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In a dynamic lifting task, the relationship between cross-sectional abdominal muscle thickness and the corresponding muscle activity is affected by the combined use of a weightlifting belt and the Valsalva maneuver

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ABSTRACT

It has been shown that under isometric conditions, as the activity of the abdominal muscles increases, the thicknesses of the muscles also increase. The purpose of this experiment was to determine whether change in muscle thickness could be used as a measure of muscle activity during a deadlift as well as determining the effect of a weightlifting belt and/or the Valsalva maneuver on the muscle thicknesses. The *Transversus Abdominis* (TrA) and Internal Obliques (IO) muscles were analyzed at rest and during a deadlift. Muscle thickness was measured using ultrasound imaging and muscle activity was simultaneously recorded using electromyography. Each subject performed deadlift under normal conditions, while performing the Valsalva maneuver, while wearing a weightlifting belt and while both utilizing the belt and the Valsalva maneuver. There was no relationship between change in muscle thickness and muscle activity for both the TrA and IO ($R^2 < 0.13$ for all conditions). However it was found that the Valsalva maneuver increased abdominal muscle thickness whereas the belt limited muscle expansion; each with an increase in activity. These results indicate that ultrasound cannot be used to measure muscle activity for a deadlift and that the belt affects how the IO and TrA function together.

1. Introduction

The Abdominal wall is composed of three muscles from deep to superficial: the *Transversus Abdominis* (TrA), Internal Oblique (IO), External Oblique (EO), and the *Rectus Abdominis* (RA) (Stevens, 2006). These muscles are tightly bound flat muscles whose fibers run at oblique angles to one another (Brown et al., 2011). This muscle group plays a crucial role in reducing the load on the spinal column as well as increasing spinal stiffness (Brown et al., 2011; John and Beith, 2007; Lee and Kang, 2002; Richardson et al., 2002; Stevens, 2006). When the abdominal wall is activated and the glottis is closed (sealing the abdominal cavity), the intra-abdominal pressure (IAP) increases due to a decrease in volume of the abdominal cavity. This increase in pressure compresses the sacroiliac joints and creates tension in the thoracolumbar fascia in turn generating stiffness (Richardson et al., 2004). Additionally, the IAP allows forces on the spine, generated by a load, to be dispersed over the torso (Brown et al., 2011).

The Valsalva maneuver is a breathing pattern that involves forced exhalation against a closed glottis thereby increasing spinal stability by increasing the IAP (Hackett and Chin-Moi Chow, 2013). Free breathing (normal breathing cycle where glottis is open) generates significantly lower intra-abdominal pressures during resistance exercises compared with the intentional or unintentional use of the Valsalva maneuver (Cresswell and Grundstrom, 1992; Harman et al., 1988; McGill and Sharrat, 1990; Williams and Lind, 1987) In addition to increased intra-abdominal pressure, the Valsalva maneuver has also been shown to increase activation of the abdominal muscles (De Troyer et al., 1990; Lee and Kang, 2002).

Lumbar supports in occupational settings or, weight lifting belts in sport settings, are a widely used tool believed to allow for lifting heavier weights and preventing injury. Whereas employees often use low-back belts in jobs that require frequent and/or heavy lifting to reduce symptoms, prevent and/or treat chronic low back pain, athletes may use a weightlifting belt to help them lift heavier weights. The proposed mechanism(s) by which these belts help reduce the risk of injury (if at all) varies through the literature. These mechanisms include physically restricting the range of

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motion, increasing proprioception, increasing the IAP and acting as a placebo (Barron and Deurstein, 1991; Calmels et al., 2009; Cholewicki et al., 1999; van Poppel et al., 2000).

In order to understand how the abdominal muscles may function to create stiffness, attempts have been made to measure the activity of the three layers of muscle. To measure deep abdominal muscle activity accurately using electromyography, the use of fine-wire electrodes inserted into the muscle is required (Costa et al., 2009; Hodges and Richardson, 1999; Tsao, 2008). This process is costly and uncomfortable for the subject, especially if they are required to perform movements (Costa et al., 2009; Hodges and Richardson, 1999; Tsao, 2008).

Recently, studies have used ultrasound imaging to measure the change in muscle thickness in order to indirectly determine muscle activity (Bunce et al., 2002; Hodges et al., 2003; McMeeken et al., 2004; Teyhen, 2006). In addition, morphological changes in muscle have been correlated with EMG measurements in low level contractions [force up to 30% of one repetition maximum (1RM) (Bakke et al., 1992; Ferreira et al., 2004; Hodges et al., 2003; McMeeken et al., 2004)], and have been found to be a reliable method to measure muscle activity (Bunce et al., 2002). More specifically, McMeeken and colleagues compared fine wire EMG data of the TrA with synchronized ultrasound motion recordings of subjects executing the abdominal hollowing maneuver. They found a linear relationship between TrA thickness and EMG activity (McMeeken et al., 2004). Moreover, Hodges et al. fit an increasing logarithmic regression to the relationship of IO muscle thickness and TrA with their respective EMG activities (Hodges et al., 2003).

Based on the current literature it is clear that the relationship between the electrical activity of a muscle and its thickness has been thoroughly researched for isometric contractions. However, the relationship between morphological changes and EMG activity in the abdominal wall muscles remains unknown for dynamic conditions. The purpose of this study is to determine if measuring the change in muscle thickness can be used to measure muscle activity and observe the effects of wearing a weightlifting belt and closing the glottis on the relationship between the IO and TrA and their electrical activity.

2. Methods

2.1. Subjects

Twenty-one healthy subjects were recruited from various varsity sports teams at a Canadian University. However, the data from 10 participants was not used because during the testing process, the head of the ultrasound transducer would sometimes shift on the skin and render the images unclear and unmeasurable. Subjects were excluded from the study if they had chronic low back pain, or had experienced any type of low back injury requiring surgical intervention. Out of the eleven remaining participants, three were women and the overall mean age was 20 years. Each subject signed the informed consent and the university Ethics Review Board approved the study.

2.2. Equipment

A real-time ultrasound scanner was used with a 7.5 MHz linear head transducer (Rising Medical Co Ltd., RUS-9000F) to determine muscle thickness as well as the Shimmer wireless EMG system to measure electrical muscle activity. Specifications for the Shimmer EMG system can be found in Table 1. A standard 12.7 cm (5 in.) weightlifting belt and Olympic style weightlifting equipment consisting of a 20 kg bar and bumper plates of weight appropriate (30%) to the individual's 1RM were used for the testing procedure.

Table 1
Shimmer EMG system specifications.

Current draw	180 μA (leads connected)
Gain	682
Max signal range before clipping	4.4 mV
Frequency range	5–482 Hz
Ground	Wilson Type Driven Ground
Input protection	ESD and RF/EMI filtering, Current limiting
Connections	Input (+), Input (−), Reference

2.3. Pilot studies

Pilot studies confirmed that the TrA, IO and EO could be viewed and measured at once while performing a deadlift with and without a weightlifting belt in both B (bright) and M (motion) modes. In B-mode (brightness mode) ultrasound, a linear array of transducers scans a plane through the body that can be viewed as a two-dimensional image. Whereas In M-mode (motion mode), pulses are emitted in quick succession – each time, a B-mode image is taken. Over time, this results in a video recording. The muscle boundaries move relative to the probe and this can be used to view structural changes over a period of 4 s. The location found to show the clearest image of the three muscles together was 25 mm anterior from the midpoint between the twelfth rib and the iliac crest of the anterolateral abdominal wall. This has been the scanning point in previous studies (Critchley and Coutts, 2002).

2.4. Testing procedure

Once the subject had consented to the study, the scan point was identified and resting measurements were taken of the abdominal wall with B mode at the end of a normal inspiration with the patient in a supine position. Following resting measurements, their 1RM was determined based on discussions with the athletes after their testing sessions with the varsity strength and conditioning staff. From these results, 30% was calculated which would be the weight lifted during the exercise. To prepare for EMG measurement, the skin over the anterior superior iliac spine was shaved with a disposable razor and cleaned with an alcohol swab. Subsequently, the maximum voluntary isometric contraction (MVIC) was determined for EMG measurements by asking the participant to contract their abdominal muscles as hard as possible while lying in the supine position with legs extended as in Dankaerts et al. (2004). This group found that both MVIC and sub-MVIC contractions, using this position, had excellent within-day reliability in both intra class correlation (mean = 0.91) and standard error of measurement (mean 5%).

Although participants were familiar with the exercise, and performed it as a part of regular workouts, the tester demonstrated the deadlift and the subject was instructed to practice in order to ensure proper form. They were also taught how to perform the Valsalva maneuver.

After this preparation phase, the test began with a series of lift presented in random order: a control lift where the subject was asked to perform a deadlift without the use of the weightlifting belt or the Valsalva maneuver; a "Valsalva" condition where the subject executed a deadlift while utilizing the Valsalva maneuver; the "Belt" condition where the participant performed the lift while wearing the 12.7 cm weight lifting belt; and the final condition involved wearing the belt and the use of the Valsalva maneuver to perform the lift. This was referred to as the "Both" condition.

In order to synchronize the Ultrasound measurements with the EMG data, the participants were instructed to suddenly contract their abdominal muscles and then suddenly relax prior to performing the deadlift. This elicited a clear reaction in both datasets and