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Effect of Low Back Pain on the Kinematics and Joint Coordination of the Lumbar Spine and Hip During Sit-to-Stand and Stand-to-Sit

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Study Design. Experimental study to describe lumbar spine and hip joint movements during sit-to-stand and stand-to-sit.

Objectives. To examine differences in the kinematics and joint coordination of the lumbar spine and hips during sit-to-stand and stand-to-sit between healthy subjects and patients with subacute low back pain (LBP).

Summary of Background Data. There is a paucity of information on the coordination of movements of lumbar spine and hips during sit-to-stand and stand-to-sit. The effect of LBP, with or without nerve root signs, is largely unknown.

Methods. A three-dimensional real-time electromagnetic tracking device was used to measure movements of the lumbar spine and hips during sit-to-stand and stand-to-sit. Sixty subacute LBP participants with or without straight leg raise signs and 20 healthy asymptomatic participants were recruited. The kinematic patterns of lumbar spine and hips were analyzed. Coordination between the two joints was studied by relative phase angle analysis.

Results. The mobility of the spine and hips was significantly limited in back pain subjects. It was observed that LBP subjects employed various strategies to compensate for the limited motions at the hips and lumbar spine. The contribution of the lumbar spine relative to that of the hip was found to be reduced for subjects with LBP. The lumbar spine-hip joint coordination was significantly altered in back pain subjects, in particular, those with positive straight leg raise sign.

Conclusion. Back pain was related to changes in the kinematics and coordination of the lumbar spine and hips during sit-to-stand and stand-to-sit. Assessment of back pain patients should include kinematic analysis of the hips as well as the spine.

Key words: kinematics, spine, hip, low back pain, joint coordination. **Spine 2005;30:1998–2004**

Low back pain (LBP) is a commonly encountered and serious health problem[1] and is frequently associated with a change in the mobility of the LS and hip.[2–4] Impairment of spinal mobility has been shown to result in various forms of functional disabilities,[5] which may have profound effects on quality of life. Clinical evidence has also shown that LBP patients with radiating leg pain tend to have a more prolonged course and are substantially more disabled than patients with LBP alone.[1]

People with LBP have been shown to have some limitations in both spinal and hip motion that compromises their function. Some research studies[6,7] have demonstrated that the contribution of the LS to forward bending is reduced in subjects with LBP. Spinal and hip movements work together in many functional activities, but only a few studies have acknowledged this relationship,[2,7,8] and those have largely been limited to two-dimensional anatomic movements. One study determined that the LS contributed approximately 56 to 66% of the flexion during sit-to-stand and stand-to-sit in healthy subjects.[9]

Previous studies have also suggested that patients with back pain who display SLR signs exhibit limitations of the hip and LS during physiologic movements.[4] This may be because, at least in part, of increased tissue stiffness and decreased stretch tolerance of the hamstring muscles, perhaps associated with abnormal tension in the sciatic nerve or its composing nerve roots.[10–12] Although the importance of radiating leg pain has been increasingly recognized by researchers and clinicians, the presence of root symptoms demonstrated by a positive SLR test has not been linked to functional limitation.

Patients with chronic LBP also show deficits in reaction time, coordination, and postural control[13] with reduced velocity and reduced range of motion compared with healthy subjects.[14] However, studies into these phenomena have been limited to simple descriptions of range of motion and peak amplitudes, which do not adequately explore coordination between movements of the LS and hips.

Rising from sitting to standing, and its reverse, are common and functionally important activities. They are mechanically demanding tasks[15] that may be affected by restriction in trunk motion[16] and that have been shown to be affected in patients with LBP.[17] While it is true to say that a considerable body of literature exists regarding this action, there seems to be little information available about the effect of subacute LBP on the kinematics of the LS and hips during sit-to-stand and stand-to-sit. Previous work has not addressed the coordination between the LS

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and hips quantitatively during this activity, neither in healthy subjects nor in clinical populations.

The purpose of this study was to investigate the effects of subacute LBP and limitation in straight leg raise (SLR) on the kinematics of the LS and the hip joints during sit-to-stand and stand-to-sit. We hypothesized that range of motion, maximum displacement, and angular velocity of the LS and hips would be reduced in patients with LBP and limited SLR. Furthermore, we hypothesized that the coordination of the hip and LS movements would be affected by the presence of LBP or limited SLR. This study attempted to address the limitations of previous work identified in the above literature review. It is hoped that the information obtained would help clinicians evaluate the functional disabilities of patients with back pain and devise treatment strategies to restore kinematic abnormalities and movement coordination.

■ Materials and Methods

Subjects. Eighty volunteers were recruited and were divided into the following three groups (Table 1):

- Group 1: able-bodied, asymptomatic subjects (n = 20);
- Group 2: subjects with LBP presenting with a negative straight leg raising (SLR) test (n = 30);
- Group 3: subjects with LBP and a positive SLR sign (n = 30).

Group 1 participants had no history of back pain or pain related to the back that required medical attention or treatment in the previous 6 months. The inclusion criteria for groups 2 and 3 were the presence of subacute back pain or buttock pain related to the back (duration between 7 days and 12 weeks) with back pain as the primary complaint, the pain being of sufficient intensity to require medical attention or treatment but not warranting complete bed rest or hospitalization.

Study participants were excluded if they had any known neurological or orthopedic disorders or previous surgery; sensory, neurological or autonomic deficits; fractures, dislocations, bony abnormalities or deformities of the trunk and lower limbs, or rheumatic disease. There were no significant differences in demographics among the groups ($P < 0.05$; Table 1). All participants recruited were routinely screened by a physiotherapist for inclusion and exclusion criteria. All participants had normal mobility of the hips. None of them were found to have leg length inequality of more than 20 mm, which could affect the kinematics of the spine and hip.[18,19] A standardized passive SLR test was performed,[12,20] and the maximum angle between the straight leg and the longitudinal axis of the trunk was measured by using an universal goniometer. SLR sign was considered to be positive if the lift angle was $\leq 65°$ with unilateral symptoms reproduced in the tested leg. This SLR angle was less than the 95% confidence interval of asymptomatic values.[21]

Subjects were asked to rate their severity of pain using a visual analogue scale (VAS) of 0 to 10, and their functional ability was evaluated by Roland-Morris Disability Questionnaire (RMQ). There were no significant differences in the value of VAS and RMQ between group 2 and group 3 subjects ($P < 0.05$; Table 1). All participants signed an informed consent statement and were supplied with information sheets before participating in this study. The study was approved by the United Christian Hospital and the Human Ethics Committees of the University of Sydney and the Hong Kong Polytechnic University, reference number 02/02/16.

Table 1. The Mean (Standard Deviation) Demographic Data of the Three Groups of Subjects

	Group 1, Able-Bodied	Group 2, LBP	Group 3, +ve SLR
n	20	30 [28 first episode]	30 [29 first episode]
Mean age	41.7 ± 8.2	40.9 ± 10.0	38.5 ± 10.2
Mean height/cm	169.6 ± 5.6	172.0 ± 3.8	173.0 ± 3.8
Mean weight/lbs	156.6 ± 23.0	150.5 ± 10.9	155.5 ± 10.5
Mean onset of pain/wk	—	7.4 ± 2.7	7.1 ± 2.7
Mean VAS	—	5.7 ± 1.6	5.9 ± 1.9
Mean RMQ	—	10.3 ± 4.5	11.6 ± 4.2
Mean angle of SLR	—	81.3 ± 2.2	44.2 ± 8.9

Instrumentation. The 3SPACE Fastrak (Polhemus Inc., Colchester, VT) was used to measure movements of the LS and hips. The device has previously been described by Lee.[22] Briefly, it consists of a source that generates a low-frequency magnetic field that is detected by sensors. The source was placed in a fixed position close to the subject (within 0.7 m). Four sensors were used to measure the movements of the LS and hips.[8] One was placed over the L1 spinous process and the second over the sacrum. The locations of the spinous processes were determined as described by Burton[23] that being the identification of the L4 spinous process as the bisection of a line joining the highest points on the iliac crests. Two other sensors were used to measure the movements of the hips by placing them over the lateral aspect of the left and right thighs. Each sensor was attached to a small, moldable plastic plate by double-sided adhesive tape. A Velcro band was threaded through the plate and tightly wrapped around the subject's trunk or leg so as to minimize the movement between the sensor and the underlying skin. The cables were attached to the skin on the side of the trunk so that they did not move the sensor erroneously during the movement. Initial testing showed that this arrangement provided the most secure sensor attachments.[8]

Lumbar spine movements were derived from the relative orientation between the L1 and sacral sensor and hip movements from that between the thigh and sacral sensors. The method of computation was based on the mathematical techniques described by earlier authors,[22,24] and joint angles were derived from the direction cosine matrices of the sensors. The flexion/extension axis of the spine and hip was orientated to the pelvis and defined by a line joining the two anterior superior iliac spines. Conventionally, LS and hip flexion was considered to be positive. Lumbar spine and hip extension was represented by negative values. Only movements in the sagittal plane are presented in this report. Preliminary analysis showed that motions out of the sagittal plane were of insignificant amplitude.

Procedure. To ensure the activity was as natural as possible, few constraints were placed on the procedure of sit-to-stand and stand-to-sit, the only restrictions being that participants were not allowed to use their hands to push up and that the feet stayed on the floor. The use of upper limbs[25] and initial foot placement[26] have been found to significantly affect both kinetic and kinematic variables and movement strategies. Participants were seated on a stool with neither armrest nor backrest. The stool provided support from the ischial tuberosities to the middle of the thighs. Its height was adjusted for each subject by placing wooden boards of appropriate thickness underneath the seat. The stool height was 110% of knee-floor length, which was defined as distance between the apex of the fibular head and the floor. They were required to look forward with an upright posture and arms hanging freely beside the body, and foot placement was not restrained. Participants were instructed to rise freely at their comfortable speed and then maintain a comfortable and erect posture for 3 seconds. They were then instructed to sit down on the chair at their own comfortable speed. There was no attempt to correct any deviations during the test. Each subject repeated the movements three times. Figure 1 shows the set-up of the experiment when a subject was performing the sit-to-stand activity.

Data Analysis. Data analysis consisted of kinematic, relative phase angle, and statistical analysis as follows.

Kinematic Analysis. The movements of each joint were plotted against time. To examine the repeatability of measurements, the coefficient of multiple determination[27] and the root mean square error were calculated to determine the degree of similarity of the three sets of angle-time curves and relative phase difference-time curves. The means and standard deviations of the maximum and minimum range in each plane of movements were determined for each subject. The repeatability of these variables among the three trials within each subject was established using intra class correlations, ICC.[1,2]

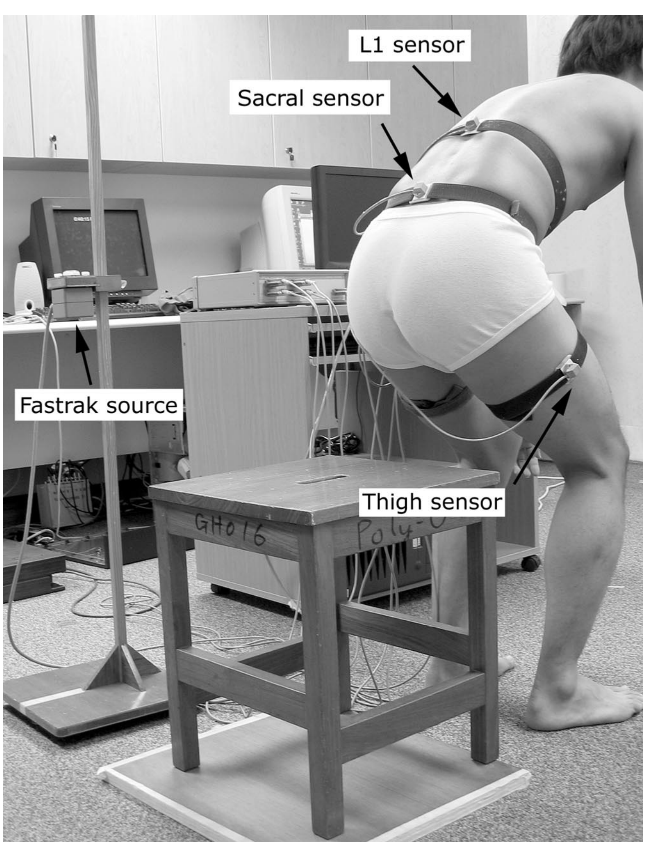

Figure 1. The experimental set-up.

The primary movements of sit-to-stand and stand-to-sit were identified. The movement-time curves of the main movements were plotted, with 95% confidence intervals. The maximum range and the time course of the primary movements were determined. The ratios of the total movements of the LS to those of the LH (LS/LH) and to the right hip (LS/RH) were computed during sit-to-stand and stand-to-sit. These ratios describe the relative contributions of the joint pairs throughout the range of the movement. The flexion and extension velocity values of the hips and the LS were also computed. The posture of the LS and hip joints was also investigated for quiet standing and sitting.

Relative Phase Angle Analysis. Interjoint coordination was assessed from relative phase angles. Phase angles are defined as the inverse tangent of angular velocity/angular displacement. The relative phase angle between two joints, which represents the joint coordination, was quantified by subtracting the phase angle of one from the other.[28] By our convention, if the relative phase angle is negative, the hip is lagging the LS. If the phase difference is positive, then the hip movement is leading the LS. The maximum and minimum phase angles and the timing of their occurrence was then determined.

Statistical Analysis. One-way analysis of variance (ANOVA) was used to examine any differences in postural alignments, maximum joints ranges, joint velocities, lumbar/hip motion ratios, and relative phase differences among three groups. Post hoc least significant difference test was used, and the alpha level was set at 0.05.

Results

The mean coefficient of multiple determination for the movement-time curves was found to be 0.94 ± 0.03, suggesting that the curves were very similar in shape in repeated measurements. The mean root square error was 2.1 ± 0.9°. There were thus minimal intrasubject differences in the movement patterns among the three trials. The mean ICC for determining the ranges of spine and hip movements was found to be 0.95 ± 0.01, indicating that there were no significant differences in ranges of movements among the three trials. It is concluded that the data obtained were highly repeatable, enabling conclusions to be drawn about the results of this study.

Table 2 shows the positions of the LS and hip in the sagittal plane in the upright sitting and standing postures. ANOVA showed that there were no significant differences in the spine and hip positions in the two postures among the three groups of subjects ($P > 0.05$).

Sit-to-Stand

Sit-to-stand was found to be mainly accomplished by movements of the LS and hips in the sagittal plane. The maximum flexion angles of left hip (LH), right hip (RH) and LS during sit-to-stand were 87°, 88°, and 41°, respectively, in able-bodied subjects. ANOVA revealed that subjects in groups 2 and 3 exhibited significant limitations in peak flexion in both hips and in the LS when compared with able-bodied subjects ($P < 0.05$; Table 2). However, there was no significant difference in the range of movements of the spine and hips between groups 2

Table 2. Mean (SD) of the Sagittal Angles and Various Kinematic Parameters of the Left (LH) and Right Hips (RH) and the Spine During Upright Sitting, Standing, Sit-to-Stand and Stand-to-Sit

	Group 1, Able-Bodied	Group 2, LBP	Group 3, SLR
Sitting posture			
Left hip/°	45 ± 9	44 ± 10	45 ± 8
Right hip/°	47 ± 9	43 ± 10	44 ± 9
Lumbar/°	14 ± 8	15 ± 7	15 ± 7
Standing posture			
Left hip/°	0 ± 3	1 ± 2	0 ± 2
Right hip/°	0 ± 3	1 ± 2	1 ± 2
Lumbar/°	0 ± 2	1 ± 2	1 ± 2
Sit to stand			
Flexion phase			
Maximum range of motion			
Left hip/°	87 ± 11	64 ± 11*	66 ± 5*
Right hip/°	89 ± 11	64 ± 10*	67 ± 6*
Lumbar/°	41 ± 8	25 ± 7*	24 ± 5*
Velocity			
Left hip/°s^{-1}	68 ± 11	45 ± 12*	40 ± 14*
Right hip/°s^{-1}	69 ± 14	47 ± 13*	40 ± 14*
Lumbar/°s^{-1}	25 ± 6	17 ± 7*	19 ± 5*
Extension phase			
Velocity			
Left hip/°s^{-1}	118 ± 23	80 ± 27*	68 ± 12*
Right hip/°s^{-1}	121 ± 25	77 ± 29*	64 ± 17*
Lumbar/°s^{-1}	43 ± 11	29 ± 10*	30 ± 12*
Ratio in the sagittal plane			
LS/LH	0.51 ± 0.15	0.40 ± 0.12*	0.38 ± 0.18*
LS/RH	0.52 ± 0.15	0.40 ± 0.13*	0.38 ± 0.14*
Stand to sit			
Flexion phase			
Maximum range of motion			
Left hip/°	86 ± 10	66 ± 11*	63 ± 10*
Right hip/°	87 ± 11	66 ± 10*	64 ± 12*
Lumbar/°	37 ± 8	22 ± 7*	25 ± 6*
Velocity			
Left hip/°s^{-1}	111 ± 10	84 ± 19*	72 ± 8*
Right hip/°s^{-1}	115 ± 21	82 ± 19*	69 ± 7*
Lumbar/°s^{-1}	41 ± 13	25 ± 9*	29 ± 12*
Extension phase			
Velocity			
Left hip/°s^{-1}	60 ± 14	44 ± 16*	37 ± 10*
Right hip/°s^{-1}	58 ± 14	41 ± 13*	36 ± 9*
Lumbar/°s^{-1}	16 ± 4	12 ± 7*	12 ± 4*
Ratio in the sagittal plane			
LS/LH	0.50 ± 0.15	0.38 ± 0.14*	0.41 ± 0.14*
LS/RH	0.49 ± 0.14	0.38 ± 0.15*	0.42 ± 0.16*

*Significant difference in symptomatic subjects (Groups 2 and 3) when compared with asymptomatic subjects (Group 1; $P < 0.05$).

and 3 ($P > 0.05$). The velocities of the hips and LS movement during flexion and extension were also found to be significantly decreased for those with LBP when compared with able-bodied participants (Table 2). Thus, it also took longer for LBP subjects to reach peak lumbar flexion and to stand from a sitting position.

The mean ratios of lumbar and hip movements for the able-bodied group were found to be approximately 0.5; thus the total contribution of the LS was about half of that of the hips. For groups 2 and 3, the mean ratios were 0.40 and 0.38 respectively, significantly smaller when compared with group 1 ($P < 0.05$), suggesting that the LS contributed less to the total movement in symptomatic subjects (Table 2).

A similar pattern of relative phase angles was observed for all participants. Before the loss of contact between the thighs and the chair, the LS led the hips (i.e., negative relative phase angle; Figure 2). However, during the subsequent extension movements to upright standing, the LS lagged behind the hips. Results of ANOVA showed that in LBP subjects (groups 2 and 3), in particular participants with positive SLR sign, the phase difference was significantly less negative during the pre-extension component of the activity when compared with group 1 ($P < 0.05$; Table 3). In the extension movement, the relative phase difference between hip and LS was significantly more positive in LBP subjects than those in group 1 ($P < 0.05$; Table 3). Although group 3 participants generally exhibited greater changes in phase angle than group 2, the differences between the two groups were not statistically significant ($P > 0.05$). The timing of maximum and minimum relative phase angles was similar among the three groups ($P < 0.05$; Table 3).

Stand-to-Sit

During stand-to-sit, the movement patterns mirror those of sit-to-stand and are mainly confined to the sagittal plane. The joints initially flex until thigh-seat contact occurs and then extend until the subject sits upright. The maximum flexion of LH, RH, and LS was found to be 86°, 87°, and 37°, respectively, in able-bodied subjects. The results of ANOVA were similar to that of sit-to-stand. Subjects in groups 2 and 3 exhibited significant limitations in lumbar and hip flexion compared to able-bodied subjects ($P < 0.05$; Table 2) but not between groups 2 and 3 ($P > 0.05$). Hip and LS flexion velocity was also found to be decreased significantly for those with LBP when compared with able-bodied subjects (Table 2). The mean spine-hip ratio for the able-bodied subjects was approximately 0.50. This ratio was significantly reduced in groups 2 and 3 ($P < 0.05$) (Table 2), suggesting that the LS contributed less to the overall movement in symptomatic subjects.

The relative phase relationship between the spine and hips during stand-to-sit is shown in Figure 3. When participants were bending forward to sit down, the LS led the hips, but the LS lagged the hips towards the end of movement until the participant was sitting erect. In the flexion stage, the relative phase angle between hip and LS of able-bodied participants was found to be −18° ± 15°. Results of ANOVA showed that in the first part of the stand-to-sit activity, the phase differences of LBP subjects were significantly more negative when compared with able-bodied subjects ($P < 0.05$; Table 3). Group 3 subjects exhibited even more negative phase differences than those in group 2 ($P < 0.05$; Table 3). In the final "sitting back" stage, the relative phase difference between hip and LS was 45° ± 12° in able-bodied subjects, and there were no significant differences among the three groups ($P > 0.05$). The timing of occurrence of maximum and

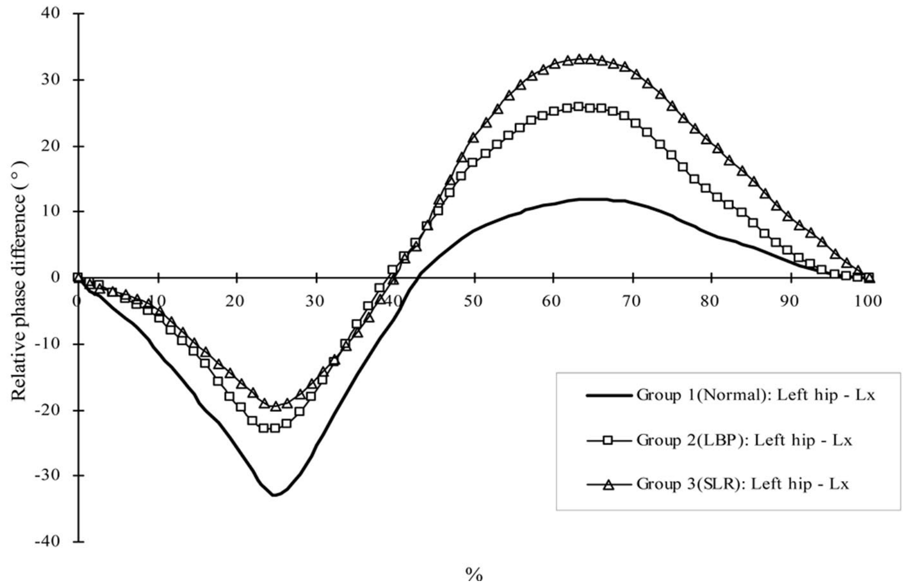

Figure 2. A plot of mean relative phase angle vs. time for the sit-to-stand activity.

minimum relative phase angle was also similar among the three groups ($P > 0.05$; Table 3).

Discussion

The present study, to our knowledge, is the first to describe the coordination of the LS and hip joints during sit-to-stand and stand-to-sit in patients with LBP. The results showed that subjects with back pain exhibited reductions in trunk and hip motion during both sit-to-stand and stand-to-sit. This finding is consistent with previous studies that have shown that patients with LBP have restricted spinal movements and that the nature of the restriction is related to the pathology.[3,4,6,29] Previous work has also shown that the relationship between the LS and hip movements is also altered.[2,6,7,30]

Table 3. Mean (SD) of Maximum and Minimum Relative Phase Difference Between Hip and Lumbar Spine During Sit to Stand and Stand to Sit

	Left Hip–Lumbar	Timing	Right Hip–Lumbar	Timing
Sit to stand				
Minimum relative phase difference				
Group 1, able-bodied	−33 ± 8	0.8 ± 0.1	−34 ± 18	0.8 ± 0.1
Group 2, LBP	−23 ± 13*	0.9 ± 0.4	−24 ± 14*	0.9 ± 0.4
Group 3, SLR	−19 ± 10*	0.9 ± 0.4	−20 ± 10*	0.9 ± 0.4
Maximum relative phase difference				
Group 1, able-bodied	12 ± 8	1.1 ± 0.7	10 ± 7	1.1 ± 0.8
Group 2, LBP	26 ± 15*	1.3 ± 0.8	30 ± 14*	1.2 ± 0.6
Group 3, SLR	33 ± 13*	1.3 ± 0.4	31 ± 13*	1.1 ± 0.6
Stand to sit				
Minimum relative phase difference				
Group 1, able-bodied	−18 ± 15	0.6 ± 1.3	−21 ± 10	0.6 ± 1.3
Group 2, LBP	−29 ± 17*	0.5 ± 0.4	−30 ± 18*	0.5 ± 0.4
Group 3, SLR	−38 ± 13*†	0.7 ± 0.5	−41 ± 14*†	0.6 ± 0.5
Maximum relative phase difference				
Group 1, able-bodied	45 ± 12	1.9 ± 1.5	49 ± 10	1.9 ± 1.6
Group 2, LBP	45 ± 18	2.1 ± 1.7	43 ± 18	2.1 ± 1.6
Group 3, SLR	41 ± 12	2.3 ± 1.1	47 ± 12	2.2 ± 1.1

*Significant difference in symptomatic subjects (Groups 2 and 3) when compared with asymptomatic subjects (Group 1; $P < 0.05$).
†Significant differences between Groups 2 and 3 subjects ($P < 0.05$).

The changes in kinematics attributed to LBP may be compensatory responses to reduce pain or to protect the injured tissues. It has been postulated that pain will result in sustained and increased muscle activation (muscle spasm).[31,32] This may limit the range of motion, preventing motion of the injured structures. Some authors believe that there are cocontraction of agonist and antagonist muscles,[31] whereas others suggest that pain decreases the activation of a muscle when it functions as an agonist and increases the activation when it acts as an antagonist.[32] Further research would be required to determine the precise effects of LBP on muscle activation pattern.

During the sit-to-stand and stand-to-sit activities, the LS was found to contribute less to the total movement for subjects with LBP. This kind of reduction would avoid extremes of lumbar flexion, thus minimizing pain. We also found that LBP subjects, especially those with a positive SLR sign, showed a significant reduction in velocity in both the LS and hip joints and took a longer time to complete the sit-to-stand and stand-to-sit movements. It is possible that back patients reduce their trunk velocities and acceleration to avoid provocation of the pain caused by muscle contraction and high levels of acceleration. Marras and Wongsman[14] revealed that LBP had more significant effects on trunk velocities than trunk mobility. The findings of this study appear to reinforce this observation.

This is the first study to examine the phase relationships between the LS and hip joints in able-bodied and LBP subjects during sit-to-stand and stand-to-sit. We

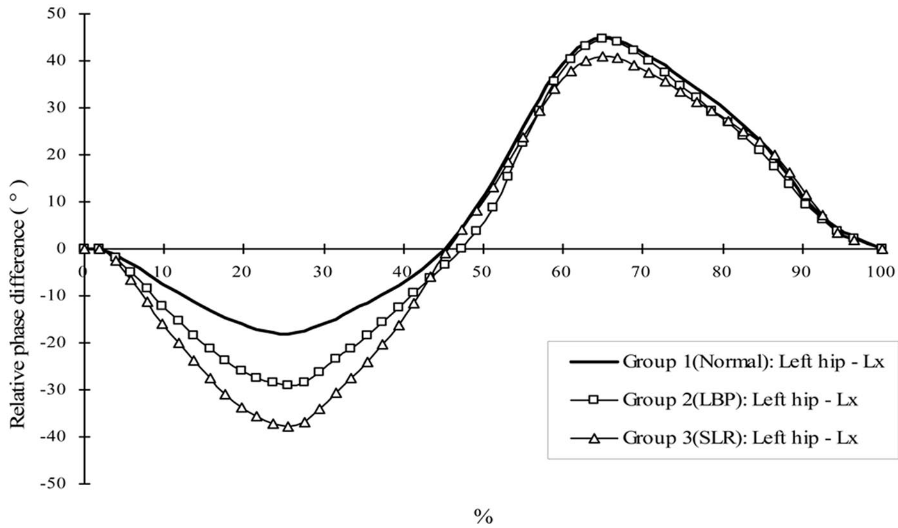

Figure 3. A plot of mean relative phase angle vs. time for the sit-to-stand activity.

found that there were significant alterations among the groups in interjoint coordination. In the initial stage of sit-to-stand, the relative phase analysis demonstrated that the LS led the hip in flexion, whereas in the later stage of the activity, the hips extended in advance of the spine. The analysis also indicated that in LBP subjects, the LS flexed in advance of the hips to a lesser extent in the initial stage and the spine was also slower than the hips in the final stage. The differences in the phase relationship may be attributed to different muscle activation patterns and different ratios of muscle moments exerted by the antagonist and agonist.[31,32] In contrast, during the stand-to-sit movement, the relative phase analysis demonstrated that the LBP subjects had a more marked LS lead in the initial "sitting down" stage. However, there was no significant difference in the phase relationship during the restoration of the upright sitting posture in the "sitting back" stage. Back pain affects the stand-to-sit activity differently probably because different muscle activities and momentum transfer strategies are involved. However, the literature has no information about these biomechanical parameters for the stand-to-sit activity.

In general, subjects with positive SLR demonstrated greater changes in joint movement coordination than those with LBP only, as shown by changes in relative phase angles between hip and spine. Pearcy *et al*[4] suggested that back pain patients with SLR signs may exhibit pain, altered muscle action, or spasm that may not only limit the LS movements but also the movements at the hips. This may be attributed to increased stiffness of the hamstring muscles or to abnormal tension in the sciatic nerve or its composing nerve roots.[10] Halbertsma *et al*[11] believed that decreased stretch tolerance of the hamstring muscle might contribute to reduced extensibility of the muscles. Tafazzoli and Lamontagne[12] also revealed that in LBP subjects with positive SLR sign, the passive elastic moment and stiffness of hip joint were significantly greater when compared with able-bodied subjects. It seems that changes in the mechanical properties and physiology of spinal and hip muscles may be responsible for the alteration in the hip-LS joint coordination in group 3 participants. Further research should be conducted to examine the biomechanical and physiologic changes of these muscles.

Sit-to-stand and stand-to-sit are essential components of everyday life and may be compromised by the presence of LBP. Our results showed that individuals with LBP have limited range and velocity of spinal motion as well as altered coordination between the LS and the hip joints. Clinical rehabilitation programs should include strategies to restore not only the primary kinematic variables but also the coordination of movements between joints. Such strategies may include medication and physical methods for pain relief and an exercise program for restoring muscle activation patterns and for stretching tight tissues. However, the biomechanical mechanisms and efficacies of these clinical methods in restoring kinematic and coordination changes have yet to be established.

Relative phase angle may be a useful clinical outcome measure for assessing the effectiveness of a rehabilitation program in restoring joint coordination. This study provides normative and clinical data on which assessment of relative phase angle could be judged. Electromagnetic motion tracking device is inexpensive, highly portable, and reliable.[22] It may be used for evaluation of activities of daily living in the clinical situation, as demonstrated in this study. Because the device is capable of providing real-time kinematic information,[8,22] clinicians and patients would be able to receive immediate feedback on the effectiveness of rehabilitation program.

Every effort was made to minimize the effects of any confounding variables that might influence the results of the experiment. For instance, the physical characteristics of the three groups of participants were similar in regard to their age, body weight, and height (Table 1). None of the subjects had leg length discrepancies or trunk deformities that might confound the kinematic measurements. The data obtained were highly repeatable and the observations were highly consistent, enabling conclusions to be drawn.

Our study was limited to analysis of sit-to-stand and stand-to-sit, and it is clear that further research into other activities of daily living is needed to extend our understanding of the effects of LBP on function. Moreover, the symptomatic groups represented the population of middle-age subjects with subacute LBP. The findings might not be generalized to other population groups. Another limitation of the present study was that we did not measure the loads and mechanical energy of the body segments, which might help explain the kinematic results. Further research should be carried out to examine the kinetics of the trunk during activities of daily living.

■ Conclusion

This study showed that the mobility of the spine and hip was significantly limited in LBP subjects whether or not they demonstrate a positive SLR sign. It was observed that patients with LBP, in particular those with positive SLR sign, had altered hip-spine coordination. This is believed to be a means to help protect spinal structures from movement that may cause pain. The biomechanical causes of the differences in hip-spine movement coordination remain to be studied. The present study provides some insight into the effect of LBP and limited SLR on activities of daily living and hence quality of life.

■ Key Points

- Kinematics and joint coordination of the LS and hips during sit-to-stand and stand-to-sit were evaluated in subjects with and without low back pain (LBP) and limitations in SLR.
- LBP subjects were found to exhibit reduced joint mobility and velocities of the spine and hip. The contribution of the LS relative to that of the hip was found to be reduced for subjects with LBP.
- The LS-hip joint coordination was significantly altered in back pain patients, in particular, those with positive SLR sign.

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