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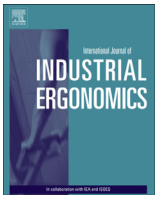

Influence of intentional breath-holding on trunk muscle activity and kinematics during patient transfer

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ABSTRACT

We investigated the effects of intentional breath-holding also known as a valsalava maneuver on the kinematics of the lumbar spine, pelvis, hips, and knees, as well as electromyographic (EMG) activity of the trunk muscle during patient transfer with and without knee flexion. The kinematics of the lumbar spine, pelvis, hip, and knee were recorded using a synchronized 3-D motion capture system. Surface EMG was used to assess the activity of the external oblique (EO), internal oblique (IO), erector spinae (ES), and rectus femoris (RF). There was a significant difference in the peak angle of the lumbar spine ($\eta2 = 0.644-0.600$), pelvis ($\eta2 = 0.514-0.294$), hips ($\eta2 = 0.897-0.746$), and knees ($\eta2 = 0.977-0.870$), as well as in normalized EMG activity of the EO ($\eta2 = 0.543-0.501$), IO ($\eta2 = 0.619-0.460$), ES ($\eta2 = 0.567-0.195$), and RF ($\eta2 = 0.607-0.144$) (except for the RF in the lowering phase, $p = 0.10$), between the different types of patient transfer, in both the lifting and lowering phases ($p < 0.001$). These findings suggest that intentional breath-holding during patient transfer contributes to decreased lumbar flexion and ES activity, thus potentially preventing low back injury. However, individuals with a history of heart and cardiovascular disease are advised to avoid the valsalava maneuver.

1. Introduction

Patient transfer refers the activity of moving a patient from a bed to another location (such as a wheelchair, shower chair, toilet) or *vice versa*. Healthcare workers ranked transfers between a bed and a wheelchair among the top 4 of 16 patient-handling tasks in terms of perceived physical stress (Owen and Garg, 1989). Patient transfer is a complex and arduous motor task, which often requires high loads on the musculoskeletal system of healthcare workers and is associated with a risk of low back disorders and injuries (Milhem et al., 2016; King et al., 2009). Repetitive or prolonged mechanical stress during trunk flexion can lead to low back pain (McGill, 2007).

To prevent injury, hospitals and long-term care facilities are moving towards safety-conscious patient lifting and moving policies that promote the use of mechanical lifting devices (Hess et al., 2007). In most home care settings, it is not always possible to accommodate such a device, such that single-person lifting and moving of patients remains common. The most common approach to preventing low back injuries has been education and training in biomechanics and lifting techniques during patient-handling tasks (Akebi et al., 2009). However, several studies have reported that these methods are ineffective in preventing back injury (Leamon, 1994; Pheasant and Stubbs, 1992).

The squat lifting technique, performed with knee flexion and a nearly straight back, has been recommended to reduce low back load in patient handlers (Akebi et al., 2009), because the range of motion (ROM) of lumbar flexion is decreased. The technique generates increased hip flexion and pelvic anterior tilt during forward bending (Norris, 2008). However, many people prefer stoop lifting to squat lifting, due to the greater convenience (Straker and Duncan, 2000) and balance control (Toussaint et al., 1997) associated with the stoop lifting. Furthermore, it is sometimes difficult to perform squat lifting due to lack of space. Although squat lifting is considered to be a safer posture than stoop lifting, due to reduced

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demand on the back muscles, it can increase the risk of developing musculoskeletal injuries in the knee (Burgess-Limerick, 2003). Thus, there is a need for a patient transfer technique that does not involve flexion of the knee.

It is a common practice to breathe in and then hold the breath during resistance exercise when great effort is required; such breath-holding during the lifting of heavy loads involves forced exhalation against a closed glottis, thereby increasing spinal stability by increasing the intra-abdominal pressure (IAP) (Hackett and Chow, 2013). IAP has been suggested to increase lumbar stability via assisting the abdominal muscles (Hodges et al., 2005) and/or stabilizing forces delivered by fascial connections to the vertebral segments (Richardson et al., 1999). De Troyer et al. (1990) reported increased external oblique (EO) activation, in addition to the frequently observed increased transversus abdominis activity, during voluntary abdominal contraction with the glottis closed. Cholewicki et al. (1999a,b) suggested that an important feature of this IAP mechanism is the ability to increase spinal stability without additional erector spinae (ES) muscle co-activation. Thus, intentionally increasing IAP by breath-holding could help prevent injury to the low back, by increasing trunk muscular activation and thus enhancing stability.

The lumbar flexion angle may be an important indicator of low back load during patient transfer (Elford et al., 2000). An increased peak lumbar flexion angle lengthens the lever arm of the low back joint moment during patient transfer (Katsuhira et al., 2008). IAP has a relieving effect on the lumbar spine due to elongation of the spine and production of trunk extensor torque, in turn unloading the ES muscles (Essendrop et al., 2002). According to Bergmark (1989), an increase in IAP via local, direct action on the vertebrae can improve lumbar lordosis.

Most previous studies overlooked the importance of movement of the pelvis and hips associated with a decrease in lumbar flexion during patient transfer. Although, the IAP is influenced significantly by trunk muscle activity during lifting tasks, there is no report of the effects of intentional breath-holding on the motion of the lumbar spine, pelvis segment, hip, and knee joint during patient transfer. Thus, the aim of this study was to investigate the effects of intentional breath-holding on the kinematics of the lumbar spine, pelvis, hips, and knees, as well as electromyographic (EMG) activity of the trunk muscles, during patient transfer with and without knee flexion. Based on previous findings and our clinical experience, we hypothesized that the peak angle of lumbar flexion and EMG activity of the ES would be decreased, whereas the peak angle of pelvic anterior tilt and hip flexion and abdominal muscle activity would be increased, under the intentional breath-holding condition during patient transfer.

2. Methods

2.1. Subjects

In total, 18 healthy male subjects were recruited from Inje University in Gimhae-si, South Korea (mean age = 24.72 ± 2.59 years; mean height = 176.94 ± 6.39 cm; mean weight = 77.11 ± 10.21 kg). The inclusion criteria were as follows: (1) no previous or current neurological or musculoskeletal pathology that could influence patient transfer; and (2) subjects who had no restriction on trunk flexion and extension for patient transfer. The exclusion criterion was experience of pain, particularly in the back or shoulder.

Prior to the experiment, all subjects were given an explanation about the transfer protocols and signed an informed consent form approved by the Inje University Ethics Committee for Human Investigations (INJE, 2016-07-004).

The sample size was calculated according to previous findings (Kang et al., 2013) that showed significantly less peak lumbar flexion in a postural taping versus no-taping condition. The results of the power analysis indicated that at least 16 participants would be required to achieve a power of 0.80 at a significance level of 0.05.

2.2. Kinematic measurements

Kinematic data on the lumbar spine, pelvis, hips, and knee in the sagittal plane were collected using eight VICON MX-T10 motion capture systems (Vicon Motion Systems Ltd., Oxford, UK) at a sampling rate of 100 Hz. Reflective markers ($n = 16$, 14 mm in diameter) were attached with double-sided adhesive tape on the bilateral anterior and posterior superior iliac spines, lateral thighs, lateral sides of the knees and tibias, lateral malleoli, second metatarsal heads, and posterior calcanei, as described in the VICON Plug-in-Gait marker set (Schwartz et al., 2008). Four reflective markers (11 mm in diameter) were placed on the first and second lumbar spinous processes and both parallel sides of the second lumbar spinous process. The lumbar segment was defined by four reflective markers, on the first and second lumbar spinous processes and parallel sides of the second lumbar spinous process. The pelvis segment was defined by four reflective markers on the bilateral anterior and posterior superior iliac spine. The thigh segment was defined by markers on the lateral thigh and lateral side of the knee. Kinematic data for each segment were measured using the Cardan angle (Kadaba et al., 1990). The angle of the pelvis reflects the absolute motion of the pelvic segment according to a laboratory coordinate system. The pelvis segment angle was defined as the angle between the pelvis and the transverse plane. The angle of the lumbar spine was determined from the rotation of lumbar spine segment with respect to the pelvic-embedded y-axis. We defined lumbar angle as the relative angle between lumbar spine and pelvic markers. The angle of the hip was determined from the rotation of the thigh segment about the pelvic-embedded y-axis. Positive angular values of the lumbar spine, pelvis, and hip were defined for lumbar flexion, anterior pelvic tilt, hip flexion, and knee flexion, respectively (Fig. 1).

To process kinematic data for the lumbar spine, pelvis, and hips, we used Nexus software (ver. 1.7; Vicon Motion Systems Ltd.). Nexus software was used to process marker trajectories with a Woltring filter at a scale of 10 and reconstruct 3-dimensional coordinates of each segment. The peak angles of lumbar flexion, pelvic anterior tilt, and hip flexion during each patient transfer were calculated. The mean values (of three trials) of peak lumbar flexion angle, pelvic anterior tilt, hip flexion, and knee flexion were used in the analysis.

2.3. Electromyography recording

Surface EMG data were recorded using a Trigno wireless EMG system (Delsys, Inc., Boston, MA, USA), synchronized with the Vicon system. Before placing electrodes, the electrode sites were shaved and cleaned with 70% isopropyl rubbing alcohol to reduce skin impedance. The single EMG sensor (27 × 37 × 15 mm) contained two stabilizing references, with a 4-bar formation electrode (5 × 10 mm) and an inter-electrode distance of 10 mm; the contact material consisted of pure silver (99.9%). The sampling rate for the EMG signal was set to 1000 Hz; the band-pass filter was set between 20 and 450 Hz, and the root-mean-square value (RMS) was then calculated. EMG data were collected from the EO, internal oblique (IO), ES, and rectus femoris (RF) on the dominant side. The electrode placements were as follows: EO, the inferior edge of the eighth rib superolateral to the costal margin; IO, 2 cm medial to the anterior superior iliac spine in the horizontal plane; ES,