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Trunk and lower limb coordination during lifting in people with and without chronic low back pain

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ABSTRACT

Differences in synchronous movement between the trunk and lower limb during lifting have been reported in chronic low back pain (CLBP) patients compared to healthy people. However, the relationship between movement coordination and disability in CLBP patients has not been investigated. A cross-sectional study was conducted to compare regional lumbar and lower limb coordination between CLBP (n = 43) and control (n = 29) groups. The CLBP group was divided into high- and low-disability groups based on their Oswestry Disability Index (ODI) score. The mean absolute relative phase (MARP) angles and mean deviation phase (DP) between the (1) lumbar spine and hip, and (2) hip and knee were measured. The relationship between MARP angle and DP and ODI were investigated using linear regression. The higher-disability CLBP group demonstrated significantly greater lumbar-hip MARP angles than the lower-disability CLBP group (mean difference = 12.97, % difference = 36, $p = 0.041$, 95% CI [2.97, 22.98]). The higher-disability CLBP group demonstrated significantly smaller hip-knee DP than controls (mean difference = 0.11, % difference = 76, $p = 0.011$, 95% CI [0.03, 0.19]). There were no significant differences in lumbar-hip and hip-knee MARP and DP between the lower-disability CLBP and control groups. Lumbar-hip MARP was positively associated with ODI ($R^2 = 0.092$, $\beta = 0.30$, $p = 0.048$). High-disability CLBP patients demonstrated decreased lumbar-hip movement coordination and stiffer hip-knee movement during lifting than low-disability CLBP patients and healthy controls.

1. Introduction

Lifting is a complex activity that requires coordination of the lower limbs and trunk (van Dieen et al., 1999). Poor movement coordination between the trunk and lower limb during lifting has been associated with the development of chronic low back pain (CLBP) given the increased loading of bony and soft tissues (Coenen et al., 2014; Nelson et al., 1995). The kinematics of CLBP-related symmetrical lifting (i.e., lifting where the load is placed anteriorly about the body's mid-sagittal plane (Lavender et al., 2003)) have been quantified by measuring the lumbar and hip range of motion (ROM) and angular velocity (Lariviere et al., 2002; McGregor et al., 1997; Sanchez-Zuriaga et al., 2011).

Studies assessing lifting-related lumbar ROM during symmetrical lifting in people with CLBP report inconsistent findings including increased (McGregor et al., 1997), decreased (Sanchez-Zuriaga et al., 2011) and no difference (Lariviere et al., 2002) in ROM compared to healthy people. Likewise, compared to healthy people, people with CLBP take longer to perform lifting tasks (Sanchez-Zuriaga et al., 2011). However, assessment of peak joint ROM and angular velocity does not provide any indication of inter-joint coordination during lifting. Thus, more sensitive and sophisticated analysis of lifting techniques are required to accurately assess trunk and lower limb coordination deficits in people with CLBP.

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An alternative method for quantifying CLBP-related lifting kinematics is relative phase angle analysis – a technique used most commonly within the ergonomics literature for analyzing coordination between the trunk and lower limb joints during lifting (Burgess-Limerick et al., 1993). This approach provides continuous spatial and temporal measurement throughout the movement cycle given that phase angles are derived from joint displacement and joint velocity (Hamill et al., 1999; Stergiou et al., 2001). A previous study utilized this technique to compare inter-joint coordination of people with and without CLBP during a trunk extension movement (Mokhtarinia et al., 2016). Mokhtarinia et al. (2016) found that in people with CLBP, lumbar movement was more 'in-phase' with hip movement compared to healthy people during trunk extension – denoting stiffer lumbopelvic movement. Whilst interesting, this study has numerous limitations. For instance, there was no measurement of vertical ground reaction force (GRF) which, in conjunction to trunk kinematics, has been used to identify compensatory movement strategies during functional tasks in people with CLBP (Shum et al., 2007b). Furthermore, CLBP participants were almost completely free of pain and disability at the time of testing. People with CLBP with higher disability levels have been found to exhibit more pronounced kinematic and kinetic mal-adaptations during lifting – as per reduced trunk ROM, lower limb ROM and vertical GRF's through each leg compared to those with lower disability levels and healthy people (Sanchez-Zuriaga et al., 2011). Importantly, the association between lifting-related inter-joint coordination, vertical GRF's and self-reported disability – commonly measured using the Oswestry Disability Index (ODI; (Fairbank and Pynsent, 2000)) – has not been previously investigated. Thus, it is currently unknown whether CLBP individuals with higher disability levels demonstrate different lifting-related trunk and lower limb inter-joint coordination and vertical GRF's compared to those with lower disability levels and healthy people.

Therefore, the primary aim of this study was to compare lifting-related kinematics (i.e., lumbar ROM, lower limb ROM, angular velocity, lumbar-lower limb inter-joint coordination) and kinetics (i.e., vertical GRF) in CLBP with lower and higher disability levels and healthy control participants. The secondary aim was to investigate the relationship between lifting-related kinematic and kinetic variables and self-reported disability level in CLBP participants. We hypothesized that compared to healthy controls, people with CLBP would demonstrate impaired lifting-related kinematics and kinetics (H_1) (i.e., increased trunk-lower limb joint coordination (Mokhtarinia et al., 2016) and decreased vertical GRF (Sanchez-Zuriaga et al., 2011)). Moreover, significant positive associations would be observed between lifting-related kinematics and kinetics and self-reported disability in people with CLBP (H_2).

2. Methods

2.1. Participants

Forty-three participants ($n_{female} = 23$) aged 25–60 years with CLBP were recruited from a large Physiotherapy clinic in Melbourne, Australia. These participants were new patients of the clinic and, as per diagnostic criteria of non-specific CLBP (Von Korff et al., 1993), reported pain between the level of the twelfth thoracic vertebra (T12) and the gluteal fold that had persisted for >3 months. Participants were excluded if they presented with overt neurological signs such as muscle weakness, previous spinal surgery, systemic or inflammatory conditions such as rheumatoid arthritis, malignancy, unstable spondylolisthesis (i.e., specific diagnosis of CLBP (Maitland et al., 2005)) or inability to understand written or spoken English. In addition, a group of 29 healthy control participants (age-, gender- and BMI-matched) with no history of CLBP were recruited from the community.

All participants completed the ODI (rated from 0 to 100% disability) and rated their pain out of 10 using the Numerical Rating Scale immediately before and after testing. The CLBP cohort was divided into low (ODI $\leq$ 20%) and moderate-high disability (ODI > 20%) sub-groups based upon their level of self-reported ODI disability (Fairbank and Pynsent, 2000). Ethics approval was obtained from The University of Melbourne's Behavioural and Social Sciences Human Ethics Committee (ethics ID: 1340715). All participants provided written informed consent prior to entering the study.

2.2. Experimental procedures

Twenty-one retro-reflective markers of 13 mm diameter were attached to anatomical landmarks of each participant using double sided tape. The thorax, pelvis, thigh and lower leg segments were formed using three retro-reflective markers per segment (see Fig. 1). The thorax marker configuration used was similar to Christe et al. (2016) and is valid for investigating lumbar flexion – i.e., thorax rotation relative to the pelvis in the sagittal plane (Burgess-Limerick et al., 1993; Kippers and Parker, 1989). Hip (pelvis to thigh segments) and knee (thigh to shank) flexion angles were defined using the longitudinal axes of each segment. Participants were instructed to step onto two Wii Balance Boards (WBB;

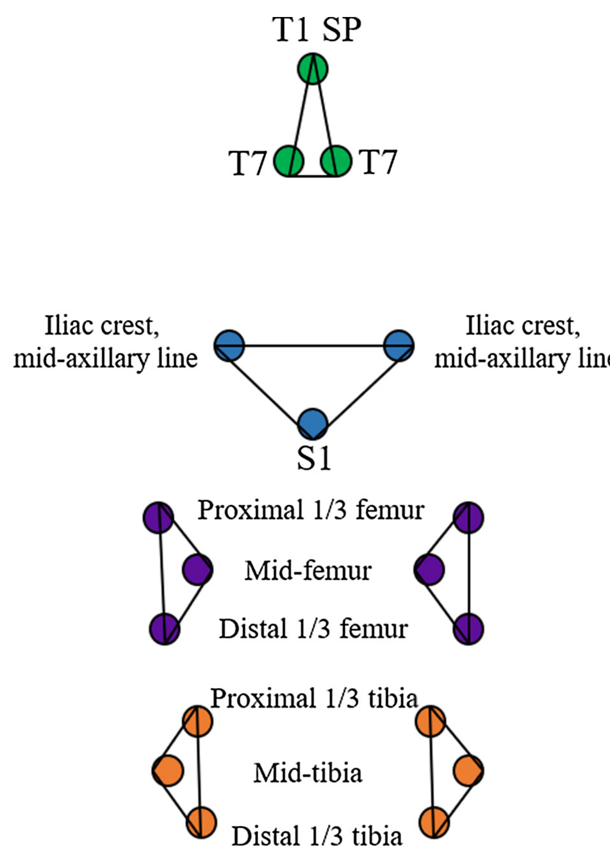

Fig. 1. The marker configuration used in this study. Three markers are used to create a rigid body: the thorax (green), pelvis (blue), thighs (purple) and shanks (orange). The T7 markers are 5 cm distal of their respective spinous processes. Dashed lines represent the defined axes of rotation, with virtual markers created based on existing marker locations where the axis did not originate or terminate at a captured marker. Post processing was performed to negate data where needed to align the direction of rotation between limbs. SP = spinous process. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)