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The effect of within-session instruction on lumbopelvic motion during a lower limb movement in people with and people without low back pain

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Abstract

The purpose of the current study was to examine how effectively people with and people without low back pain (LBP) modify lumbopelvic motion during a limb movement test. Nineteen subjects with LBP and 20 subjects without LBP participated. Kinematic data were collected while subjects performed active hip lateral rotation (HLR) in prone. Subjects completed trials (1) using their natural method (Natural condition) of performing HLR, and (2) following standardized instructions to modify lumbopelvic motion while performing HLR (Modified condition). Variables of interest included (1) the amount of HLR completed prior to the start of lumbopelvic motion, and (2) the maximum amount of lumbopelvic motion demonstrated during HLR. Compared to the Natural Condition, all subjects improved their performance during the Modified condition by (1) completing a greater amount of HLR prior to the start of lumbopelvic motion, and (2) demonstrating less lumbopelvic motion ($P<0.01$ for all comparisons). There was a tendency for people without LBP to demonstrate a greater difference in maximal lumbopelvic rotation between the Natural and Modified conditions ($P=0.07$). In conclusion, people are able to modify lumbopelvic motion following instruction. Further study is needed to determine if people without LBP improve lumbopelvic motion following instruction to a greater extent than people with LBP.

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Keywords

spine; limb; hip lateral rotation; instruction; lumbopelvic motion

INTRODUCTION

Low back pain (LBP) is a musculoskeletal condition that affects up to 80% of the population at some point in their lifetime (Lawrence et al., 1998). Although as many as 90% of individuals who initially seek medical treatment for an acute episode of LBP stop seeking medical treatment within 3 months of the initial consultation, as many as 75% of these individuals state they are not fully recovered one year later (Croft et al., 1998). The economic and social impact of the persistent and recurrent course of LBP has led to the development and study of many diverse treatment options.

Despite the numerous studies that have been conducted, no treatment has been found to be consistently effective for alleviating the persistent symptoms and functional limitations associated with LBP. One proposal for the inconsistent findings is that previous treatments have not adequately addressed the potential importance of movements performed frequently across the day (Sahrmann, 2002). If movements are performed repeatedly across the day, then these movements could contribute to the often persistent and recurrent course of LBP.

Many of the activities frequently performed throughout the day involve limb movements. Limb movements are important in the examination of people with LBP because limb movements produce forces on the lumbopelvic region and, therefore, could induce movement of the lumbopelvic region. Repetitive lumbopelvic motion with limb movements could contribute to accumulation of lumbopelvic region tissue stress, microtrauma, and, eventually, LBP (McGill, 1997). Investigators have examined the effect of limb movements on the lumbopelvic region in people with and people without LBP. During active movements that involved the limbs, people with LBP demonstrated decreased trunk control (Mok et al., 2007) and different lumbopelvic movement patterns (Shum et al., 2005) compared to people without LBP.

Of interest to our work is how far a person can move the limb before the lumbopelvic region begins to move. How far the limb moves prior to the start of lumbopelvic motion is important because many daily activities are performed in the early to mid ranges of limb movements (Bukowski, 2009; Rose & Gamble, 2006; Shum et al., 2005; Shum et al., 2007). If the lumbopelvic region begins to move during the early to mid ranges of the limb movement, and the limb movement is performed frequently across the day, then there could be an increase in frequency of lumbopelvic motion across the day (Sahrmann, 2002). We previously have reported that (1) people with LBP demonstrate earlier lumbopelvic motion during active limb movements than people without LBP (Scholtes et al., 2009), and (2) people with LBP report a decrease in symptoms when the lumbopelvic region is manually restricted during a limb movement (Van Dillen et al., 2003; Van Dillen et al., 2007).

Although modifying lumbopelvic motion during a limb movement has been found to be beneficial, the procedures previously used to modify the motion are limited. During the clinical examination, modification of lumbopelvic motion occurs through verbal instruction provided to the patient, coupled with manual stabilization provided by the clinician. This method eliminates lumbopelvic motion and decreases symptoms. Thus, prescribing an activity that reduces lumbopelvic motion during a limb movement as part of a home program may be beneficial. Successful performance of a limb movement as part of a home

program however, would require the patient to be able to control movement of the lumbopelvic region independently, without manual assistance.

The purpose of the current study, therefore, was to examine how effectively people with and people without LBP independently modify lumbopelvic motion during an active limb movement test following standardized, within-session instruction. Hip lateral rotation (HLR) was examined in the current study because (1) it provokes symptoms in people with LBP (Gombatto et al., 2006; Van Dillen et al., 2001), and (2) lumbopelvic motion during HLR is different between people with and people without LBP (Scholtes et al., 2009). We hypothesized that, following instruction, all people would (1) complete a greater amount of HLR prior to the start of lumbopelvic motion, and (2) demonstrate less lumbopelvic motion during HLR. We also hypothesized that people without LBP would demonstrate greater improvements in both variables than people with LBP. The current study is important because it provides information about how quickly and how effectively people independently modify a movement pattern. This information may help guide a clinician to provide the most appropriate home program for a person with LBP or a different musculoskeletal pain condition.

METHODS

Subjects

Nineteen subjects with LBP and 20 subjects without LBP participated in the study. Table 1 includes subject and LBP-related characteristics of the sample. Subjects were excluded from the study if they reported having (1) a height and weight consistent with a body mass index (BMI) greater than 30, (2) a hip or knee injury that limited activities of daily living, (3) a history of a spinal fracture or surgery, or (4) a diagnosis by a physician of a spinal deformity, systemic inflammatory condition, or other serious medical condition that could affect the ability to move (e.g., Parkinson's disease). Subjects were included in the LBP group if they reported chronic or recurrent LBP of more than 6 months (Von Korff, 1994). Subjects were excluded from the group without LBP if they reported any prior LBP episode that affected activities of daily living for more than 3 days or for which they sought medical or allied health intervention. Prior to participation in the study, all subjects provided informed consent approved by the Human Research Protection Office of Washington University School of Medicine.

Clinical Measures

All subjects completed self-report questionnaires including a demographic and LBP history questionnaire and a Baecke Habitual Activity Questionnaire (Baecke et al., 1982). Subjects with LBP also completed (1) a verbal numeric pain rating scale (Jensen et al., 1994), (2) a modified Oswestry Disability Index (Fritz and Irrgang, 2001), and (3) a Fear Avoidance Beliefs Questionnaire (FABQ) (Waddell et al., 1993).

Laboratory Measures

Subjects performed the test of active HLR in prone (Sahrmann, 2002). At the start of each trial, the tester manually supported the tested limb in a position of neutral femoral abduction/adduction, 5° of hip medial rotation, and 90° of knee flexion. The non-tested limb was positioned in full hip and knee extension. Prior to each trial, the subject was instructed to bring the foot in as far as possible (i.e., lateral rotation) and then return the foot to the start position. Prior to the first trial, the tester assisted the subject in understanding the desired direction of motion by manually rotating the hip a few degrees. All trials were performed on the right and left limbs separately. Subjects performed 5 trials using their natural movement pattern (Natural condition) and 10 trials following standardized instructions (Modified

condition). Ten Modified trials were completed to assess whether greater improvement in performance occurred with repetition. Prior to each Modified trial, the tester provided verbal and tactile information that was intended to assist the subject in modifying lumbopelvic motion during HLR. The subjects were instructed verbally to contract the abdominal muscles and not allow the pelvis to rotate during HLR. While giving verbal instructions, the tester also provided tactile information to the abdominal muscles and posterior pelvis. Following each Natural or Modified trial, symptom response (increased, decreased, same) compared to the starting position, was assessed.

Kinematic data were collected using a 6-camera 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 limb and lumbopelvic rotation during testing. Data were collected at a sampling rate of 60 Hz. The static resolution of the motion capture system was 1mm per cubic meter.

Data Processing

Angular displacement and velocity of movement for the lower leg and lumbopelvic region were calculated across time. Hip lateral rotation was indexed using the lower leg segment; the segment was defined by a vector from a marker superficial to the lateral malleolus to a marker superficial to the lateral knee joint line. Hip lateral rotation was calculated as a change in the angle of the lower leg segment relative to the initial position (Gombatto et al., 2006). Lumbopelvic rotation was indexed using a pelvic segment; the segment was defined by a vector between markers placed superficial to the posterior superior iliac spines. Lumbopelvic rotation was calculated as a change in angle of the pelvic segment relative to the initial position (Figure 1).

Motion capture data were initially filtered using a 4th order, dual pass, butterworth filter with a cut-off frequency of 2.5 Hz. After this initial filtering, the start and end points of HLR and lumbopelvic rotation were determined and movement time was calculated. Because subjects were allowed to move at a self-selected speed, the raw data was then re-processed using a subject-specific cut-off frequency ($f_{c_{ss}}$) to filter the data (Winter, 2005). The subject-specific cut-off frequency was calculated by taking the reciprocal of 15% of the period, $f_{c_{ss}} = 1 / (0.15 * 2 * \text{movement time})$ (Gombatto et al., 2006).

The start of HLR was defined as the point at which angular velocity exceeded 5% of the maximal angular velocity of the lower leg segment. The start of lumbopelvic rotation was defined as the point at which angular velocity exceeded 10% of the maximal angular velocity of the pelvic segment. The end of movement for each segment was defined as the point at which 99.5% of the maximal angle had been achieved.

Dependent Variables

Limb and lumbopelvic kinematics were examined from the start of HLR to the end of HLR. Two dependent variables were used to evaluate performance during the HLR test. First, how far the limb moved prior to the start of lumbopelvic motion was indexed by the angle of HLR achieved before the lumbopelvic region began to move. Completion of a greater amount of HLR prior to the start of lumbopelvic motion would indicate better performance. Second, maximal lumbopelvic rotation was defined as the maximal angle of lumbopelvic rotation achieved between the start and end of HLR. A smaller angle would indicate better performance.

Data Analyses

SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to perform all statistical analyses. Chi-square goodness-of-fit analyses or two-tailed, independent samples t-tests were used to test for differences between groups on relevant subject characteristics. A paired t-test was used to test for a difference in the percentage of Natural and Modified trials for which subjects with LBP reported an increase in symptoms. The average of the 5 Natural trials and the average of the 10 Modified trials were examined. The Modified trials were averaged because there was no systematic improvement across the 10 repetitions. Trials from the right and left limbs were averaged for both conditions. Two-way, repeated measures, mixed-model analysis of variance tests were conducted separately on all dependent variables. The main and interaction effects of group (LBP, No LBP) and condition (Natural, Modified) were examined. The effect size for each comparison was indexed using Cohen's *d* statistic and was calculated as the difference in the group means divided by the pooled standard deviation (Cohen, 1988). Statistical significance for all analyses was set at $P < 0.05$.

RESULTS

There were no differences between people with and people without LBP in sex distribution, age, or BMI (Table 1). There was also no difference between the Natural and Modified conditions in the percentage of trials people with LBP reported increased symptoms (Natural: 11 people, 28.42% of trials; Modified: 11 people, 35.79% of trials; $t = 0.97$, $P = 0.34$).

Overall, there was no difference between groups in maximal HLR angle (LBP: $42.54^\circ \pm 8.95^\circ$, No LBP: $46.95^\circ \pm 8.60^\circ$; $F = 2.57$, $P = 0.12$). Compared to the Natural condition, both groups decreased their maximal HLR angle in the Modified condition (Natural: $46.63^\circ \pm 7.60^\circ$, Modified: $42.86^\circ \pm 9.95^\circ$; $F = 26.79$, $P < 0.01$). The difference in HLR angle between conditions for each group, however, was not different (mean difference between conditions: LBP: $3.65^\circ \pm 2.93^\circ$, No LBP: $3.88^\circ \pm 5.66^\circ$; $F = 0.03$, $P = 0.87$).

Means and standard deviations for the dependent variables of interest for each condition are provided in Table 2.

Angle of hip lateral rotation at the start of lumbopelvic rotation

Compared to people with LBP, people without LBP completed a greater angle of HLR prior to the start of lumbopelvic rotation during the HLR test (LBP: $7.69^\circ \pm 5.70^\circ$, No LBP: $12.46^\circ \pm 8.17^\circ$; $F = 5.92$, $P = 0.02$, $d = 0.48$). Following instruction in the Modified condition, subjects in both groups demonstrated a greater angle of HLR at the start of lumbopelvic motion compared to the Natural condition. (Natural: $5.62^\circ \pm 3.80^\circ$, Modified: $14.53^\circ \pm 10.06^\circ$; $F = 32.85$, $P < 0.01$, $d = 0.91$). The groups, however, did not differ in how well they modified lumbopelvic motion following instruction in the Modified condition (mean difference between conditions: LBP: $6.37^\circ \pm 6.33^\circ$, No LBP: $11.43^\circ \pm 12.05^\circ$; $F = 2.65$, $P = 0.11$, $d = 0.53$).

Maximal lumbopelvic rotation angle

Overall, there was no difference in the maximal lumbopelvic rotation angle demonstrated during HLR between people with and people without LBP (LBP: $6.68^\circ \pm 3.36^\circ$, No LBP: $5.94^\circ \pm 2.79^\circ$; $F = 0.64$, $P = 0.43$, $d = 0.14$). Following instruction in the Modified condition, both groups demonstrate a smaller maximal lumbopelvic rotation angle compared to the Natural condition (Natural: $8.07^\circ \pm 3.13^\circ$, Modified: $4.56^\circ \pm 6.02^\circ$; $F = 91.29$, $P < 0.01$, $d = 1.49$). Compared to people with LBP, there was a tendency for people without LBP to

demonstrate a greater decrease in the maximal lumbopelvic rotation angle in the Modified condition (mean difference between conditions: LBP: $2.83^{\circ} \pm 2.41^{\circ}$, No LBP: $4.20^{\circ} \pm 2.18^{\circ}$; $F=3.47$, $P=0.07$, $d=0.59$).

DISCUSSION

The purpose of the current study was to examine how effectively people modify lumbopelvic motion during HLR following standardized, within-session instruction. Consistent with our first hypothesis, all people improved their HLR performance following instruction. People in both groups (1) completed a greater amount of HLR prior to the start of lumbopelvic rotation, and (2) demonstrated less lumbopelvic rotation during HLR.

We also hypothesized that people without LBP would be more effective at modifying lumbopelvic motion following instruction than people with LBP (i.e. a group by condition interaction). Inspection of the data (Table 2) suggests a tendency for people without LBP to perform better than people with LBP, but neither interaction was significant (HLR angle at the start of lumbopelvic motion; $P=0.11$; maximal lumbopelvic rotation angle: $P=0.07$).

The medium effect size for both interactions ($d>0.5$), however, suggests that the lack of statistical significance is likely due to insufficient power (Cohen, 1988). Therefore, although there was no statistically significant difference in how effectively people with and people without LBP modify lumbopelvic motion following instruction, the presence of a medium effect size suggests further analysis of group differences in effectiveness of modification is warranted.

Our prior work suggests that modifying lumbopelvic motion during a limb movement by manually stabilizing the lumbopelvic region improves a person's LBP symptoms immediately (Van Dillen et al., 2003; Van Dillen et al., 2007). Learning to modify lumbopelvic motion during limb movements, therefore, may be beneficial for people with LBP. The current study demonstrates that people with LBP are able to modify lumbopelvic motion independently within one testing session. Thus, it is reasonable to expect that people with LBP would be able to perform an activity to improve lumbopelvic motion during a limb movement as part of a home program.

People with and people without LBP, however, did not demonstrate a complete elimination of lumbopelvic motion during HLR. Performance in the Modified condition followed a very simple instruction set with no external feedback. Although encouraging that people with and people without LBP were able to modify motion with such a simple instruction set, identification of (1) the most effective instruction set and (2) types of external feedback that would be beneficial for improving performance may further enhance how effectively people with LBP are able to perform an exercise to improve lumbopelvic motion as part of a home program.

Further examination of differences in how effectively people with LBP modify lumbopelvic motion compared to people without LBP may also lead to improved intervention strategies for people with LBP. Prior studies have reported on differences between people with and people without LBP in trunk muscle strength (Bayramoglu et al., 2001; Beimborn and Morrissey, 1988; Mayer et al., 1985; McNeill et al., 1980) and trunk muscle recruitment (Hodges, 2001; Hodges and Moseley, 2003; Hodges and Richardson, 1999). Reproduction of pain as well as anticipation of pain have also been found to influence how a person moves (Hodges et al., 2003; Vlaeyen and Linton, 2000; Zedka et al., 1999). Each of these variables may contribute to the potential differences in performance between people with and people without LBP suggested in the current study. To design the most effective intervention

strategies, future work should confirm the potential differences in ability to modify movement, and identify the variables contributing to the differences.

A potential limitation of the current study is that the findings are specific to changes in performance within one session. We did not address whether people were able to retain the ability to modify a movement pattern. The results of the current study, however, are encouraging; people in both groups were able to improve their performance independently in a relatively short period of time. Thus, further study to identify the ability of people with LBP to modify a movement pattern during a second session may result in better outcomes for people with LBP.

A second potential limitation of the current study is that there was no significant difference in the percentage of trials resulting in an increase in LBP during the Natural and the Modified conditions. There are 4 reasons why there may not have been an improvement in symptoms in the current study. First, in previous studies a decrease in symptoms occurred after a modification that included manual stabilization of the lumbopelvic region. In these studies, the manual stabilization resulted in elimination of the majority of lumbopelvic motion (Van Dillen et al., 2003; Van Dillen et al., 2007). In the current study, although subjects with LBP demonstrated a decrease in lumbopelvic motion, there was not always a complete elimination of motion. It is possible that some subjects in the current study did not attain a sufficient decrease in lumbopelvic motion to result in a decrease in symptoms. Second, we did not manually stabilize the lumbopelvic region at any point during kinematic data collection. It is possible that performing trials that involve manual stabilization of the lumbopelvic region during HLR may provide additional tactile and proprioceptive information that would have resulted in a greater decrease in lumbopelvic motion and, potentially improvements in symptoms reproduction. Third, the modification, intended to decrease lumbopelvic motion during HLR, may not have been an appropriate modification for all subjects. We believe this is a possible, but less probable, possibility. In some people, LBP may be the result of anatomical deviations, which may not be amenable to improvement following a movement-based modification. In the current study, however, pain was monitored during movement; a reported increase in pain during movement would suggest an association between pain and movement. An association between pain and movement would suggest a movement-based modification would result in decreased pain. It is also possible that the movement-based modification prescribed may not have modified the appropriate movement for all people with LBP. The lumbopelvic region, however, is designed to move more in the sagittal plane (38–95°) than the frontal (15–45°) or transverse (4–14°) planes (White, III & Panjabi, 1990). Therefore, limiting excessive motion in the transverse plane, as performed in this study, should be a biomechanically optimal modification. Fourth, it is possible that subjects who reported an increase in symptoms during the Modified condition may have used a muscle activation pattern that did not allow an improvement in symptoms. For example, people may have co-contracted the trunk muscles resulting in compression of the lumbar region tissues and an increase in symptoms (Cholewicki et al., 1995; Granata et al., 2005). Additional study is needed to understand (1) the most optimal method of modifying lumbopelvic motion, and (2) why there was no change in symptom reproduction with the modification procedures used in the current study.

CONCLUSION

The findings of the current study suggest that people with and people without LBP are effective at modifying lumbopelvic motion during the test of active HLR in prone following standardized, within-session instruction. Both groups are able to (1) delay the onset of lumbopelvic rotation during HLR and (2) decrease the maximal amount of lumbopelvic rotation demonstrated during HLR. The data suggest it is reasonable to expect people with

LBP would be able to perform independently an exercise to improve lumbopelvic motion as part of a home program. Additional study is needed to (1) further explore differences in how effectively people with and people without LBP modify lumbopelvic motion and (2) better identify the most optimal instruction and feedback to maximize how well people with LBP independently modify lumbopelvic motion.

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Figure 1. Kinematic model with hip lateral rotation (β) and lumbopelvic rotation (θ) calculations. LM: lateral malleolus, K: knee, PSIS: posterior superior iliac spine.

Table 1

Subject characteristics.

	People with LBP (N=19)	People without LBP (N=20)	95% Confidence Intervals of the Mean Difference	Statistical Value, Degrees of Freedom, P-value
Sex	M=10, F=9	M=10, F=10	NA	$\chi^2=0.027$, df=1, $P=0.869$
Age (years)	27.3 (6.6)	26.5 (5.9)	-3.3 — 4.9	$t=0.405$, df=37, $P=0.688$
Body mass index (kg/m ²)	24.5 (2.9)	24.9 (2.8)	-1.5 — 2.2	$t=0.380$, df=37, $P=0.706$
Current pain score ^a (0–10)	1.8 (1.0)	NA	NA	NA
Duration of LBP (years)	8.5 (4.2)	NA	NA	NA
Number of acute flare-ups ^b in previous 12 months	6.2 (4.4)	NA	NA	NA
Modified Oswestry Disability Index ^c (0–100 %)	13.9 (9.2)	NA	NA	NA
Fear Avoidance Beliefs Questionnaire ^d				
Work subscale (0–42)	10.1(6.8)	NA	NA	NA
Physical activity subscale (0–24)	11.1(3.6)	NA	NA	NA

Abbreviation: LBP, low back pain

Values expressed as mean (standard deviation)

^aPain measured using a verbal numeric pain rating scale (Jensen et al., 1994).^bA flare-up is defined as a period (usually a week or less) when back pain is markedly more severe than usual (Von Korf, 1994).^cDisability measured using Modified Oswestry Disability Index (Fritz and Irrgang, 2001).^dFear avoidance measured using Fear Avoidance Beliefs Questionnaire (Waddell et al., 1993).

Table 2

Means and standard deviations for dependent variables of interest for people with and people without low back pain.

Variable	People with LBP (N=19)	People without LBP (N=20)
Natural Condition^a		
HLR angle at the start of lumbopelvic rotation	4.5 (3.6)	6.8 (4.0)
Maximal lumbopelvic rotation angle	8.1 (3.4)	8.0 (2.8)
Modified Condition^b		
HLR angle at the start of lumbopelvic rotation	10.9 (7.8)	18.2 (12.3)
Maximal lumbopelvic rotation angle	5.3 (3.3)	3.8 (2.7)

Abbreviations: LBP, low back pain; HLR, hip lateral rotation

Values expressed as mean (standard deviation)

^a Natural condition: subjects performed hip lateral rotation using their preferred method

^b Modified condition, subjects performed hip lateral rotation following instruction