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The effect of on-body lift assistive device on the lumbar 3D dynamic moments and EMG during asymmetric freestyle lifting

Mohammad Abdoli-E [a,*], Joan M. Stevenson [b]

[a] *School of Occupational and Public Health, Ryerson University, Toronto, Ontario, Canada M5B 2K3*
[b] *School of Kinesiology and Health Studies, Queen's University, Kingston, Canada K7L 3N6*

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Abstract

Background. A new on-body personal lift assistive device was developed to reduce force requirements of back muscles during lifting and static holding tasks.

Methods. Nine male subjects participated in the study. Twelve Fastrak™ sensors were used to record positions and rotations of the segments. Trunk muscles were normalized to maximum and integrated electromyographic amplitudes of the left and right thoracic erector spinae, lumbar erector spinae, external obliques, and rectus abdominalis were compared in asymmetrical lifting for three different loads (5 kg, 15 kg, 25 kg) using free style under two conditions: with and without a lift assistive device.

Findings. The assistive device significantly reduced the required muscular effort of the lumbar and thoracic erector spinae ($P = 0.001$) with no significant differences in the level of abdominal muscular activity. Average integrated electromyography amplitudes were reduced across all subjects by 23.9% for lumbar erector spinae, 24.4% for thoracic erector spinae, and 34.9% for the contralateral external oblique muscles. The assistive device had its greatest impact on smaller moments with 30% reduction in lateral bending, and 24% reduction in rotational moments, with only 19.5% a reduction in larger flexion–extension moments. To investigate whether the lift assistive device affected lifting kinematics, the device tensions were zeroed mathematically. No kinematic differences in lifting technique would explain this magnitude of moment reduction.

Interpretation. The on-body assistive device reduced the required muscular effort of the lumbar and thoracic erector spinae without adversely affecting the level of abdominal muscle activity. These reductions were mirrored by similar 3D moment reductions.

Keywords: Biomechanics; Manual handling; Ergonomics; Assistive device; Lifting aid; Electromyography; Erector spinae; Asymmetry; Spinal moments

1. Introduction

Asymmetric lifting is considered an important factor in explaining the incidence of low back pain (LBP), especially for prolapsed discs (Andersson, 1981; Marras et al., 1994). Using epidemiological data, Snook (1978) identified that 33% of low back pain costs were due to twisting and turning in workplaces; Marras and Davis (1998) confirmed this percentage with electromyography-assisted biomechanical and epidemiological evidence. When a movement combines forward flexion with lateral bending, the probability of injury is increased (Adams and Hutton, 1985; McGill and Hoodless, 1990) due to compressive force exerted on the facet joints (Adams and Hutton, 1981). The etiology of torsional injuries includes: rupture of the disc annulus, rupture of posterior ligamentous tissues, damage to the facets joints (Bogduk, 1999) and/or joint capsule (Lannuzi and Khalsa, 2005). All of these injuries can lead to displacement of the neural elements to one side of the intervertebral canal, hence stretching or pinching the nerve roots. But yet, despite training initiatives to avoid asymmetrical lifts, workers often twist their trunks during lifts (Nordin et al., 1992; Wu, 2000).

* Corresponding author.
E-mail address: m.abdoli@ryerson.ca (M. Abdoli-E).

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During lifting tasks, both trunk and hip muscles provide extensor moments to lift the upper body upward. The trunk muscles provide good control over body movement, while the hip muscles provide an excellent mechanical advantage during lifting (Farfan, 1988). During lifting, the erector spinae must be assisted by additional musculoskeletal mechanisms to provide sufficient extensor moment. Some possible structures for additional moment contribution include: inter-abdominal pressure (White and Panjabi, 1990); contributions of muscles, discs and ligaments (McGill and Norman, 1986); thoracolumbar fascia and posterior ligamentous system (Gracovetsky et al., 1981) combined with intervertebral discs (Dolan et al., 1994); additional recruitment of non-primary agonistic muscles (Davis and Marras, 2000) and hydraulic effect of the cylindrical trunk (Bogduk, 1999). These structures have been shown to contribute 20–30% of the required trunk extensor torque. Although researchers have devoted considerable time to understanding the mechanisms causing LBP, the main remediation strategies recommended to date specific exercise regimes, worker education and ergonomic solutions.

The concept of off-loading the trunk musculature by some mechanical means, such as hoists, is one of the most common off-body ergonomic aids. The feasibility of on-body ergonomic aids is starting to be explored using non-motorized mechanisms (Abdoli-E et al., 2006a; Barrett and Fathallah, 2001) and motorized mechanisms (Kazerooni, 2002; Kawai and Yokoi, 2004). Some non-motorized devices are designed more for static holding tasks (Barrett and Fathallah, 2001), whereas Abdoli-E, 2006b have developed an on-body personal lift assistive device (PLAD) that is designed for both dynamic lifting and static holding tasks. The PLAD (see Fig. 1) has six elastic elements anchored at the shoulders and knees that are situated parallel to the erector spinae and hamstring muscles. The upper four elastic elements (two straight and two crossed) were held in place by the shoulder straps of a dismantled back pack and a pelvic spacer bar on the waist belt. The lower elastic elements travel from the pelvic spacer on the waist belt to anchors attached to the back of knee pads. The metal pelvic spacer created a 0.15 m moment arm at the pelvis so that the elastic elements had a mechanical advantage over the erector spinae. The four upper elastic elements, with an elastic coefficient (k) of 1610 N/m, were made of Theraband™ (Akron, OH, USA), while the two lower bands, with $k = 1800$ N/m, were bungee cords. All six elastic elements had strain gauges mounted in series at the waist belt to measure the applied stretching force during lifting tasks. Abdoli-E et al. (2007) proved mathematically that there should be erector spinae moment off-loading when the elastic elements were stretched during sagittal plane lifting. This result was confirmed with empirical testing whereby integrated L4/L5 moments amplitudes were reduced between 14% and 20% (Abdoli-E, 2006b) and integrated electromyography (iEMG) amplitudes of the left and right thoracic and lumbar erector spinae were reduced between 14.4% and 27.6% when lifting symmetric loads of 5, 15, and 25 kg Abdoli-E et al. (2006a).

The purpose of this investigation is to assess the PLAD's effectiveness for asymmetric lifting by examining the myoelectric activity of the back and abdominal muscles and the 3D moments at L4/L5 during lifts. It was hypothesized that the PLAD would not change erector spinae nor abdominal muscles activation on both ipsilateral and contra-lateral

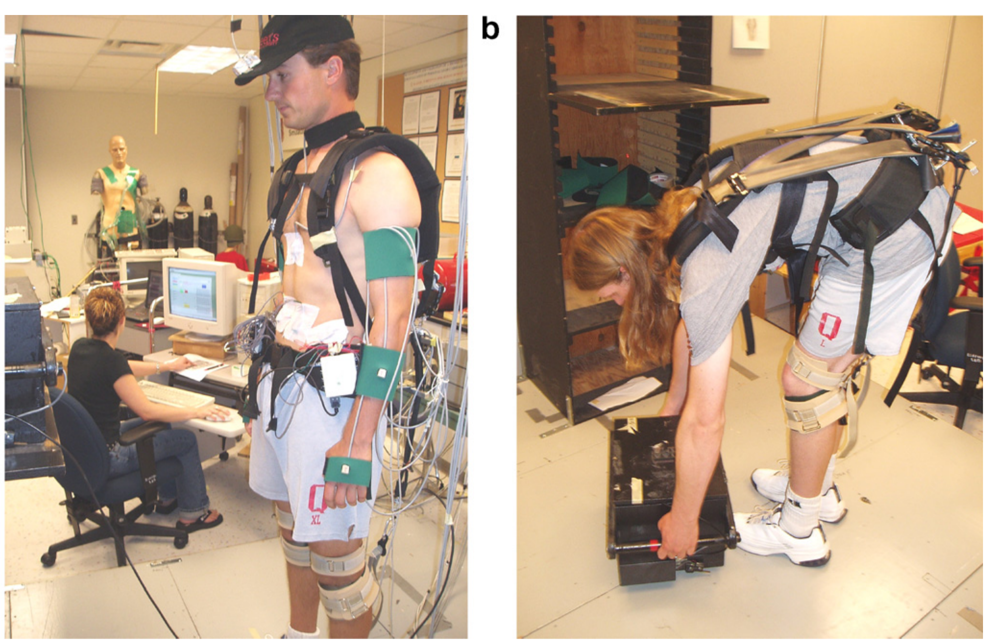
a b


Fig. 1. View of the personal lift assist device (PLAD) from the front (a) and rear (b). The shoulder straps and waist belt (made from back pack parts) are connected to the knee straps by elastic elements with strain gauges in series. A metal frame on the waist belt creates a longer moment arm for the elastic elements.