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Sex differences in lumbopelvic movement patterns during hip medial rotation in people with chronic low back pain

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Abstract

Objective—To examine sex differences in lumbopelvic motion and symptom behavior during hip medial rotation in people with low back pain (LBP). We hypothesized that men would demonstrate greater and earlier lumbopelvic motion and would be more likely to report increased symptoms compared to women.

Design—Cross-sectional observational study.

Setting—University musculoskeletal analysis laboratory.

Participants—Thirty men and 29 women with chronic LBP were recruited from the community and a university-based physical therapy clinic.

Interventions—Not applicable.

Main Outcome Measures—Lumbopelvic rotation range of motion, amount of hip rotation completed prior to the start of lumbopelvic motion, and provocation of LBP symptoms during the test of prone hip medial rotation were measured.

Results—Men demonstrated significantly more lumbopelvic rotation (men: $10.0^\circ \pm 5.1^\circ$, women: $4.5^\circ \pm 3.9^\circ$; $P < 0.001$) and completed less hip rotation prior to the start of lumbopelvic motion (men: $5.4^\circ \pm 3.8^\circ$, women: $16.0^\circ \pm 13.2^\circ$; $P < 0.001$) compared to women. Additionally, a significantly greater percentage of men (60.0%) than women (34.5%; $P = 0.050$) reported increased symptoms with hip medial rotation.

Conclusions—Men could be at greater risk than women for experiencing LBP symptoms related to hip medial rotation as a result of greater and earlier lumbopelvic motion.

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Keywords

chronic low back pain; hip; rotation; sex differences

Previous investigations have supported a link between factors related to hip motion and low back pain (LBP). In particular, decreased hip medial rotation range of motion (ROM) has been associated with LBP.¹⁻⁶ People with LBP demonstrate less active hip medial rotation ROM than people without LBP.¹ People with LBP who participate in rotation-related sports, such as golf and tennis, display deficits in lead-leg passive and active hip medial rotation ROM, whereas people without LBP do not display these deficits.²⁻⁴ Additionally, people with LBP tend to have less hip medial rotation either unilaterally or bilaterally compared to hip lateral rotation.^{5,6}

The link between decreased hip medial rotation ROM and LBP, however, may vary by sex. In both healthy individuals⁷ and people with LBP,⁸ adult men demonstrate less active hip medial rotation than adult women. Furthermore, less active hip medial rotation ROM is associated with greater LBP severity for adult men, but not adult women.⁸ Similarly, LBP is associated with decreased active hip medial rotation ROM in adolescent boys, but not girls.⁹ Although sex differences in hip joint anatomy, muscle stiffness or activation may be a factor, there is not a clear explanation for why the relationship between hip medial rotation ROM and LBP differs between men and women.

To date, much of the literature relating hip medial rotation to LBP has focused on hip joint ROM.¹⁻⁶ However, motion of the lumbopelvic region that occurs during hip medial rotation may also be critical to understanding the relationship between hip medial rotation and LBP. Several authors propose that lumbopelvic motion occurring early or excessively during trunk and limb movements, including hip medial rotation, may contribute to LBP.¹⁰⁻¹² Specifically, these authors suggest that lumbopelvic motion that occurs early in the range of a trunk or limb movement used with regular daily activities is more likely to be frequently repeated over time. Such frequent motion of the lumbopelvic region, in addition to excessive motion of the lumbopelvic region, may lead to high concentrations of stress in lumbopelvic region tissues and eventually microtrauma and LBP. In fact, many authors have reported that increased or early lumbopelvic motion with trunk or limb movements during clinical examination tests and activities of daily living is associated with LBP.¹³⁻¹⁹

Several studies have specifically examined the relationship between LBP and lumbopelvic movement patterns during a related lower limb movement, hip *lateral* rotation. People with LBP demonstrate a greater total amount of lumbopelvic motion during hip lateral rotation compared to people without LBP.¹⁹ The onset of this lumbopelvic motion also occurs earlier during hip lateral rotation in people with LBP compared to people without LBP.¹⁹ This relationship between greater and earlier lumbopelvic motion and LBP may be related to the mechanism of increased lumbopelvic region tissue stress described above. In people with LBP, there are also differences in lumbopelvic movement patterns with hip lateral rotation between sexes. During active hip lateral rotation, men use a greater percentage of their total lumbopelvic motion early in the range of hip motion compared to women.¹⁸ Additionally, more men than women report symptoms with active hip lateral rotation.¹⁸ Similarly, more men than women demonstrate lumbopelvic motion within the first half of the range of hip lateral rotation.²⁰ These findings suggest that earlier and greater lumbopelvic motion with hip lateral rotation is more likely to be related to LBP symptoms in men than women.^{18,20} Possible explanations for these differences in lumbopelvic movement patterns between men and women include differences in passive limb tissue stiffness, tissue extensibility, patterns of muscle recruitment, muscle strength, and anthropometric variables.^{18,20}

These studies have found a relationship between hip lateral rotation and LBP related to the presence of increased and early lumbopelvic motion during the movement.^{18,20} However, many other studies of hip rotation suggest that hip medial rotation findings are also important in the study of LBP.^{1–6} Decreased hip medial rotation ROM has been related to LBP.^{1–6} However, sex appears to affect the relationship between hip medial rotation ROM and LBP.^{8,9} Lumbopelvic motion is thought to contribute to LBP.^{10–12} Additionally, sex differences in lumbopelvic motion have been found with hip lateral rotation.^{18,20} No studies, however, have reported on sex differences in lumbopelvic movement patterns during hip medial rotation. The purpose of this study was to examine sex differences in the magnitude of lumbopelvic motion and the relative timing of motion between the hip and lumbopelvic region during active hip medial rotation in people with LBP. We hypothesized that men would demonstrate greater and earlier lumbopelvic motion during hip medial rotation compared to women. We also hypothesized that more men than women would report LBP symptoms with hip medial rotation.

METHODS

Subject Selection

All subjects in the study reported chronic LBP, as defined by Von Korff.²¹ Data for 62 subjects were selected to be analyzed from a larger randomized controlled clinical trial studying two nonsurgical treatments for chronic LBP. Subjects were stratified by sex. Equal numbers of men and women (N=31 each) were randomly selected from the larger data set by a member of the research team who was not involved in the processing or analysis of kinematic data. Data for the current study were collected prior to subject participation in the intervention phase of the clinical trial. To be included in the clinical trial, people were required to be between 18 and 60 years old, to be able to stand and walk independently, and to report having LBP for a minimum of 12 months. They were also required to be experiencing their typical LBP symptoms, but to not be experiencing an acute flare up.²¹ Exclusion criteria were as follows: physician diagnosis of spinal deformity, physician diagnosis or clinical signs and symptoms of disc herniation,^{22,23} pain or paresthesia below the knee, history of spinal fracture or surgery, presence of a primary hip problem, systemic inflammatory or other serious medical condition, pregnancy, receiving worker's compensation or disability benefits or in litigation for LBP, referred from a specialized pain clinic, or presentation of magnified symptom behavior.²⁴ The University's Human Research Protection Office approved the study. Subjects provided written informed consent to participate in the study.

Laboratory Procedures

For descriptive purposes, subjects first completed self-report measures including a verbal numeric rating scale of symptoms,^{25,26} a demographic and LBP history questionnaire,²⁷ the modified Oswestry Low Back Pain Disability Questionnaire,²⁸ and the Fear-Avoidance Beliefs Questionnaire.²⁹ Both the modified Oswestry Questionnaire and the Fear-Avoidance Beliefs Questionnaire have been shown to be reliable and valid, and higher scores represent greater disability or fear-avoidance beliefs, respectively.^{28–30} Subjects then participated in a standardized physical therapy examination based on the Movement System Impairment model for LBP.^{12,31} Kinematic data were then collected for 14 laboratory-based tests of movements and postures, including hip medial rotation.

Kinematics

Subjects were instructed to lie prone, with one knee flexed to 90 degrees and the hip neutral with regard to rotation and abduction/adduction. They were then instructed to actively medially rotate their hip as far as possible and return to the starting position. In prone, hip

medial rotation occurs as the lower leg and foot rotate away from midline. Subjects were given up to 10 seconds to complete the full movement. The test was performed on both the left and right sides; limb order was randomized.

A six-camera, three-dimensional motion capture system (EvaRT, Motion Analysis Corporation, Santa Rosa, CA) was used to collect and process kinematic data. Retro-reflective markers placed 7 cm to each side of the first sacral vertebra (S1), on the lateral knee joint line, and at the most distal aspect of the lateral malleolus were used for this analysis. Data were captured at a sampling rate of 60 Hz. A vector between the markers on the left and right sides of S1 defined the pelvic segment. A vector between the markers on the lateral knee joint line and distal lateral malleolus defined the lower leg segment. Marker placement and pelvic and lower leg segment vectors are depicted in Figure 1.

A fourth-order, dual-pass, Butterworth filter with a cutoff frequency of 2.0 Hz was initially used to filter the data. The initiation and termination of movement and the movement times for the pelvic and lower leg segments were calculated. Specific parameters for initiation and termination of movement were similar those used in previous studies of hip lateral rotation.^{18,19} The initiation of pelvic segment rotation was defined as the point when both (1) the angular displacement of the pelvic segment exceeded 0.5°, and (2) the angular velocity of the pelvic segment exceeded 15% of its maximum. The termination of pelvic segment rotation was defined as the first point at which the angle reached 99% of its maximum rotation angle or the end of lower leg segment movement, whichever occurred first. The initiation of movement of the lower leg segment was defined as the point when both (1) the angular displacement of the lower leg segment exceeded 1.5°, and (2) the angular velocity of the lower leg segment exceeded 5% of its maximum. The termination of lower leg segment rotation was defined as the first point at which the angle reached 99% of its maximum rotation angle. For analysis of all dependent variables, raw data were then filtered at a subject-specific cut-off frequency³² calculated as the reciprocal of 15% of the period of movement with the following equation: $1/[0.15 \times (\text{movement time})]$, based on individual pelvic segment movement times. Angular displacements between the initial and final positions of pelvic (θ) and lower leg (φ) segments in the transverse plane were calculated. The initiation, termination, and angular displacement of the pelvic segment were used to determine the start, end, and total amount of lumbopelvic rotation. The initiation and termination of the lower leg segment were used to determine the start and end of hip rotation.

Dependent Variables

For each test of hip medial rotation, total lumbopelvic motion was calculated. The amount of hip rotation completed prior to the start of lumbopelvic rotation was also calculated to determine earlier or later lumbopelvic motion within the range of hip medial rotation. Additionally, total hip medial rotation motion was calculated in order to assess whether hip rotation ROM was a potential factor affecting lumbopelvic motion. The amount of total lumbopelvic motion was defined as the angular displacement of the pelvic segment. The amount of hip rotation was defined as the angular displacement of the lower leg segment *minus* the angular displacement of the pelvic segment. Paired-samples t-tests revealed no systematic differences between the right and left sides for lumbopelvic rotation ($t=0.693$, $P=0.491$), hip rotation ($t=-1.624$, $P=0.110$), or hip rotation at the start of lumbopelvic motion ($t=0.454$, $P=0.652$); therefore, values were averaged between sides. Subjects verbally reported whether or not they experienced an increase in their LBP symptoms, relative to the starting position, during the performance of hip medial rotation. If a subject reported an increase in symptoms with the limb movement on at least one side, or on both sides, an increase in symptoms with hip medial rotation was recorded for that subject.

Data Analysis

Independent-samples t-tests were used to compare baseline subject characteristic data between men and women. Independent-samples t-tests were also used to compare kinematic dependent variables (total lumbopelvic rotation, hip rotation completed prior to the start of lumbopelvic rotation, and total hip rotation) between sexes. Because these kinematic variables were expected to be correlated, a Bonferroni adjustment to alpha was applied.³³ Alpha for the comparisons of kinematic variables between men and women was set at 0.017 (.05/3). Levene's test was performed to test for equality of variances of each variable for men and women. When Levene's test was significant and variances were not equal, the t-statistic calculation was based on the actual sample sizes and standard deviations for each sex.³⁴ Cohen's *d* was calculated to estimate effect size.³⁵ A chi-square test for independence was used to compare whether or not there was a difference in the proportion of subjects reporting increased symptoms during hip medial rotation between sexes. Because an a priori hypothesis was proposed for this single comparison, alpha was set at 0.05. Statistical analyses were performed in *SPSS 17*.

RESULTS

Subject Characteristics and Self-Report Measures

Data for 59 of the 62 original subjects were included in the analysis. Data for 2 women were removed because these subjects extended their knees while performing hip medial rotation, interfering with accurate hip rotation calculations. Data for 1 man were eliminated because he was an outlier, demonstrating extreme total lumbopelvic rotation greater than 4 standard deviations away from the mean for the entire sample.³³ Subject characteristics and self-report data are presented in Table 1. On average, men were significantly taller and heavier than women, but there was not a significant difference in body mass index between sexes. No other variables were significantly different between men and women.

Kinematic Data

Mean values for total lumbopelvic motion, active hip medial rotation completed before the start of lumbopelvic motion, and total active hip medial rotation ROM are presented in Table 2. Men demonstrated significantly more total lumbopelvic rotation motion (mean $\pm$ standard deviation; $10.0^\circ \pm 5.1^\circ$) than women ($4.5^\circ \pm 3.9^\circ$; $P < 0.001$). Additionally, men completed less hip medial rotation prior to the start of lumbopelvic rotation ($5.4^\circ \pm 3.8^\circ$) than women ($16.0^\circ \pm 13.2^\circ$; $P < 0.001$). Finally, men demonstrated less total hip medial rotation ROM ($30.4^\circ \pm 8.5^\circ$) than women ($41.7^\circ \pm 11.3^\circ$; $P < 0.001$).

Symptom Behavior

A significantly greater proportion of men (60.0%) than women (34.5%; $P = 0.050$) reported increased symptoms on one or both sides during hip medial rotation (Table 2).

DISCUSSION

Many researchers consider the movement of hip medial rotation, particularly decreased active or passive ROM, to be important in the study of LBP.¹⁻⁶ Results of the current study support previous research showing that men with LBP display less active hip medial rotation ROM than women with LBP.⁸ This study is the first, however, to also document differences between men and women in lumbopelvic motion and LBP symptom behavior during hip medial rotation. Men demonstrated earlier and greater lumbopelvic rotation ROM during active hip medial rotation compared to women. Additionally, more men than women reported that their LBP symptoms increased in intensity with active hip medial rotation. The results of this study are important because they lend greater insight into the relationship

between decreased hip medial rotation ROM and LBP, and they may also have implications for our understanding of the development and treatment of LBP.

Understanding the effect of lumbopelvic motion that occurs during hip medial rotation may be central to understanding the relationship between decreased hip medial rotation ROM and LBP. Several studies have shown that people with LBP display altered lumbopelvic motion across a variety of trunk and limb movements.^{13–17,19} Theoretically, if lumbopelvic motion occurs frequently as a result of repeated trunk or limb movement, then tissue stress to the lumbar region may accumulate, leading to tissue injury and LBP.^{10–12} In the current study, in addition to demonstrating earlier and greater lumbopelvic motion, a greater proportion of men reported an increase in LBP symptoms with hip medial rotation compared to women. This difference in symptom behavior during hip medial rotation was observed despite the fact that men and women were not different on variables related to baseline LBP history, intensity, disability, or fear-avoidance behavior (Table 1). Similar results were found during a related lower limb movement, hip lateral rotation.¹⁸ These results are consistent with the proposal that increased magnitude or frequency of lumbopelvic motion in a specific direction is related to symptoms of LBP.

Although this study does not directly address the underlying causes of differences in lumbopelvic movement patterns during hip medial rotation between men and women, we can propose some potentially plausible mechanisms. Sex differences in the *amount* of lumbopelvic rotation observed during hip medial rotation may be attributable to differences in available hip ROM. Potentially, greater lumbopelvic motion could occur to compensate for limited available hip medial rotation ROM in men. Men demonstrated less active hip medial rotation than women, which likely reflects less available passive hip medial rotation ROM, although this was not specifically measured. Limited active hip medial rotation ROM may be related to inherent differences in muscle length or bony structure between men and women. Healthy men demonstrate decreased lower limb muscle length compared to women.^{36–38} If muscle length of the hip lateral rotators were decreased in men compared to women, it could account for differences in hip medial rotation ROM. Studies of healthy adults have also shown that men tend to demonstrate less femoral³⁹ and acetabular⁴⁰ anteversion than women, both of which are structural variations in the shape of the femur or pelvis that influence the degree of available hip medial rotation ROM. Specifically, decreased femoral or acetabular anteversion are consistent with decreased hip medial rotation ROM.⁴¹ Therefore, men in this study may have demonstrated greater lumbopelvic motion than women due to decreased available hip medial rotation ROM, driven by sex differences in muscle length or bony structure.

However, *earlier* lumbopelvic rotation in men compared to women is not likely related to decreased available hip medial rotation ROM. On average, lumbopelvic motion started before full active hip medial rotation ROM was achieved (Table 2). These results suggest that something other than available hip medial rotation ROM was contributing to how early the lumbopelvic region started to move. Sex differences in relative lumbopelvic region and lower limb tissue stiffness may account for differences in when the lumbopelvic region started to move. Stiffness is defined as the ratio of force or resistance applied to the tissue to the change in length or displacement of the tissue.⁴² Several studies have reported sex differences in trunk *or* lower limb tissue stiffness.^{43–48} None, however, have examined sex differences in relative tissue stiffness between the trunk and lower limb. For example, if the tissues of the trunk that limit lumbopelvic rotation are relatively less stiff than tissues about the hip that limit medial rotation, earlier lumbopelvic rotation may be expected in order to overcome the resistance from the hip while continuing to move the lower limb. Alternatively, differences in activation patterns of the trunk and hip muscles may explain why the relative timing of lumbopelvic motion differs between men and women in the

current study. Other studies have documented differences between men and women in muscle activation patterns of the trunk and lower limb during other movements.^{49,50} Decreased recruitment or later activation of the oblique abdominal muscles while an individual attempts to medially rotate the hip, for example, could lead to earlier lumbopelvic motion.

Regardless of the underlying mechanism(s) contributing to the sex differences in lumbopelvic motion during hip medial rotation, the results of the current study suggest that the movement of hip medial rotation may be more problematic for men than women with LBP. If LBP symptoms are related to lumbopelvic motion during limb movements, sex differences in lumbopelvic movement patterns and symptom behavior with certain limb movements could suggest different contributing factors to LBP for men and women. Potentially, men may be at more risk for experiencing LBP symptoms during the performance of functional or recreational activities during which the hip medially rotates. For example, turning the torso and pelvis on a planted foot, as may occur when changing directions with ambulation, in standing with certain occupations (e.g., cashier), or during certain rotation-related sports (e.g., golf or tennis), can move the hip joint into medial rotation. Based on the results of the current study, for men in particular, the repeated performance of these or similar activities could result in early or excessive lumbopelvic motion and potentially lead to LBP symptoms. However, future studies are required to confirm this hypothesis. Hip medial rotation in the current study was performed as a non-functional, open-chain movement. We believe our results represent what would also be observed during functional, closed-chain movements. We propose this because factors affecting relative motion between the hip and lumbopelvic region, such as ROM or stiffness, should theoretically remain the same whether the movement is open- or closed-chain. Furthermore, because controlling multiple segments during a functional movement is more difficult than controlling lumbopelvic motion during the isolated movement of one segment (the hip), we would hypothesize that the issues of lumbopelvic control we identified would be as prevalent, if not more prevalent, than what we identified with the hip medial rotation test.

Sex differences in lumbopelvic movement patterns and symptom behavior with hip medial rotation could also indicate differences in the focus of treatment for men and women with LBP. If lumbopelvic motion during limb movement is related to LBP, then changing lumbopelvic movement patterns may be an effective way to reduce LBP symptoms. In fact, research has shown that in people who report increased LBP symptoms with lower limb and trunk movements, such as hip medial rotation, symptoms are often decreased or eliminated when lumbopelvic motion is manually restricted.^{51,52} It is therefore logical that treatment focusing on teaching people with LBP to actively restrict lumbopelvic motion during a limb movement may be effective for reducing symptoms associated with that limb movement. During hip medial rotation, this could be accomplished by teaching a patient to activate their abdominal muscles and instructing them to hold their lumbopelvic region still while focusing on moving the hip more. Studies have demonstrated that people with LBP can learn to restrict lumbopelvic region motion during hip rotation both within a session and over a 6-week treatment period.^{53,54} Alternatively, some individuals may need to be instructed to avoid or modify the performance of certain activities that involve hip medial rotation, particularly if the movement pattern is the result of a structural variation (e.g., decreased femoral or acetabular anteversion). The sex differences in lumbopelvic movement patterns and symptom behavior in this study suggest that these strategies may be more important components of treatment for men than women.

Study Limitations

This study cannot confirm the underlying mechanisms producing different lumbopelvic movement patterns between men and women. Measures of passive hip medial rotation ROM, trunk and hip stiffness, or trunk and hip muscle activation patterns may have provided additional information to improve our understanding of the relationship between hip medial rotation ROM, lumbopelvic motion, and LBP. However, we believe that the results of this study are important. Lumbopelvic movement patterns are becoming an increasing focus in LBP research. This is the first study, to our knowledge, to document differences in lumbopelvic motion and LBP symptom behavior between men and women with a movement many researchers consider to be important in the study of LBP. The findings of this study further progress our understanding of factors that could influence the development of LBP and may have important treatment implications.

An additional limitation of this study is that we assessed motion of the pelvis in space to infer motion of the lumbopelvic region. It is possible that motion above the lumbopelvic region (i.e., in the thoracic spine) may be reflected in the motion of the pelvic segment. However, visual inspection of the individual kinematic data reveals that a substantial amount of motion is occurring in the lumbopelvic region. Furthermore, using motion of the pelvis to index lumbopelvic motion is consistent with other studies of lumbopelvic motion during limb movements.^{18,19}

CONCLUSIONS

In the current study, men demonstrated earlier and greater lumbopelvic motion with hip medial rotation. Additionally, men were more likely to report LBP symptoms during hip medial rotation than women. These results further support a relationship between lumbopelvic motion and LBP. Identifying differences in lumbopelvic motion between men and women during hip medial rotation is an important step to help further our understanding of sex differences in contributing factors and the treatment of LBP. Hip medial rotation and associated lumbopelvic motion may be more problematic for men than women with LBP, and thus limiting lumbopelvic motion during activities involving hip medial rotation may be a greater focus of treatment for men than women.

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LIST OF ABBREVIATIONS

LBP	low back pain
ROM	range of motion

REFERENCES

1. Chesworth BM, Padfield BJ, Helewa A, Stitt LW. A comparison of hip mobility in patients with low back pain and matched healthy subjects. *Physiother Can.* 1994; 46:267–274.

2. Vad VB, Gebeh A, Dines D, Altchek D, Norris B. Hip and shoulder internal rotation range of motion deficits in professional tennis players. *J Sci Med Sport*. 2003; 6:71–75. [PubMed: 12801212]
3. Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, Andrews JR. Low back pain in professional golfers: the role of associated hip and low back range-of-motion deficits. *Am J Sports Med*. 2004; 32:494–497. [PubMed: 14977679]
4. Murray E, Birley E, Twycross-Lewis R, Morrissey D. The relationship between hip rotation range of movement and low back pain prevalence in amateur golfers: an observational study. *Phys Ther Sport*. 2009; 10:131–135. [PubMed: 19897166]
5. Cibulka MT, Sinacore DR, Cromer GS, Delitto A. Unilateral hip rotation range of motion asymmetry in patients with sacroiliac joint regional pain. *Spine*. 1998; 23:1009–1015. [PubMed: 9589539]
6. Ellison JB, Rose SJ, Sahrmann SA. Patterns of hip rotation range of motion: a comparison between healthy subjects and patients with low back pain. *Phys Ther*. 1990; 70:537–541. [PubMed: 2144050]
7. Simoneau GG, Hoenig KJ, Lepley JE, Papanek PE. Influence of hip position and gender on active hip internal and external rotation. *J Orthop Sports Phys Ther*. 1998; 28:158–164. [PubMed: 9742472]
8. Mellin G. Correlations of hip mobility with degree of back pain and lumbar spinal mobility in chronic low-back pain patients. *Spine*. 1988; 13:668–670. [PubMed: 2972070]
9. Sjolie AN. Low-back pain in adolescents is associated with poor hip mobility and high body mass index. *Scand J Med Sci Sports*. 2004; 14:168–175. [PubMed: 15144357]
10. Adams, MA.; Bogduk, N.; Burton, K.; Dolan, P. *The Biomechanics of Back Pain*. 1st ed.. Edinburgh: Churchill Livingstone; 2002.
11. McGill SM. The biomechanics of low back injury: implications on current practice in industry and the clinic. *J Biomech*. 1997; 30:465–475. [PubMed: 9109558]
12. Sahrmann, SA. *Diagnosis and Treatment of Movement Impairment Syndromes*. 1st ed.. St. Louis: Mosby, Inc.; 2002.
13. Burnett AF, Cornelius MW, Dankaerts W, O'Sullivan PB. Spinal kinematics and trunk muscle activity in cyclists: a comparison between healthy controls and non-specific chronic low back pain subjects—a pilot investigation. *Man Ther*. 2004; 9:211–219. [PubMed: 15522646]
14. Luomajoki H, Kool J, de Bruin ED, Airaksinen O. Movement control tests of the low back; evaluation of the difference between patients with low back pain and healthy controls. *BMC Musculoskelet Disord*. 2008; 9:170–181. [PubMed: 19108735]
15. Roussel N, Nijs J, Truijen S, Mottram S, Van Moorsel A, Stassijns G. Altered lumbopelvic movement control but not generalized joint hypermobility is associated with increased injury in dancers: a prospective study. *Man Ther*. 2009; 14:630–635. [PubMed: 19179101]
16. Esola MA, McClure PW, Fitzgerald GK, Siegler S. Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. *Spine*. 1996; 21:71–78. [PubMed: 9122766]
17. McClure PW, Esola M, Schreier R, Siegler S. Kinematic analysis of lumbar and hip motion while rising from a forward, flexed position in patients with and without a history of low back pain. *Spine*. 1997; 22:552–558. [PubMed: 9076888]
18. Gombatto SP, Collins DR, Sahrmann SA, Engsberg JR, Van Dillen LR. Gender differences in pattern of hip and lumbopelvic rotation in people with low back pain. *Clin Biomech*. 2006; 21:263–271.
19. Scholtes SA, Gombatto SP, Van Dillen LR. Differences in lumbopelvic motion between people with and people without low back pain during two lower limb movement tests. *Clin Biomech*. 2009; 24:7–12.
20. Scholtes SA, Van Dillen LR. Gender-related differences in prevalence of lumbopelvic region movement impairments in people with low back pain. *J Orthop Sports Phys Ther*. 2007; 37:744–753. [PubMed: 18560183]
21. Von Korff M. Studying the natural history of back pain. *Spine*. 1994; 19:2041S–2046S. [PubMed: 7801181]

22. Deyo RA, Rainville J, Kent DL. What can the history and physical examination tell us about low back pain? *J Am Med Assoc.* 1992; 268:760–765.
23. van der Windt DAWM, Simons E, Riphagen II, et al. Physical examination for lumbar radiculopathy due to disc herniation in patients with low-back pain (Review). *Cochrane Database Syst Rev.* 2010; (Issue 2):1–83.
24. Waddell G, McCulloch JA, Kummel E, Venner RM. Nonorganic physical signs in low-back pain. *Spine.* 1980; 5:117–125. [PubMed: 6446157]
25. Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. *Ann Rheum Dis.* 1978; 37:378–381. [PubMed: 686873]
26. Jensen MP, Turner JA, Romano JM. What is the maximum number of levels needed in pain intensity measurement? *Pain.* 1994; 58:387–392. [PubMed: 7838588]
27. Deyo RA, Andersson G, Bombardier C, et al. Outcome measures for studying patients with low back pain. *Spine.* 1994; 19:2032S–2036S. [PubMed: 7801179]
28. Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. *Phys Ther.* 2001; 81:776–788. [PubMed: 11175676]
29. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain.* 1993; 52:157–168. [PubMed: 8455963]
30. Jacob T, Baras M, Zeev A, Epstein L. Low back pain: reliability of a set of pain measurement tools. *Arch Phys Med Rehabil.* 2001; 82:735–742. [PubMed: 11387576]
31. Van Dillen LR, Sahrmann SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom NJ. Movement system impairment-based categories for low back pain: stage 1 validation. *J Orthop Sports Phys Ther.* 2003; 33:126–142. [PubMed: 12683688]
32. Winter, DA. *Biomechanics and Motor Control of Human Movement.* 2nd ed.. New York: John Wiley & Sons; 1990. Kinematics; p. 11-50.
33. Tabachnick, BG.; Fidell, LS. *Using Multivariate Statistics.* 5th ed.. Boston: Pearson Education, Inc; 2007.
34. Norusis, MJ. *SPSS Statistics 17.0 Guide to Data Analysis.* Upper Saddle River: Prentice Hall Inc.; 2008. Two-way analysis of variance; p. 333-363.
35. Cohen, J. *Statistical power analysis for the behavioral sciences.* 2nd ed.. Hillsdale: Hove and London; 1988. The t test for means; p. 19-74.
36. Chow RS, Medri MK, Martin DC, Leekam RN, Agur AM, McKee NH. Sonographic studies of human soleus and gastrocnemius muscle architecture: gender variability. *Eur J Appl Physiol.* 2000; 82:236–244. [PubMed: 10929218]
37. Youdas JW, Krause DA, Hollman JH, Harmsen WS, Laskowski E. The influence of gender and age on hamstring muscle length in healthy adults. *J Orthop Sports Phys Ther.* 2005; 35:246–252. [PubMed: 15901126]
38. Corkery M, Briscoe H, Ciccone N, et al. Establishing normal values for lower extremity muscle length in college-age students. *Phys Ther Sport.* 2007; 8:66–74.
39. Braten M, Terjesen T, Rossvoll I. Femoral anteversion in normal adults. Ultrasound measurements in 50 men and 50 women. *Acta Orthop Scand.* 1992; 63:29–32. [PubMed: 1738965]
40. Maruyama M, Feinberg JR, Capello WN, D'Antonio JA. The Frank Stinchfield Award: Morphologic features of the acetabulum and femur: anteversion angle and implant positioning. *Clin Orthop Relat Res.* 2001:52–65. [PubMed: 11764371]
41. Oatis, CA. *Kinesiology: The Mechanics & Pathomechanics of Human Movement.* 2nd ed.. Baltimore: Lippincott Williams & Wilkins; 2009.
42. White, AA., III; Panjabi, MM. *Clinical Biomechanics of the Spine.* 2nd ed.. Philadelphia: Lippincott – Raven Publishers; 1990.
43. McGill S, Seguin J, Bennett G. Passive stiffness of the lumbar torso in flexion, extension, lateral bending, and axial rotation: effect of belt wearing and breath holding. *Spine.* 1994; 19:696–704. [PubMed: 8009335]

44. Brown MD, Holmes DC, Heiner AD, Wehman KF. Intraoperative measurement of lumbar spine motion segment stiffness. *Spine*. 2002; 27:954–958. [PubMed: 11979169]
45. Blackburn JT, Riemann BL, Padua DA, Guskiewicz KM. Sex comparison of extensibility, passive, and active stiffness of the knee flexors. *Clin Biomech*. 2004; 19:36–43.
46. Granata KP, Wilson SE, Padua DA. Gender differences in active musculoskeletal stiffness. Part I. Quantification in controlled measurements of knee joint dynamics. *J Electromyogr Kinesiol*. 2002; 12:119–126. [PubMed: 11955984]
47. Granata KP, Padua DA, Wilson SE. Gender differences in active musculoskeletal stiffness. Part II. Quantification of leg stiffness during functional hopping tasks. *J Electromyogr Kinesiol*. 2002; 12:127–135. [PubMed: 11955985]
48. Wojtys EM, Huston LJ, Schock HJ, Boylan JP, Ashton-Miller JA. Gender differences in muscular protection of the knee in torsion in size-matched athletes. *J Bone Joint Surg Am*. 2003; 85-A:782–789. [PubMed: 12728025]
49. Zazulak BT, Ponce PL, Straub SJ, Medvecky MJ, Avedisian L, Hewett TE. Gender comparison of hip muscle activity during single-leg landing. *J Orthop Sports Phys Ther*. 2005; 35:292–299. [PubMed: 15966540]
50. Sigward SM, Powers CM. The influence of gender on knee kinematics, kinetics and muscle activation patterns during side-step cutting. *Clin Biomech*. 2006; 21:41–48.
51. Van Dillen LR, Sahrmann SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom N. The effect of modifying patient-preferred spinal movement and alignment during symptom testing in patients with low back pain: a preliminary report. *Arch Phys Med Rehabil*. 2003; 84:313–322. [PubMed: 12638097]
52. Van Dillen LR, Maluf KS, Sahrmann SA. Further examination of modifying patient-preferred movement and alignment strategies in patients with low back pain during symptomatic tests. *Man Ther*. 2009; 14:52–60. [PubMed: 18032090]
53. Scholtes SA, Norton BJ, Lang CE, Van Dillen LR. The effect of within-session instruction on lumbopelvic motion during a lower limb movement in people with and people without low back pain. *Man Ther*. 2010; 15:496–501. [PubMed: 20627798]
54. Hoffman SL, Johnson MB, Zou D, Harris-Hayes M, Van Dillen LR. Effect of classification-specific treatment on lumbopelvic motion during hip rotation in people with low back pain. *Man Ther*. 2010 In Press.

Figure 1.

Representation of relevant markers and segment angles in the initial (a) and final (b) positions of hip medial rotation in prone

LS1: marker to the left of the first sacral vertebra; RS1: marker to the right of the first sacral vertebra; θ : angular displacement of the pelvic segment; ϕ : angular displacement of the lower leg segment

Table 1

Subject characteristics.

	Mean (SD)		Mean difference (95% CI)*	t value	P-value
	Women (N=29)	Men (N=30)			
Age (years)	42.8 (12.4)	42.8 (9.3)	0.0 (-5.7 to 5.7)	0.01	0.99
Height (cm)	164.2 (6.1)	177.2 (8.6)	-13.0 (-17.0 to -9.2)	-6.73	<0.01
Weight (kg)	66.3 (7.9)	82.3 (12.7)	-16.1 (-21.6 to -10.5)	-5.79	<0.01
BMI (kg/m ²)	24.6 (3.0)	26.1 (2.9)	-1.5 (-3.0 to 0.06)	-1.93	0.06
LBP onset (years) [†]	10.0 (8.7)	10.5 (7.4)	-0.5 (-4.8 to 3.9)	-0.22	0.83
Oswestry (0-100%) [‡]	21.2 (9.4)	20.4 (7.0)	0.8 (-3.5 to 5.2)	0.39	0.70
FABQ - PA (0-24)	12.2 (5.2)	12.5 (5.3)	-0.3 (-3.0 to 2.4)	-0.21	0.83
FABQ - work (0-42) [§]	12.9 (7.1)	12.7 (7.5)	0.2 (-4.0 to 4.3)	0.08	0.94
Current pain (0-10)	2.9 (1.9)	3.2 (1.9)	-0.3 (-1.3 to 0.7)	-0.62	0.54
Average pain (0-10) [¶]	3.6 (1.4)	3.9 (1.6)	-0.3 (-1.0 to 0.6)	-0.62	0.54
Lowest pain (0-10) [¶]	1.7 (1.4)	1.8 (1.5)	-0.1 (-0.8 to 0.7)	-0.25	0.81
Highest pain (0-10) [¶]	5.8 (2.0)	5.7 (2.0)	0.1 (-1.0 to 1.1)	0.15	0.88

Abbreviations: Standard deviation (SD), Confidence interval (CI), Body mass index (BMI), Time since low back pain symptoms began (LBP onset), Fear Avoidance Beliefs Questionnaire (FABQ),²² Physical Activity (PA).

* Mean Difference: women minus men.

[†] Responses were missing for three male subjects.

[‡] Modified Oswestry Low Back Pain Disability Questionnaire.²¹

[§] Scores missing for three male and six female subjects.

[¶] Over the past 7 days.

Lumbopelvic movement pattern variables, hip rotation range of motion, and symptom behavior for women and men during prone hip medial rotation.

Table 2

	Mean (SD)		Mean difference (95% CI)*	Probability value	P- value	Cohen's <i>d</i> †
	Women (N=29)	Men (N=30)				
Lumbopelvic rotation range of motion (°)	4.5 (3.9)	10.0 (5.1)	-5.5 (-7.9 to -3.1)	<i>t</i> = -4.63	<0.001	-1.21
Hip medial rotation at start of lumbopelvic motion (°)‡	16.0 (13.2)	5.4 (3.8)	10.6 (5.6 to 15.6)	<i>t</i> = 4.16	<0.001	1.11
Hip medial rotation range of motion (°)	41.7 (11.3)	30.4 (8.5)	11.3 (6.1 to 16.5)	<i>t</i> = 4.36	<0.001	1.13
Increased symptoms (%)	34.5 (NA)	60.0 (NA)	0.4 (0.1 to 1.0)	X ² = 3.85	0.050	NA

Abbreviations: Standard deviation (SD), Confidence interval (CI)

* Mean Difference: women minus men. Odds ratio used for increased symptoms instead of confidence interval

† Interpretation of Cohen's *d* has been reported as follows: 0.2 to 0.3 is a small effect, near 0.5 is a medium effect, and greater than 0.8 is a large effect.²⁶

‡ Levene's test was significant and variances were not equal between women and men. The t-statistic calculation was based on the actual sample sizes and standard deviations for each sex.²⁵