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Original article

Investigating the contribution of the upper and lower lumbar spine, relative to hip motion, in everyday tasks

Raee S. Alqhtani [a], Michael D. Jones [a, *], Peter S. Theobald [a], Jonathan M. Williams [b]

[a] Bioengineering Research Group, School of Engineering, Cardiff University, CF24 3AA, UK
[b] Faculty of Health and Social Sciences, Bournemouth University, UK

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ABSTRACT

Background: It is commonplace for clinicians to measure range of motion (ROM) in the assessment of the lumbar spine. Traditional single 'joint' models afford measuring only a limited number of regions along the spine and may, therefore, over-simplify the description of movement. It remains to be determined if additional, useful information can be gleaned by considering the traditional 'lumbar region' as two regions.
Objective: The aim of this study was to determine whether modelling the lumbar spine as two separate regions (i.e. upper and lower), yields a different understanding of spinal movement relative to hip motion, than a traditional single-joint model. This study is unique in adopting this approach to evaluate a range of everyday tasks.
Method: Lumbar spine motion was measured both by being considered as a whole region (S1 to T12), and where the lumbar spine was modelled as two regions (the upper (L3-T12) and lower (S1-L3)).
Results: A significant difference was evident between the relative contribution from the lower and upper spine across all movements, with the lower lumbar spine consistently contributing on average 63% of the total ROM. A significant difference was also evident between the whole lumbar spine-hip ratio, and the lower lumbar spine-hip ratio, for the movement of lifting only. The lower lumbar spine achieved greater velocity for all tasks, when compared to the upper lumbar spine.
Conclusion: This study has consistently demonstrated differences in the contribution of the upper and lower spinal regions across a range of everyday tasks; hence, it would appear that greater focus should be given to performing more detailed assessments to fully appreciate spinal movement.

1. Introduction

Measuring lumbar range of motion (ROM) is typically performed using 2 sensors or markers, one at each end of the lumbar spine. This includes technologies relying on electromagnetics (Shum et al., 2005, 2007), inertial sensors (Ha et al., 2013; Williams et al., 2013) and fibre-optics (Williams et al., 2010). Calculating the resultant angle between these 2 sensors provides an estimate of lumbar range of motion, with the lumbar spine modelled as a single 'joint'. The lumbar spine, however, consists of many segments or 'joints' (L1-S1) and thus this single joint model may result in lost information about more regional lumbar spine movement behaviour. Whilst previous authors have suggested that the upper and lower lumbar spines display differences in their kinematic behaviour (Williams et al., 2012; Parkinson et al., 2013; Williams et al., 2013), traditional single 'joint' models would fail to identify such subtleties and may, therefore, over simplify the description of movement. Significant scope exists to better understand and appreciate the relationship between lumbar spine and hip kinematics, given how it both underpins rehabilitation programmes (Lee and Wong, 2002) and is associated with various forms of functional disabilities, which may have a serious impact on an individual's quality of life (Cox et al., 2000).

The dominant functional tasks such as flexion, extension, lifting and transiting from stand-to-sit or sit-to-stand have long been associated with spinal disorders and spinal pain (McGill, 1997; Dempsey, 1998). Spine and hip kinematics are closely coordinated when performing many daily tasks (Mayer et al., 1984; Pearcy et al., 1985; Strand and Wie, 1999), suggesting that lumbar spine-hip

* Corresponding author.
E-mail addresses: AlqhtaniRS@cardiff.ac.uk (R.S. Alqhtani), JonesMD1@Cardiff.ac.uk (M.D. Jones).

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disorders may affect functional tasks as well as the cardinal movements often employed in the clinic. Indeed, sit-to-stand and stand-to-sit activities are very regular daily tasks (Lomaglio and Eng, 2005), performed 60 times per day on average by working people (Dall and Kerr, 2010). The most important task that influences lumbar and hip kinematics is lifting objects from the floor, which is a common daily activity particularly amongst those working in jobs involving physical labour (Shum et al., 2005).

A series of studies have previously focused on quantifying the relationship between the lumbar spine relative to hip motion, during everyday tasks (Paquet et al., 1994; Lee and Wong, 2002; Wong and Lee, 2004; Shum et al., 2005; Shum et al., 2007); however, in all cases the lumbar spine was only considered as a single region. More recently, authors have adopted multi-regional lumbar spine models across clinical populations (Williams et al., 2012, 2013) and healthy subjects (Leardini et al., 2011; Parkinson et al., 2013), identifying differences in regional contribution. No study has yet, however, considered a multi-regional lumbar spine model versus hip motion, across a series of everyday tasks. Such data would significantly assist in achieving a better understanding of lumbar spine kinematics, especially when supplemented by multi-regional velocities (Shum et al., 2010), as the relative movement behaviour of the hip and its interaction with the lumbar spine has been suggested as being important (Lee and Wong, 2002; Sahrmann, 2002; O'Sullivan, 2005). Clinical studies have previously confirmed differences in this ratio between those with and without back pain (Shum et al., 2005, 2007), whilst alterations in this ratio affect the bending and compressive stresses on the lumbar spine (Dolan and Adams, 1993; Tafazzol et al., 2014).

Subsequently, this study investigated how the upper and lower lumbar regions contributed to spinal movement – relative to hip motion, when performing a range of everyday tasks. Comparison was drawn both to a traditional 'single-joint' measuring method, and to previous studies evaluating a single, everyday tasks (i.e. sit-to-stand).

2. Methods

2.1. Participants

Fifty-three male participants were recruited from Cardiff University (age = 29.4 ± 6.5 years; mass = 75.3 ± 16.4 kg; height = 1.69 ± 0.15 m). No participants had a history of lower extremity problems or spinal pain, surgery, rheumatological or neurological disorders. All participants provided written informed consent prior to data collection. The study was approved by the Cardiff School of Engineering Ethics Committee.

2.2. Instrumentation

Data describing lumbar spine and hip kinematics were collected using four tri-axial accelerometers (THETAMetrix, Waterlooville, UK), each with a 24 mm^2 footprint. Each sensor was then placed, using double-sided tape, over the spinous processes of S1, L3, T12 and the lateral aspect of the right thigh, mid-way between the lateral epicondyle and greater trochanter on the iliotibial band (ITB) (Fig. 1). Each accelerometer provided axial acceleration data pertaining to absolute orientation (tilt), with respect to gravity. Sensors were wired together in a 'daisy chain' arrangement and connected to a PC, running data collection software via USB. Data were captured at 30 Hz using the supplied 3A sensor software (THETA-Metrix, Waterlooville, UK), and stored for retrospective processing. This system has been found previously to have excellent repeated-measures reliability relating to spinal movement analysis, with the intraclass correlation coefficient ranging from 0.88 to 0.99, and a standard error of measurement ranging from 0.4° to 5.2° (Alqhtani et al., 2015).

2.3. Procedure

Participants' height and weight were determined prior to sensor attachment. Participants completed a warm up exercise, which included flexion, extension and rotation of the trunk, and then a period of sensor familiarisation for the participants. Prior to starting the actual trial, participants were asked to do one trial to familiarise themselves with the experimental procedure. Each participant stood barefoot on assigned markers and focused on a wall marker, set at a height of 2 m, with arms relaxed by their side. Participants were asked to complete forward bending, backward bending, lifting an object (wooden box with handles weighing 3 kg) from the floor and returning to a standing position, moving from stand to sit on a stool and then returning to standing. No further instructions on how to move were provided.

2.4. Data analysis

Raw data were transferred to MATLAB (MathWorks Inc, Natick, MA) and filtered at 6 Hz (low-pass, Butterworth) to remove high frequency noise (Scholz et al., 2001). Sagittal plane absolute angles for each sensor were determined, with respect to gravity and regional ROM was defined as the relative motion between adjacent distal and proximal sensors (relative angles). The whole lumbar spine was defined as the relative angle between the S1 and T12 sensors. The upper lumbar spine (ULS) was defined as the relative angle between the T12 and L3 sensors, and lower lumbar spine (Mills et al., 2007) as the relative angle between the L3 and S1 sensors. As the whole lumbar spine consists of six spinal joints and the ULS and LLS only three spinal joints, the regions were normalised per segment (i.e. the WLS kinematics divided by six and ULS and LLS kinematics divided by three). This normalisation enabled comparisons between the regions to be possible. The kinematics of ROM was determined as relative angle across time and angular velocity calculated by 5-point differentiation of the ROM-time data (Williams et al., 2013). The ratios of lumbar-to-hip motion for each region (ULS, LLS and WLS) were determined for each task. Therefore, the dependent variables for this study were ROM, peak velocity (negative and positive) and lumbar-hip ratio.

As this study aimed to evaluate the contribution of ULS and LLS relative to hip motion, an ANOVA was used to test for differences between the WLS, ULS and LLS (SPSS ver. 20). Post–hoc analysis was applied using the Tukey procedure to determine the location of any differences. Statistical significance was accepted at the 5% level for all tests.

3. Results

3.1. ROM

The mean (SD) ROM (normalised per segment) are presented in Table 1.

There was a significant difference in the ROM displayed by the ULS compared with the WLS for flexion, lifting and sit-to-stand (Table 2). Significant differences were also present between the LLS and WLS for flexion and lifting (Table 2).

A significant difference was evident between the relative contribution from the LLS and ULS across all movements (Table 2), with the lower lumbar spine consistently contributing on average 63% of the total ROM (Fig. 2).

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