence to support an association between femoroacetabular anteversion and NSLBP (Tansey, 2015). Although further research is needed to determine the precise nature of any associations between hip ROM in individuals with NSLBP and anatomical variations, these may influence hip ROM as a mechanism of compensation for any malalignment of the femoral head in the acetabulum, and as such may need to be considered as a confounder (Chadayammuri et al., 2016; Buckland et al., 2015).

Although this review did not find strong and consistent evidence to support a difference in hip ROM between individuals with and without NSLBP, it is plausible that any impaired or asymmetrical hip movement in any plane could affect the rest of the kinematic chain and may contribute to altered coordination of the lumbo-pelvic-hip complex during functional movement, and vice versa. This could result in increased or abnormal mechanical forces acting on the lumbar spine, potentially contributing to the onset or persistence of NSLBP (Zafereo et al., 2015; Malarvizhi and Kishorekumar, 2016; Kim et al., 2014; Dolan and Adams, 1993). In addition, as individuals with NSLBP tend to move less from their lumbar spine, normal hip ROM is important for adequate function (Hart et al., 2009).

4.1. Hip movement directions

Although there appears to be a tendency for slightly reduced hip flexion in participants with NSLBP, there is not enough evidence from the current review to confirm or refute such an association. Mellin (1990) and Adegoke and Fapojuwo (2010) both found significantly limited hip flexion in NSLBP participants compared to healthy individuals, however these limitations were minor, unilateral and mainly in men. Consistent with this, limited hip flexion has been reported elsewhere to be a predictive risk factor for severe LBP at three-year follow-up (Adams et al., 1999), however this relationship was not replicated in a recent study at 5-year follow-up (McGill et al., 2015). Further, there is emerging evidence, albeit low level consisting mainly of case series, supporting conservative treatment for improving hip flexion ROM as being associated with reduced pain and improved function in individuals with NSLBP (Burns et al., 2011a).

Hip extension ROM was commonly measured using the Thomas test or its modified version, both of which have been recently found to have poor validity for measuring hip joint extension ROM, especially in individuals with NSLBP (Kim et al., 2013; Bruno et al., 2014; Vigotsky et al., 2016). This serious limitation has contributed to the very low quality grading of this evidence. In those studies reporting reduced extension on active movement testing in the prone lying position, this was found mainly in females and unilaterally (Mellin, 1990; Ashmen et al., 1996; respectively). However, it is noteworthy that active hip extension performed in prone lying has been proposed to be a provocative test for NSLBP and it has thus been suggested that it should not be used as a hip movement impairment test in people with NSLBP (Zafereo et al., 2015; Carlsson and Rasmussen-Barr, 2013). This variation in testing may also have contributed to inconsistency of findings between studies, and therefore a reduction in the overall quality of the evidence.

Although the findings in the current review related to hip rotation ROM were inconsistent, there were a greater number of studies reporting reduced or asymmetric IR ROM than ER ROM in individuals with NSLBP, regardless of their occupation and sport-related activities. This variability in findings in the horizontal plane and evidence being of very low quality is interesting given that IR ROM $\geq 35^0$ of at least one hip is one of the criteria in a commonly cited clinical prediction rule for selecting patients with NSLBP likely to benefit from manipulation of the lumbar spine (Flynn et al., 2002). Similarly, Stolze et al. (2012) found that average hip rotation $\geq 25^0$ unilaterally was a criterion associated with improvement following a Pilates-based program for individuals with NSLBP. In addition, hip IR has recently been reported to be associated with LBP in a systematic review by Sadeghisani et al. (2015) (Sadeghisani et al., 2015a), and has been found to be a provocative test for LBP (Prather et al., 2017). The studies comprising the evidence for hip IR ROM changes in the present review were overall of very low quality, perhaps somewhat accounting for the inconsistency in findings.

Whilst the various study's findings regarding ER ROM limitations in LBP subjects are somewhat inconsistent, impaired pelvic-hip coordination, such as greater and early lumbopelvic rotation, during hip ER in prone lying in individuals with LBP has been reported elsewhere (Harris-Hayes et al., 2009; Scholtes et al., 2009; Sadeghisani et al., 2015b). Hence, it is possible there may be some relationship between hip movement in the horizontal plane and NSLBP, and this is supported by growing evidence of improvement in NSLBP following manual therapy treatment directed at increasing hip IR and ER ROM (Lejkowski and Poulsen, 2013; Miller et al., 2012; Burns et al., 2011b).

Frontal plane movement was the least commonly investigated, and all studies that examined abduction and adduction ROM differences between people with and without NSLBP found no significant difference (Prather et al., 2017; Scholtes et al., 2009). However, it should be noted the lack of research on differences in adduction ROM precludes any meaningful conclusions being drawn. Further research is needed to determine whether there is an association between frontal plane ROM and NSLBP.

5. Limitations

There are several limitations to this review. First, we did not consider different levels of pain or disability and different durations of NSLBP. This may be of importance as hip ROM in acute LBP may present quite differently to that at other stages due to pain intensity and related muscle spasm, especially as some hip ROM tests have been proposed to be provocative in cases of NSLBP (Prather et al., 2017). Second, the inclusion of studies measuring muscle length may have contributed to the difficulty in comparing between studies and drawing conclusions. However, in many of those studies it was not clear as to what was actually tested, and this did not become fully apparent until afterwards at data extraction. Last, as all included studies were cross-sectional in design (level 3.c evidence) (JBI, 2014), this limits the inferences about relationships which may be drawn (Bowling and Ebrahim, 2006).

6. Conclusions

This systematic review of cross-sectional studies (level 3 evidence) has revealed there is very low quality evidence to either support or refute there being differences in hip ROM in individuals with NSLBP as compared to healthy controls. The majority of studies showing some reduction in hip ROM in participants with NSLBP were mainly in internal rotation, despite the variability in the findings between different studies. Whilst some clinical prediction rules and clinical guidelines recommend that measurement of hip ROM be considered in the clinical examination of NSLBP patients (Delitto et al., 2012; Sadeghisani et al., 2015a), the very low quality of evidence in this review and the associated inconclusive findings, suggest the practitioner should exercise caution in interpreting limitations of hip ROM in their clinical practice. Better designed studies with stronger internal validity are needed to resolve this question.

Future studies might particularly address passive hip extension ROM testing, frontal plane (abduction, adduction) ROM testing, and whether asymmetry in hip ROM in all planes of movement is associated with NSLBP. In addition, future research should also address the minimal clinically important difference in hip ROM in individuals with NSLBP in order to establish whether any significant reduction in ROM found should be addressed in the management of NSLBP.

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Conflicts of interest

The authors have no relationship/conditions/circumstances that present a potential conflict of interest.

Clinical trial registration and number

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.03.002.

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