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Different coordination and flexibility of the spine and pelvis during lateral bending between young and older adults

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ABSTRACT

This study examined coordination of the spine and pelvis during lateral bending of the trunk in older adults. Thirty-four healthy subjects (17 young and 17 older adults) demonstrated lateral bending at a controlled speed while holding a bar at approximately 180 degrees of shoulder flexion. Kinematic data collection was completed on the thoracic spine, lumbar spine, and pelvis. The coupling angle was calculated to examine the thorax–lumbar, lumbar–pelvis, and thorax–pelvis coordination patterns. The older adults demonstrated a reduced range of motion (ROM) of the lumbar spine, while both groups revealed similar ROM in the thorax and in the pelvis. The coupling angle between the straightening and bending phases was different only for the older adults in the thorax–lumbar (23.4 ± 8.0 vs. -1.6 ± 4.4, $p = 0.004$) and the lumbar–pelvis (65.4 ± 7.2 vs. 86.1 ± 7.8, $p = 0.001$) coordination. However, there was no group difference in the thorax–pelvis coordination. These findings indicate that age-related changes in the lumbar region affect coordination patterns only during the bending phase. The older adults preserved a similar pattern of movement to the young adults during the straightening phase, but the coordination variability of the coupling angles was greater for the older adults than for the young adults. This movement pattern suggests that the older adults lacked consistent trunk control in an attempt to optimize lateral bending coordination.

1. Introduction

Clinicians frequently assess trunk motion to observe biomechanical deficits related to the degeneration of sensory and motor functions in older adults (Brumagne, Cordo, & Verschueren, 2004; Genevay & Atlas, 2010). Several studies reported that older adults demonstrated more trunk-on-pelvis rotation since their segmental spinal range of motion (ROM) is associated with postural instability as well as decreased muscular force-generating capabilities (Baird & Van Emmerik, 2009; Sung, Lee, & Park, 2012a). These studies indicated the importance of trunk coordination and motor control with aging.

As spinal flexibility decreases with age (Einkauf, Gohdes, Jensen, & Jewell, 1987), older adults demonstrate less rotational ROM on the thoracic spine, increased postural instability during a standing turning task (Baird & Van Emmerik, 2009), and reduced reaching distance due to less use of thoracolumbar rotation than young adults (Cavanaugh et al., 1999; Doriot & Wang, 2006; Schenkman, Shipp, Chandler, Studenski, & Kuchibhatla, 1996). Although the coordination of the trunk and pelvis has been reported in dynamic tasks such as trunk forward bending (Larivière, Gagnon, & Loisel, 2000; Silfies,

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Bhattacharya, Biely, Smith, & Giszter, 2009) and axial trunk rotation (Sung et al., 2012a), there is a lack of investigation on lateral bending of the trunk.

The altered movements during lateral bending need to be coordinated since higher activity of the antagonistic muscle as compared to the agonistic muscle is observed (Huang, Andersson, & Thorstensson, 2001). Asymmetric lateral bending has been identified as a risk factor for spinal dysfunction, and a lack of trunk integration resulted in poor trunk coordination in older adults (Burton, 1986; Hultman, Saraste, & Ohlsen, 1992; Janda, 1978). This asymmetric pattern of lateral bending during tasks was reported (Lariviere, Gagnon, & Loisel, 2000); however, the specific altered coordination of the trunk, lumbar spine, and pelvis segments was not carefully investigated in older adults.

One of the prominent features of age-related changes in spinal structure is degeneration of the vertebral discs in the lumbar region (Buckwalter, 1995; Savage, Whitehouse, & Roberts, 1997; Shao, Rompe, & Schiltenwolf, 2002). A reduction of disc height in older adults may result in decreased lateral flexion of the trunk. However, there is a lack of understanding on the reduced lateral flexion of the lumbar region and its relation to the movements of the adjacent thoracic and pelvic regions. It would be necessary to investigate a dynamic systems approach to analyze coordination and stability of integrated spinal motion. Trunk motion requires stabilized compensatory motions to prevent falls and to maintain coordination for functional performance during dynamic activities (Johanson et al., 2011; Sung et al., 2012a). The majority of functional activities requires a combination of three-dimensional rotational movements, and the thorax–lumbar spine is a complex structure that harmonizes multi-axial motion as spinal coordination patterns need to be adjusted (Hindle, Pearcy, Cross, & Miller, 1990).

The facet joints in thorax and lumbar segments have different orientations that contribute to their primary functions. The thoracic region facet joints, oriented to 60 degrees in the frontal plane, are mostly for lateral flexion and rotation, whereas the lumbar region facet joints are better suited for flexion and extension, as they are oriented to 90 degrees in the sagittal plane (Bogduk, 1991; Jaumard, Welch, & Winkelstein, 2011). Integrated thorax and lumbar motion during dynamic activities should be incorporated with harmonized trunk coordination (Leboeuf-Yde, Nielsen, Kyvik, Fejer, & Hartvigsen, 2009; Sung, Park, & Kim, 2012b). It is valuable to present coordination with traditional segmental angle data to assess the effect of specific inter-segmental coordination patterns (Needham, Naemi, & Chockalingam, 2014).

In addition to the comparison between kinematic measures, the angle to angle plots might contribute to a further understanding of postural adjustability in lateral bending. The quantification of kinematic analysis by the coupling angle could be used to quantify thorax–lumbar spine coordination, which is valuable to understanding aging-related coordination patterns. Therefore, the angle to angle plots of lumbar and thorax kinematic data were investigated by the coupling angle to quantify thorax–lumbar spine coordination (Rodrigues, Chang, TenBroek, van Emmerik, & Hamill, 2015). The coupling angle was determined using a vector coding technique (Heiderscheit, Hamill, & van Emmerik, 2002b), which is a three-dimensional quantification of joint coordination based on the relative motion plots between lumbar and thoracic spine angular displacements. The continuous coupling angle can also be used to compare the coordination patterns between the young and older adult groups as well as between the straightening and bending phases during lateral bending.

The purpose of this study was to investigate age-related changes in coordination of the spine and pelvis during lateral bending of the trunk. It was hypothesized that older adults would demonstrate out of phase coordination patterns between the trunk, lumbar spine, and pelvis segments, and the coordination variability would be greater in the older adults during trunk lateral bending activities.

2. Methods

2.1. Subjects

Subjects were recruited from the University community, and the procedures, goals, and potential risks of the study were explained to them. Those subjects who met study inclusionary criteria signed a copy of the Institutional Review Board approved consent form (IRB#8-15B).

Subjects were eligible to participate if they: (1) were 25 years of age or older, (2) had no current episode of pain referral to the upper/lower extremities at least one month prior to data collection, (3) had no structural dysfunction of the spine or lower extremities at the time of data collection, and (4) had no acute pain primarily of muscular origin, all of which were determined by the subjects' primary physicians. Dysfunction was defined as a disturbing impairment or abnormality of functioning (Sung, 2003).

Subjects were excluded from participation if they: (1) had a diagnosed psychological illness that might interfere with the study protocol, (2) had overt neurological signs (sensory deficits or motor paralysis), (3) had a structural spinal problem, and/or (4) were pregnant. Participants were withdrawn from the study if they requested to withdraw. All participants were right-handed since a previous study found that handedness could be a confounding factor (Sung, Spratt, & Wilder, 2004). Handedness was determined based on a modified Edinburg Handedness Inventory (Oldfield, 1971).

2.2. Procedures

The subjects performed lateral bending of the trunk in a standing position while holding a bar (1 meter long and weighing 1 kilograms) with both hands. During the experiment, the subjects separated their feet slightly in order to maintain a