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Full Length Article

Age-related differences in the timing aspect of lumbopelvic rhythm during trunk motion in the sagittal plane

Milad Vazirian, Iman Shojaei, Babak Bazrgari *

F. Joseph Halcomb III, M.D. Department of Biomedical Engineering, University of Kentucky, Lexington, KY, USA

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ABSTRACT

Forward bending and backward return of the human trunk in the sagittal plane are associated with a specific lumbopelvic rhythm, which consists of magnitude and timing aspects. In this study, the age-related differences in the timing aspect of lumbopelvic rhythm were investigated using the continuous relative phase method. Specifically, the mean absolute relative phase (MARP) between the thoracic and pelvic motions as well as variation in MARP under repetitive motions, denoted by deviation phase (DP), were characterized in sixty participants between 20 and 70 years old. MARP and DP were determined for trunk forward bending and backward return tasks with self-selected slow and fast paces. The MARP and DP were both smaller ($p = 0.003$, $p < 0.001$ respectively) in the older versus younger age participants with no gender-related difference. In fast versus slow pace task, the MARP was smaller ($p < 0.001$) only in forward bending, whereas the DP was smaller ($p < 0.001$) in both the forward bending and backward return. A more in-phase and more stable lumbopelvic rhythm denoted respectively by smaller MARP and DP in older versus younger individuals maybe a neuromuscular strategy to protect the lower back tissues from excessive strain, in order to reduce the risk of injury.

1. Introduction

Frequent trunk bending and return[1] has been suggested to be a risk factor for occupational low back pain (LBP) (Damkot, Pope, Lord, & Frymoyer, 1984; Hoogendoorn et al., 2000; Punnett, Fine, Keyserling, Herrin, & Chaffin, 1991), a disorder which still remains of a high morbidity in industrial societies, and adversely affects the well-being of people and economy (Buchbinder et al., 2013; Hoy et al., 2014). Thus, obtaining a detailed knowledge about the pattern of trunk movement during bending and return is an important step for LBP management. Trunk bending and return result from rotation of the pelvis as well as flexion/extension of the lumbar spine. The patterns of pelvic rotation and lumbar flexion/extension have been studied generally from the magnitude and timing-related perspectives, under the so-called topic of lumbopelvic rhythm (Kim et al., 2013; Phillips, Bazrgari, & Shapiro, 2014; Pries, Dreischarf, Bashkuev, Putzier, & Schmidt, 2015; Silfies, Bhattacharya, Biely, Smith, & Giszter, 2009; Thomas & Gibson, 2007; Vazirian, Van Dillen, & Bazrgari, 2016a; Wong & Lee, 2004), As a magnitude-based measure of lumbopelvic rhythm, the lumbar contribution has been shown to be larger in the early stage,

* Corresponding author at: Department of Biomedical Engineering, University of Kentucky, 514E Robotic and Manufacturing Building, Lexington, KY 40506, USA.

E-mail address: babak.bazrgari@uky.edu (B. Bazrgari).

[1] Bending and return in this manuscript refer to respectively bending forward from the upright standing posture to the trunk flexed posture, and returning backward from the flexed trunk posture to the upright standing posture in the sagittal plane.

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to decrease gradually, and to be minimum in the late stage of bending. Conversely, the return starts with a minimum lumbar contribution which gradually increases throughout the course of return (Vazirian, Shojaei, & Bazrgari, 2016). On the other hand, studies on the timing aspects of lumbopelvic rhythm have shown that the lumbar spine versus pelvis tends to move sooner in the bending, and remains ahead in the phase of motion. However, in the return, the lumbar spine is behind the pelvis in phase, and finishes the motion later (Pal, Milosavljevic, Sole, & Johnson, 2007). An important requirement for application of lumbopelvic rhythm to prevention, treatment, and rehabilitation of LBP is an understanding of the effects of personal differences (e.g., age and gender) on measures of lumbopelvic rhythm (Vazirian, Van Dillen, & Bazrgari, 2016b). In a recent study, we showed that individuals older versus younger than 50 years of age, implemented smaller lumbar contribution during trunk bending and return motion irrespective of gender or pace of motion (Vazirian, Shojaei, et al., 2016). However, no study yet, to our best knowledge, has investigated the age-related differences in the lumbopelvic rhythm from the timing perspective.

Generally the timing aspect of lumbopelvic rhythm has been studied using three different methods: (1) critical points method wherein a time difference is calculated between different event times (e.g., events like onset, termination, maximum displacement, or maximum velocity) of lumbar and pelvic motion (Pal et al., 2007; Thomas & Gibson, 2007), (2) cross-correlation method in which the lumbar and pelvic motion are cross-correlated by determining a time lag (phase) that is associated with the maximum correlation between the temporal variations of both lumbar and pelvic motion during the task (Lee & Wong, 2002; Wong & Lee, 2004), and (3) continuous relative phase (CRP) method wherein the difference between the phase angles of lumbar and pelvic motions at each time instant is obtained from their phase planes (Hu, Ning, & Nussbaum, 2014; Silfies et al., 2009; Zhou, Ning, & Fathallah, 2015). The CRP method is essentially a dynamical system approach and as compared to the other two methods can provide insight related to the stability of trunk motion in addition to the timing aspects of the lumbopelvic rhythm (Stergiou, Jensen, Bates, Scholten, & Tzetzis, 2001). Therefore, the objective of this study was set to find the age-related differences in the timing aspects of lumbopelvic rhythm using the CRP method. Using this method, it has been shown that LBP patients have a more in-phase and less variable (i.e., more stable) lumbopelvic rhythm in the sagittal plane (Mokhtarinia, Sanjari, Chehrehrazi, Kahrizi, & Parnianpour, 2016; Seay, Van Emmerik, & Hamill, 2011; Selles, Wagenaar, Smit, & Wuisman, 2001). Considering this phenomenon as a protective strategy adopted to prevent the spinal segments from potentially harmful movements relative to each other (van Dieen, Selen, & Cholewicki, 2003), and on the other hand, since the aging is associated with tissues degeneration and impaired functioning of spinal segments (Hoy et al., 2014), it may be speculated that such a protective strategy is also adopted in the elderly. Therefore, it was hypothesized that the older versus younger participants to have a more in-phase and less variable lumbopelvic pattern.

2. Methods

2.1. Study Design and Participants

Sixty individuals were recruited to form five equal-sized and gender-balanced age groups, in order to participate in a cross-sectional study. Each age group represented a working decade of life between 20 and 70 years. To increase the chances for capturing any potential between-group differences in our outcome measures, especially between the adjacent age groups, two years were cut off from each side of the age range of each group, resulting in the age groups of 22–28, 32–38, 42–48, 52–58 and 62–68 year-old. All volunteers consented to participate by completing a procedure approved by the Institutional Review Board of the University of Kentucky. They were then further screened for the following exclusion criteria: 1) back pain during the last year, 2) spinal deformity, surgery or any other musculoskeletal abnormality in the trunk, 3) a history of work in physically demanding occupations (e.g., occupations involving frequent lifting, twisting, bending, driving), and 4) body mass index <20 or >30. Such exclusion criteria were adopted to minimize any confounding effects on the outcome measures due to any back pain history (Seay et al., 2011; Selles et al., 2001) or exposure to LBP risk factors associated with physically demanding occupations (Hu et al., 2014). There were no significant differences in stature ($p = 0.917$) or body mass ($p = 0.234$) between the age groups as determined using univariate analysis of variance (ANOVA) (see Table 1).

2.2. Testing procedure

Two magnetic inertial motion trackers (MT) (Xsens MTw, Xsens Technologies, Enschede, Netherlands) were strapped around the participants' thorax at the level of T10 (Bazrgari et al., 2011; Hendershot et al., 2011; Shojaei, Vazirian, Croft, Nussbaum, & Bazrgari, 2016), and pelvis at the level of S1 to measure the thoracic and pelvic rotations. The three-dimensional orientation of the MTs as rotation matrices, at the sampling rate of 50 Hz were recorded by a computer, after a Kalman filter was utilized to minimize any potential effect of noise on the data (Xsens., 2012) (see Fig. 1).

Each participant completed two sessions of data collection with at least 48 h in between. In order to minimize the diurnal and occupational effects on the results, all data collection sessions were held in the morning. Each session included two trunk bending-return (BR) tests with slow and fast paces. In the slow BR test, the participants bent their trunk from an upright standing posture to their full-bent posture. Participant were instructed to pause for five seconds at their full-bent posture, guided by an examiner, and then returned backward to the upright standing posture. The fast BR test was similar, except that participants performed the bending and return as fast as possible without a pause at the full-bent posture. Slow