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Changes in Trunk Kinematics in People with Chronic Non-Specific Low Back Pain Using Wearable Inertial Sensors †

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Abstract: Low back pain (LBP) is one of the most common musculoskeletal conditions and the leading cause of disability. It is estimated that at least 8 out of 10 people experience low back pain during their lifetime. The purpose of this study was to determine trunk kinematics in individuals with and without non-specific chronic LBP during flexion extension and hurdle step tests. A total of 90 participants (45 participants with LBP and 45 without LBP), aged between 18 and 50, participated in this study. The wearable inertial sensors were used to capture three-dimensional movements during both trunk flexion extension and the hurdle step test. Altered trunk kinematics during the flexion-extension and the hurdle step test was observed in individuals with non-specific chronic low back pain.

Keywords: low back pain; kinematics; wearable sensors

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1. Introduction

Low back pain (LBP) is one of the most common musculoskeletal conditions and the leading cause of disability [1]. It is estimated that 8 out of 10 people experience LBP during their lifetime [1]. Non-specific LBP, where no pathological or anatomical changes a [2] re found, accounts for 85 percent of all LBP cases [1]. Muscle stiffness and movement impairment or limitation are the common symptoms of non-specific LBP [1]. Researchers have reported changes in lumbar lordosis and spinal range of motion (ROM) in persons with LBP when compared with controls [3–5]. Zubierer et al. [3] studied the convergence and discriminant validity for lumbar range of motion tests and LBP. Alaa Haj et al. [4] reported on the ROM, average speed, maximum speed, and maximum acceleration of lumbar rotation in the neutral position and full flexion. Ng et al. [5] compared the lumbar kinematics of flexion extension and lateral flexion ROM test between persons with LBP and controls. Other researchers have measured lumbar kinematics using a hurdle step test [2,6]. However, few studies have focused on trunk kinematics during both ROM and the hurdle step test using wearable motion capture systems, although these systems have been extensively used in human motion analysis [7,8]. The purpose of this study was to determine trunk kinematics in individuals with and without non-specific chronic LBP during flexion extension and hurdle step tests.

2. Material and Methods

2.1. Participants Information

A cross-sectional study design was conducted with a total of 90 participants (45 participants with LBP and 45 without LBP), aged between 18 and 50. The study was approved by the Ethics Committee of the Mongolian National University of Medical Sciences (N° 2022\3-7).

2.2. Experimental Procedure

The full-body wearable, Xsens motion capture system (MVN, Xsens Technologies BV, Netherlands) was used to capture the three-dimensional (3D) movements of the trunk during flexion-extension in standing and during the hurdle step test at a sampling rate of 120 Hz. Each participant performed both movement tasks three times. Trunk flexion-extension was performed in the standing position by bending forward and backward with the knees locked in extension (Figure 1a). In the hurdle step test, participants started in a standing position and stepped over the hurdle (Figure 1b). The height of the hurdle is adjusted to equal the height of the person's tibial tuberosity [2].

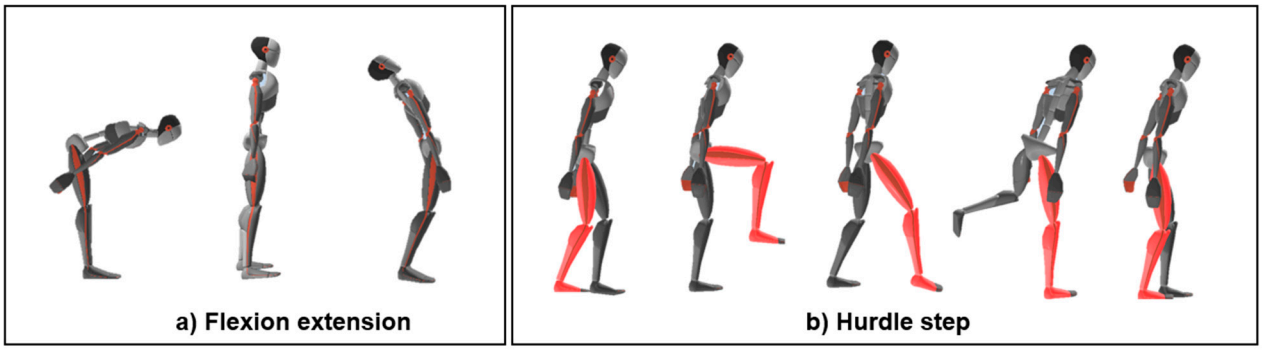

Figure 1. Trunk flexion-extension and hurdle step tests were performed by the participants: (**a**) From a standing position, bending forward and backward with locked knees. Repeat 3 times; (**b**) Step over the hurdle from a standing position start right leg. Repeat 3 times. The height of the hurdle is equal to the height of the person's tibial tuberosity (5).

The wearable captain system includes 15 inertial measurement unit (IMU) sensors, which were attached on the head, sternum, pelvis, left/right shoulder, upper and forearm arm, upper and lower leg, and foot. With sensors attached, each participant performed trunk flexion-extension and the hurdle step test three times, according to the protocol of previous studies[2]. The trunk joint angles and velocity in the sagittal (flexion-extension), frontal (lateral bending), and transversal (axial rotation) planes were calculated using a relative orientation between pelvis and thorax segments, and averaged for the LBP and control groups [9].

2.3. Statistical Analysis

Statistical analysis of participant characteristics and trunk kinematics was performed using IBM SPSS Statistics Version 25. Mean values and standard deviations for age, weight, height, and gender were calculated using descriptive statistics. Differences in parameters between people with and without non-specific low back pain were determined using age and weight-adjusted analysis of variance (ANOVA).

Flexion-Extension Range of Movement and Hurdle Step Tests for spine motion according to the protocol [2] provided by the Xsens software (Figure 1).

3. Results

Table 1 shows the characteristics of the participants. We compared the measurement of trunk range of motion (ROM) and velocity in three planes during the flexion-extension ROM test (Table 2) and the hurdle step test (Table 2) between the LBP and control groups. We found that some trunk kinematics were different between people with and without LBP (Table 2). For instance, during the flexion-extension test, trunk lateral bending and rotation range of motion angles had statistically significant differences between the group with LBP and the control group, as highlighted in red in Table 2. Additionally, during the hurdle step test, there were significant differences in trunk rotation velocity between the group with LBP and the control group.

Table 1. Participants' characteristics.

Subjects	LBP n = 45	Control n = 45
Age (years)	33 ± 10.1	24.5 ± 8.0 *
Height (cm)	162.9 ± 8.1	163 ± 8.1
Weight (kg)	67.4 ± 16.5	59.4 ± 10.2 *
Gender (female)	36 (80%)	31 (69%)

* $p \leq 0.05$- a significant difference, Mean ± SD.

Table 2. Comparison of trunk ROM and velocity during Flexion-Extension and Hurdle Step Tests in LBP and control groups.

Variables		Control (n = 45)	LBP (n = 45)	Differences in Range of Motion
Flexion-Extension Test	**Flexion (degree)**	11.3 (1.2)	7.7 (1.2)	3.6 (−0.03 to 7.2)
	Extension (degree)	−14.2 (1.0)	−17.2 (1.0)	−2.9 (−0.2 to 6.1)
	Lateral bending (degree)	12.6 (0.7)	8.8 (0.7) *	3.7 (1.5 to 5.9)
	Rotation (degree)	8.2 (0.5)	6.0 (0.5) *	2.1 (0.6 to 3.6)
	Flexion-Extension Velocity (m/s)	0.61 (0.09)	0.69 (0.09)	−0.07 (−0.3 to 0.2)
	Lateral bending Velocity (m/s)	0.2 (0.03)	0.2 (0.03)	0.03 (−0.08 to 0.14)
	Rotation velocity (m/s)	0.29 (0.04)	0.25 (0.04)	0.03 (−0.08 to 0.16)
Hurdle Step Test	**Flexion-extension (degree)**	4.4 (1.0)	3.5 (1.0)	0.9 (−2.2 to 4.0)
	Lateral bending (degree)	12.0 (1.1)	12.3 (1.1)	−0.3 (−3.8 to 3.2)
	Rotation (degree)	66.8 (3.2)	63.7 (3.2)	3.0 (−6.6 to 12.6)
	Flexion-Extension Velocity (m/s)	37.2 (3.2)	41.3 (3.2)	−4.1 (−13.6 to 5.3)
	Lateral bending Velocity (m/s)	47.6 (3.4)	46.3 (3.4)	1.2 (−5.8 to 11.3)
	Rotation velocity (m/s)	56.6 (3.9)	40.8 (3.9 *)	15.7 (4.1 to 27.3)

* $p \leq 0.05$- significant different, Mean (Standard Error), Mean-Covariates age and weight.

4. Discussion and Conclusions

In this study, we used a wearable IMU sensor to compare trunk kinematics during flexion-extension and hurdle step tests between LBP and control groups (Table 2). We used flexion-extension ROM to determine the range of motion and velocity of the trunk. During trunk flexion-extension, lateral bending, and rotation, the range of motion angles

showed statistically significant differences between the LBP and control goups. Some studies of persons with LBP, using IMU sensor measures, have shown decreased range of flexion, extension, lateral bending, and axial rotation [9–11], which results are consistent with the results of our current study. The results indicate that trunk kinematic changes of the spine can be evaluated using an IMU sensor in persons with non-specific LBP. In addition, trunk joint angle and velocity measured during the hurdle step test showed trunk rotation significantly less in the LBP group than in the control group. The hurdle stepping task requires stability and coordination between the hips and torso during the stepping motion. Ko, et.al suggested that patients with chronic LBP lack this stability and coordination [6]. The low score of chronic LBP patients on the hurdle step task confirms that spine and hip mobility is limited in chronic LBP [12]. In LBP the movement of the trunk and hips may limit the range of motion velocity of the trunk rotation during functional tasks such as the hurdle step test. The main limitation of the present study is that the subjects in the control group were younger and leaner than those in the LBP group. However, the statistical analysis adjusted for age and weight. In conclusion, altered trunk kinematics during the flexion-extension and hurdle step test were observed in individuals with non-specific chronic LBP. This result may be useful in further investigations into movement analysis of persons with low back pain and potentially support development of kinematic outcome measures.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and by the Ethics Committee, Mongolian National University of Medical Sciences (N° 2022\3-7).

Informed Consent Statement: Informed content was obtained from all subjects involved in the study.

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Conflicts of Interest: The authors declare no conflict of interest.

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