Full Paper

LUMBAR KINEMATIC PATTERN AMONG ADULTS WITH LOW BACK PAIN: A STUDY PROTOCOL

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Graphical abstract
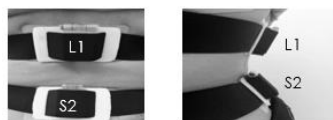
Abstract

Non-Specific Low back pain (NSLBP) is associated with lumbar spine kinematics and curvature changes. However, there is limited information regarding lumbar spine kinematics and curvature in normal daily living when both static and dynamic postures are adopted interchangeably during extended periods. The aim of this study is to evaluate the differences in lumbar kinematic patterns and curvature when adopting various static and dynamic postures over an extended period of time among adults with acute, chronic and without NSLBP. Lumbar kinematic patterns and curvature of adults with chronic and acute NSLBP will also be reassessed at six weeks and three months follow-up. This is a cross-sectional and prospective design study. Seventy-two adults aged between 20 and 45 years will be recruited for three study groups (acute, chronic and without NSLBP). Kinematic parameters that include a lumbar range of movements, velocities, accelerations and lumbar curvature changes will be assessed for a continuous two-hour period using an inertial measurement system. During the two hours of monitoring, participants will be required to perform a list of functional tasks in a simulated home environment. Participants will be free to adopt any postures as in a normal home/work environment during performing these tasks. Lumbar curvature angles and kinematic patterns of lumbar spine will be analysed and compared between three groups. This study will add to the knowledge regarding lumbar curvature and kinematic patterns of lumbar spine when adopting various static and dynamic postures interchangeably over an extended period among adults with NSLBP.

Keywords: Lumbar range of motion, kinematics, accelerations, velocities, curvature

1.0 INTRODUCTION

Low back pain (LBP) is one of the most common musculoskeletal disorders affecting the population of all ages. Approximately 90% of the population will experience LBP in their lifetime and adults of working age are the most exposed group [1]. In Malaysia, the prevalence of LBP varies between 10-63% [2]. Compared to individuals younger than 20 years of age, adults aged 20 to 40 years old have the highest rate of low back pain [3]. It is reported that in 85% of adults with acute low back pain, the aetiology is nonspecific in manner [3].

Numerous factors can result in symptoms of LBP. Individual factors such as age, sex, genetic predisposition, race, psychological issues and anthropometry are some of the factors reported to be related to LBP [3]. For activity related factors, physical inactivity, sedentary lifestyle and mechanical loads on the spine are the most common factors reported [4].

Trunk kinematic changes in dynamic motions and static postures are also identified as potential risk factors for LBP. Trunk dynamic motions, particularly when the motion occurs in various planes simultaneously significantly increases LBP risk [5]. LBP is associated with side bending, twisting and various asymmetrical movements of the trunk [6,7]. Individuals exposed to certain static postures for over an extended period are also found to be at higher risk of developing LBP [8, 9].

LBP has a substantial impact on individuals and their families, communities and the health-care system [10]. Impact of individual includes pain, activity, limitation and/or impairment of movements and psychological disturbances [4]. Some of the major functional activity limitations recorded are the inability to do lifting, climbing, carrying and walking [11]. Changes in lumbar spine kinematics are found to be associated with limitations in functional activities in adults with LBP [12]. These changes may be reflected in this population as limitations in terms of degree, velocity and acceleration of spinal movements.

Kinematic measurements in particular tasks were demonstrated to be able to distinguish between adults with and without LBP [13]. However, the effects of back pain on the range of motions (ROM) of the lumbar spine were inconclusive. In the study by Wong and Lee (2004), it was noted that the contribution of the lumbar spine to forward bending was reduced in adults with LBP. In contrast, in other studies, it was found that there was increased ROM in both adults with and without LBP with a past history of back pain [14,15].These inconsistent results of previous investigations could be due to the differences in the clinical diagnosis and characteristics of the participants that were examined [15].

In addition, higher order kinematics such as accelerations and velocities during movements decreased in adults with LBP pain during functional activities [16–18]. Kinematic patterns of the lumbar spine in sit-to-stand showed differences between adults with and without LBP [19]. ROM of flexion/extension of the lumbar spine in the adults with LBP was greater than those without LBP during stair-climbing [20]. Deficits were also noted in angular velocities and accelerations among adults with and without LBP [21]. However, no correlation existed between lumbar ROM and functional activities in adults with LBP [21].

Lumbar curvature evaluation during static and dynamic postures among adults with LBP is important to identify any dysfunction of the lumbar spine [22]. This is because the degree of lumbar of curvature affects the level of trunk muscle activation and load sharing across a motion segment of the spine [23]. Measuring lumbar curvature during dynamic and static postures using measurement tools such as inertial sensors or electromagnetic sensor have been extensively studied [22, 24, 25]. However, the changes in lumbar curvature before and after a few tasks over a certain period are unclear due to limited information.

Higher order spinal kinematic measurements, such as velocity and acceleration other than ROM may be beneficial to clinicians. This is because ROM and functional performance in adults with LBP are not correlated [21]. Moreover, differences in higher order spinal kinematics during functional activities between adults with and without low back pain were reported [21]. A previous study showed that decreased spinal motion velocity is related to the recovery of low back pain [22]. However, details regarding the correlation between functional disability, pain and lumbar spine higher order kinematics such as velocity and accelerations are still lacking.

Information regarding lumbar spine kinematics during static and dynamic postures in isolation among adults with LBP in previous studies has contributed to further knowledge on LBP management. However, there may be disparity in lumbar spine kinematics in normal daily living when both static and dynamic postures are adopted interchangeably during extended periods.The primary objective of this study is to evaluate the differences in kinematic patterns of lumbar spine when adopting various static and dynamic postures over an extended period of time among adults with (acute and chronic LBP) and without low back pain. Kinematic patterns will be reassessed at six weeks and three months follow-up to examine the changes from initial assessment in adults with LBP.

2.0 METHOD AND DESIGN

2.1 Design and Setting

This is a cross-sectional and prospective design study.

2.2 Recruitment and Eligibility

Participants for this study will be recruited from the list of adults with NSLBP in the physiotherapy department or orthopaedic clinic at Pusat Perubatan University Kebangsaan Malaysia Hospital (PPUKM, Kuala Lumpur, Malaysia) and Hospital Kuala Lumpur. Participants without LBP will be recruited through a local advertisement regarding the study. All eligible participants will be provided with an information sheet and/or verbal information by the researcher regarding the study and procedure in the study. Those who agree to take part in the study will be asked to sign a consent form. The inclusion and exclusion criteria are as shown in Table 1.

Table 1 The inclusion and exclusion criteria for participants in Group one (acute low back pain), Group two (chronic low back pain) and Group 3 (Without Low back pain)

Inclusion criteria	Exclusion criteria
Group 1 and 2(Acute and chronic NSLBP): Males and females aged between 20 to 45 years, Diagnosed by a doctor to have acute or chronic low back pain. With or without medication	Experienced serious trauma leading to fractures and dislocations of the spine prior surgery to the back
	Any known underlying pathologies such as a tumour, spinal infections, and tuberculosis
Group three (without low back pain): Without a history of back pain or leg pain that could be related to the spinal problem or requiring medical attention/treatment in the past 12 months.	Any known inflammatory joint diseases and rheumatological conditions have been diagnosed to have spinal deformities such as scoliosis, ankylosing spondylitis, spondylolisthesis and spondylolysis, pregnancy or less than six months post-partum.
	Any neurological deficits.

2.3 Ethical Approval

Ethical approval has been obtained from the Secretariat for research and ethics, Universiti Kebangsaan Malaysia (UKM 1.5.3.5/244/NN-147-2013) and the Ministry of Health Medical Research Ethics Committee (MREC), Malaysia (NMRR-14-512-21153). The involvement in this study by participants will be voluntary, and the identity of the participants will be anonymised in all the records. The data obtained will be saved and coded for reference purposes. After data analysis, participants will be provided with the information about their kinematic data on request.

2.4 Sample Size and Power Calculation

Power analysis was calculated based on the G*Power Software (Version 3.1.5, University of Dusseldorf, Germany). F tests - ANOVA: Repeated measures, within-between interactions indicated that a sample of at least 60 participants will be required for this study. Power analysis showed that this sample size will be sufficient to reveal any significant differences between three different groups of participants (effect size = 0.25[23], power = 0.80, $p < 0.05$). Considering 20% dropouts, the total number of participants recruited will be 72, with 24 participants in each group.

2.5 Procedure

A laboratory will be set up to simulate a functional home environment for this study. A computer will be set up in the laboratory for data logging. Prior to the study, pilot studies will be performed to refine the method of the procedure to measure kinematic patterns of lumbar spine when adopting various static and dynamic postures in a series of various functional activities over an extended period.

Demographic data that include age, gender, occupation, body mass index (BMI), activities of work and leisure, physiotherapy treatment, medication and amount of sick leave taken will be obtained from participants. This will be followed by assessments for low back pain intensity using visual analog scale (VAS). Participants will be requested to mark their pain intensity on the scale before performing the functional tasks. Participants will also be informed to provide feedback regarding any increase in pain during the test and will be allowed to discontinue the test if they are uncomfortable.

Participants will then be required to fill out an ODI questionnaire. The researcher will palpate and mark the position of the first lumbar and second sacral spinous process using a skin pencil. An inertial sensor will be attached at each of these vertebral levels using a customised belt (Figure 1). Data collection will be started with the measurement of range of movements (flexion, extension, lateral flexion and axial rotation on both left and right sides) and lumbar curve (participant required to stand still within 20 seconds before the movement begin).
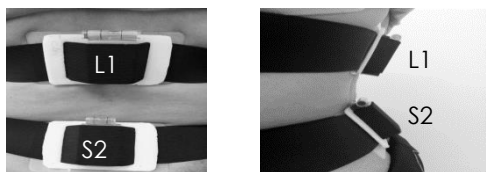
Figure 1 Attachment of Inertial sensors at 1st Lumbar (L1) and 2nd Sacrum (S2) vertebral levels

After completing the ROM and lumbar curve measurements, the participant will be given a list of functional tasks before the test began as a guideline. The list of functional tasks consists of walking on flat surface, walking up and down the stairs, lifting (3kg basket), and sit to stand/stand to sit at sofa and office chair. Participants will be required to complete three sets of tasks with different sequences in each set within the two hours. For each of the set, the participant will be required to space out the tasks and accomplish this in approximately 40 minutes. This is to mimic normal daily routine, performing multiple tasks within an extended period.

The researcher will observe the participants' postures and record it into an observation form during each set of activity. The record time will be used to extract each of the posture activities during the two hours activities. After two hours of data collection, measurements of ROM, lumbar curve and VAS will be repeated to study any significant changes in relation to the postures and activities adopted by the participants.

Adults with LBP will be followed up at six weeks and three months for reassessment using the same study protocol.

2.6 Measurement Tools and Instrumentation

Lumbar spine kinematic parameters that include lumbar ROM, velocities and accelerations; and lumbar curvature changes will be assessed using an inertial measurement system, (MTx, Xsens Technologies, Netherlands). These sensors incorporate 3D gyroscopes, accelerometers and magnetometers that are reported to provide drift-free motion data [25]. The manufacturers reported a static accuracy of 0.5 degrees for roll and pitch, 1 degree for yaw, and a 2 degree RMS dynamic accuracy [25]. It was demonstrated that lumbar spine kinematic measurements using these initial sensors were correlated (r2, 0.99, p<0.05) with measurements using an electromagnetic tracking system [26]. There were also no significant differences between measurements and the two instruments with a small mean difference of between -0.81° and 1.26° [26].

Previous studies indicated that sensors attached in the ideal position can help to provide precision to the measurement [24]. In the present study, sensors will be attached by the same assessor all the time to minimize inter-reliability issues. Participants' L1 and S2

spinous processes will be located in standing by palpation performed by the same trained physiotherapist before sensor attachments. In addition, spirit level will be used to align the sensors to horizontal planes for precision. Inter-day reliability of using the sensors will be performed in the pilot study.

The level of pain will be measured using Visual Analog Scale (VAS). It has been demonstrated to have high reliability (ICC: 0.96 to 0.98) [27].Functional disability will be assessed using the English or Bahasa Malaysia version Oswestry Disability Index (ODI). Good test-retest reliability (ICCs ranging from 0.90 to 0.99) has been found with ODI [28–30].

2.7 Data Management and Statistical Analysis

The sensors will be connected to a purpose-built data logger and software (MT Manager, Xsens Technologies, Netherlands), and data will be captured at 50Hz [20]. The MT Manager Software interface will be used to facilitate visualisation, recording and exportation of inertial sensor data that includes 3D acceleration (linear acceleration) and angular velocity. Data for angular acceleration will be calculated by double differentiated from angular velocity. ROM (in degrees) of the six physiological movements will be obtained by calculating the relative angles between the two sensors using direction cosine matrix that transform vectors in the body frame to the reference frame analysis using MATLAB (The MathWorks, Inc., USA) and expressed as 3D Euler angles in ZYX order. A line graph, which displays the ROM of each axis for six trunk physiological movements against time, will be plotted using Microsoft Excel. The maximum (peak) ROMs values for flexion, extension, right/left lateral flexion and right/left rotation will be obtained. In addition, the maximum and minimum angular velocity (deg/s) and angular acceleration (deg/s^2) of the sagittal, frontal and horizontal plane of each trunk physiological movement will be obtained from three repetitions of movements respectively before, after and during each set of functional tasks of the two hours data.

Lumbar curvature (LC) during standing will be calculated using the same principles as the Cobb method that is often used to measure lumbar lordosis on radiographic measurement (21). In this study, LC angle in a static position (standing) will be derived from the angles between the two tangents of L1 and S2. LC angle will be calculated using inclination information from the Z-axis, the horizontal axis of the accelerometer pointing from the anterior aspect of the spine. Accelerometers measure both accelerations due to movement and gravity. Accelerometers can be used as inclinometers to measure tilt angles when there is no acceleration due to body movement or the acceleration due to body movement is relatively small when compared to gravity. Figure 2 illustrates how these angles will be calculated.
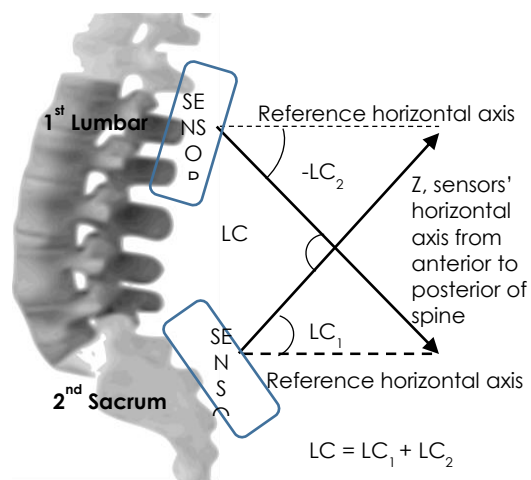
Figure 2 Lumbar curvature angle (LC)

The collected data will be analysed using the SPSS statistic software version 21.0 (SPSS Inc. Chicago, USA). Descriptive data analysis will be obtained in mean and standard deviation for ROM, lumbar curvature, velocity and acceleration among adults with and without LBP. Normality of the data will establish first. Repeated measures ANCOVA will be performed to compare the results lumbar kinematics between acute, chronic and without LBP at baseline and follow-up.

3.0 DISCUSSION

Some risk factors and implications of back pain have been identified. However, prevention of low back pain is not successful because of the complexity of back pain disorders. Furthermore, the lack of information on spinal kinematics in functional activities in a continuous period may have led to the failure in managing back pain problems. Therefore, more insight is required on lumbar spinal kinematics during static and dynamic postures in continuous and prolonged periods.

The main aim of this study is to evaluate lumbar curvature and kinematic patterns of the lumbar spine during static and dynamic postures in an extended period among adults with acute, chronic and without NSLBP. The procedure of the study is designed in such a way that it is as close to mimicking how the spine acts and experiences different loads during normal daily living. To the best of the authors' knowledge, there is no information in the literature regarding lumbar curvatures and kinematic patterns of lumbar spine when adopting various static and dynamic postures interchangeably over an extended period among adults with acute, chronic and without NSLBP.

This study will add to the knowledge regarding lumbar curvature and kinematic patterns of lumbar spine when adopting various static and dynamic

postures interchangeably over an extended period among adults with NSLBP. Furthermore, a more objective and functional method of measuring lumbar curvature and higher order kinematic assessment will be established in the present study. Thus, a method to effectively measure and analyse lumbar curvature and higher order kinematics using pre-written software may be possible for research and clinical monitoring.

The follow-up phase of the present study will provide more knowledge about the change in the pattern of lumbar curvature and kinematic within six weeks and three months among adults with acute and chronic NSLBP. This information may be important for the physiotherapists to provide specifically tailored exercises and to plan for the prevention of recurrent and chronic LBP.

The results of the study will be disseminated through publications. It is hoped that this new knowledge may lead to further studies regarding new and improved prevention and rehabilitation strategies in the management of adults with NSLBP.

Acknowledgement

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