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Full Length Article

Changes of lumbar posture and tissue loading during static trunk bending

Faisal Alessa[a,b,1], Xiaopeng Ning[a,*]

[a] Department of Industrial and Management Systems Engineering, West Virginia University, Morgantown, WV 26506, USA
[b] Industrial Engineering Department, College of Engineering, King Saud University, Riyadh, Saudi Arabia

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ABSTRACT

Static trunk bending is an occupational risk factor for lower back pain (LBP). When assessing relative short duration trunk bending tasks, existing studies mostly assumed unchanged spine biomechanical responses during task performance. The purpose of the current study was to assess the biomechanical changes of lumbar spine during the performance of relatively short duration, sustained trunk bending tasks. Fifteen participants performed 40-s static trunk bending tasks in two different trunk angles (30° or 60°) with two different hand load levels (0 or 6.8 kg). Results of the current study revealed significantly increased lumbar flexion and lumbar passive moment during the 40 s of trunk bending. Significantly reduced lumbar and abdominal muscle activities were also observed in most conditions. These findings suggest that, during the performance of short duration, static trunk bending tasks, a shift of loading from lumbar active tissues to passive tissues occurs naturally. This mechanism is beneficial in reducing the accumulation of lumbar muscle fatigue; however, lumbar passive tissue creep could be introduced due to prolonged or repetitive exposure.

1. Introduction

Lower back pain (LBP) remains one of the most prevalent health issues worldwide (Deyo, Mirza, & Martin, 2006). It is estimated that approximately 80% of U.S. population will experience at least one episode of LBP in their lifetimes (Hellmann & Imboden, 2009). Although the majority of people recover, approximately 20% of patients with acute LBP will experience chronic back problems (Weiner & Nordin, 2010). Globally, occupational-related LBP has been among the leading causes of lost work days. According to the World Health Organization 2010 Global Burden of Disease (GBD) study, LBP was ranked the 6th, (rising from the 11th in 1990), among top diseases and injuries that cause the largest number of Disability Adjusted Life-Years, which is a measure of the overall disease burden, expressed as the number of years lost caused by illness, disability or early death (Murray et al., 2012). In the United States, the economic burden associated with LBP is extremely large. Previous studies have estimated that the direct (e.g. medical) and indirect (e.g. lost work time, reduced productivity, etc.) cost related to LBP is around 100 billion dollars annually (Luo, Pietrobon, Sun, Liu, & Hey, 2004; Katz, 2006).

The etiology of LBP is complex and multifactorial. Studies have found that LBP is associated with genetic (Junqueira et al., 2014), psychosocial (Gatchel, Polatin, & Mayer, 1995), individual (Richard & Edward, 1989), and biomechanical (Bernard, 1997; Marras et al., 1995) factors. Previously the association between the mechanical loading on spinal tissues and the risk of LBP has been

* Corresponding author at: Industrial and Management Systems Engineering, P.O. Box 6070, West Virginia University, Morgantown, WV 26506, USA.
E-mail addresses: fmalessa@mix.wvu.edu (F. Alessa), xiaopeng.ning@mail.wvu.edu (X. Ning).
[1] The Ergonomics Lab, Industrial and Management Systems Engineering, West Virginia University, Morgantown, WV 26506, USA.

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demonstrated; it was found that excessive loading could cause fracture in the vertebral body (Brinckmann, Biggemann, & Hilweg, 1988) and herniation in intervertebral discs (Adams, Freeman, Morrison, Nelson, & Dolan, 2000), which further lead to spinal disorder and pain (Marras, Davis, Ferguson, Lucas, & Gupta, 2001a). Although occasionally performed trunk flexion with moderate hand load is unlikely to cause immediate damage to the spinal structure, studies have found that prolonged and/or repetitive trunk flexion could generate micro damages to the spinal structure and eventually lead to LBP over a period of time (e.g. in months or years) (Brinckmann et al., 1988; Coenen, Kingma, Boot, Bongers, & van Dieën, 2012; Coenen et al., 2013; Hoogendoorn et al., 2000; Norman et al., 1998). Thus, a clear understanding of the spinal tissue loadings during task performance is critical for the prevention of LBP.

The human lumbar spine mainly consists of two types of tissues: active tissues (e.g. the contractile component of muscles) and passive tissues (ligaments, fascia, discs, bone, and non-contractile component of muscles). It has been observed that during the performance of trunk bending, lumbar extensor muscle contraction will quickly diminish and cease action when reaching to the bottom range of the motion. Termed flexion relaxation phenomenon (Floyd & Silver, 1951; Floyd & Silver, 1955), this phenomenon indicates a complete transition of load from lumbar active tissues to passive tissues (Ning, Haddad, Jin, & Mirka, 2011; Ning, Jin, & Mirka, 2012), which is part of the load sharing synergy between these two types of lumbar tissues. Studies have shown that this load sharing synergy can be altered by a number of factors including ligament creep caused by prolonged trunk bending (Shin, D'Souza, & Liu, 2009), the direction and speed of the trunk bending motion (Ning et al., 2011; Sarti, Lison, Monfort, & Fuster, 2001), and lumbar muscle fatigue (Descarreaux, Lafond, Jeffrey-Gauthier, Centomo, & Cantin, 2008).

Previous studies suggested that maintaining prolonged flexed trunk posture could elevate the risk of developing LBP due to increased spinal loading (Solomonow, Baratta, Banks, Freudenberger, & Zhou, 2003; Bazrgari & Shirazi-Adl, 2007) and muscle fatigue (Shin et al., 2009). Flexed trunk postures are commonly seen in several occupations such as construction (Boschman, van der Molen, Sluiter, & Frings-Dresen, 2011), agriculture (Fathallah, 2010) and mining (Gallagher, 2008). In such postures, the interactions between lumbar active and passive tissues are mainly determined by lumbar postures (McGill, Hughson, & Parks, 2000). As lumbar angle increases (i.e. flexed posture), lumbar passive tissues elongate and generate larger passive forces. Consequently, less lumbar active muscle forces are needed to counterbalance external moment (Arjmand, Plamondon, Shirazi-Adl, Lariviére, & Parnianpour, 2011; Potvin, McGill, & Norman, 1991). Previous efforts in studying prolonged static trunk bending postures have mostly focused on its contribution to lumbar passive tissue creep (McGill & Brown, 1992) and the associated changes in lumbar biomechanics after prolonged flexion (Solomonow et al., 2003; Shin & Mirka, 2007; Toosizadeh, Nussbaum, Bazrgari, & Madigan, 2012). Other studies mostly assumed lumbar posture to be uniform and unchanged when holding static flexed trunk postures (Arjmand & Shirazi-Adl, 2005; McGill et al., 2000; Kahrizi, Parnianpour, & Firoozabadi, 2007). There is evidence that demonstrated the changes of lumbar biomechanics after prolonged static trunk bending (Hu & Ning, 2015a, 2015b); however, the gradual changes of lumbar posture and its associated lumbar tissue load sharing profiles during the course of static trunk bending remains unclear.

Therefore, the aim of the current study was to investigate the changes of lumbar posture and the associated lumbar tissue loadings during the performance of relatively short duration, sustained trunk bending motions. Previous studies suggested that different lumbar postures may be used to adjust the level of lumbar extensor muscle exertions (Adams & Dolan, 1995; McGill et al., 2000), such changes may be used to avoid or delay lumbar muscle fatigue during prolonged trunk flexion (Shin et al., 2009). Therefore, we hypothesized that when maintaining bended trunk postures, one may unconsciously increase lumbar flexion to shift external loading from lumbar active tissues to passive tissues in order to avoid muscle fatigue. Thus, we expect to observe increased lumbar flexion angle, reduced lumbar extensor muscle activity, and increased lumbar passive loading during the course of static trunk bending. We also hypothesized that these effects will increase at deeper trunk angles and with added external load.

2. Materials and methods

2.1. Participants

Fifteen male participants from the university student population (average body weight 76.2 ± 11.6 kg, body height 173.7 ± 8.9 cm, age 24.9 ± 4.0 years) participated in the current study. All participants reported no current or history of LBP. Prior to the data collection, participants provided informed consent. The experimental design and procedure were approved by the Institutional Review Board of West Virginia University.

2.2. Equipment

Lumbar and trunk kinematics were collected using a magnetic field based motion tracking system (Motion Star, Ascension, Burlington, VT, USA). Three motion sensors were placed over the skin of C7, T12, and S1 vertebrae using double-sided tape (Ning et al., 2011). Muscular activities were sampled via eight bi-polar surface EMG electrodes (Bagnoli, Delsys, Boston, MA, USA), placed bilaterally over L3 and L4 paraspinals (L3P & L4P) (4 cm and 2 cm away from the mid-line of the spinal column respectively), rectus abdominus (RA) (1 cm above and 2 cm away from the umbilicus) and external oblique (EO) (15 cm away from the umbilicus). Both EMG signals and kinematics data were sampled at 1024 Hz. Finally, a custom-made reference frame was used for participants to reach and maintain designated trunk angles (Fig. 1).