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Lumbar spine kinematics during walking in people with and people without low back pain

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ABSTRACT

Low back pain (LBP) is a problem that can contribute to functional limitations and disability. Understanding kinematics during walking can provide a basis for examination and treatment in people with LBP. Prior research related to kinematics during walking is conflicting. However, investigators have not considered regional differences in lumbar spine kinematics or movement-based LBP subgroups. In the current study, three-dimensional kinematics of the upper and lower lumbar regions were examined in people with and without LBP. A clinical examination then was conducted to assign people with LBP to a movement-based subgroup and differences in kinematics among subgroups were examined. All subjects displayed significantly more upper than lower lumbar movement in the axial and coronal planes ($P < .01$). People with LBP displayed significantly less overall lumbar rotation than controls ($P < .05$). There were no significant group differences in sagittal plane kinematics ($P > .05$). Walking was limited by or provocative of pain in <25% of subjects with LBP. There were predictable differences in kinematics among some movement-based LBP subgroups that approached statistical significance ($P = .09–.11$). Walking was provocative of LBP in few subjects, and differences between people with and without LBP and among LBP subgroups were minimal. Limitations include that attempts to standardize gait speed may have minimized observed effects, and there was limited power to detect movement-based LBP subgroup differences.

1. Introduction

Low back pain (LBP) is a problem that affects up to 80% of people at some point in their lives and is second only to respiratory illness for days of lost work [1]. However, in 57–89% of people with LBP, no specific etiology can be identified [2,3]. Clinicians and researchers appear to agree that repetitive and prolonged stresses on the spine associated with a person's posture and movement are related to the development and persistence of LBP problems [4–6]. Comparing posture and movement in people with and without LBP is essential to determine the mechanical factors that may be related to the development and persistence of a LBP problem.

Walking is an activity that is repeated frequently throughout the day. Impairments with walking can contribute to functional limitation, disability, and pain in people with LBP. Several investigators have specifically examined temporal parameters and kinematics during walking in people with and without LBP. Based on the prior research, it appears that people with LBP who are allowed to self-select walking speed, consistently walk slower [7–9]. However, findings related to kinematics during walking are conflicting. Some investigators have reported that people with LBP display less axial plane movement [9–11], while others have reported that people with LBP display greater spine or pelvis rotation [9,12]. Further, Crosbie et al. reported that the degree of lumbar spine axial rotation depended on temporal parameters of the gait cycle [8]. Findings related to variability of kinematics during walking also are conflicting and dependent on the method used to calculate variability [8,10,11,13–15]. The conflicting results could be attributed to the reported differences in walking speed [16], walking surfaces used (overground vs. treadmill), lumbar spine kinematic model used, or based on the heterogeneous nature of LBP.

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One limitation of this prior work is that the whole trunk, or the whole lumbar spine has been considered a single rigid segment. However, with other functional tasks, there is evidence to support that different regions of the lumbar spine move differently [17,18]. Determining regional differences in lumbar spine kinematics during walking in people with and without LBP is essential to understand the potential stresses being regularly applied to each region during walking how these stresses may be related to tissue injury and back pain. A second limitation of the prior research on walking kinematics is the lack of consideration for the heterogeneous nature of LBP. Several investigators have reported that lumbar spine kinematics during other tasks are different among subgroups of people with LBP [19–21]. Therefore, movement-based LBP subgroups may be important to consider when analyzing lumbar spine kinematics during walking.

The purposes of the current study were to: (1) determine differences in magnitude and symmetry of the upper and lower lumbar spine kinematics between people with LBP and people without LBP during walking, and (2) determine differences in lumbar spine kinematics during walking among movement-based LBP subgroups. We hypothesized that people with LBP would display greater and more asymmetric lower lumbar rotation during walking, and that movement-based subgroups would display kinematic differences based on the direction of lumbar region movement impairment that is associated with LBP.

2. Methods

2.1. Subjects

Subjects with LBP were recruited from two different outpatient orthopedic clinics. Each patient with a diagnosis related to LBP was offered the opportunity to participate. Subjects without LBP were recruited by posting flyers on a college campus and in the surrounding community. Subjects who were between the ages of 18–65 were eligible. Subjects were excluded if they had: a body mass index above 30 kg/m^2, a history of serious medical condition affecting the spine, spinal surgery, current or unresolved cancer, current pregnancy, an inability to perform simple movements of the spine and extremities, or currently receiving physical therapy treatment elsewhere for LBP. Each subject without a history of LBP was matched to a subject with LBP based on age ($\pm$5 years), gender, height ($\pm$2 inches), weight ($\pm$5 pounds), and BMI ($\pm$1 kg/m^2). Hand dominance was established for each subject by self-report. Subject characteristics are reported in Table 1. This study was approved by the Human Subjects Research Committee at Nazareth College, and subjects gave informed consent before participating in the study.

2.2. Outcome measures

Subjects with LBP completed a modified Oswestry Disability Index (ODI), and Fear Avoidance Based Questionnaire (FABQ). The modified ODI provides information about perceived functional limitation and disability related to the LBP problem [22]. Scores on the ODI range from 0% to 100%, with 0% indicating no disability and 100% indicating maximum disability. The score (0–5) for ''Walking'' on the ODI (item #4) was examined, because it relates to limitations with walking as a result of LBP. The FABQ is self-report measure to index the extent to which a person with pain has limited physical activity due to fear of pain with work (FABQ-W) and other physical activities (FABQ-PA) [23]. The scores on the work subscale (FABQ-W) range from 0 to 42 and on the physical activity subscale (FABQ-PA) range from 0 to 24, with higher scores indicating more fear-avoidance behaviors. Summary data for these measures are included in Table 1.

Table 1
Subject characteristics in the low back pain (LBP) and no LBP groups, and self-report measures for the LBP group; mean (standard deviation).

	LBP (*N* = 18)	No LBP (*N* = 18)	*P*-value
Characteristics			
Age (years)	28.1 (13.1)	27.6 (12.4)	P = 0.91
Gender	M = 7, F = 11	M = 8, F = 10	P = 0.74
Height (cm)	169.9 (11.5)	167.8 (12.5)	P = 0.60
Weight (kg)	71.2 (15.3)	72.0 (14.5)	P = 0.90
BMI (kg/m^2)	24.4 (2.9)	25.5 (3.6)	P = 0.31
Hand dominance	R = 15, L = 3	R = 16, L = 2	P = 0.63
Self-report measures			
Numeric Rating Scale for LBP (0–10)	2.1 (1.9)	N/A	N/A
Duration of LBP (years)	4.8 (7.9)	N/A	N/A
Number of episodes of LBP in the past year	3.9 (4.1)	N/A	N/A
Modified Oswestry Score (%)	18.0 (12.7)	N/A	N/A
''Walking'' Score, Item #4 from Modified Oswestry (0–5)	''0'' = 14, ''1'' = 4	N/A	N/A
FABQ – physical activity (0–24)	13.4 (4.5)	N/A	N/A
FABQ – work (0–42)	11.5 (8.3)	N/A	N/A

2.3. Motion capture measures

A 9-camera, three-dimensional movement analysis system (Vicon, Inc.) was used to measure kinematics of the upper and lower lumbar spine, and pelvis during walking. Using palpation, a physical therapist identified anatomical landmarks for each subject and placed reflective markers on the landmarks to capture kinematics of each segment with the movement analysis system. Specifically, reflective markers were placed 4 cm lateral to L1 and L4, centrally on L3 and L5, on bilateral PSIS, ASIS, and iliac crests (Fig. 1).

Each subject was asked to stand in a relaxed position and resting alignment of the spine was captured in standing. Each subject then performed at least three walking trials, across a 10-m walkway with three force platforms at the center. Subjects were asked to pace steps during walking to the beats of a metronome at 96 bpm, to reach a target pace of 1.2 m/s. An attempt was made to control walking speed because differences in walking speed between groups could be an alternative explanation for kinematic differences [7–9]. For subjects with LBP, change in LBP symptoms was recorded for each walking trial.

2.4. Clinical examination

Within 24 h after motion capture testing, a clinical examination was conducted for each subject with LBP. An experienced physical therapist, with extensive training in the Movement System Impairment (MSI) [24] approach (first author), conducted a standardized MSI examination and assigned each subject to a movement-based LBP subgroup based on direction of lumbar spine movement impairments and LBP symptom behavior across the examination. The MSI examination has been described in detail elsewhere, and has been tested for and demonstrated acceptable reliability and validity [24–26]. Possible LBP subgroups included: Flexion, Extension, Rotation, Rotation with Flexion, or Rotation with Extension. For example, a subject with lumbar rotation and extension impairments during movement tests, who reported increased LBP with these impairments, would be assigned to the Rotation with Extension subgroup. Detailed inclusion criteria for each subgroup are described by Harris-Hayes (Appendix A) [26].

2.5. Data analysis

Data were post-processed in Nexus software (Vicon, Inc.) and exported to Visual 3D (C-Motion, Inc.) for identification of gait