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Abdominal bracing during lifting alters trunk muscle activity and body kinematics

Pieter Coenen, PhD, Amity Campbell, PhD, Kevin Kemp-Smith, PhD, Peter O'Sullivan Prof, Leon Straker Prof *

School of Physiotherapy and Exercise Science, Curtin University, Perth, Australia

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We assessed whether participants are able to perform abdominal bracing during lifting, and described its effects on trunk muscle activity and body kinematics.

Fourteen participants performed 10 lifts (symmetrical lifting of a 15 kg load from floor level), 5 with abdominal bracing and 5 without. Activity of the lumbar multifidus (LM) and internal oblique (IO) muscles, and trunk and lower body kinematics were obtained.

During non-bracing lifting, IO activity did not increase beyond rested standing levels (with average muscle activity ranging between 8.2 and 9.1% maximum voluntary contraction; %MVC), while LM activity did (range: 8.5–21.0 %MVC). During bracing lifting, muscle activity was higher compared to non-bracing in IO and LM at the start of the lift (with average between condition differences up to 10.9 %MVC). Upper leg, pelvis and lumbar spine angles were smaller, but thorax flexion angles were larger while lifting with bracing compared to without (with average between condition differences ranging from 0.7° to 4.3°).

Although participants do not typically brace their abdominal muscles while lifting, they can be trained to do so. There appears to be no clear advantage of abdominal bracing during lifting, leaving its value for low-back pain prevention unclear.

1. Introduction

Low-back pain (LBP) is highly prevalent (Hoy et al., 2012) and is the worldwide leading cause of years lived with disability (Global Burden of Disease Study Collaborators,2015). Furthermore LBP places a large burden on our society (Murray et al., 2012) through care seeking and medication use (O'Sullivan et al., 2012), work disability (Matsudaira et al., 2012), sick leave (Geuskens et al., 2008) and early retirement (Picavet and Schouten, 2003).

Lifting heavy loads is generally considered to be an important predictor of LBP (Coenen et al., 2014a), as lifting tasks create substantial loading on the spine, in particular, when performed repetitively (Coenen et al., 2014b). Lifting is therefore often targeted in occupational safety and health guidelines (National Institute for Occupational Safety and Health, 2007; Safe Work Australia, 2011) and training (Verbeek et al., 2011), as well as in recommendations for lifting during household and sports activities (Behm and Anderson, 2006; Willardson, 2007). Some of this advice focuses on stabilizing the trunk during lifting (Aasa et al., 2015) with pre-activation of the abdominal wall muscles as a key element (McGill, 2002). This strategy is proposed to increase spinal stiffness, thereby reducing the impact of unwanted spinal perturbations and reducing the risk of injury during lifting (McGill, 1998). Therefore, exercises involving bracing of the abdominal muscles have been broadly adopted in clinical, ergonomic and athletic training strategies (Behm et al., 2010; Hibbs et al., 2008) and have formed a major focus of interventions for the prevention and management of LBP (McGill, 2002; Richardson and Jull, 1995).

Although the actual benefit of abdominal bracing has been questioned based on evidence collated in systematic reviews (Hibbs et al., 2008; Saragiotto et al., 2016), a number of laboratory studies have confirmed that muscle activation around the spine, such as abdominal bracing, can increase spinal stiffness (Vera-Garcia et al., 2006) and reduce spinal movements (Brown et al., 2006). These supposedly preventive mechanisms come however at the cost of increased spinal loading (Vera-Garcia et al., 2006) which may have negative consequences for spinal health and LBP

* Corresponding author. School of Physiotherapy and Exercise Science, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
E-mail address: L.Straker@curtin.edu.au (L. Straker).

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(Hodges et al., 2009). The current evidence therefore suggests that abdominal bracing may have both beneficial and detrimental impacts on the spine, potentially affecting the risk of LBP.

The aforementioned studies on muscle activation are mainly laboratory studies in which external loads are applied to the spine in non-functional tasks (Brown et al., 2006; Vera-Garcia et al., 2006). However, as far as we are aware the characteristics of abdominal bracing during functional lifting have not been studied yet. In the current study, we aimed to assess whether healthy people are able to perform abdominal bracing before and during lifting. Secondly, we aimed to assess the effect of abdominal bracing on trunk muscle activity and body kinematics during lifting. To do so, a laboratory study was conducted in which participants performed a series of lifting trials with and without abdominal bracing.

2. Methods

2.1. Participants

For a within-participants laboratory experiment, 16 healthy adults without a history of low-back, trunk, or lower limb symptoms (of musculoskeletal, neurological or vascular origin) in the 6 months prior to testing and/or any other co-morbidity that would prevent physical activity participation in the week prior to testing were recruited. This study population consisted of 7 females and 9 males with a mean (standard deviation) age of 27 (7) years, height of 170.7 (8.7) cm and mass of 68.1 (12.7) kg. These participants were asked to attend a single data collection session in the Curtin University motion analysis laboratory for a within-participants experiment of standardised lifting tasks. The study was approved by Curtin University Human Research Ethics Committee (PT0163/2011) and all participants provided written informed consent prior to participation.

2.2. Measurements

During the experiment, trunk muscle activity and body kinematics were collected simultaneously. After preparing the participant's skin through cleaning the skin with alcohol and light sand paper abrasion (Hermens et al., 1999), pairs of 12 mm diameter Ag-AgCl self-adhesive electrodes (Ambu A/S, Ballerup, Denmark) were attached to the skin parallel to the muscle fibres of the bilateral transverse fibres of the internal oblique (IO) and lumbar multifidus (LM) muscles. For IO, electrodes were placed 1 cm medial of the anterior superior iliac spines (ASIS), below a line connecting the left and right ASISs (Dankaerts et al., 2004). For LM, electrodes were aligned at the L5 level, directly superior to the posterior superior iliac spine (De Foa et al., 1989). For all electrode placements, skin impedance was assessed using an impedance meter, with <5 kΩ impedance considered acceptable (Dankaerts et al., 2004). Muscle activity was collected using a 8-channel Octopus Cable Telemetric Surface Electromyography (EMG) system (Bortec Electronics Inc., Calgary, Canada) with a cable telemetry system utilising analogue-differential amplifiers (frequency response: 10–1000 Hz, common mode rejection ratio: 115 dB). Muscle activity was sampled at a rate of 1000 Hz using Vicon Nexus software (Oxford Metrics Inc., Oxford, UK).

To be able to do EMG amplitude normalization, participants were asked to perform a series of maximum voluntary contraction (MVC) trials (Dankaerts et al., 2004). To generate a MVC of the IOs, participants were asked to lay supine with their lower limbs secured to a plinth using an adjustable belt. Participants were asked to lift their shoulders similar to when performing a curl sit-up, using as much force as possible against the manual resistance provided by researchers. For MVC of the LM muscles, the participants lay prone with their lower limbs secured. Participants were asked to lift their shoulders off the table, using as much force as possible against the manual resistance provided by researchers. For each muscle group, three MVC trials of three seconds each were obtained alternating LM and IO trials with two minutes rest between trials and the average contraction of the three tests used as the MVC for normalization (Dankaerts et al., 2004).

Lower limb, lumbar and thorax kinematics were collected using a 14-camera Vicon three-dimensional motion analysis system, operated at 250 Hz (Oxford Metrics Inc., Oxford, UK). Retro-reflective markers were affixed to anatomical landmarks on the participant's lower limbs, lumbar region and thorax as outlined previously (Besier et al., 2003), with placements known to be reliable (Wade et al., 2012) and in accordance to International Society of Biomechanics recommendations (Wu et al., 2002). For each participant, a static trial was collected for anatomical landmark calibration (Besier et al., 2003).

2.3. Protocol

A qualified physiotherapist instructed the participants in the technique of abdominal bracing (McGill and Karpowicz, 2009) with the assistance of a customised real-time EMG feedback program (LabView; National Instruments Inc., Austin, USA). Training was performed until the participant could contract their IO from rest to 30 ± 5% MVC without difficulty (typically 15–30 min s) (Vera-Garcia et al., 2006). The real-time EMG feedback program displayed a line graph of the relative strength of the left IO contraction (in %MVC) on a computer screen placed in view of the participant. Participants were led to believe that the feedback was generated from both left and right IO muscles. The vertical axis of the graph ranged from 0 to 100 %MVC, with the target contraction area of 30 ± 5% MVC being highlighted, according to recommendations (Richardson and Jull, 1995).

Participants were asked to perform a series of lifting trials in which a 15 kg load (10 kg bar with two 2.5 kg weights) was lifted from ground level. Participants were instructed to lift according to lifting guidelines (National Institute for Occupational Safety and Health, 2007; Safe Work Australia, 2011). This included being asked to place their feet shoulder width apart, to bend from through their lower limbs, and maintain the bar close to their body. Practice trials were performed to make participants familiar with the task, after which five lifting trials were performed without abdominal bracing (and no visual feedback) and five trials with abdominal bracing (with visual feedback). The trials without abdominal bracing were always performed prior to the ones with abdominal bracing to minimise the potential for the participant's natural technique to be influenced by the bracing trials. Lifting trials with abdominal bracing began with 20 s of 'pre-bracing' in order to achieve the required 30 ± 5% level. Once this level of bracing was achieved for a minimum of 3 s the participants executed the lifting trial, with the instruction to maintain the abdominal brace throughout the trial.

2.4. Data analyses

Prior to processing raw EMG data, a customised quality control program in conjunction with visual inspection was used to detect and eliminate possible contamination of the EMG signal by heartbeat and other artefacts. Raw EMG data were de-meaned, rectified, filtered with a 4 Hz low-pass filter, and normalized to MVC using a customized LabView program (National Instruments, Austin, USA).

Kinematic data were processed using Vicon Nexus software (Oxford Metrics Inc., Oxford, UK). Trajectories were checked for missing values, which were imputed using standard biomechanical