RESEARCH ARTICLE

Relationship of Impaired Lumbar Spine-Hip Coordination During Sit To Stand and Stand To Sit with Functional Disability in Chronic Nonspecific Low Back Pain Patients

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Abstract

Background: This study aimed to investigate the relationships of lumbar spine-hip discoordination during sit-to-stand (STD) and stand-to-sit (SIT) with pain and functional disability in chronic nonspecific low back pain (CNLBP) patients.

Methods: A cross-sectional observational study was conducted in a biomechanics laboratory of the physical therapy department located at the School of Rehabilitation Sciences, Iran University of Medical Sciences (Tehran–Iran). A total of 16 CNLBP patients (men 9, female 7) aged 18–40 years (mean 31.48) were selected according to our eligibility criteria. Furthermore, ten reflective markers were placed on the spinous processes of T12 and S2, posterior and anterior superior iliac spines, greater trochanters, and lateral epicondyles. The patients were instructed to perform STD and SIT tasks at a preferred speed without using their hands. Relative phase angle was used as an indicator of coordination and was identified as the inverse tangent of angular displacement/angular velocity. Moreover, the relative phase angle between the lumbar spine and right and left hip joints was measured by subtracting the phase angle of the hip joint from the lumbar spine joint. The ratios of the total movements of the lumbar spine to the total movements of the right and left hip joints were also calculated in the sagittal plane. Finally, Pearson correlation coefficients (*r*) were utilized to assess the association between variables.

Results: The results of this study indicated that kinematic parameters of the pain had statistically significant direct relationships with functional disability in CNLBP participants during STD and SIT with *r* values ranging from 0.57 (*Pvalue = 0.021*) to 0.85 (*Pvalue<0.001*) and 0.54 (*Pvalue=0.053*) to 0.82 (*Pvalue<0.001*), respectively.

Conclusion: Out of the results of this study, it could be stated that pain and functional disability play a major role in lumber spine-hip discoordination, and it altered the movement ratio in CNLBP patients during STD and SIT. In clinical practice, clinicians should improve lumber spine-hip discoordination in patients with CNLBP since there is a linear relationship between kinematic parameters of the pain and functional disability in patients with CNLBP.

Level of evidence: II

Keywords: Hip, Functional activity, Joint coordination, Low back pain, Lumbar vertebrae

Introduction

Low back pain (LBP) is a globally leading cause of functional disability and has great influence on individuals and society as a whole.[1] Although the great majority of LBP episodes improve substantially within a few weeks or months, around 20% of individuals affected by acute LBP will develop a chronic LBP problem with symptoms that last one year.[2-4] Furthermore, LBP is the fifth leading cause of doctor's visits annually with

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56.8% of those visiting for nonspecific LBP.[5] Chronic nonspecific low back pain (CNLBP) is identified as persistent LBP of at least 12-week without any specific cause.[6]

Researchers and clinicians have indicated that impairments of movement and posture may be related to the development of a chronic LBP problem.[4, 7-9] Because of the potential association of movement and posture with chronic LBP development, movement during functional tasks is especially important to evaluate.[10] It has been proved that the kinematics of the spine and the ratio of the total movements of the lumbar spine to those of the left and right hips may have deteriorated in the LBP population during functional tasks such as sit-to-stand (STD) and stand-to-sit (SIT).[11, 12] In addition, LBP individuals show a lack of coordination between the lumbar spine and the hip joint during STD and SIT tasks.[11-13] Coordination between different body parts and muscle groups is fundamental to controlling multi-joint movement in a fluent manner.[13] It is assumed that this synergy might be affected by factors such as pain, muscle guarding, muscle stiffness, decreased joint range of motion (ROM), and neurological conditions.[11, 14, 15] However, there is limited evidence to determine whether greater pain intensity and disability are associated with greater lumbar spine-hip discoordination. In 2005, Shum et al. described a method to assess lumbar spine-hip coordination during STD and SIT tasks in patients with subacute LBP (i.e., relative phase angle).[11] Shafizadeh mentioned that relative phase angle is an indicator of positional changes in coordination of two joints.[13] The results of Shum et al. studies demonstrated that the lumbar spine-hip joint coordination has significantly deteriorated in LBP patients.[10, 11]

In clinical settings, a few techniques have been developed to measure spine kinematics. Clinicians have routinely performed radiographic assessments and visual analysis of back shape and spinal posture.[16] Many authors have investigated spine ROM, but it is not easy to assess the ROM of the spine and make a decision about the back shape because spinal motions are complex. In addition, various instruments have been introduced and used for spine kinematics assessment, ranging from measurements using a simple tape to computer application devices (e.g., motion analysis systems). Motion analysis systems are noninvasive systems that allow clinicians and researchers to repeat the assessment more times within a short period of time, and present detailed 3-dimensional (3D) and quantitative data.[17]

To date, several studies have demonstrated lumbar spine-hip discoordination in LBP patients.[10, 11, 13] However, to the best of the author's knowledge, no published paper has examined the mentioned subject. Therefore, the purpose of this study was to investigate the relationships of lumbar spine-hip discoordination during STD and SIT with pain and functional disability in CNLBP patients. It has been hypothesized that there is a positive linear relationship of pain and disability with lumbar spine-hip discoordination.

Materials and Methods

Study design

This single-center, cross-sectional observational study was performed between November 2016 and April 2017. This study was conducted at the School of Rehabilitation Sciences, Iran University of Medical Sciences (Tehran–Iran).

Ethics

Approval for the study protocol was given by the Ethics Committee at the Iran University of Medical Sciences (IUMS) (IRB approval number: IR.IUMS.REC 1395.9211342207). A written and signed informed consent was taken from all patients and the procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki. All personal information was kept strictly confidential and anonymous. None of the participants received any rewards for participation.

Recruitment

The target population of the present study was a convenience sample, recruited by a snowball approach. Moreover, colorful posters and flyers were placed in the university community and surrounding neighborhood area.

Study population

The sample size of the current study was estimated based on a pilot study (i.e., 8 patients with CNLBP) using Stata statistical software (version 12, STATA Corp., Texas, USA). One of the primary variables of the present study was the correlation between relative phase difference (i.e., right hip, lumbar, spine) and functional disability (Oswestry Disability Index [ODI]) during STD. The results showed a correlation coefficient of 0.65. The null hypothesis was set at 0, with the power set at 80%, and the type I error rate fixed at 5%. Therefore, the results revealed that a minimum of 16 CNLBP participants was needed. The participants ranged in age from 18–40 years with a mean of 31.48 years. The inclusion criteria were as follows: age between 18 and 40 years, LBP lasting for >3 months without recognizable pathology, and ability to accomplish STD and SIT tasks without an aid.[18] The exclusion criteria were apparent deformity of the spine, pelvis, and lower extremities, pregnancy, neurological or rheumatological diseases, infection, history of back surgery, spinal fractures, and tumors or radicular symptoms.[12, 18]

Examiner

All biomechanical measurements were obtained by a physical therapist (MP) who is a Ph.D. in physical therapy with >8 years of experience in treatment of LBP patients.

Equipment

STD and SIT kinematic variables were collected at a sampling frequency of 100 Hz using 6 Oqus–300 cameras with 1.3-megapixel resolution, and a 3D Qualisys motion capture system (Sweden). Furthermore, Qualisys Track Manager (QTM) software® (Qualisys, Gothenburg, Sweden) was used to synchronize the six

Oqus–300 cameras that recorded marker motion data. Kinematic data of the lumbar spine and the hip joints were analyzed using the QTM software®, Microsoft Excel 365 (Microsoft Corporation®) and MatLab (version R2015b; MathWorks, Natick, MA). Before carrying out the testing procedure, the Qualisys system was calibrated by recording an L–frame and dynamic movement of a T–wand for approximately 60 seconds.

Marker setup

Two retro-reflective spherical markers of 25.4 mm diameter were placed over the spinous processes of T12 and S2 using nonallergenic double-sided adhesive tape. Other spherical markers were positioned on the pelvis, at the left/right anterior superior iliac spines (ASISs), left/right posterior superior iliac spines (PSISs), left/right greater trochanters, and left/right femur lateral epicondyles.[18] The intercrestal line, which was first proposed by Chakraverty et al., was utilized to find the L3 spinous process or L3-L4 spinal level.[19, 20] After identifying the L3 spinous process or L3-L4 spinal level, the assessor positioned the patient in a flexed standing posture and carefully palpated the spinous processes in the midline, and traced them from the inferior to the superior direction to find the T12 spinous process.[18, 20] The process was double-checked to make sure that all spinous processes from L3 to T12 were palpated. The PSIS line was also used to identify the S2 spinous process.[18] The same assessor (M.P.) found the anatomical landmarks for every individual with CNLBP following the same procedure. [Figure 1] shows the model description.

Experimental protocol

Data collection was initiated with the capture of a reference standing posture for three seconds. Afterwards, participants with CNLBP were requested to sit in their usual posture on an adjustable metal stool with neither an armrest nor a backrest. The adjustable stool height was 110% of the knee–floor length, which was described as the distance between the apex of the fibular head and the laboratory floor.[11] To standardize head posture, a visual target was used according to Pourahmadi et al.[21] Participants were requested to stand up at a comfortable speed without using their upper limbs, following a loud voice command ("Start"), maintain their standing posture for 3 seconds, and then sit down.[18] The CNLBP participants practiced the procedure for a few minutes and then, three STD and SIT movements were recorded and the mean of three trials was utilized for statistical analysis. Each CNLBP participant was examined at the same time of the day to minimize the effects of diurnal variations in the joint mechanics.[22] It took a participant roughly 20 minutes to conduct all biomechanical tests. All measurements occurred in the morning from 8:00 to 11:00 AM. Moreover, pain during the last 24 hours, and functional disability were assessed for the CNLBP participants using the Numeric Pain Rating Scale and the Persian-translated versions of the Ronald-Morris Disability Questionnaire, and Oswestry Disability Index.[23]

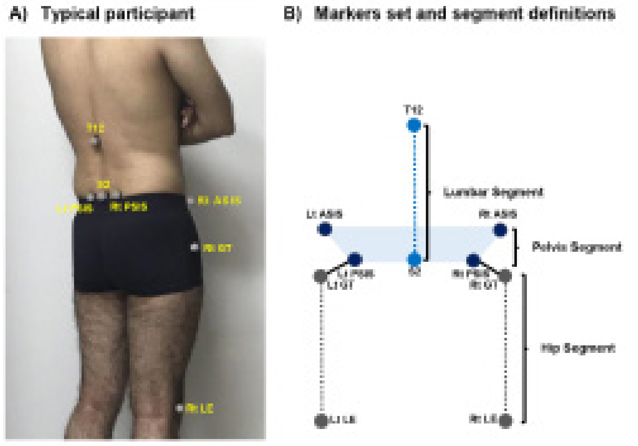

Figure. 1. Model description. (A) Picture of a typical participant with the markers, (B) markers set, and segment definitions. (Rt ASIS = right anterior superior iliac spine; Lt ASIS = left anterior superior iliac spine; Rt PSIS = right posterior superior iliac spine; Lt PSIS = left posterior superior iliac spine; Rt GT = right greater trochanter; Lt GT = left greater trochanter; Rt LE = right lateral epicondyle; Lt LE = left lateral epicondyle).

Outcomes

Mean relative phase angle was reported in patients with CNLBP during STD and SIT. Phase angle was described as the inverse tangent of angular velocity/angular displacement and was computed for each data point through the entire cycle (i.e., φ tan−1 [angular velocity/angular displacement]).[11, 18] By convention, if the phase difference is positive, then the hip movement is leading the lumbar spine, and if the phase difference is negative, the hip is lagging the lumbar spine.[11] Furthermore, the ratios of the total movements of the lumbar spine to the total movements of the left and right hips were also calculated in the sagittal plane during STD and SIT.

Data Processing

Lumbar spine and hip sagittal plane joint angles were computed following filtering of the raw data using a fourth-order, dual pass, and Butterworth filter with a cut-off frequency of 6 Hz to determine movement initiation and termination.[18, 24] Markers trajectories were used to calculate the position and orientation of the anatomical frames of the four segments (lumbar spine, pelvis, right and left hips). The coordinate systems of the lumbar and the pelvis were established during an upright reference posture: X-axis pointing forward, Y-axis pointing to the left, and Z-axis pointing upward. Lumbar spine and hip joints kinematics were determined according to the study conducted by Pourahmadi et al.[21] The STD and SIT movement initiations and terminations were defined according to the change of the combined lumbar spine and right hip flexion angles. Movement initiation was distinguished when the combined angle changed five degrees and reached 7% of its maximum velocity.[25] movement termination was distinguished when the combined lumbar spine and right hip segment velocity was zero.

Statistical analysis

All statistical analyses were performed using Stata 14.0 (Stata Corp, College Station, TX). Normality was evaluated using the Kolmogorov-Smirnov test and by examining histograms. To explore the relationship of lumbar spine-hip discoordination and lumbar spine-to-hip movement ratio with pain and functional disability, Pearson correlation coefficients (r) were calculated. The Pearson correlation coefficients were classified according to Hopkins' extension of Cohen's guidelines (0.00–0.09 nonexistent, 0.10–0.29 small, 0.30–0.49 medium, 0.50–0.69 large, 0.70–0.89 very large, 0.90-0.99 nearly perfect, and 1.00 perfect).[26] After statistically analyzing the variables, all values were rounded to two decimal places. The statistical significance level was set at a *P value < 0.05*.

Results

The baseline characteristics of the CNLBP participants are presented in [Table 1]. The mean and SD of the lumbar spine to hips movement ratios in the sagittal plane and lumbar spine-hip discoordination during STD and SIT are reported in [Table 2]. Correlations of kinematic parameters of the spine and hips during STD and SIT with pain and functional disability were reported in [Table 3]. The results demonstrated a statistically significant direct relationship of kinematic parameters with pain and functional disability in CNLBP participants. The r values ranged from 0.57 (*Pvalue= 0.021*) to 0.85 (*Pvalue < 0.001*) during STD and range from 0.54 (*P value = 0.053*) to 0.82 (*P value < 0.001*) during SIT.

Table 1. Participant characteristics

Characteristic	CNLBP[a] participants
Sex (*n*)	9M (56%), 7F (44%)
Age (years)	31.48 (6.35)
Body mass (kg)	67.20 (10.41)
Height (m)	1.69 (0.07)
BMI[b] (kg/m^2)	23.49 (3.51)
Duration of LBP[c] (months)	42.28 (26.36)
Mean NPRS[d]-24 h (mm)	45.23 (16.01)
ODI[e] (pts)	34.80 (16.12)
RMQ[f] (pts)	11.87 (4.70)

Values are presented as mean ± standard deviation (SD)
a Chronic non-specific low back pain
b Body mass index
c Low back pain
d Numeric Pain Rating Scale
e Oswestry Disability Index
f Ronald-Morris Disability Questionnaire

Table 2. Descriptive statistics for kinematic parameters of the lumbar spine, right and left hips during STD and SIT in CNLBP patients

Kinematic variable	CNLBP[a] participants
STD[b] movement	
Ratio in the sagittal plane	
Lumbar spine / Right hip	0.27 (0.08)
Lumbar spine / Left hip	0.28 (0.10)
Relative phase difference	
Right hip – Lumbar spine (°)	4.01 (8.49)
Left hip – Lumbar spine (°)	5.99 (6.78)
SIT[c] movement	
Ratio in the sagittal plane	
Lumbar spine / Right hip	0.31 (0.12)
Lumbar spine / Left hip	0.37 (0.20)
Relative phase difference	
Right hip – Lumbar spine (°)	2.44 (7.52)
Left hip – Lumbar spine (°)	2.96 (6.61)

Values are presented as mean ± standard deviation (SD)
a Chronic non-specific low back pain
b Sit-to-stand
c Stand-to-sit

Discussion

The present study aimed to assess the relationships of lumbar spine-hip discoordination during STD and SIT with pain and functional disability in CNLBP patients. The current study indicated that impairments of lumbar spine-hip coordination and lumbar spine-to-hip movement ratio during STD and SIT had a statistically significant linear relationship with pain and functional disability.

LBP patients often demonstrate deficits in reaction time, coordination, and postural control with reduced ROM and velocity compared with the asymptomatic population.[27-29] Silfies et al. indicated that lumbar spine-pelvic coordination was more separated in time and more variable in chronic LBP people.[14] Shum et al. showed that LBP individuals demonstrated different lumbar spine-hip coordination relative to asymptomatic people.[11] The contribution of the lumbar spine in STD and SIT movements was decreased due to immobility in these joints induced to protect the spine against further injury. Likewise, Shafizadeh mentioned that people with LBP had discoordination in the function of lumbar spine and hips segments, which resulted in pausing of one segment while the other segment moved independently.[13] Shum et al. in another study reported that decreased muscle moment of the lumbar spine in the sagittal plane is the reason for changes in STD and SIT strategies in LBP individuals.[11] The LBP patients minimize the spine motion and velocity; thereby, decreasing the muscle

Table 3. Pearson correlation coefficients (r) between kinematic parameters and pain and functional disability during STD and SIT in CNLBP patients

Kinematic variable	Pain (NPRS[a])	Functional disability (ODI[b])	Functional disability (RMQ[c])
STD			
Ratio in the sagittal plane			
Lumbar spine / Right hip	0.76 (*P* value < 0.001*)	0.83 (*P* value < 0.001*)	0.81 (*P* value = 0.002*)
Lumbar spine / Left hip	0.67 (*P* value = 0.001*)	0.85 (*P* value = 0.001*)	0.59 (*P* value = 0.096)
Relative phase difference			
Right hip – Lumbar spine (°)	0.77 (*P* value = 0.026*)	0.85 (*P* value < 0.001*)	0.79 (*P* value = 0.004*)
Left hip – Lumbar spine (°)	0.57 (*P* value = 0.021*)	0.64 (*P* value = 0.008*)	0.72 (*P* value = 0.012*)
SIT			
Ratio in the sagittal plane			
Lumbar spine / Right hip	0.79 (*P* value < 0.001*)	0.78 (*P* value = 0.005*)	0.59 (*P* value = 0.066)
Lumbar spine / Left hip	0.82 (*P* value < 0.001*)	0.71 (*P* value = 0.003*)	0.67 (*P* value = 0.023*)
Relative phase difference			
Right hip – Lumbar spine (°)	0.73 (*P* value = 0.001*)	0.62 (*P* value = 0.011*)	0.67 (*P* value = 0.021*)
Left hip – Lumbar spine (°)	0.78 (*P* value = 0.023*)	0.54 (*P* value = 0.053)	0.69 (*P* value = 0.059)

* Statistically significant: $P < 0.05$.
a Numeric Pain Rating Scale
b Oswestry Disability Index
c Ronald-Morris Disability Questionnaire

moment on the joint which in turn causes an interjoint discoordination.[10, 13] It has been demonstrated that in the initial stage of the STD task, LBP people flex the lumbar spine in advance of the hips to a lesser extent compared to healthy subjects.[11] In contrast, during SIT task, the LBP population has a more marked lumbar spine lead in the initial "sitting down" stage compared to healthy individuals.[11] Investigators and clinicians suggested that this interjoint discoordination in LBP patients may be due to muscle spasms, muscle coactivation, and difficulty in transferring the muscle force from the pelvis to the lower limbs. Sung pointed out that coactivation/cocontraction of the trunk paraspinal muscles is often used to immobilize the lumbar spine as a protective strategy to avoid the provocation of LBP.[30] The results of our study indicated that lumbar spine-hip discoordination had a statistically significant direct relationship with pain and functional disability. This means that pain can play a fundamental role in causing lumbar spine-hip discoordination. Perhaps this discoordination acts as a protective strategy to prevent exacerbations of pain during STD and SIT tasks.[30] Our hypothesis was confirmed that impairment of lumbar spine-hip coordination during STD and SIT had a statistically significant linear relationship with pain and functional disability.

The STD and SIT tasks are complex activities and usually take 2~3 seconds to be accomplished.[31] The STD movement requires adequate postural control during the motor transfer from a stable three-point base (sitting position) to a two-point base (standing position) and needs adequate torques to be developed around each body joint.[17] Furthermore, STD and SIT are frequently performed functional activities and may be compromised by the presence of LBP. Results of previous studies suggest that reducing angular velocity in the lumbar spine is helpful to prevent the risk of losing balance.[10, 13] However, reducing the angular velocity beyond the normal values relative to hip movement is a preventive mechanism that is present in LBP people that could alter the mechanics of STD and SIT movements into hesitant behaviors.[13]

As with other studies, there are some limitations. In the current study, the symptomatic group represented the population of middle-aged participants with CNLBP. The finding might not be generalized to other population groups such as recurrent LBP or patients with lumbar radiculopathies. In addition, we evaluated only STD and SIT tasks, and further research into other activities of daily living (e.g., ascending and descending stairs) is needed to extend our understanding of the relationships of lumbar spine-hip discoordination with pain and functional disabilities.

The present study demonstrated that impaired lumbar-hip coordination and altered lumbar spine-to-hip movement ratio during STD and SIT had a statistically significant direct relationship with pain and functional disability in CNLBP patients. Perhaps lumbar spine-hip discoordination and altered lumbar spine-to-hip movement ratio act as preventive strategies to protect spinal structures from a movement that may exacerbate pain.

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