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Examination of Lumbopelvic and Lower Extremity Movements in two Subgroups of People with Chronic Low Back Pain Based on the Movement System Impairment Model During a Stair Descending Task

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SUMMARY

Background. Excessive and early lumbopelvic motion during functional tasks is associated with increased pain and symptoms in people with low back pain. The purpose of the current study was to compare lumbopelvic and lower extremity movements in two subgroups of chronic low back pain sufferers and healthy subjects during a stair descending task based on a movement system impairment model.

Material and methods. A clinical examination was conducted to assign people with low back pain to movement system impairment-based subgroups. A control group included 18 healthy subjects, a lumbar Rotation with Flexion group included 12 subjects, and a lumbar Rotation with Extension group included 16 subjects. Differences in kinematics data between the groups were recorded during a stair descending task using a 7-camera 3-dimensional motion capture system.

Results. In the lumbar Rotation with Flexion group, the onset of lumbar movement occurred earlier than in the control group ($p = 0.043$). In the lumbar Rotation with Flexion group, axial and frontal plane rotation of the pelvis and lower extremity were significantly greater than in the control group. Mean differences between the lumbar Rotation with Extension and control group were minimal for the motion assessed.

Conclusion. Early and excessive lumbopelvic movement and more axial rotation in the lower extremities during a stair descending task were found in the lumbar Rotation with Flexion subgroup, which can be an important factor contributing to the development or persistence of low back pain in this group.

Key words: low back pain, descending stairs, kinematics, lumbopelvic movement

BACKGROUND

Low Back Pain (LBP), with an annual prevalence of 80%, is a common musculoskeletal disorder [1,2]. LBP is the leading cause of activity limitation and work absence worldwide, imposing an enormous economic burden on individuals, industries, and health care providers [3]. Approximately 20% of those affected by acute LBP will develop chronic LBP with symptoms that persist for more than a year [4,5]. In almost 95% of cases, the source of LBP is unknown as it cannot be attributed to specific clinical or radiographic findings. It is then called Non-Specific Chronic LBP (NSCLBP) [6-8]. The results of previous studies investigating the efficacy of treatment strategies in chronic LBP are inconsistent [6]. Researchers have proposed that the lack of consistent evidence to support the effectiveness of conservative treatments may be due to heterogeneity of patients with LBP [6-9]. Therefore, there have been continuing efforts among clinicians to develop diagnostic classification systems for LBP [6]. In the last two decades, multiple classification systems, such as Treatment Based Classification, Mechanical Diagnosis and Treatment, Movement System Impairment (MSI) and O'Sullivan Classification Scheme, have been introduced to classify people with LBP into homogeneous subgroups in order to improve diagnostic accuracy and treatment outcomes [6].

Developed by Shirley Sahrmann, the MSI model is a popular model for LBP classification [6,10]. The MSI model suggests that a sustained posture and/or repeated movement in a specific direction(s) impose an excessive load on motion segments and soft tissues engaged in mechanical interaction, alter the translational motion of the motion segment, and ultimately produce LBP [10,11]. The MSI model classifies patients with LBP into multiple subgroups based on the direction of movement impairments and behavior of the symptoms across the examination [12]. In the MSI model, patient assessment relies on a visual observation of lumbopelvic and lower extremity motion patterns [9]. However, our knowledge about kinematic differences in lumbopelvic motion patterns in various subgroups of patients with LBP, classified based on the MSI model, is limited.

Numerous studies have proposed that movement control and kinematics during functional motor tasks in individuals with LBP differ from patterns observed in healthy individuals [5,11,13,14]. Previous studies found significant differences in lumbopelvic and lower extremity kinematics between people with and without LBP during walking, stair climbing, sit-to-stand maneuvers, and picking up an object [5,11,12, 14-16]. In general, the findings of these studies indicate that people with chronic LBP display reduced sagittal plane and increased axial and frontal plane lumbar spine movement [5].

Moreover, excessive and/or early lumbopelvic motion during various activities may be associated with increased pain and symptom provocation [17]. Most of the studies which focused on differences in kinematic and control differences between healthy and LBP individuals have generally relied on non-functional tasks and/or one heterogenic group of patients with LBP. Understanding abnormal movements during daily activities in specific subgroups of people with LBP can help identify contributors to chronic LBP as well as effective movement-based interventions and rehabilitative treatment strategies in people with LBP [14-19].

Patients with LBP often report pain and difficulty during functional activities [7,8]. Evaluation and identification of differences during functional activities can be helpful in planning functional movement rehabilitation. However, no published study has yet investigated the pattern of lumbopelvic and lower extremity movement in people with LBP, classified based on the MSI model, during functional tasks.

It seems that kinematic movement differences between subgroups of people with LBP are observed during activities that impose a high demand on the movement system. Thus, in the present study we hypothesized that descending stairs could demonstrate differences between subgroups of people with LBP. The aim of the present study was to compare lumbopelvic and lower extremity movements during a stair descending task between two subgroups of individuals with chronic LBP and a group of healthy people.

MATERIAL AND METHODS

Study design

This cross-sectional study was conducted to analyze differences in lumbopelvic and lower limb kinematics between 3 groups, including 2 LBP subgroups and a healthy group. The two LBP subgroups were people with Lumbar Rotation with Flexion Syndrome (RF) and Lumbar Rotation with Extension Syndrome (RE) based on the MSI classification.

Participants

A total of 46 females participated in the study. The control group included 18 healthy subjects [33.89 ± 9.62 y] with no history of LBP during the preceding year, and the LBP group was divided into two subgroups using a standardized clinical MSI model, i.e., 12 subjects were assigned to an RF subgroup (37.09 ± 11.92 y), and 16 subjects to an RE subgroup (37.38 ± 9.06 y). The RF and RE are the most prevalent subgroups based on the MSI model [13]. Patients with LBP were included if they had NSCLBP and had been experiencing symptoms for at least six months, and were able to climb stairs without any aid. The exclusion criteria comprised a history of serious spinal medical condition, spinal surgery, fracture/dislocation of the vertebral column, inflammatory joint disease, neurological signs, current malignancy, pregnancy, BMI > 35 kg/m^2, VAS > 3 on the assessment day, inability to climb stairs [5,12]. To eliminate the confounding effect of gender, only female subjects were enrolled in the study [20,21]. All subjects signed an informed consent form approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (no: IR.AJUMS.REC. 1395.728).

Instrumentation and data processing

To measure the level of pain, subject with LBP completed a Numeric Rating Pain Scale (NRS) questionnaire on the test day and seven days prior to the examination. The level of disability in daily activities was assessed and quantified using the Persian version of the Oswestry Disability Index (ODI) questionnaire [22]. The level of physical activity over the previous 12 months was examined using the Persian version of the Baecke Habitual Physical Activity Questionnaire (BHPAQ) [23]. Pain-related fear of movement was assessed using the Persian version of the Tampa Scale of Kinesiophobia (TSK) [24]. The examination was conducted by two expert physiotherapists with 12 years of clinical experience in managing people with musculoskeletal conditions and with advanced training in the MSI approach [25, 26]. The reliability of the examiners with regard to sub-categorizing people with LBP based on the MSI model was found to be acceptable. There was an overall 87.4% agreement in the pairs of classification judgments with a kappa coefficient of 0.81 (95% CI: 0.79, 0.83) [26].

Kinematic data were acquired while subjects performed stair descending by capturing the displacement of 30 infrared retro-reflective markers using seven cameras (Qualisys Medical AB Sweden, Gothenburg). The sampling rate was 120 Hz [27]. Prior to the test, reflective markers were attached to the anatomical landmarks of the spine, pelvis and lower extremities including bilateral posterior superior iliac spines (PSIS), bilateral anterior superior iliac spines (ASIS), bilateral acromions, spinous processes of T3, T12, L3 and L5, and 4 cm to the right and left of the spinous process at L1 and L4. Three markers were placed on each of the following segments bilaterally: thigh, knee and foot [5,12]. The physical therapist who collected kinematic data was blinded to the group allocation of the subjects.

Prior to each stair descending trial, a static calibration trial was performed to define the spine, pelvis and lower extremity segments and to measure the standing alignment of each segment. The pelvic segment was defined by the markers on the PSIS and ASIS, bilaterally. Anatomic knee joint centers were identified based on the static trial, and markers were placed on the femoral condyles, bilaterally. The lumbar spine tracking model has been shown to be reliable and valid [5,11,12]. Segment excursion in the sagittal, frontal and axial plane was calculated for the lumbar spine, pelvis and hip joint. The initiation of stair descending was defined as the first instant in which the heel of the leading limb lifted from the floor. The lumbar and pelvic movement onset time was calculated relative to the initiation of stair descending. Segment movement initiation was scored when its velocity first exceeded 10 percent of maximum velocity. The marker data was exported to the c3d format and a kinematic analysis was performed in Visual 3D software. The coordinates were digitally filtered using a fourth-order, zero-lag Butterworth 6 Hz low-pass filter before kinematic calculations.

Procedures

For the stair descending task, subjects were asked to descend from a staircase consisting of three steps (step height 18 cm, width 100 cm, and depth of 30 cm) [27]. Each participant performed 3 trials of stair descending, three times leading with the right foot and three times leading with the left foot [11]. The mean values of the outcome measures were calculated and used for data analysis. The participants were not provided with specific instructions on how to accomplish the task or to control the descent. All subjects were instructed to place only one foot on each step and to perform the task at their own comfortable speed [5].

Statistical analysis

The statistical analysis performed using SPSS (version 22) software and the threshold for significance was set at $\alpha=0.05$. Mean and standard deviations were calculated for all variables. Normality of the data distribution was initially assessed using the Kolmogorov-Smirnov test. Differences between the three groups were tested by one-way ANOVAs. Multiple comparisons were adjusted for the Bonferroni correction.

RESULTS

Individual characteristics

The demographics for the three groups and self-reported data for the LBP subgroups are summarized in Table 1. Three groups were matched for age, weight, height, BMI, and score in the Baecke questionnaire for activity level. No significant differences were observed in characteristics and anthropometric variables between the groups ($p > 0.05$). Participants in the RE group obtained a higher score in the ODI and TSK questionnaires when compared with the RF group ($p < 0.05$).

Lumbar and pelvic movement onset time

An earlier onset of lumbar movement was observed in subjects with RF syndrome when compared with the healthy group ($p = 0.043$), and the RE group (p> 0.05). No significant difference was found between the groups for the pelvic movement onset time (Table 2).

Lumbar kinematics

The results of group differences in lumbar spine kinematics are presented in Figure 1 and the results of statistical tests are presented in Table 3. In the sagittal ($p = 0.132$), and axial planes ($p = 0.273$), no significant differences were found between the groups regarding lumbar excursion. There was a significant group effect ($p = 0.012$) for frontal plane lumbar excursion. The post-hoc Bonferroni correction revealed that people in the RF group displayed more side bending excursion in the lumbar region than the control group.

Pelvic kinematics

There was no significant difference between the groups for pelvic excursion in the sagittal plane ($p = 0.606$) during the stair descending task. The main group effect was significant for pelvic excursion in the frontal ($p= 0.032$) and axial plane ($p= 0.026$). In the axial plane, subjects in the RF group displayed significantly greater pelvic excursion than the control group. In the frontal plane, the RF group showed greater pelvic excursion than the RE and control group. The results for group differences in the pelvic kinematics are presented in Table 3 and Figure 1.

Lower extremity kinematics

There was no significant group effect on hip kinematics in the sagittal ($p = 0.286$) and frontal planes ($p = 0.830$). There was a marked group effect on hip excursion in the axial plane ($p = 0.028$). People in the RF group displayed significantly more hip axial rotation ($p = 0.024$) when compared to the control group. There was a significant difference between the RF

Tab. 1. Subject characteristics (mean, SD) in the three groups (RF, RE, control)

Variable	Control (n= 18)	RE (n= 16)	RF (n= 12)	P-value
Age (yrs)	33.89 (9.62)	37.38 (9.06)	37.09 (11.92)	0.547
Height (cm)	161.67 (4.85)	161.81 (5.78)	162.73 (6.84)	0.880
Mass (kg)	66.61 (8.05)	69.69 (9.03)	68.82 (5.70)	0.516
BMI (kg/m^2)	25.71 (3.98)	26.90 (3.12)	26.29 (2.91)	0.951
NRS	N/A	1.47 (1.12)	1.62 (1.36)	0.732
Average Pain in preceding week	N/A	2.35 (0.5)	2.50 (0.85)	0.712
Duration of LBP (yrs)	N/A	7.94 (3.53)	5.45 (3.88)	0.097
ODI	N/A	27.13 (6.32)	18.73 (4.02)	**0.001**[A]
TSK	N/A	51.56 (2.18)	39.36 (5.39)	**0.000**[A]
BHPAQ_Work	2.81 (0.40)	2.59 (0.29)	2.67 (0.39)	0.224
BHPAQ _Sport	2.31 (0.46)	2.23 (0.53)	1.97 (0.45)	0.190
BHPAQ _Leisure	2.20 (0.44)	2.14 (0.34)	2.09 (0.29)	0.626

A: Significant differences are reported in bold with the significance value set at p < 0.05.
BMI: Body Mass Index, NRS: Numeric rating scale, ODI: Oswestry Disability Index, TSK: Tampa Scale Kinesiophobia, BHPAQ: Baecke Habitual Physical Activity Questionnaire, RE: Rotation with Extension syndrome; RF: Rotation with Flexion syndrome

Tab. 2. Movement onset time variable during stair descending task between the three groups (RF, RE, control)

Variables	Control	RE	RF	One-way ANOVA P-value	Post-hoc Bonferroni correction
Lumbar movement onset time (second)	-0.41	-0.47	-0.59	0.049	RF vs. control: 0.043 RE vs. control: 0.645 RF vs. RE: 0.235
Pelvic movement onset time (second)	-0.28	-0.31	-0.30	0.971	RF vs. control: 0.991 RE vs. control: 0.968 RF vs. RE: 0.996

Significant differences are reported in bold with the significance value set at $p < 0.05$.
RE: Rotation with Extension syndrome; RF: Rotation with Flexion syndrome.

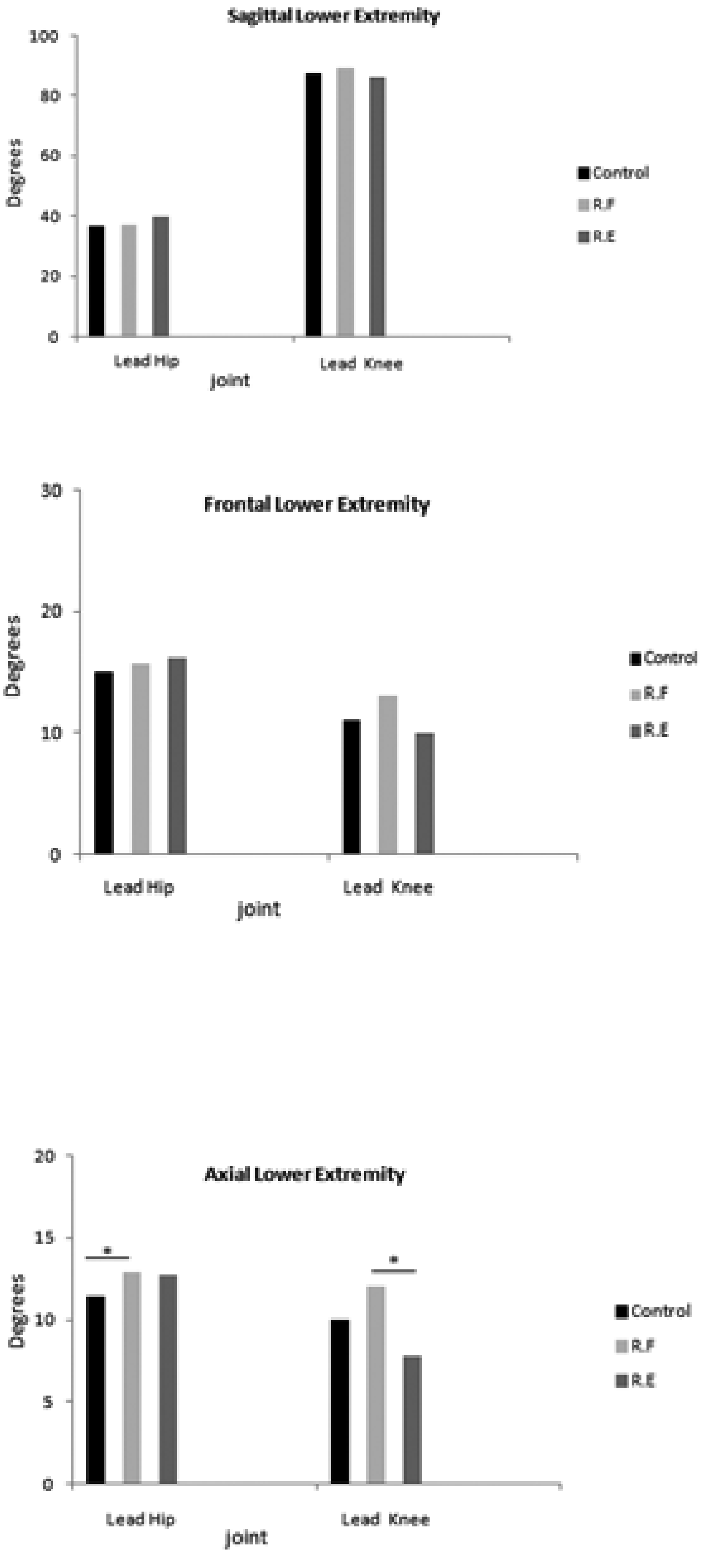

Fig. 1. Mean differences in 3D kinematics of lumbar and pelvic region during stair descending task between groups (Rotation with Extension syndrome (RE), Rotation with Flexion syndrome (RF), control). *indicates statistical significance $p < 0.05$

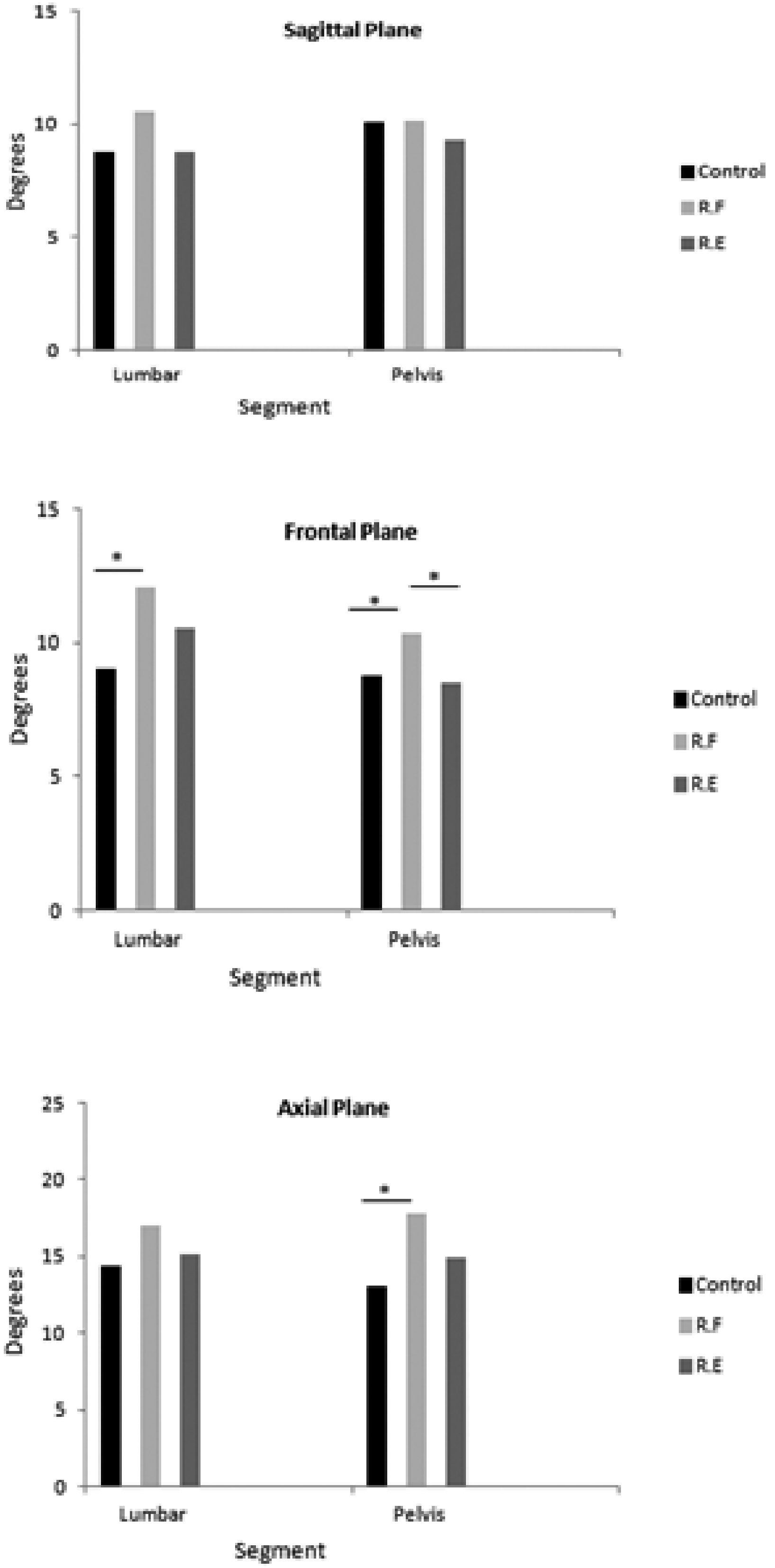

Fig. 2. Mean differences in 3D kinematics of lower extremity during stair descending task between groups (Rotation with Extension syndrome (RE), Rotation with Flexion syndrome (RF), control). *indicates statistical significance $p < 0.05$

Tab. 3. Statistical value for segment excursion (mean ± SD in degree). ANOVA test between three groups (RF, RE, control)

Segment excursion (°)	Control	RE	RF	*p-value*
Lumbar				
Sagittal	8.78 (2.40)	8.76 (2.53)	10.54 (2.54)	0.132
Frontal	9.03 (2.28)	10.57 (2.67)	12.04 (2.77)	0.012
Axial	14.39 (3.70)	15.20 (4.92)	16.96 (3.51)	0.273
Pelvis				
Sagittal	10.07 (3.01)	9.31 (2.13)	10.13 (1.95)	0.606
Frontal	8.44 (1.34)	8.47 (1.69)	10.34 (3.02)	0.032
Axial	13.05 (2.92)	14.88 (5.41)	17.82 (4.77)	0.026
Hip				
Sagittal	36.76 (3.79)	37.15 (4.95)	39.91 (5.68)	0.286
Frontal	15.05 (4.50)	16.18 (4.80)	15.66 (5.04)	0.803
Axial	11.44 (2.70)	12.71 (4.70)	12.88 (4.05)	0.028
Knee				
Sagittal	87.25 (3.20)	85.97 (5.30)	89.33 (6.79)	0.247
Frontal	11.03 (3.50)	9.99 (3.38)	12.96 (4.36)	0.134
Axial	10.04 (3.80)	7.76 (2.42)	12.01 (4.26)	0.012

and the RE groups for axial plane knee excursion. No significant differences were found between the groups for knee excursion in the sagittal ($p = 0.247$) and frontal planes ($p = 0.134$). The results of between-group comparisons for lower extremity kinematics are presented in Figure 2 and Table 3.

DISCUSSION

The purpose of the present study was to examine the lumbopelvic and lower extremity excursion in the sagittal, frontal and axial planes, during a stair descending task between two MSI-based subgroups of individuals with LBP compared with healthy subjects. In general, our results indicate an earlier lumbar movement onset time while performing stair descent in people with RF syndrome compared to the control group. Furthermore, subjects in the RF group displayed significantly greater lumbar, pelvis and lower extremity excursion in the axial plane than the control group.

In our study, lumbar movement occurred earlier in the RF group than in the healthy group during the stair descending task. Also, we found no significant differences in lumbar movement onset time between the RF and RE groups. Similar findings have been reported by previous studies. Earlier lumbopelvic movement in patients with LBP compared with healthy individuals was found during prone hip rotation and knee flexion [18,20].

This is the first study which investigated the timing of lumbopelvic movement between MSI-based subgroups of individuals with LBP during a functional task. Thus, there is no similar study to compare our results with. However, changes in the timing of lumbopelvic movement can be explained by an imbalance in the activation of the lumbar erector spinae in the RF group during the sit-to-stand maneuver and standing trunk flexion reported by Orakifar *et al.,* and Kim *et al.*, respectively [13,28,29]. Moreover, Tateuchi *et al.,* maintains that altered muscle activation timing is an important contributing factor to disrupted normal movement patterns with subsequent pain development [30].

In our study, we observed no significant difference in sagittal plane lumbar excursion between the two subgroups of LBP patients while previous studies reported that people with LBP displayed less lumbar movement in the sagittal plane than healthy individuals. This inconsistency can be explained by the heterogeneity of the participants and small sample sizes in the previous works [5,11,14,31]. In our study, the RF group showed greater lumbopelvic axial rotation than those in the RE and control groups during stair descending. The RF group also displayed more lateral bending excursion in the lumbar spine than the other two groups. In general, our findings in this respect were consistent with those reported by previous studies suggesting that people with RF syndrome have greater flexibility in lumbopelvic movements in the middle range of motion during activities [4,10, 32]. Various factors, such as strength, tension, and stiffness of muscles or ligaments, may affect the static or dynamic postures of the pelvis and lumbar spine [13].

Comparison between the RE and RF groups revealed less pelvic excursion in the frontal and axial plane in the RE group. There are several potential explanations for this. In our study, subjects in the RE group were characterized by more severe disability and a longer duration of symptoms than those in the RF group. Therefore, they might have adapted a habitual pattern of movement that was either the result of LBP or a compensatory strategy to prevent pain. Other factors that may contribute to a relatively limited mobility in the RE group include soft tissue or joint stiffness [5,7,11]. In our findings, mean pain intensity was not significantly different between the two LBP subgroups, but the ODI score was greater in the RE than the RF group. Another explanation is the difference in kinesiophobia scores between the subgroups. Several studies have recognized that psychological factors are related to disability in patients with LBP [24,33,34].

Moreover, our results indicate that there were no significant differences in sagittal excursion in the hip and knee joints. This finding is consistent with the finding of Hernandez *et al.*, who reported no significant differences in sagittal motion of the lower extremity while descending stairs between people with LBP and healthy subjects [5]. We found greater axial rotation in the hip and knee joints for the RF group when compared with the control group, which is consistent with Hernandez *et al.*'s finding [5]. A similar finding was reported by Shum *et al.*, who found excessive hip motion during a reaching task in patients with LBP compared with healthy subjects [15]. These findings indicate that altered lumbopelvic kinematics can induce changes in lower extremity motion. More extensive lower extremity motion in the axial plane during functional daily tasks in people with LBP could be a probable mechanism for increasing the risk of secondary lower extremity injuries [5,11].

It is clear that functional tasks are performed differently by the RF and RE subgroups. Based on our finding and previous ones, descent from stairs may be used as an assessment tool to identify abnormal movement of the lumbopelvic and lower extremities in people with LBP. Our findings also highlight the need for assessment of the pelvis and lower extremities in addition to lumbar movement in patients with LBP [5,11]. According to the results of the present study, individuals in the RF subgroup display early and excessive lumbopelvic motion when descending stairs. Therefore, treatment programs should include strategies for movement rehabilitation in patients with RF syndrome focusing on spinal stabilization and movement reeducation during functional activities [11]. For example, people with RF syndrome may benefit from instructions to facilitate abdominal control of trunk movement, which could become a part of therapeutic core stabilization exercises [35].

The limitations of the present study are as follows: first, the lumbar spine has been considered a single rigid segment. In future research, determining regional differences in lumbar spine kinematics during functional tasks in people with LBP is essential. Second, all the participants in the current study were female subjects, because it was assumed that specific differences in motion patterns could occur between genders. Therefore, the results of the study cannot be generalized to males. Another limitation is a lack of evaluation of reliability of measurements of the kinematic parameters. The data presented in the Results section indicates that the observed differences are small and may be not clinically important even statistically. Therefore, we suggest presenting the results in respect of the standard error of measurement in future research.

CONCLUSION

Early and excessive lumbopelvic movement and more axial rotation in the lower extremities during a stair descending task were found in the lumbar Rotation with Flexion subgroup, which can be an important factor contributing to the development or persistence of low back pain in this group.

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REFRENCES

1. Andersson GB. Epidemiological features of chronic low-back pain. The lancet 1999;354:581-5.
2. Lawford BJ, Walters J, Ferrar K. Does walking improve disability status, function, or quality of life in adults with chronic low back pain? A systematic review. Clin rehabil 2016;6:523-36.
3. Hoy D, March L, Brooks P, et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis 2014;6:968-74.
4. O'Sullivan P. Diagnosis and classification of chronic low back pain disorders: maladaptive movement and motor control impairments as underlying mechanism. Man Ther 2005;4:242-55.
5. Hernandez A, Gross K, Gombatto S. Differences in lumbar spine and lower extremity kinematics during a step down functional task in people with and people without low back pain. Clin Biomech 2017;47:46-52.
6. Spoto MM, Dixon G. An integrated approach to the examination and treatment of a patient with chronic low back pain. Physiother Theory and Pract 2015;1:67-75.
7. Hemming R. Regional spinal kinematics and muscle activity in non-specific chronic low back pain during functional tasks: evaluation of a sub-classification approach. Cardiff University; 2015.
8. Hemming R, Sheeran L, van Deursen R, Sparkes V. Non-specific chronic low back pain: differences in spinal kinematics in subgroups during functional tasks. Eur Spine J 2018;1:163-70 .

9. Kajbafvala M, Ebrahimi-Takamjani I, Salavati M, et al. Validation of the movement system impairment-based classification in patients with knee pain. Man Ther 2016;25:19-26.
10. Sahrmann S. Diagnosis and treatment of movement impairment syndromes: Elsevier Health Sciences; 2002.
11. Mitchell K, Porter M, Anderson L, et al. Differences in lumbar spine and lower extremity kinematics in people with and without low back pain during a step-up task: a cross-sectional study. BMC Musculoskelet Disord 2017;18[1]:369.
12. Gombatto S, Brock T, Delork A, et al. Lumbar Spine Kinematics During Walking In People With And Without Low Back Pain. Gait Posture 2015;4:539-44.
13. Kim M-h, Yoo W-g, Choi B-r. Differences between two subgroups of low back pain patients in lumbopelvic rotation and symmetry in the erector spinae and hamstring muscles during trunk flexion when standing. J Electromyogr Kinesiol 2013;2:387-93.
14. Lee JK, Desmoulin GT, Khan AH, Park EJ. Comparison of 3D spinal motions during stair-climbing between individuals with and without low back pain. Gait posture 2011;2:222-6.
15. Shum GL, Crosbie J, Lee RY. 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. Spine 2005;17:1998-2004.
16. Shum GL, Crosbie J, Lee RY. Movement coordination of the lumbar spine and hip during a picking up activity in low back pain subjects. Eur Spine J 2007;6:749-58.
17. Hoffman SL, Johnson MB, Zou D, Harris-Hayes M, Van Dillen LR. Effect of classification-specific treatment on lumbopelvic motion during hip rotation in people with low back pain. Man Ther 2011;4:344-50.
18. Sadeghisani M, Manshadi F, Kalantari K, et al. Correlation between Hip Rotation Range-of-Motion Impairment and Low Back Pain. A Literature Review. Ortop Traumatol Rehabil 2015;5:455-62.
19. Van Dillen LR, Gombatto SP, Collins DR, Engsberg JR, Sahrmann SA. Symmetry of timing of hip and lumbopelvic rotation motion in 2 different subgroups of people with low back pain. Arch Phys Med Rehabil 2007;3:351-60.
20. Hoffman SL, Johnson MB, Zou D, Van Dillen LR. Differences in end-range lumbar flexion during slumped sitting and forward bending between low back pain subgroups and genders. Man Ther 2012;2:157-63.
21. Hoffman SL, Johnson MB, Zou D, Van Dillen LR. Gender differences in modifying lumbopelvic motion during hip medial rotation in people with low back pain. Rehabil Res Pract 2012;2012.
22. Mousavi SJ, Parnianpour M, Mehdian H, Montazeri A, Mobini B. The Oswestry disability index, the Roland-Morris disability questionnaire, and the Quebec back pain disability scale: translation and validation studies of the Iranian versions. Spine 2006; 14:454-9.
23. Sadeghisani M, Manshadi FD, Azimi H, Montazeri A. Validity and reliability of the Persian version of Baecke habitual physical activity questionnaire in healthy subjects. Asian J Sports med 2016;3.
24. Askary-Ashtiani A, Ebrahimi-Takamejani I, Torkaman G, Amiri M, Mousavi SJ. Reliability and validity of the Persian versions of the fear avoidance beliefs questionnaire and Tampa Scale of Kinesiophobia in patients with neck pain. Spine 2014;18:1095-102.
25. Van Dillen LR, Sahrmann SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom NJ. Movement system impairment-based categories for low back pain: stage 1 validation. J Orthop Sports Phys The 2003;3:126-42.
26. Henry SM, Van Dillen LR, Trombley AR, Dee JM, Bunn JY. Reliability of novice raters in using the movement system impairment approach to classify people with low back pain. Man Ther 2013;1:35-40.
27. Protopapadaki A, Drechsler WI, Cramp MC, Coutts FJ, Scott OM. Hip, knee, ankle kinematics and kinetics during stair ascent and descent in healthy young individuals. Clin Biomech 2007;2:203-10.
28. Kim S-h, Kwon O-y, Park K-n, Kim M-H. Comparison of erector spinae and hamstring muscle activities and lumbar motion during standing knee flexion in subjects with and without lumbar extension rotation syndrome. J Electromyogr Kinesiol 2013;6:1311-6.
29. Orakifar N, Shaterzadeh-Yazdi MJ, Salehi R, Mehravar M, Namnik N. Comparison of muscle recruitment patterns during sit to stand and stand to sit in "movement system impairment" subgroups of low back pain and healthy women. J Rehabil Scien Res 2018;1:5-12.
30. Tateuchi H, Taniguchi M, Mori N, Ichihashi N. Balance of hip and trunk muscle activity is associated with increased anterior pelvic tilt during prone hip extension. J Electromyogr Kinesiol 2012;3:391-7.
31. Lee JK, Park EJ. 3D spinal motion analysis during staircase walking using an ambulatory inertial and magnetic sensing system. Med Biol Eng Comput 2011;7:755-64.
32. O'Sullivan PB, Dankaerts W, Burnett AF, et al. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. Spine 2006;19:707-12.
33. Leeuw M, Houben R, Severeijns R, Picavet HSJ, Schouten EG, Vlaeyen JW. Pain-Related fear in low back pain: A prospective study in the general population. Eur J Pain 2007;3:256-66.
34. Vlaeyen JW, Kole-Snijders AM, Boeren RG, Van Eek H. Fear of movement/[re] injury in chronic low back pain and its relation to behavioral performance. Pain 1995;3:363-72.
35. Van Dillen LR, Norton BJ, Sahrmann SA, et al. Efficacy of classification-specific treatment and adherence on outcomes in people with chronic low back pain. A one-year follow-up, prospective, randomized, controlled clinical trial. Man Ther 2016; 24:52-64.

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