

Published in final edited form as:

Clin Biomech (Bristol, Avon). 2009 January ; 24(1): 7–12. doi:10.1016/j.clinbiomech.2008.09.008.

Differences in lumbopelvic motion between people with and people without low back pain during two lower limb movement tests

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Abstract

Background—Clinical data suggest that active limb movements may be associated with early lumbopelvic motion and increased symptoms in people with low back pain.

Methods—Forty-one people without low back pain who did not play rotation-related sports and 50 people with low back pain who played rotation-related sports were examined. Angular measures of limb movement and lumbopelvic motion were calculated across time during active knee flexion and active hip lateral rotation in prone using a three-dimensional motion capture system. Timing of lumbopelvic motion during the limb movement tests was calculated as the difference in time between the initiation of limb movement and lumbopelvic motion normalized to limb movement time.

Findings—During knee flexion and hip lateral rotation, people with low back pain demonstrated a greater maximal lumbopelvic rotation angle and earlier lumbopelvic rotation, compared to people without low back pain ($P < 0.05$).

Interpretation—The data suggest that people with low back pain who play rotation-related sports may move their lumbopelvic region to a greater extent and earlier during lower limb movements than people without low back pain. Because people perform many of their daily activities in early to midranges of joint motion the lumbopelvic region may move more frequently across the day in people with low back pain. The increased frequency may contribute to increased lumbar region tissue stress and potentially low back pain symptoms. Lower limb movements, therefore, may be important factors related to the development or persistence of low back pain.

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Conflict of Interest Statement The authors acknowledge that we do not have any financial or personal relationships with other people or organizations that could inappropriately influence the work described in the current manuscript.

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Keywords

limb; lumbopelvic motion; low back pain

Introduction

Limb movements result in forces on the spine and could, therefore, affect the lumbopelvic region. Some investigators have studied the effect of active, voluntary limb movements on the trunk, comparing people with and people without low back pain (LBP). Many of these investigators have focused on postural responses with rapid limb movements in standing, examining anticipatory trunk muscle activity (Bouisset and Zattara, 1981; Friedli et al., 1984; Hodges and Richardson, 1996; Hodges and Richardson, 1997; Hodges and Richardson, 1998; Hodges and Richardson, 1999), as well as preparatory trunk and hip movement (Mok et al., 2007). Lumbar region and hip joint kinematics have been studied with bending forward in standing and during a few everyday activities in people with and people without LBP (Esola et al., 1996; Mok et al., 2007; Porter and Wilkinson, 1997; Shum et al., 2005a; Shum et al., 2005b). The effect of active, voluntary limb movements on lumbopelvic kinematics during standardized limb movement tests, however, has not been extensively studied. These limb movement tests are considered important because clinical data suggest that active limb movements performed during standardized limb movement tests can be associated with (1) early lumbopelvic motion in people with LBP (Scholtes and Van Dillen, 2007), (2) an increase in LBP symptoms during preferred movement (Van Dillen et al., 2001), and (3) a decrease in LBP symptoms (Van Dillen et al., 2003a; Van Dillen et al., 2007b) when lumbopelvic motion is modified during limb movements. In addition, intervention that includes exercise to modify lumbopelvic movement patterns with limb movements appears to contribute to positive short- and long-term outcomes (Harris-Hayes et al., 2005; Maluf et al., 2000; Scholtes et al., 2006; Van Dillen et al., 2005).

Lumbopelvic motion that occurs early during an active, voluntary limb movement is considered to be important because people perform many of their daily activities in early to midranges of joint motion. It has been proposed that, if the lumbopelvic region moves during the early ranges of a limb movement, then the frequency of lumbopelvic motion may be increased across the day. The increased frequency of lumbopelvic motion may contribute to increased tissue stress in the lumbopelvic region (Adams et al., 2002), particularly if the lumbopelvic motion is always in the same direction. With time, the increase in stress may contribute to cumulative microtrauma, tissue failure, and the development of LBP symptoms (Adams et al., 2002; McGill, 1997). Previously, investigators have reported on differences in timing of lumbopelvic motion between LBP subgroups (Van Dillen et al., 2007a) and between men and women (Gombatto et al., 2006) during the active limb movement test of hip lateral rotation in prone. To our knowledge, however, no studies have examined differences in timing of lumbopelvic motion between people with and people without LBP during active, voluntary limb movement tests. Examining differences between people with and people without LBP in timing of lumbopelvic motion may provide insight into the importance of early lumbopelvic motion to the development, persistence, or recurrence of a LBP problem. Furthermore, identifying differences between people with and people without LBP highlights the importance of the previously identified LBP subgroup differences with the test of hip lateral rotation (Gombatto et al., 2006; Van Dillen et al., 2007a).

The purpose of the current study was to examine timing of lumbopelvic motion between people with and people without LBP during two active lower limb movement tests. It was hypothesized that, compared to people without LBP, people with LBP would demonstrate earlier lumbopelvic motion during two active lower limb movement tests performed in prone: knee

flexion and hip lateral rotation. Identifying differences in timing of lumbopelvic motion between people with and people without LBP during lower limb movement tests may lead to improved understanding of the factors contributing to LBP and help refine LBP intervention strategies.

Methods

Subjects

Forty-one subjects without LBP who did not regularly participate in a rotation-related sport and 50 subjects with LBP who regularly (minimum of two times per week) participated in a rotation-related sport were enrolled in the study. Table 1 includes subject and LBP-related characteristics of the sample. A rotation-related sport was defined as a sport that required repeated rotation of the trunk and hips to perform most aspects of the activity (e.g. tennis, racquet ball). All subjects with LBP associated their symptoms with their sport activity. Subjects were included in the study and assigned to groups based on LBP history and sport participation information provided through a telephone screening process. Subjects were excluded from the study if they verbally reported (1) a history of a spinal fracture or surgery, or (2) a diagnosis by a physician of a spinal deformity, a systemic inflammatory condition, or another serious medical condition. All subjects provided informed consent approved by the Human Research Protection Office of Washington University Medical School prior to participating in the study.

Clinical Measures

Subjects completed self-report measures and participated in a standardized examination based on the Movement System Impairment model of LBP (Sahrmann, 2002; Van Dillen et al., 1998; Van Dillen et al., 2003b). The self-report measures included (1) a demographic and LBP history questionnaire, (2) a numeric pain rating scale (Jensen et al., 1994), (3) the modified Oswestry Disability Index (Fritz and Irrgang, 2001), (4) a racquet sport participation questionnaire, and (5) the Baecke Habitual Activity questionnaire (Baecke et al., 1982).

Laboratory Measures

Subjects completed the tests of active knee flexion in prone (KF) and active hip lateral rotation in prone (HLR). For KF, the subject was positioned in prone with both lower limbs fully extended and the hips in neutral abduction/adduction and femoral rotation. For HLR, the subject was positioned in prone with both lower limbs in neutral hip abduction/adduction and femoral rotation and the tested lower limb in 90° of knee flexion. When instructed to move, the subject flexed the knee or laterally rotated the hip at a self-selected speed as far as possible and then returned to the initial position. Subjects were given a maximum of 10 seconds to complete each trial. Left and right KF and HLR were performed separately, one time. Kinematic data were collected using a six camera, three-dimensional, motion capture system (EVaRT, Motion Analysis Corporation, Santa Rosa, CA, USA). Reflective markers were placed on landmarks of the trunk, pelvis, and limbs to capture both limb and lumbopelvic motion. The data were collected at a sampling rate of 60 Hz. The static resolution of the motion capture system was 1 mm per cubic meter.

Data processing

Angular displacement and velocity of movement for the lower leg, thigh, and pelvis were calculated across time. The lower leg segment was defined by a vector from a marker on the lateral knee joint line to a marker on the lateral malleolus. The thigh segment was defined by a vector from a marker on the lateral knee joint line to a marker on the greater trochanter. The transverse plane pelvic segment was defined by a vector from a marker on the right iliac crest

to a marker on the left iliac crest. The sagittal plane pelvic segment was defined by a vector from a point at the mid-distance of the right and left iliac crest markers to a marker superficial to the second sacral vertebrae (S2). The knee flexion angle (β) was calculated as the angle between the lower leg segment and a line extending the thigh segment. The hip lateral rotation angle was calculated as the change in angle of the lower leg segment relative to the initial position across time (Gombatto et al., 2006). For both KF and HLR, lumbopelvic rotation (θ) was defined as the change in angle of the transverse plane pelvic segment across time (Figure 1). For KF, anterior pelvic tilt (λ) was calculated as the change in angle of the sagittal plane pelvic vector across time (Figure 2). Anterior pelvic tilt was not calculated during HLR since expected and observed motion was in the transverse plane. The intraclass correlation coefficients and standard error of the measure for all variables were found to be acceptable. The reliability of measurements from HLR have been previously reported (Gombatto et al., 2006). The reliability statistics for the KF test are reported in Table 2.

Motion capture data was filtered using a 4th order, dual pass, butterworth filter with an initial cutoff frequency of 2.5 Hz. After filtering, the start and end points of movement were determined and movement time was calculated. Because subject's were allowed to move at a self-selected speed for each movement test, raw data were filtered at a subject-specific cut-off frequency (Winter, 2005) (fc_{ss}) that was calculated by taking the reciprocal of 15% of the period, $fc_{ss}=1/.15*(2*\text{movement time})$.

The start of knee flexion and hip lateral rotation was defined as the point at which angular velocity exceeded 5% of the maximal angular velocity for the lower leg segment. The start of lumbopelvic motion was defined as the point at which angular velocity exceeded 15% of the maximal angular velocity for the pelvic segment. The end of movement for each segment was defined as the point at which the angle reached 99.5% of its maximum.

Dependent Variables

Limb and lumbopelvic kinematics were examined from the start to the maximal angle of the lower limb movement. To index timing of lumbopelvic motion during the limb movement, the difference in time between the start of the limb movement and lumbopelvic motion was calculated. The timing variable was then normalized to limb movement time by dividing the start time difference by the time it took to complete the limb movement (Gombatto et al., 2006).

Data Analyses

All statistical analyses were performed with SPSS 15.0 for windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated for relevant subject characteristics. Chi-square goodness of fit analyses or independent sample t-tests were used to test for differences between groups on relevant subject characteristics. Two-way, repeated measures mixed-model analysis of variance tests were conducted separately on all dependent variables for the KF and HLR tests. The main and interaction effects of group (No LBP, LBP) and side (Right, Left) were examined. Because body mass index (BMI) and velocity of limb movement could potentially affect the dependent variables of interest, analysis of covariance tests were also conducted including BMI and velocity as covariates. The significant group effects remained evident; therefore the results are reported for the analysis of variance tests only. Because there were no significant interaction effects for any of the dependent variables, data for right and left trials were averaged. If groups did not demonstrate equal variance for a particular dependent variable, an independent samples t-test with equal variances not assumed was conducted. The significance level for all testing was set at $P<0.05$.

Results

There were no differences between people with and people without LBP in sex distribution, age, BMI, or activity level (Table 1).

Knee Flexion

Compared to people with LBP, people without LBP demonstrated a greater maximal KF angle. Compared to people without LBP, people with LBP demonstrated a greater maximal lumbopelvic rotation angle and earlier lumbopelvic rotation during KF. There were no differences between groups in magnitude or timing of anterior pelvic tilt during KF (Table 3).

Hip Lateral Rotation

There was no difference in maximal hip lateral rotation angle between people with and people without LBP. Compared to people without LBP, people with LBP demonstrated a greater lumbopelvic rotation angle as well as earlier lumbopelvic rotation during HLR (Table 3).

Discussion

The purpose of the current study was to examine differences in timing of lumbopelvic motion between people with and people without LBP during two lower limb movement tests. Consistent with our hypotheses, compared to people without LBP who do not regularly participate in rotation-related sports, people with LBP who regularly participate in rotation-related sports demonstrated earlier lumbopelvic motion during KF and HLR. Although we did not hypothesize group differences in lumbopelvic angle during KF or HLR, compared to people without LBP, people with LBP also demonstrated a greater maximal angle of lumbopelvic rotation during both tests.

Lumbopelvic motion that occurs early in the range of an active, voluntary limb movement is considered important because such a finding may provide an index into movement of the lumbopelvic region during everyday activities. Specifically, in people with LBP, these findings suggest that the lumbopelvic region may potentially move more frequently during lower limb movements across the day. Increased frequency of lumbopelvic motion could contribute to increased stress on lumbopelvic region tissues, microtrauma, and eventually LBP (Adams et al., 2002; McGill, 1997). The group differences in timing and magnitude of lumbopelvic motion during lower limb movements also suggest that people with LBP may be more mobile in the lumbopelvic region than people without LBP. Increased mobility of the lumbopelvic region has been found to be associated with degeneration of lumbopelvic region tissues (Leone et al., 2007). Therefore, the early and increased lumbopelvic motion demonstrated by people with LBP in the current study may be important to the development or persistence of a LBP problem.

Shum et al. compared performance of people with LBP to people without LBP during two different everyday activities: putting on a sock and performing sit to stand. Because of the nature of the activities the focus was on examining sagittal plane lumbar region and hip joint kinematics and coordination. In both studies people with LBP demonstrated less lumbar and hip flexion compared to people without LBP during the activity. Interestingly, though, in the study of putting on a sock, motion of the lumbar spine and hip in the transverse and frontal planes was also examined. When compared to people without LBP, people with LBP displayed (1) a greater amount of lumbar spine rotation, and (2) larger peak cross-correlations of lumbar rotation with each of the three hip motions (flexion, lateral rotation, abduction) needed to put on a sock. These findings support our finding of greater lumbar rotation in people with LBP compared to people without LBP when moving the lower limb. Importantly, the findings also

suggest that the movement pattern of the lumbopelvic region, ie., early lumbopelvic rotation, during the two lower limb movement tests in the current study may reflect the movement patterns people with LBP use in everyday activities. In the Shum et al study lumbar rotation was more closely coupled to hip movements needed to put on a sock in people with LBP when compared to people without LBP. Thus, the Shum findings suggest that movement patterns during standardized lower limb movement tests may provide an index of the movement patterns used during everyday activities. It is proposed that the repetition of the lumbopelvic movement patterns used during everyday activities may be important to the development as well as the course of LBP problems (Sahrmann, 2002).

To our knowledge, only two studies have examined tests in which the intended action is active limb movement with relatively minimal lumbopelvic motion. Van Dillen et al. (2007) examined timing of lumbopelvic motion during HLR between two LBP subgroups identified using the Movement System Impairment classification system (Sahrmann, 2002; Van Dillen et al., 2003b). The majority of subjects in both groups displayed early lumbopelvic rotation during HLR, but people classified into the Rotation with Extension subgroup demonstrated more asymmetrical timing, right versus left, of lumbopelvic motion than people classified into the Rotation LBP subgroup (Van Dillen et al., 2007a). Gombatto et al (Gombatto et al., 2006) examined sex differences in timing of lumbopelvic motion during HLR in a cohort of people with LBP. Compared to women, men with LBP moved through a greater amount of their total lumbopelvic motion during the first 60% of the HLR motion (Gombatto et al., 2006). Although investigating differences in movement between different subgroups of people with LBP is important for refining LBP classifications and interventions for people with LBP, the findings from the two prior studies do not provide information about whether early lumbopelvic motion during a limb movement is a potential contributing factor to LBP. Data from the current study, specifically comparing people with and people without LBP, provide some support for the proposal that early lumbopelvic motion during a limb movement, particularly in the transverse plane, may be relevant to the development or persistence of a LBP problem.

The increased and earlier lumbopelvic motion demonstrated with active limb movements in the current study were specific to motion in the transverse plane. During HLR, it was expected that lumbopelvic motion would occur only in the transverse plane. However, during KF, lumbopelvic motion was expected to occur in both the transverse and sagittal planes. The findings of differences in lumbopelvic motion between people with and people without LBP only in the transverse plane during KF were unexpected. Although we did not hypothesize that the identified differences in lumbopelvic motion would be specific to a particular plane of motion, we do consider such a finding to be important and unique. One might predict that a short or stiff rectus femoris muscle could contribute to pelvic motion in the sagittal plane because the rectus femoris is being stretched across two joints during KF (Kendall et al., 1993). Although a stiff or short rectus femoris or tensor fascia latae/iliotibial band may also contribute to lumbopelvic motion in the transverse plane, there is no obvious biomechanical explanation for why the lumbopelvic region would move earlier in the transverse plane with knee flexion in the LBP group compared to the group without LBP. The lack of an obvious biomechanically-based explanation, coupled with the early transverse plane motion with two different lower limb movement tests, would suggest that the differences demonstrated in the LBP group may be a result of a learned movement strategy and not just a biomechanical limitation. Such a finding is clinically important because treatment of the early lumbopelvic motion will vary depending on the factors contributing to the identified movement pattern. The current study suggests treatment may require not only stretching of structures that contribute to early movement, but also training to move in the hip or knee while simultaneously limiting movement of the lumbopelvic region during the limb movement.

One potential limitation of the current study is that we examined differences in lumbopelvic motion between people with LBP who perform repeated rotation-related activities and a group of people who do not regularly perform rotation-related activities. It is possible that the early and increased lumbopelvic motion demonstrated by people with LBP who play rotation-related sports is only an adaptation to the sport requirements and does not contribute to the person's LBP problem. However, all LBP subjects included in the current study reported an increase in LBP symptoms associated with their rotation-related sport and during rotation-related tests during the clinical examination. Additionally, LBP has been reported to be associated with participation in rotation-related sports suggesting the nature of the movements associated with the sport may contribute to the LBP problem (Perkins and Davis, 2006; Trainor and Trainor, 2004).

It is unknown whether the findings of the current study would be generalizable to a group of people with LBP who do not regularly perform rotation-related sports. However, it is logical that people who regularly perform other rotation-related activities as part of their leisure-non-sports or work activities may develop similar movement patterns. In support of such a relationship are findings from a secondary analysis of data from people with LBP. In this prior study we found that those who participated in asymmetric leisure activities (sport or leisure non-sport) displayed more rotation-related impairments during a clinical examination than people who participated in symmetric leisure activities. Work-related activities were not examined due to insufficient data (Van Dillen et al., 2006). Considering these prior findings and that many everyday activities and jobs require rotation, there may be a significant percentage of people for whom the findings of the current study are relevant. Future studies are necessary to further analyze whether the early lumbopelvic motion during limb movements is found in all people with LBP, regardless of activity.

A second potential limitation is that the generalizability of the data may be limited due to the characteristics of the sample. The LBP group consisted of people with chronic or recurrent LBP who reported a minimal level of disability as indexed by their score on the modified Oswestry Disability Index. It is unknown whether similar results would be found in a group of people with more acute LBP or higher reports of disability. Although we cannot generalize the findings of the current study to a more acute or disabled sample, the people included in the current sample did report an increase in symptoms with rotation-related activities suggesting the excessive or early lumbopelvic motion these people display may be an important contributing factor to the LBP problem regardless of acuity. The sample also was relatively young (range: 18–45 years). Although there is some evidence to suggest that spine mobility decreases with age (Troke et al., 2001; Van Herp et al., 2000), we have previously reported that age does not appear to affect the prevalence of early lumbopelvic motion demonstrated by people with LBP during clinical tests (Scholtes and Van Dillen, 2007). It is possible, though, that age could influence the variables reported on in the current study. Future research examining timing of lumbopelvic motion in people with a variety of acuity levels and ages is warranted.

A third potential limitation is the design of the study. Because the study design is cross-sectional, it is unknown whether people in the LBP subgroup developed LBP as a result of the early and increased lumbopelvic motion demonstrated with limb movements, or if the early and increased lumbopelvic motion is a result of the LBP problem. Regardless of the causal relationship, we consider the current findings to be important. Clinical data suggests that altering the lumbopelvic motion demonstrated during limb movements results in decreased LBP symptoms (Maluf et al., 2000; Van Dillen et al., 2003a; Van Dillen et al., 2005; Van Dillen et al., 2007b). Thus, regardless of whether the early lumbopelvic rotation we have identified caused the initial LBP problem, the early and increased lumbopelvic motion identified in the current study may contribute to the persistence or recurrence of a LBP problem.

Conclusion

The current findings suggest that a greater magnitude of and earlier lumbopelvic motion in the transverse plane during lower limb movements may be important factors contributing to the development or persistence of a LBP problem in people who regularly participate in rotation-related sports. Future work should focus on identifying (1) the factors that contribute to the increased and earlier lumbopelvic motion identified in people with LBP in the current study and (2) whether similar movement patterns are identified in people with LBP who do not participate in rotation-related sports. Identifying contributing factors to examination findings will help to better direct examination and specify interventions for people with LBP.

Acknowledgements

We would like to acknowledge Jack Engsborg, Ph.D. for his assistance with project planning and David Collins, Ph.D. for his assistance with data processing.

Funding Sources This work was funded in part by the National Institute of Child Health and Human Development, National Center for Medical Rehabilitation Research, Grant # K01HD-01226, Grant # 5 R01 HD047709, and Grant # T32HD007434, as well as a scholarship from the Foundation for Physical Therapy, Inc. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NICHD, NIH, or the Foundation for Physical Therapy.

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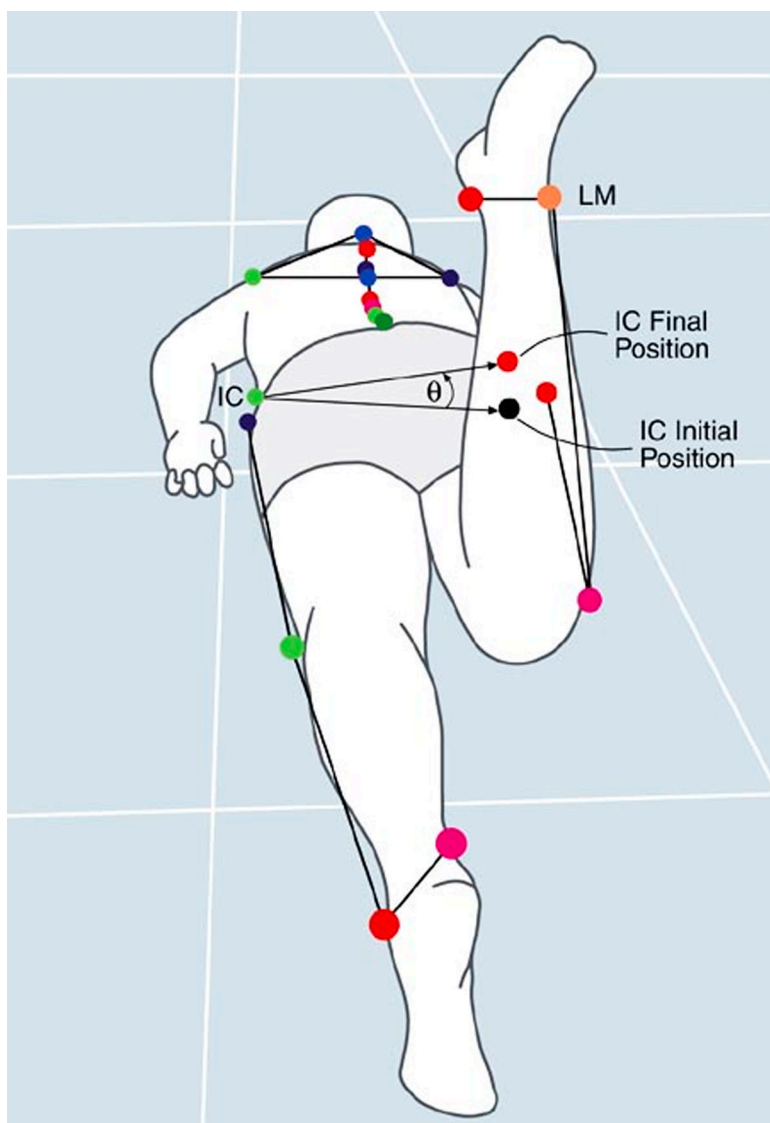


Figure 1.
Kinematic model with lumbopelvic rotation (θ) calculation. IC = iliac crest.

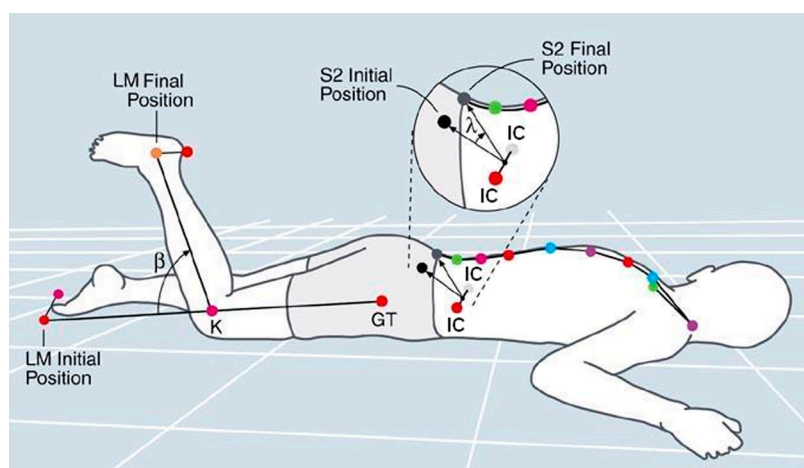


Figure 2. Kinematic model with calculations for knee flexion (β) and anterior pelvic tilt (λ). LM = lateral malleolus, K = lateral knee joint line, GT = greater trochanter, IC = iliac crest.

Table 1

Subject characteristics

	People without LBP (N=41)	People with LBP (N=50)	95% Confidence Intervals of the Mean Difference	Statistical Value, Degrees of Freedom (df), P-value
Sex	M=22, F=19	M=32, F=18	NA	$\chi^2=0.318$, df=1, $P=0.392$
Age (y)	27.9 (7.4)	28.2 (8.1)	-3.62 – 2.92	$t=-0.208$, df=89, $P=0.836$
Body Mass Index (kg/m ²)	23.3 (2.8)	24.8 (3.5)	-2.33 – 0.015	$t=-1.961$, df=88, $P=0.053$
Baecke Habitual Activity Questionnaire (3–15)	8.1 (1.3)	8.3 (0.7)	-0.28–0.64	$t=0.783$, df=60.1, $P=0.437$
Modified Oswestry Disability Index (0–100 %)	NA	14.6 (7.6)	NA	NA
Current Pain Score (0–10)	NA	2.9 (1.7)	NA	NA
Duration of LBP (y)	NA	6.5 (5.4)	NA	NA
Number of Acute Flare-ups in Previous 12 Months	NA	7.1 (3.8)	NA	NA

Abbreviation: LBP, Low Back Pain

Values expressed as mean (standard deviation)

Table 2
Standard error of the measure and ICC values for dependent variables calculated for tests of right and left knee flexion in prone.

Test Movement	Standard Error of the Measure *	ICC Value
Knee Flexion in Prone		
Left knee flexion	2.2	0.96
Left lumbopelvic rotation	0.6	0.78
Left anterior pelvic tilt	0.5	0.94
Right knee flexion	2.0	0.96
Right lumbopelvic rotation	0.7	0.70
Right anterior pelvic tilt	0.6	0.91

* Values expressed in degrees

Table 3

Means, standard deviations, mean differences, confidence intervals and statistical values for timing and magnitude of knee flexion and hip lateral rotation variables for people with and people without low back pain (LBP).

	People without LBP	People with LBP	Mean Difference	95% Confidence Intervals of the Mean Difference	Statistical Values, Degrees of Freedom (df), <i>P</i> -value
Knee Flexion Test					
Maximal Knee Flexion Angle	119.95 (9.31)	114.28 (8.60)	5.67 (4.73%)	1.92–9.43	$F=9.010$, $df=1$, $P=0.003$
Average Knee Flexion Velocity	66.90 (23.36)	60.50 (20.66)	6.40 (9.57%)	–2.82–15.62	$F=1.901$, $df=1$, $P=0.171$
Maximal Lumbopelvic Rotation Angle	2.32 (1.48)	3.24 (1.73)	0.92 (39.66%)	0.23–1.60	$F=7.096$, $df=1$, $P=0.009$
Maximal Anterior Pelvic Tilt Angle	3.31 (1.90)	3.40 (1.95)	0.08 (2.41%)	–0.72–0.89	$F=0.041$, $df=1$, $P=0.840$
Timing of Lumbopelvic Rotation	0.39 (0.33)	0.26 (0.22)	0.13 (33.33%)	0.02–0.25	$t=2.228$, $df=66$, $P=0.029$
Timing of Anterior Pelvic Tilt	0.26 (0.29)	0.25 (0.21)	0.01 (3.85%)	–0.10–0.10	$F=0.005$, $df=1$, $P=0.941$
Hip Lateral Rotation Test					
Maximal Hip Lateral Rotation Angle	41.59 (6.62)	44.28 (6.38)	2.69 (6.47%)	–0.03–5.40	$F=3.867$, $df=1$, $P=0.052$
Average Hip Lateral Rotation Velocity	23.54 (8.15)	21.40 (8.82)	2.14 (9.09%)	–1.43–5.71	$F=1.415$, $df=1$, $P=0.237$
Maximal Lumbopelvic Rotation Angle	4.47 (2.55)	5.85 (2.99)	1.38 (30.87%)	0.20–2.55	$F=5.445$, $df=1$, $P=0.022$
Timing of Lumbopelvic Rotation	0.31 (0.26)	0.19 (0.14)	0.12 (38.71%)	0.03–0.21	$t=2.561$, $df=60$, $P=0.013$

Values expressed as mean (standard deviation)