Human Movement Science 48 (2016) 153–160

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Investigating the effects of movement speed on the lumbopelvic coordination during trunk flexion

Jie Zhou [a,*], Xiaopeng Ning [b,1], Fadi Fathallah [a,2]

[a] Department of Biological and Agricultural Engineering, University of California, Davis, Davis, CA 95616, USA
[b] Department of Industrial and Management Systems Engineering, West Virginia University, Morgantown, WV 26506, USA

ARTICLE INFO

Article history:
Received 11 January 2016
Revised 6 May 2016
Accepted 16 May 2016
Available online 19 May 2016

Keywords:
Movement speed
Lumbopelvic coordination
Spinal loading
Neuromuscular control
Trunk flexion

ABSTRACT

Movement speed during trunk flexion has long been reported to affect task performance and biomechanical responses. The current study investigated how movement speed changed lumbopelvic coordination, especially lumbopelvic continuous relative phase and phase variability during trunk flexion. Eighteen subjects executed a paced trunk flexion routine over time periods of 3, 7, 11 and 15 seconds. The results demonstrated that compared with the 3-s condition, lumbopelvic continuous relative phase was 98.8% greater in the 15-s condition, indicating a more anti-phase coordination pattern. This pattern is suggested to mitigate the increased spinal loading associated with the longer duration of muscle exertion. Additionally, phase variability was 18.8% greater in the 15-s trials than the 3-s trials, such an unstable coordination pattern is likely caused by the more active neuromuscular control. Findings of this study provide important information about the effects of movement speed on lumbopelvic coordination during trunk flexion.

1. Introduction

Trunk flexion is associated with lumbar flexion and pelvic anterior rotation, and the relative coordination pattern between lumbar and pelvis, namely lumbopelvic coordination, has been demonstrated to significantly affect spinal loading, thereby the risk of low back pain (LBP) (Arjmand, Plamondon, Shirazi-Adl, Lariviere, & Parnianpour, 2011; Arjmand & Shirazi-Adl, 2005; Chow, Wang, & Pope, 2014; Granata & Sanford, 2000; Shirazi-Adl, El-Rich, Pop, & Parnianpour, 2005). In previous studies of lumbopelvic coordination, it has been reported that people with a history of LBP demonstrated a more in-phase coordination and a decreased coordination variability compared with a non-symptomatic population when performing running, walking, and sit-to-stand tasks, because these coordination patterns were believed to compensate for impaired neuromuscular control (Esola, McClure, Fitzgerald, & Siegler, 1996; Porter & Wilkinson, 1997; Shum, Crosbie, & Lee, 2005). Granata and Sanford (2000) examined the effect of load magnitude on lumbopelvic coordination during lifting tasks. They found a greater lumbar contribution to trunk motion (i.e. a more anti-phase coordination) with increased load. Chow et al. (2014) investigated how backpacks of differing weights affected lumbopelvic coordination in forward reaching movements. It has been demonstrated that when carrying heavier backpacks, a more anti-phase and unstable motion pattern was observed.

* Corresponding author at: Department of Biological and Agricultural Engineering, University of California, Davis, One shields Avenue, Davis, CA 95616, USA.

E-mail addresses: jiezhou@ucdavis.edu (J. Zhou), xiaopeng.ning@mail.wvu.edu (X. Ning), fathallah@ucdavis.edu (F. Fathallah).

[1] Address: Industrial and Management Systems Engineering, P.O. Box 6070, West Virginia University, Morgantown, WV 26506, USA.

[2] Address: Department of Biological and Agricultural Engineering, University of California at Davis, One shields Avenue, Davis, CA 95616, USA.

http://dx.doi.org/10.1016/j.humov.2016.05.005
0167-9457/

A more recent study demonstrated that compared with trunk extension, a more anti-phase coordination and an increased coordination variability were observed in trunk flexion, since these coordination patterns were believed to mitigate the greater spinal compression force associated with trunk flexion motion (Zhou, Ning, & Fathallah, 2015a).

Trunk movement speed has extensively been shown to affect task performance and biomechanical responses. High speed movements have been associated with the risk of LBP (Fathallah, Marras, & Parnianpour, 1998; Marras & Kim, 1993). Fathallah et al. (1998) demonstrated that movement speed significantly influenced loading rates (both compression and shear forces) of lumbar spine during lifting, high loading rates derived from faster movement were associated with increased risk of LBP. Trunk movement speed has also been shown to be an important determinant on quantifying the extent of LBP (Marras & Kim, 1993). Increased movement speed has been associated with greater difficulty in achieving dynamic stability, due to a faster excursion of the center of pressure relative to base of support (Hof, Gazendam, & Sinke, 2005; Riach & Starkes, 1994). Significantly different neuromuscular recruitment patterns have also been discovered at different trunk angular velocities, at high velocity, the ratio of muscle activity between lumbar multifidus and iliocostalis pars thoracis was significantly larger than low velocity (Van Damme et al., 2013).

Even though the influences of movement speed have long been examined, the way it changes lumbopelvic coordination, especially lumbopelvic continuous relative phase (CRP) and CRP variability, has not been investigated. Traditional methods (e.g., lumbar-pelvic rotation ratio, discrete relative phase) of analyzing lumbopelvic coordination only quantify angular displacements of segments in a static manner (Esola et al., 1996; Granata & Sanford, 2000), whereas with a dynamic system perspective, CRP examines both angular displacements and velocities of intersegmental coordination and provides continuous quantitative information on motion pattern (Chow et al., 2014; Kurz & Stergiou, 2004; Stergiou, 2004). Therefore, CRP provides a more advantageous method of quantifying lumbopelvic coordination pattern such that more information about the continuous dynamic interaction between lumbar and pelvis as well as the underlying neuromuscular control mechanisms can be obtained. A smaller or larger lumbopelvic CRP value indicates a more in-phase or anti-phase coordination pattern between lumbar and pelvis, respectively; in addition, a smaller or larger coordination variability indicates a more stable and unstable coordination, respectively (Chow et al., 2014).

According to the findings of these previous studies, it is believed that movement speed also affects lumbopelvic coordination during trunk flexion. Therefore, the objective of the current study is to investigate the way that movement speed influences lumbopelvic coordination, especially lumbopelvic CRP and CRP variability during trunk flexion. It is hypothesized that low speed trunk flexion will result in greater lumbopelvic CRP and CRP variability, which implies a more anti-phase and unstable coordination pattern.

2. Methods

2.1. Subjects

Eighteen healthy male students with no previous history of LBP (by self-reporting) volunteered for the present study. Their mean (SD) age, stature and body mass were 24.7 (3.7) years, 175.8 (4.3) cm and 75.8 (7.3) kg, respectively. The experiment procedure was approved by the Institutional Review Board of West Virginia University, informed consent forms were signed by the subjects before their participation.

2.2. Equipment

In the present study, lumbar and pelvic kinematics data were recorded using a magnetic field based 3D motion tracking system with a sampling frequency of 1024 Hz (Motion Star, Ascension, Burlington, VT, USA). Two magnetic sensors were placed at the L1 and S1 levels of spinous processes, respectively. Lumbar flexion angle was defined as the sagittal angular difference between the L1 and S1 sensors, and pelvic anterior rotation was defined as the sagittal rotation of the S1 sensor (Fig. 1). A metronome was used to help keep the trunk flexion at a preassigned speed.

2.3. Experiment design

The independent variable of the experiment was trunk flexion duration (DURATION), which included four time durations for attaining full trunk flexion (from upright posture): 3, 7, 11 and 15 s, corresponding to very fast, fast, slow and very slow, respectively. Each routine was repeated four times (i.e., sixteen experimental trials). The dependent variables were lumbopelvic CRP and CRP variability which were defined as the average difference in phase plane angles between lumbar and pelvis, and the average standard deviation of this angular difference during the trunk flexion motion, respectively. The details of calculating lumbopelvic CRP and CRP variability are in the 'Data processing' session, below.

2.4. Procedure

The subjects were first lead through a five-min warm-up, in which they were familiarized with the trunk flexion motion, especially the four speed levels. Two magnetic sensors were then placed at the L1 and S1 spinous processes of the subjects.