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Gender differences in pattern of hip and lumbopelvic rotation in people with low back pain

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Abstract

Background. Findings from previous studies suggest gender may affect the pattern of hip and lumbopelvic motion during a multi-segmental movement. To date, no studies have examined movement patterns and low back pain symptom behavior during hip lateral rotation.

Methods. Forty-six people (27 males and 19 females) with low back pain were examined. Three-dimensional kinematic data and low back pain symptoms were recorded during active hip lateral rotation. Percent of maximum lumbopelvic rotation was calculated for each 10% increment of maximum active hip lateral rotation.

Findings. Men exhibited a greater percent of maximum lumbopelvic rotation (mean 49.3, SD 13.3) during the first 60% of hip lateral rotation than women (mean 36.2, SD 16.4) ($P < 0.01$). Nineteen (70.4%) of the men and seven (36.8%) of the women had pain with the hip lateral rotation test ($P = 0.02$).

Interpretation. Men exhibited more lumbopelvic rotation in the early part of hip lateral rotation than women, and hip lateral rotation was more likely to be associated with symptoms in men than women. Greater lumbopelvic motion, earlier in hip lateral rotation, may make men more vulnerable to low back pain associated with hip lateral rotation. Factors that contribute to these gender differences should be investigated further.

Keywords: Low back pain; Hip; Rotation; Racquet sports; Gender

1. Introduction

A number of investigators have examined the relationship between hip rotation motion and low back pain (LBP) (Chesworth et al., 1994; Coplan, 2002; Ellison et al., 1990; Vad et al., 2003). Specifically, degree of hip rotation has been compared between back healthy controls and people with LBP (Chesworth et al., 1994; Ellison et al., 1990), and has also been examined in people with LBP who put regular rotational demands on the hip and low back (Coplan, 2002; Vad et al., 2003). Based on these studies it appears that people with LBP may have (1) less hip rotation range of motion, either active or passive, and (2) more asymmetry in hip rotation mobility. The relationship between hip rotation motion and LBP is important because external forces can be sequentially transmitted from distal body segments to more proximal ones during movement. Movement at the hip could, therefore, influence movement and loading at the lumbar spine. When performed repeatedly, such hip movement could result in excessive loading on tissues in the low back region, and eventually LBP (Sahrmann, 2002).

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Although prior studies have provided some insight into the relationship between LBP and hip rotation, two issues have not been addressed. First, the primary outcome variable in previous studies has been the amount of hip rotation range of motion. To our knowledge, the pattern of hip and lumbopelvic movement during hip rotation has not been examined in people with LBP. Second, the relationship between hip rotation movement and presence of LBP symptoms has not been studied. Detailed measurements of movement pattern and symptom behavior could provide more specific information about the nature of the relationship between hip rotation mobility and LBP. Such information may be important because (1) the movement pattern identified during the hip lateral rotation (HLR) test may be related to the movement patterns a person uses during daily activities, and (2) it may provide insight into how a person's movements during daily activities may contribute to LBP (Harris et al., 2005; Maluf et al., 2000; Van Dillen et al., 2005).

Sahrmann has described a HLR movement impairment that she has observed in people with LBP (Sahrmann, 2002). The impairment is described as early coupling (Panjabi and White, 2001) of the primary hip rotation motion with lumbopelvic rotation during a clinical test of active HLR in prone. Specifically, the hip joint and lumbopelvic region move together during the early part of the HLR motion. The HLR impairment is considered important because the coupled movement can be associated with an increase in LBP symptoms (Maluf et al., 2000; Sahrmann, 2002; Van Dillen et al., 2003b, 2005), and restricting lumbopelvic motion during the HLR test results in a decrease in the associated LBP (Van Dillen et al., 2003a). Sahrmann has proposed that when there is early coupling of hip and lumbopelvic rotation, repetition of hip rotation has the potential to contribute to cumulative micro-trauma of lumbar tissue, and eventually LBP symptoms (Sahrmann, 2002). The relationship between LBP and repeated early coupling of hip and lumbopelvic rotation may be of particular importance in people who put rotational demands on both the hip and lumbopelvic region.

To date, the HLR test has been studied only within the context of a clinical examination (Van Dillen et al., 1998, 2001, 2003c). Based on these studies, we know that not all people with LBP display the described HLR impairment, and symptoms are not always associated with the presence of an impairment. It is not known, however, what factors influence who will present with the HLR impairment, and who is likely to have LBP symptoms with the test. One factor that may contribute to differences in movement pattern of the hip and low back is gender. Theoretically, given that men and women are different structurally and physiologically (Chow et al., 2000; Granata et al., 2002; Staron et al., 2000; Toft et al., 2003), it would follow that they may demonstrate differences in movement pattern. Also, the literature suggests there are gender differences in kinematics and motor performance during a variety of activities and at various joints (Decker et al., 2003; Ford et al., 2005; Lindbeck and Kjellberg, 2001; Thomas and French, 1985).

While observing people with LBP clinically, we have noted that men and women appear to move very differently during clinical tests of movement, including HLR (Sahrmann, 2002). Also, in a study of healthy men and women, Thomas et al. identified gender differences in the pattern of hip and lumbopelvic movement during a reaching task (Thomas et al., 1998). In a study of movement patterns with a forward bending task, however, Esola et al. reported no gender differences in hip and back movement patterns in people with and without a history of LBP (Esola et al., 1996). Thus, gender may be a factor that contributes to the pattern of hip and back movement, but not for all tasks that require movement of both regions. The current study extends our previous work by objectively examining both (1) the pattern of hip and lumbopelvic motion during the HLR test, and (2) symptoms during the HLR test in people with LBP who regularly participated in a sport that required repeated rotation of the trunk and hips (e.g. racquet sports and golf).

The primary purposes of the current study were to (1) identify potential gender differences in pattern of movement in people with LBP, and (2) examine the relationship between movement pattern and LBP symptom reproduction during the HLR test. We hypothesized that men and women would exhibit different patterns of hip and lumbopelvic movement during the HLR test. We also hypothesized that people who displayed the early coupling which is considered a HLR impairment (Sahrmann, 2002) would be more likely to report LBP symptoms during the test. A secondary purpose was to examine whether or not there were differences in select characteristics of people who displayed early coupling compared to those who did not. The current study is important because it provides clinicians with information (1) about who is most likely to present with the described HLR impairment, (2) about factors that may be related to the presence of the impairment, and (3) that can assist in directing treatment of the LBP problem.

2. Methods

2.1. Subjects

Forty-six people (27 males and 19 females) between the ages of 18 and 45, with chronic or recurrent LBP (Von Korff, 1994), participated in the study (Table 1). The subjects were individuals who (1) reported regular

Table 1
Gender differences in subject characteristics

Variable	Gender				Statistical and probability value
	Men		Women		
	Mean	SD	Mean	SD	
Age (y)	29.7	8.1	26.6	7.9	$t = 1.31$; $P = 0.20$
Height (cm)[a]	177.0	7.2	161.5	5.6	$t = 8.26$; $\mathbf{P = 0.00}$
Weight (kg)[a]	81.1	13.1	62.3	13.5	$t = 4.72$; $\mathbf{P = 0.00}$
Duration of LBP (y)[a]	8.1	6.2	3.5	3.0	$t = 3.33$; $\mathbf{P = 0.00}$
Location of symptoms (Spitzer et al., 1987)	Low back = 23 Low back and proximal lower extremity = 3		Low back = 16 Low back and proximal lower extremity = 0		$\chi^2 = 1.99$; $P = 0.16$
Pain intensity rating over previous week (0–10) (Downie et al., 1978)	2.9	1.4	3.9	1.9	$t = -1.90$; $P = 0.07$
Episodes of LBP (prior 12 months) (Von Korff, 1994)	6.3	3.6	7.2	4.3	$t = -0.70$; $P = 0.49$
Oswestry disability questionnaire scores (0–100%) (Fairbank et al., 1980)	14.7	11.8	18.3	9.6	$t = -1.12$; $P = 0.27$
Total Baecke score (3–15) (Baecke et al., 1982)	8.4	0.7	8.2	0.8	$t = 1.03$; $P = 0.31$
Pelvic width SD (cm)[a]	35.6	2.9	32.6	3.8	$t = 2.91$; $\mathbf{P = 0.01}$
Spine length (cm)[a]	49.3	2.3	44.9	3.0	$t = 5.47$; $\mathbf{P = 0.00}$
Shank length (cm)[a]	42.5	2.6	37.7	1.9	$t = 7.32$; $\mathbf{P = 0.00}$

[a] Significant gender effect.

participation (minimum of two times per week) in a sport that placed repetitive rotational demands on the hip and lumbopelvic region, and (2) associated participation in their sport with an increase in their LBP, either during or after play.

People were excluded from the study if they reported any of the following: serious spinal complications (e.g. tumor or infection), previous spinal surgery, marked kyphosis or scoliosis, spondylolisthesis, spinal stenosis, spinal instability, spinal fracture, ankylosing spondylitis, degenerative disc disease, disc herniation, lower extremity impairment such as previous lower extremity surgery or leg length discrepancy, severe neurological involvement, rheumatoid arthritis, neurological disease which required hospitalization, history of unresolved cancer, osteoporosis, or current pregnancy. All participants read and signed an informed consent statement approved by the Washington University School of Medicine Human Studies Committee before participating in the study.

2.2. Procedures

Testing included completion of self-report measures, laboratory- and clinically-based movement testing.

2.2.1. Self-report measures

Subjects first completed the following: (1) demographic and LBP history questionnaire, (2) numerical rating scale of symptoms (Downie et al., 1978), (3) Oswestry LBP disability questionnaire (Fairbank et al., 1980), (4) racquet sports activity questionnaire, (5) Baecke habitual activity questionnaire (Baecke et al., 1982).

2.2.2. Laboratory tests

The HLR test was one of a series of laboratory-based impairment tests. HLR is the only test that is reported on in the current study. The HLR test was performed with the subject in prone, the knee flexed to 90°, and the hip in neutral rotation and neutral abduction/adduction. At a self-selected movement speed, subjects were asked to laterally rotate the hip as far as possible toward the opposite leg, and then return it to the starting position. Each participant was given 10 s within which to complete the movement. The HLR movement was performed one time with the right extremity, followed by the left. A six camera, three-dimensional, motion measurement system (EVaRT, Motion Analysis Corporation, Santa Rosa, CA) was used to examine the kinematics during each HLR test. Retro-reflective markers were placed on predetermined anatomical landmarks of the trunk, pelvis, and extremities to capture lumbopelvic and extremity movement (Fig. 1). The data were collected at a sampling rate of 60 Hz. Patient reports of change in LBP symptoms with the HLR test, relative to symptoms in prone, were also recorded. Possible symptom responses included (1) remained the same, (2) increased, (3) decreased, or (4) eliminated.

2.2.3. Clinical tests

Subjects were then examined by a trained physical therapist using a standardized examination procedure (Sahrmann, 2002; Van Dillen et al., 1998, 2001, 2003c). The history included questions related to the person's LBP history and characteristics of the current LBP symptoms. The physical examination included

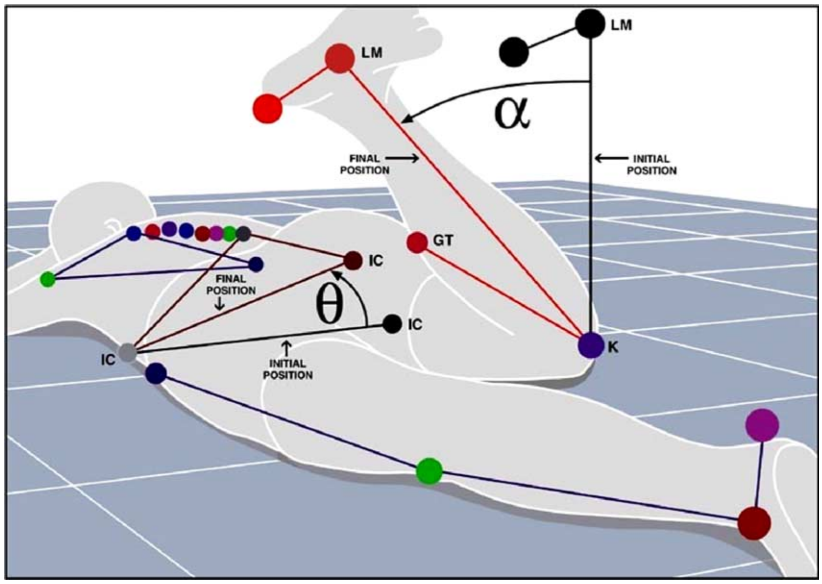

Fig. 1. Kinematic model with calculations for hip lateral rotation (HLR) and lumbopelvic rotation. α = Hip lateral rotation (HLR) angle (deg), θ = lumbopelvic rotation angle (deg), IC = iliac crest marker, GT = greater trochanter marker, K = knee marker, LM = lateral malleolus marker.

clinical tests of movements and positions. Change in LBP symptoms with each test relative to symptoms with a reference position or movement were recorded. The HLR test was one item from the examination. Procedures and instructions for the clinical test of HLR were the same as those for the laboratory test of HLR.

In addition to active HLR testing, clinical measures of passive hip rotation were taken with an inclinometer. The subject was positioned in prone with the knee flexed to 90° and the pelvis stabilized. The start position for passive HLR range of motion testing was achieved when the tibial plateau was parallel to the table and the hip was in neutral abduction/adduction. After zeroing the inclinometer to a fixed vertical reference, it was positioned on the distal 1/3 of the fibula to capture the starting position of the lower leg. The lower limb was passively rotated a total of three times on each leg. Passive HLR was calculated as the difference between the initial and final position of the leg, averaged across the three trials.

2.3. Data processing

2.3.1. Kinematics—hip and lumbopelvic rotation

Angular displacements and velocities of the lower leg and pelvis were calculated across time. The lower leg segment was defined by a vector from a marker on the lateral aspect of the knee joint line to a marker at the distal aspect of the lateral malleolus. Angle α was calculated as the change in angle of the lower leg segment across time, relative to its initial position (Fig. 1). Assuming that no relative motion occurs between the tibia and femur, movement of the tibia should reflect rotation of the femur. Degree of HLR was then defined by subtracting, from angle α, pelvic motion that occurred in the plane of the lower leg. Thus, movement of the pelvis that resulted in movement of the lower leg was not included in the hip rotation calculation.

To determine degree of lumbopelvic rotation, the pelvic segment was defined as a vector formed by the right and left iliac crests. Relative to the initial position of the pelvic segment, the position of the pelvic vector was calculated across time during the hip rotation motion to calculate θ, the degree of lumbopelvic rotation (Fig. 1). Reliability of HLR and lumbopelvic rotation measures was tested in a sample of 10 subjects without a history of LBP. The intraclass correlation coefficient (ICC 3,1) (Hopkins, 2000) and typical error (Batterham and George, 2003; Hopkins, 2000) were used to index reliability. The values for each motion, for each extremity, were found acceptable and are reported in Table 2.

The end of movement for the hip and lumbopelvic segments was defined by the first point at which each angle reached 99% of its maximum during the hip rotation movement. The start of movement for HLR was defined as the time at which both (1) angular displacement of the lower leg segment exceeded a threshold of

Table 2
Typical error measures (in deg) (Batterham and George, 2003) and ICC (3, 1) values for right and left hip lateral rotation and lumbopelvic rotation

Movement	Typical error (in deg)	ICC (3, 1)
Left hip lateral rotation	1.5°	0.99
Left lumbopelvic rotation	0.8°	0.82
Right hip lateral rotation	1.4°	0.97
Right lumbopelvic rotation	0.8°	0.80

1°, and (2) angular velocity exceeded 5% of the maximum angular velocity for the lower leg segment. The start of movement for lumbopelvic rotation was defined as the time at which both of the following criteria were met: (1) the angular displacement of the pelvic segment exceeded a threshold of 1°, and (2) the angular velocity exceeded 15% of the maximum angular velocity for the pelvis segment.

Initially, all marker data were filtered using a fourth-order, dual-pass, Butterworth filter with a cutoff frequency of 2.5 Hz. The initial cutoff frequency was chosen because the movements being measured were relatively slow. After the data were filtered, the start and end points for HLR were determined, and HLR movement time was calculated. Because subjects performed the test movement at self-selected speeds, a filtering frequency based on individual movement times was then used. Based on the HLR movement time, raw data were filtered at a subject-specific cutoff frequency (fc_{ss}) that was calculated by taking the reciprocal of 15% of the period, $fc_{ss} = 1/(.15 * (2 * \text{HLR movement time}))$.

2.3.2. Anthropometrics

Measures of pelvic width, spine length, and shank length were calculated using the reflective markers placed on the pelvis, spine and lower extremities. These anthropometric measures were derived from the three-dimensional linear distance between two respective markers. Pelvic width was measured from the right to left iliac crest marker, spine length from the C7 to S2 marker, and shank length from the knee joint line to lateral malleolus marker, averaged across the right and left lower extremities. Anthropometric measures were then normalized to the subject's height (e.g. pelvic width/height).

2.3.3. Dependent variables

All hip and lumbopelvic movements were examined from the start of the HLR movement to the maximum HLR angle. To quantify the movement patterns during the HLR test, the percentage of maximum lumbopelvic rotation was calculated at each 10% increment of HLR. To examine coupling of lumbopelvic rotation during the *early* portion of HLR motion, we calculated the percentage of maximum lumbopelvic rotation that occurred during the first 60% of the HLR motion, averaged across the right and left motions. Characteristics such as (1) passive HLR motion, (2) anthropometrics, (3) LBP-related variables, and (4) activity level were examined for differences between people who displayed the coupled pattern associated with a HLR impairment and those who did not.

2.4. Statistical analysis

Data analysis was performed using SYSTAT version 10.2 for Windows. Descriptive statistics were calculated on patient characteristics. A student's t-test for independent samples was conducted to test for gender differences in degree of HLR and lumbopelvic rotation during the active HLR test. The *primary analysis* conducted was a t-test to test for gender differences in the percentage of maximum lumbopelvic rotation that occurred from 0% to 60% of HLR. A t-test was also conducted to test for differences in the percentage of maximum lumbopelvic rotation that occurred from 0% to 60% HLR, between people with increased pain during the HLR test compared to those with no increase in pain during the HLR test, across genders. An increase in LBP during the HLR test was indicated if a subject reported an increase in LBP during either right or left HLR, during either the laboratory or clinical test. A χ^2 analysis was performed to test for differences in distributions of men and women who experienced increased LBP symptoms during the HLR test. A t-test for gender differences in the percentage of maximum lumbopelvic rotation that occurred from 0% to 60% of HLR was then conducted on the subgroup of people who experienced an increase in LBP during the HLR test.

Secondary analyses were conducted to examine whether or not people who displayed the coupled pattern were different with regard to various characteristics. An analysis of variance with two between-groups factors, gender and LBP symptoms, was conducted on (1) passive HLR measures, (2) anthropometrics, (3) LBP-related variables, and (4) activity level.

3. Results

3.1. Primary analyses

Mean degree of HLR ($P = 0.29$) and lumbopelvic rotation ($P = 0.08$) during the HLR test were not different for men and women (Table 3). To address our first primary purpose, examination of gender differences in pattern of movement, the results indicated that the percentage of maximum lumbopelvic rotation that occurred during the first 60% of HLR was different for men and women ($P < 0.01$) (Fig. 2a). On average, men completed a larger percentage of their total lumbopelvic rotation (mean 49.3%, SD 13.3) during the first 60% of HLR compared to women (mean 36.2%, SD 16.4). To address our

Table 3
Degree of active hip lateral rotation (HLR) and lumbopelvic rotation during kinematic testing based on gender

Variable	Gender			
	Men ($N = 27$)		Women ($N = 19$)	
	Mean	SD	Mean	SD
Active HLR	44.7	7.1	42.7	5.2
Lumbopelvic rotation	6.1	3.2	4.6	2.0

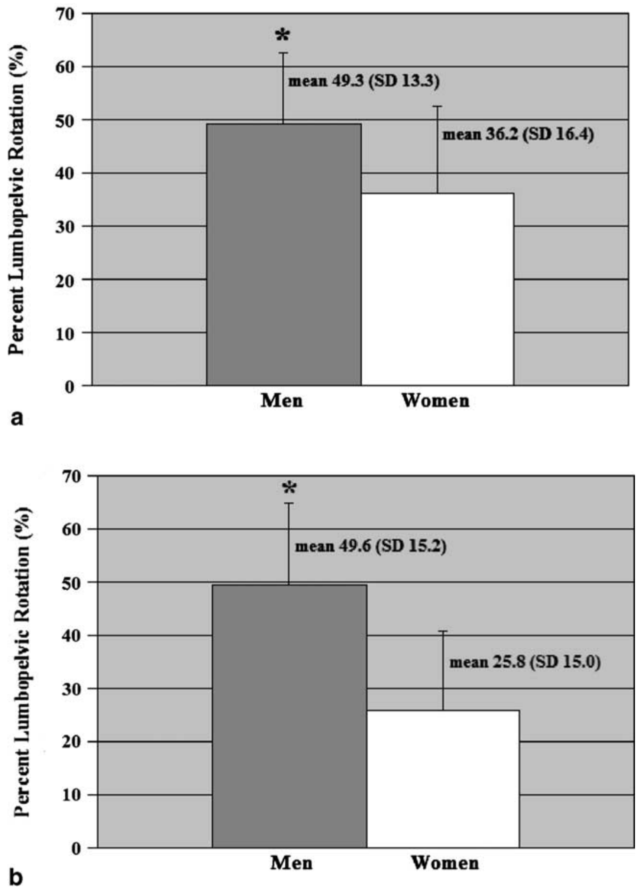

Fig. 2. Gender differences in percent lumbopelvic rotation from 0% to 60% hip lateral rotation (HLR) during HLR impairment test. (a) All participants ($N = 46$), (b) People with an increase in low back pain symptoms during the hip lateral rotation impairment test ($N = 26$).

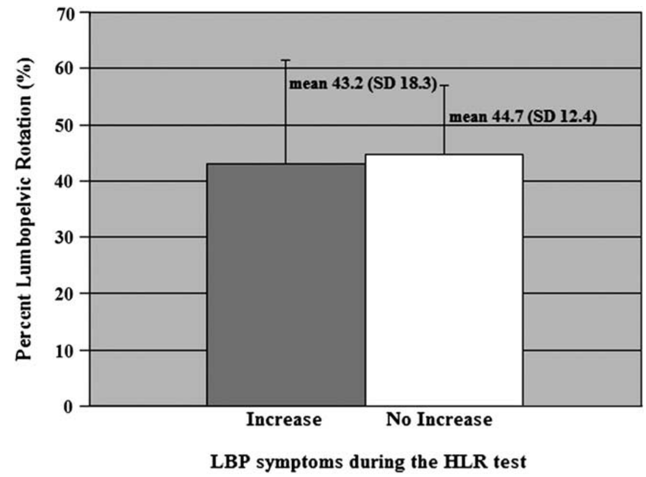

Fig. 3. Differences between people with increased low back pain (LBP) during hip lateral rotation (HLR) compared to those with no increase in LBP during HLR ($N = 46$).

Table 4
Gender differences in degree of passive hip lateral rotation (HLR) motion during clinical testing

Variable	Gender				Statistical and probability value
	Men		Women		
	Mean	SD	Mean	SD	
Passive right HLR (deg)	27.1	4.4	26.9	7.1	$t = 0.11$; $P = 0.91$
Passive left HLR (deg)	25.9	5.3	26.3	7.0	$t = -0.19$; $P = 0.85$

second primary purpose, to examine the relationship between movement pattern and LBP symptoms, the results indicated there were no differences in movement pattern between people with increased LBP during the HLR test (mean 43.2%, SD 18.3) compared to those with no increase in LBP during the test (mean 44.7%, SD 12.4) ($P = 0.75$) (Fig. 3). However, taking gender into account, our results indicated that a greater percentage of the men (70.4%; $N = 19$), experienced LBP symptoms during the HLR test than women (36.8%; $N = 7$) ($P = 0.02$). Further, the gender difference in percentage of maximum lumbopelvic rotation in the first 60% of HLR was even larger for the subgroup of people who experienced an increase in LBP with the HLR test ($P < 0.01$) (Fig. 2b) compared to the group as a whole (Fig. 2a).

3.2. Secondary analyses

To address our secondary purpose, whether or not there were differences in characteristics of people who displayed the coupled pattern compared to those who did not, we tested for gender differences in various subject characteristics. These data are summarized in Table 1. The results indicated that men and women were different with regard to all anthropometric characteristics (all Ps < 0.05). On average, men had a significantly (1) wider pelvis, (2) longer spine, and (3) longer shank than women (Table 1). When anthropometric measures were normalized to subject height, however, there were no gender differences in spine length ($P = 0.86$) or pelvic width ($P = 0.87$), and minimal differences in shank length (men: mean .24, SD .01; women: mean .23, SD .01) ($P < 0.01$). Men also had a longer history of LBP symptoms compared to women (Table 1).

No differences were found between men and women in degree of passive HLR motion (Table 4). There were also no differences between men and women in (1) the number of episodes of LBP in the last year, (2) LBP intensity during the week prior to testing, and (3) LBP-related disability (Table 1). Finally, there were no gender differences in overall activity level (Table 1).

4. Discussion

In our previous studies of people with LBP, a HLR impairment was identified with clinically-based measures (Maluf et al., 2000; Van Dillen et al., 1998; Van Dillen et al., 2003c, 2005). Based on these data, we know that not all people with LBP present with the described impairment or report LBP symptoms during the test (Van Dillen et al., 2001, 2003a,b). The current study identifies the characteristics of individuals who are likely to (1) present with the HLR impairment, and (2) have increased LBP during the test. To our knowledge, the current study is the first to examine both the pattern of hip and lumbopelvic movement through kinematic analysis *and* symptom behavior during the HLR test. We consider the analysis of both kinematics and symptom behavior to be important because such analysis provides more insight into the relationship between movement pattern and LBP.

The results from the current study suggest that movement patterns during the HLR test vary based on gender. Specifically, men appear to move in the lumbopelvic region earlier in the range of HLR than women. Men are also more likely to experience LBP with the HLR test. When examining gender effects in the subgroup of people who experienced an increase in LBP symptoms during the HLR test, the gender difference in percentage of maximum lumbopelvic rotation was even larger than for the LBP group as a whole. In the current study, a HLR impairment is defined as early coupling of the primary hip rotation motion with lumbopelvic rotation during a clinical test of active HLR in prone. Thus, our data suggest that men may be more susceptible than women to developing the described HLR impairment, and the HLR impairment is more likely to be related to LBP symptoms in men than women.

Gender differences in pain sensitivity could be a potential explanation for the gender differences in reports of increased LBP symptoms during HLR. Although some authors report that men are at higher risk for complaints of LBP with particular tasks (Hooftman et al., 2004), the majority of the literature on pain sensitivity with experimentally-induced pain suggests that *women* have heightened pain sensitivity compared to men (Fillingim et al., 1996; Ge et al., 2005; Jones and Zachariae, 2002; Robinson et al., 2001; Sarlani et al., 2003; Wise et al., 2002). If the gender differences in reports of LBP during the HLR test were due to gender differences in pain sensitivity alone, based on the majority of the literature examining pain sensitivity, we would expect that women in our sample would be more likely to complain of increased LBP during HLR. However, in our sample, the men were more likely to report increased LBP with HLR.

Anthropometrics did not appear to explain gender differences in movement pattern. When the anthropometric measures were normalized to height, there were no substantial differences between men and women. Men merely appear to be proportionally larger than women. There also were no differences between men and women with regard to LBP severity, level of LBP-related disability, or activity level (Table 1). There was, however, a gender difference in the number of years of LBP duration. If men are predisposed to the early lumbopelvic movement pattern, and participate in an activity that places rotational demands on the hip and low back, men may be more likely than women to develop a HLR impairment associated with LBP symptoms.

Differences in measures of passive HLR also did not explain the differences in movement pattern between men and women during active HLR. Men and women were not different with regard to passive HLR as measured in our study (Table 4). However, our clinical measures of passive HLR are less than our laboratory measures of active HLR. We recognize that passive HLR should be greater than active HLR. The lesser degree of passive relative to active range of motion is likely due to the way we measured passive HLR and, in particular, the way end-range was defined for a passive movement. We believe that our passive measures likely underestimated the passive motion at the hip joint. If end-range passive movement were defined differently, differences between men and women may have been observed. However, we do not believe that differences in *end-range* passive HLR motion are related to movement of the lumbopelvic region *early* during the active HLR motion.

Considering the lack of differences between men and women with regard to many of the variables we tested, we propose that there may be other factors that contribute to the gender differences with HLR. For example, passive tissue stiffness about the hips has the potential to contribute to early motion of the lumbopelvic region during HLR. Passive stiffness is defined as the ratio of change in passive resistance (change in torque) to change in displacement (change in joint angle) (Gajdosik, 2001). A greater amount of hip stiffness during HLR would offer more resistance to the HLR movement. Lumbopelvic movement may then be induced early during HLR in an attempt to continue moving the lower extremity. A number of investigators have reported that men have increased passive and active stiffness in the lower extremities compared to women (Blackburn et al., 2004; Gajdosik et al., 1990; Granata et al., 2002; Wojtys et al., 2003). The increased stiffness in men has been attributed to greater lower extremity muscle mass and cross-sectional area in men compared to women (Chow et al., 2000; Granata et al., 2002; Staron et al., 2000; Toft et al., 2003). Men may, therefore, demonstrate lumbopelvic movement early during HLR because they have a greater amount of passive stiffness in the hip musculature compared to women.

Another potential factor contributing to gender differences in pattern of movement during active HLR is a difference in pattern of muscle activity (timing or magnitude) between men and women. For example, men may co-contract their trunk and hip muscles during the early part of the HLR movement, resulting in the two segments moving together during HLR. Based on our clinical studies of people with LBP, however, we believe that the gender difference in pattern of movement during the HLR test may be the result of an interaction of biomechanical factors, such as passive tissue stiffness, and motor control factors, such as timing and magnitude of muscle activity.

Identifying how movement patterns differ during a clinical test is important because it provides information that can assist the clinician with treatment of a person with LBP. For example, our clinical studies suggest that limiting lumbopelvic motion can reduce LBP symptoms during the HLR test (Van Dillen et al., 2003a). Addressing this impairment as part of treatment also appears to contribute to improved short- and long-term outcomes in people with LBP (Harris et al., 2005; Maluf et al., 2000; Van Dillen et al., 2005). Since our data suggest that men may be more susceptible than women to developing the described HLR impairment, for men with LBP, treatment may include limiting lumbopelvic motion during HLR. Limiting such lumbopelvic motion would require training the person to stabilize the pelvis while moving only in the hip joint during HLR. Specifically, in treatment, the person would be instructed to contract his abdominal muscles prior to the HLR movement and not allow pelvic movement when he moves his leg. If the person is unable to stabilize his lumbopelvic region using muscle contraction, he may initially require manual stabilization of the pelvis by the clinician. The patient would then be progressed to self-stabilization using his abdominal muscles as tolerated. The clinician would also identify functional activities that elicit LBP and during which the patient demonstrates the pattern of coupled lumbopelvic rotation with HLR. The clinician would instruct the patient to dissociate the pelvis and hip during these functional activities, through verbal and manual cueing to contract the abdominal muscles and avoid lumbopelvic rotation.

There are some potential limitations of the current study. The first is that pelvic movement, angle θ, was calculated based only on movement of the iliac crest markers and did not account for movement of the upper trunk that may have contributed to movement of the pelvis. However, on visual inspection of the kinematic data, we were not able to identify any cases in which upper trunk movement occurred with pelvic movement. A second limitation is that with the use of surface markers to index bone movement, there will be artifact due to skin movement (Cappozzo et al., 1996). Because the average pelvic movements (angle θ) were small, such skin movement artifact may have had an impact on our measures. However, while observing individual subjects during data collection, it appeared that any skin movement of the iliac crest markers (used to derive lumbopelvic rotation) was in the direction such that it would have resulted in an underestimation of lumbopelvic rotation angle. This observation was noted in both men and women. Therefore, we believe our effects may have actually been larger without the skin movement artifact. A third potential limitation is that the HLR test, although used during clinical examination, is not a functional movement. Therefore, the application of the current findings to patterns of movement during daily activities is not known. In our previous work, however, when the HLR impairment was addressed in physical therapy intervention, symptoms were decreased and functional outcomes improved (Maluf et al., 2000; Van Dillen et al., 2005). Examining the relationship between the kinematics with the HLR test and those with a symptomatic functional movement would be an important question to pursue in the future. Lastly, a potential limitation is that our sample included only people with LBP who participated in an activity that required repeated rotational movements of the hip and the spine. Thus, the current findings may not be as prevalent in a general population of people with LBP. However, in earlier studies of people with LBP that reported a much wider range of activity types and levels, we identified similar proportions of men and women with the HLR impairment based on standardized clinical criteria (unpublished data).

5. Conclusions

Men and women exhibited different movement patterns during HLR and men were more likely to have LBP symptoms during the hip movement. None of the other variables examined appeared to explain the gender differences in movement and symptoms with the HLR tests.

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