Interaction Between Thoracic Movement and Lumbar Spine Muscle Activation Patterns in Young Adults Asymptomatic for Low Back Pain: A Cross-Sectional Study

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Abstract

Objective: The purpose of this study was to investigate the interaction between thoracic movement and lumbar muscle co-contraction when the lumbar spine was held in a relatively neutral posture.
Methods: Thirty young adults, asymptomatic for back pain, performed 10 trials of upright standing, maximum trunk range of motion, and thoracic movement tasks while lumbar muscle activation was measured. Lumbar co-contraction was calculated, compared between tasks, and correlated to thoracic angles.
Results: Movement tasks typically exhibited greater co-contraction than upright standing. Co-contraction in the lumbar musculature was 67%, 45%, and 55% greater than upright standing for thoracic flex, thoracic bend, and thoracic twist, respectively. Generally, the thoracic movement task demonstrated greater co-contraction than the maximum task in the same direction. Co-contraction was also correlated to thoracic angles in each movement direction.
Conclusion: Tasks with thoracic movement and a neutral lumbar spine posture resulted in increases in co-contraction within the lumbar musculature compared with quiet standing and maximum trunk range-of-motion tasks. Findings indicated an interaction between the 2 spine regions, suggesting that thoracic posture should be accounted for during the investigation of lumbar spine mechanics. (J Manipulative Physiol Ther 2019;42:461-469)
Key Indexing Terms: *Spine; Biomechanical Phenomena; Electromyography; Superficial Back Muscles; Abdominal Muscles; Muscle Contraction*

Introduction

The body of literature surrounding the thoracic spine is growing,[1-6] although few studies have investigated thoracic influence on the lumbar spine. Considering the thoracic and lumbar spines are closely linked and function in tandem to achieve specific motion patterns, it is logical that thoracic motion may affect the behavior of the lumbar spine.[2] However, most studies have focused on only lumbar[7,8] or general trunk motion.[9-11] Thoracic motion tasks may provide an opportunity to more clearly elucidate the interaction between thoracic motion and muscle activation patterns in the lumbar spine.

Muscle co-contraction, or the concurrent activation of the opposing muscles around a joint,[12] represents a measure of activation patterns. Co-contraction serves various functions, such as equilibrating the moments created by agonist muscles in other axes, stiffening spinal joints, and increasing spinal stability.[13-16] Although beneficial to the spine in some respects, there are also penalties to co-contraction, such as increased compressive forces in spinal joints,[17] increased metabolic cost,[12,18] and inefficiency of movement.[19] The resulting fatigue may impair muscle coordination,[20] which may reduce spinal stiffness and stability.[21,22] A further increase in co-contraction is then necessary to maintain an appropriate level of spinal stability at the expense of additional spinal compression.[21] As such, it appears that a balance between too little and too much co-contraction is necessary to maintain sufficient spinal stability without excessive levels of compression or fatigue, thereby minimizing the risk for injury.

There is general agreement within the literature that individuals with low back pain (LBP) and those in remission from LBP, demonstrate altered neuromuscular

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control during various tasks.[10,14,23-25] Increased global[23] and localized lumbar[10] co-contraction has been identified in individuals with LBP relative to healthy participants. Further, links between co-contraction and both transient and clinical LBP have been identified. Nelson-Wong and Callaghan[26] and Schinkel-Ivy et al[27] assessed co-contraction in prolonged standing and sitting exposures, respectively. In both contexts, individuals who developed pain over the course of the exposure demonstrated greater co-contraction within the trunk musculature.[26,27] In a follow-up study, Nelson-Wong and Callaghan[28] concluded that pain development during prolonged standing was predictive of future clinical LBP in the following 3 years.

Although previous literature has established the importance of co-contraction in both injury and pain development in the low back, the thoracic spine has been largely neglected in this body of literature; no study to date has examined the interaction between thoracic movement and lumbar behaviors with respect to muscle activation patterns. Owing to the potential clinical implications relating to spine injury risk, measures of co-contraction in the lumbar spine provide crucial information about neuromuscular control, and therefore warrant further investigation. Therefore, the purpose of this study was to examine the interaction between thoracic movement and co-contraction in the lumbar musculature. Further, this study aimed to quantify the relationships between the angles of the thoracic spine and co-contraction within the lumbar spine.

Methods

Participants

Fifteen men and 15 women participated in the study (mean [standard deviation] age, height, and weight for men/women were 25.0 [3.8] years/22.8 [2.7] years, 79.64 [8.75] kg/59.12 [6.38] kg, and 1.80 [0.05] m/1.66 [0.05] m, respectively). This sample size was deemed sufficient based on power analyses using co-contraction data from Silvestri et al,[29] α of 0.05, and power of 0.80 (G-Power version 3.1, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). All participants were right-hand dominant and had been asymptomatic for back pain for at least 1 year before the collection, in that they had not missed any days of school or work owing to, or sought treatment for, back pain. All procedures were approved by York University's Office of Research Ethics, and informed consent was obtained from all participants before collection. Data were collected as part of a larger study investigating trunk muscle activation and 3-dimensional motion.[30-33]

Instrumentation

Clusters of 5 markers were attached to the skin using double-sided tape over the spinous processes of the C_7, T_3, T_6, T_9, T_{12}, and L_5 vertebrae.[30,32,33] Each cluster consisted of a base from which 4 markers projected in a rectangular pattern (top left, top right, bottom left, bottom right) and a fifth marker projected posteriorly. Markers were also placed on the head (left and right front and back of the head, middle back of the head), pelvis (iliac crests, anterior superior iliac spines), trunk (acromia, sternum, T_{10} vertebra), and legs (greater trochanters, lateral and medial knee joint spaces, lateral malleoli, 4 on each thigh). For the present study, the clusters at the C_7, T_{12}, and L_5 vertebrae were used in the calculation of thoracic and lumbar angles.[30,33] Marker motion was recorded using a 7-camera Vicon motion capture system (Vicon MX, Vicon Systems Ltd, Oxford, United Kingdom) at a sampling rate of 50 Hz.

Participants were instrumented with 16 pairs of disposable electromyography (EMG) Ag/Ag-Cl electrodes (Ambu BlueSensor N, Ambu A/S, Ballerup, Denmark) over 8 muscles bilaterally[31]: external oblique (EO),[34,35] internal oblique (IO),[34] latissimus dorsi,[34] lumbar erector spinae (lumbar ES),[35,36] lower-thoracic erector spinae,[34,36] rectus abdominis (RA),[35] upper trapezius,[37] and upper-thoracic erector spinae.[36,38] Only the EO, IO, lumbar ES, and RA were of interest for the present study as muscles whose function predominantly affect the lumbar spine. The EMG signals were differentially amplified (frequency response 10-1000 Hz, common mode rejection 115 dB at 60 Hz, input impedance 10 GΩ; model AMT-8, Bortec Biomedical, Calgary, Canada) and sampled at 2400 Hz (Vicon MX, Vicon Systems Ltd, Oxford, United Kingdom).

Procedures

Electrode sites were shaved and swabbed with rubbing alcohol before electrode application to promote adherence and reduce skin impedance. Maximum voluntary contractions (MVCs) were then elicited for each muscle. For the trunk flexors, a modified sit-up protocol was performed in which participants isometrically flexed, bent, and twisted the trunk against manual resistance.[39] For the trunk extensors, the trunk was cantilevered off the end of a therapy table, and participants performed a resisted isometric back extension.[39] Three trials lasting 3 to 5 seconds were performed for each exercise, with rest between each trial to minimize the effects of fatigue. The MVC for each muscle consisted of the maximum EMG value from any of the 3 trials.

After marker application, participants performed a kinematic calibration trial consisting of quiet standing with the arms abducted to 90° (T-pose). Ten trials each of upright standing (upright) and standing maximum trunk range-of-motion and thoracic movement tasks in each plane of movement (maximum flexion [MaxFlex], maximum bend [MaxBend], maximum twist [MaxTwist]; thoracic flexion [ThorFlex], thoracic bend [ThorBend], thoracic twist [ThorTwist]) were then completed, totaling 70 trials. Trials were presented in a random order, and all bending and twisting was performed to the right side. Upright trials were 10 seconds in length. The arms hung to the floor for MaxFlex and MaxBend, and at the sides for upright, MaxTwist, and thoracic movement tasks. For all movement tasks, participants first moved the head in the direction of motion, then continued to move either the trunk or thoracic spine to its full range of motion in a smooth, continuous motion. For the thoracic movement tasks, participants were required to maintain the lumbar spine in an upright, neutral position to the greatest extent possible, which was monitored by an investigator. Each movement trial lasted for approximately 10 seconds, during which participants moved to the position, held the position for 3 seconds, and moved back to their starting upright position. Full instructions and time for practice were given to participants before the protocol. Throughout the protocol, prompts were given to the participant before each trial.

Data Processing

Kinematic data were processed using Visual3D version 4 (C-Motion, Inc, Germantown, Maryland). Thoracic and lumbar angles were calculated as the relative angles between the local coordinate systems created by the C_7 and T_{12} clusters (thoracic) and T_{12} and L_5 clusters (lumbar).[30,33] The angle time-series data were low-pass filtered with a dual-pass, fourth-order Butterworth filter (cut-off frequency: 2.5 Hz, determined by residual analysis[40]). The mean thoracic and lumbar angles for upright were calculated and all experimental trials were zeroed to these values. The mean angles during the holding phase of each movement trial were then determined.

Initial processing of the EMG data was also completed using Visual3D version 4 (C-Motion, Inc). Contamination from heart rate within the raw EMG data was minimized by applying a dual-pass, fourth-order high-pass Butterworth filter (cut-off frequency: 30Hz[41]). Data were then full-wave rectified and low-pass filtered using a dual-pass, fourth-order low-pass Butterworth filter (cut-off frequency: 2.5Hz[42]). The MVC for each muscle was identified and used to normalize the EMG signals from the experimental trials, yielding a percentage of each individual's maximum activation levels (%MVC). The EMG data were then down-sampled as a data reduction measure[26] from 2400 Hz to 50 Hz.[27]

The present study defined co-contraction as the concurrent activation of 2 muscles.[12,29,43,44] The co-contraction index (CCI) (Equation 1) quantifies the extent to which 2 muscles are concurrently activating over a specified number of data points.[26,27,29,43] The CCI quantifies the similarities of the EMG signals from the pair of muscles for 2 characteristics: activation level (% MVC) and activation timing.[27,44,45] The output of the CCI is a single value for the period that incorporates both characteristics (although it does not provide a means of quantifying either characteristic separately). Higher values represent scenarios in which 2 muscles are activated with similar timing for a long period, one or both muscles is activated at a high level, or a combination thereof.[29] The highest outputs are produced when 2 muscles activate at high magnitudes and with similar timing over the interval.[44] The maximum CCI that can be obtained in a single frame occurs when both muscles activate to 100%, resulting in a CCI of 200%MVC [(100 / 100)(100 + 100)]. Because the CCI equation is cumulative over time,[44] the maximum value that could possibly be attained for a task in the present study (100 frames) was 20,000 %MVC

$$CCI = \sum_{i=1}^{N} \left(\frac{\text{EMG\_low}(i)}{\text{EMG\_high}(i)} \right) [\text{EMG\_low}(i) + \text{EMG\_high}(i)] \tag{1}$$

where N is the number of data points and EMG_{low} and EMG_{high} are the relative magnitudes of the normalized EMG for the 2 muscles in the pairing (EMG_{low} and $EMG_{high}$are the signals with the lower and higher magnitude at each sample in time, respectively).[26,43]

For the present analysis, CCIs (expressed as %MVC) were calculated for every possible pairing within the lumbar spine (left/right EO, IO, lumbar ES, RA) using a custom program written in Matlab version 2012a (The MathWorks, Inc, Natick, Massachusetts) for a total of 28 pairings. A standardized number of frames[10,43] were used to ensure that CCI values were comparable between tasks. For the upright standing trials, 100 frames[43] from the middle portion of the trial were analyzed. For the movement trials, the hold phase was time-normalized to 200 frames, with the middle 100 frames used for CCI calculation to avoid the transitional stage between the movement and the holding phase. The analysis yielded 28 CCI values for each trial, and each CCI was then averaged within the 10 trials for each of the 7 movement tasks.

Data Analysis

Statistical analyses were performed using IBM SPSS Statistics version 21 (IBM Corp, Armonk, New York). The angles and CCIs were input into mixed-factor analyses of variance with a within-subject factor of task (upright, MaxFlex, MaxBend, MaxTwist, ThorFlex, ThorBend, and ThorTwist) and a between-group factor of sex. Data were collapsed across sex when there was no significant effect of that factor. Greenhouse-Geisser corrections were used to calculate the degrees of freedom when the assumption of sphericity was not achieved. The α was set to 0.05, and pairwise comparisons with Bonferroni corrections were used for post hoc testing. In addition, the relationships between the maximum thoracic angles for both tasks in each direction of movement and the CCIs for the lumbar muscles were determined using Pearson product moment correlations. Pearson coefficients (r) were considered to be very weak, weak, moderate, strong, and very strong when falling

Table 1. *Mean (SD) Thoracic and Lumbar Angles (Degrees) Obtained During Each Task in the Movement Plane of Interest (Flexion for MaxFlex and ThorFlex, Lateral Bend for MaxBend and ThorBend, Axial Twist for MaxTwist and ThorTwist)*

Angle	Sex	Task		
Flexion		Upright	MaxFlex	ThorFlex
Thoracic ($F_{3.595,104.242}$ = 171.52, P < .001)	–	-0.07 (0.25)	18.53 (10.64) [a]	36.11 (10.82)[a,b]
Lumbar ($F_{3.308,95.923}$ = 172.54, P < .001)	–	-0.02 (0.17)	49.52 (11.99) [a]	22.32 (9.45)[a,b]
Lateral bend		Upright	MaxBend	ThorBend
Thoracic ($F_{2.964,85.945}$ = 168.98, P < .001)	–	0.00 (0.11)	26.53 (7.64) [a]	27.95 (6.48) [a]
Lumbar ($F_{3.551,99.423}$ = 3.171, P = .021)	Male	-0.02 (0.05)	20.32 (4.41) [a]	3.79 (3.91) [b]
	Female	0.01 (0.10)	23.55 (6.26) [a]	5.44 (6.10)[a,b]
Axial twist		Upright	MaxTwist	ThorTwist
Thoracic ($F_{3.002,84.049}$ = 9.438, P < .001)	Male	-0.02 (0.17)	56.78 (10.87) [a]	51.16 (12.20) [a]
	Female	0.00 (0.13)	39.78 (9.22) [a]	35.84 (7.70) [a]
Lumbar ($F_{3.252,91.053}$ = 13.273, P < .001)	Male	0.00 (0.10)	-8.70 (6.11) [a]	-5.88 (3.44) [a]
	Female	-0.02 (0.14)	-1.81 (5.30)	1.06 (6.08)

Positive values indicate flexion, lateral bend to the right, and axial twist to the right. Thoracic and lumbar flexion angles and thoracic lateral bend comparisons represent a main effect of task; lumbar lateral bend and thoracic and lumbar axial twist comparisons represent an interaction between task and sex.
MaxBend, maximum bend; *MaxFlex*, maximum flexion; *MaxTwist*, maximum twist; *SD*, standard deviation; *ThorBend*, thoracic bend; *ThorFlex*, thoracic flexion; *ThorTwist*, thoracic twist.
[a] Significant difference from upright standing.
[b] Significant difference from maximum trunk range-of-motion movement task (P < .05).

into the ranges of 0.00 to 0.19, 0.20 to 0.39, 0.40 to 0.59, 0.60 to 0.79, and 0.80 to 1.00, respectively.[46]

Results

Significant main effects of task or task-by-sex interactions were identified for both thoracic and lumbar angles for all movement directions (Table 1). Generally, the angles achieved in the maximum and thoracic movement tasks were significantly greater than those in upright.

Significant main effects of task were identified for 16 of the 28 pairings within the lumbar spine; significant task-by-sex interactions were identified for 5 pairings (Table 2). Co-contraction within the lumbar muscle pairings ranged from 255.83 %MVC (177.87) to 2781.97 %MVC (1927.40) (Table 3). The CCIs were always greater in movement tasks compared with upright, when significant differences were identified. For the flexion and bending directions, significant pairwise comparisons indicated that the thoracic movement task produced greater levels of lumbar co-contraction than the corresponding maximum trunk range-of-motion task, whereas the opposite trend was observed for the twisting direction. The CCIs ranged from 16.46% (16.31) (MaxFlex) to 86.92% (48.80) (MaxTwist) greater than upright.

Of the 28 pairings within the lumbar musculature, the CCIs for 8, 9, and 3 pairings were significantly correlated to thoracic angle for the flexion, lateral bend, and axial twist movements, respectively (Table 4). All significant correlations were of weak or moderate strength, ranging from r = 0.27 to r = 0.46.

Discussion

Overall, participants displayed higher levels of lumbar co-contraction in the movement tasks compared to upright, ranging from 16% (MaxFlex) to 87% (MaxTwist) when averaged across all pairings. Although it was not possible with our study design to distinguish between co-contraction occurring specifically as a result of the movement of the thoracic spine, versus that required to maintain a neutral lumbar posture, these findings suggest an interaction between the 2 spine regions and may have implications for the study of spinal mechanics. Furthermore, as high levels of muscle activity may be associated with the development of LBP,[26,27] the results of this study may provide an indication of tasks that should potentially be avoided to decrease the risk of LBP or injury.

The present study differed from past investigations in the tasks examined and the method of co-contraction

Table 2. *ANOVA Statistics for All Lumbar Muscle Pairings With a Significant Effect of Task on Co-contraction (P < .05)*

Muscle Pairing	Effect	*F*-Statistic
Left EO–left IO	Task	$F_{3.585,103.951} = 5.20, P = .001$
Left EO–left LES	Task	$F_{3.125,90.616} = 11.27, P < .001$
Left EO–left RA	Task	$F_{3.217,93.292} = 3.13, P = .026$
Left EO–right EO	Task	$F_{2.326,67.451} = 15.59, P < .001$
Left EO–right IO	Task × sex	$F_{2.622,73.420} = 7.70, P < .001$
Left EO–right LES	Task	$F_{3.305,95.843} = 19.34, P < .001$
Left EO–right RA	Task	$F_{3.387,98.231} = 1.59, P = .19$
Left IO–left LES	Task × sex	$F_{3.659,102.464} = 2.90, P = .029$
Left IO–left RA	Task	$F_{2.158,62.573} = 1.54, P = .22$
Left IO–right EO	Task	$F_{3.451,100.080} = 2.89, P = .033$
Left IO–right IO	Task	$F_{2.838,82.301} = 2.60, P = .061$
Left IO–right LES	Task	$F_{3.711,107.605} = 15.47, P < .001$
Left IO–right RA	Task	$F_{2.386,69.208} = 1.95, P = .14$
Left LES–left RA	Task × sex	$F_{3.312,92.745} = 3.82, P = .010$
Left LES–right EO	Task	$F_{2.817,81.679} = 12.23, P < .001$
Left LES–right IO	Task × sex	$F_{3.027,84.743} = 3.11, P = .030$
Left LES–right LES	Task	$F_{2.997,86.924} = 18.29, P < .001$
Left LES–right RA	Task	$F_{3.302,95.767} = 13.88, P < .001$
Left RA–right EO	Task	$F_{3.105,90.041} = 3.35, P = .021$
Left RA–right IO	Task	$F_{2.172,62.985} = 1.26, P = .29$
Left RA–right LES	Task	$F_{2.536,73.548} = 16.75, P < .001$
Left RA–right RA	Task	$F_{2.615,75.834} = 5.01, P = .005$
Right EO–right IO	Task	$F_{1.510,43.788} = 10.04, P = .001$
Right EO–right LES	Task	$F_{2.697,78.205} = 21.06, P < .001$
Right EO–right RA	Task	$F_{3.551,102.991} = 2.31, P = .070$
Right IO–right LES	Task	$F_{2.556,74.126} = 26.53, P < .001$
Right IO–right RA	Task	$F_{2.610,75.679} = 1.93, P = .14$
Right RLES–right RA	Task x sex	$F_{2.669,74.741} = 3.59, P = .021$

ANOVA, analysis of variance; *EO*, external oblique; *IO*, internal oblique; *LES*, lumbar erector spinae; *RA*, rectus abdominis.

calculation. Previously, trunk muscle co-contraction has been examined during isometric trunk exertions,[16,47-49] maximum trunk flexion-extension,[10] or prolonged low-level exposures[26,27] as opposed to using thoracic movement tasks to investigate interactions with the lumbar spine. Thoracic movements are relatively common during activities of daily living and occupational tasks, although it is likely that individuals would not consciously target those body positions, but instead use the movements as a means of accomplishing an outcome task. Regarding co-contraction calculation, several approaches group muscles together to produce global co-contraction measures,[16,23,47-50] as opposed to quantifying co-contraction between 2 muscles through the co-contraction index.[10,26,27,43] Although generalized flexor-extensor co-contraction measures have been recommended for the knee joint,[50] these muscles function primarily as flexors or extensors. This approach may not be as suitable in the trunk, in which muscles contribute to multiplanar motion. Therefore, analyzing individual muscle pairings to identify common trends may constitute a more appropriate means of investigating trunk muscle co-contraction. The co-contraction magnitudes calculated in the present study were comparable to previously reported CCI values when accounting for differences in experimental tasks.[26,27] The values reported in the present study represent approximately 1.3% to 13.9% of the maximum CCI that could theoretically be obtained over 100 frames of data (20,000 %MVC).

Thelen et al[16] reported co-contraction ratios of 25% to 29%, 35% to 46%, and 46% to 58% during isometric trunk flexion, lateral bend, and axial twist, respectively. Similarly, Graham et al[10] observed higher co-contraction in asymmetric trunk flexion than symmetric flexion. The results for the maximum trunk range-of-motion tasks followed a similar trend, in that the flexion and twisting tasks demonstrated the lowest and highest CCIs, respectively. The twisting tasks likely required the muscles to contract against the forces of passive tissues and opposing muscles while holding the posture,[29] as opposed to the flexion and bending postures, which would have been assisted by gravity to an extent. The thoracic movement tasks displayed a different pattern, in which the lowest and highest average CCIs were identified for ThorBend and ThorFlex. The lumbar flexion angles (on average, 22°) during the ThorFlex task may have contributed to these findings by creating a greater moment around the lumbar spine, thereby requiring greater levels of activation to maintain the posture. Conversely, the smaller moments in ThorBend and ThorTwist may have required less activation in the lumbar musculature to maintain the posture. When comparing the maximum trunk and thoracic movement tasks within each direction, greater co-contraction was identified in the flexion and bending thoracic movement tasks relative to the equivalent maximum trunk range-of-motion tasks. Increased activation may have been required in the lumbar spine during thoracic flexion and bending to counteract the moments created by the mass of the trunk and provide support to the lumbar spine to maintain the

Table 3. *Mean (SD), Minimum, and Maximum CCI Values (%MVC) and Difference From Upright Standing (%) for All Possible Pairings of Lumbar Muscles (28 in Total)*

Task	Overall Mean (SD) CCI (%MVC)	Minimum (SD) CCI (%MVC)	Maximum (SD) CCI (%MVC)
Upright	601.84 (226.87)	331.91 (192.81)	972.90 (760.35)
MaxFlex	723.62 (329.05)	255.83 (177.87)	1154.21 (546.26)
MaxBend	771.49 (346.68)	338.34 (171.44)	1558.87 (1113.11)
MaxTwist	1063.80 (395.63)	493.75 (162.09)	2781.97 (1927.40)
ThorFlex	917.88 (185.78)	560.38 (209.61)	1429.61 (1210.34)
ThorBend	847.57 (291.48)	476.44 (206.48)	1554.90 (1037.18)
ThorTwist	900.05 (322.67)	444.17 (174.55)	1939.81 (1701.30)
	Mean (SD) % Difference From Upright Standing	Minimum % Difference From Upright Standing	Maximum % Difference From Upright Standing
MaxFlex	16.46 (16.31)	-22.92	51.11
MaxBend	25.70 (18.68)	-0.08	75.74
MaxTwist	86.92 (48.80)	14.26	259.29
ThorFlex	66.78 (44.98)	15.61	185.69
ThorBend	45.03 (22.41)	13.59	147.28
ThorTwist	55.26 (30.27)	6.47	150.53

CCI, Co-contraction Index; *MaxBend*, maximum bend; *MaxFlex*, maximum flexion; *MaxTwist*, maximum twist; *MVC*, maximum voluntary contraction; *SD*, standard deviation; *ThorBend*, thoracic bend; *ThorFlex*, thoracic flexion; *ThorTwist*, thoracic twist.

static position. Alternatively, it is possible that during the maximum trunk flexion task, the lumbar ES muscles underwent flexion-relaxation or quieting of the muscles near the end range of trunk motion[51]; this would have resulted in reduced co-contraction during this task.

Although it is intuitive that lumbar co-contraction would differ between upright and movement tasks, the extent of the differences was of interest. Co-contraction in the lumbar musculature during the movement tasks ranged from approximately 16% (MaxFlex) to 87% (MaxTwist) greater than upright, with the thoracic movement trials displaying differences of 67% (ThorFlex), 45% (ThorBend), and 55% (ThorTwist). These findings suggest that when maintaining a neutral posture in the lumbar spine and moving the thoracic spine, there may be a requirement for increased spinal stiffness and stability in the lumbar spine, which may be achieved through increased muscle stiffness resulting from co-contraction.[52] Over time, greater levels of co-contraction, the corresponding increased metabolic cost,[12,18] and resulting fatigue may introduce a cycling effect. Fatigue has been observed to impair muscle coordination,[20] thereby reducing spinal stiffness and stability.[21,22] In turn, co-contraction may be further increased to maintain an appropriate level of stability, contributing to additional fatigue. Taken together, this process may represent an increased risk for pain or injury in the low back.

These findings are important in the investigation of lumbar spine mechanics because thoracic spine movement combined with a neutral lumbar spine posture may contribute to altered muscle activation behavior of the lumbar spine. Furthermore, individuals with LBP, and those in remission from LBP, have been shown to demonstrate altered neuromuscular control during various tasks.[10,14,23-25] Although this study focused on individuals who were asymptomatic for LBP, the increases in co-contraction resulting from the thoracic movement tasks, coupled with the increased co-contraction often observed during the development of LBP,[26,27] may act to further increase fatigue and risk of pain and injury. Therefore, future work should seek to quantify lumbar co-contraction in individuals with LBP to be compared with the data reported in the present study.

Clinical Application

We suggest that exposure to the thoracic movement tasks tested in this study should be limited during occupational tasks or activities of daily living, especially in those with LBP, because lumbar co-contraction increased even while the low back remained in a neutral posture, and may thereby increase risk of LBP or injury.

Table 4. *Significant Correlations Between Thoracic Angles and Co-contraction in the Lumbar Musculature for Each Direction of Movement*

Muscle/Muscle Pairing	*r* (*P* Value)
Flexion	
Left IO–left LES	0.27 (.04)
Left LES–left RA	0.31 (.02)
Left LES–right EO	0.29 (.02)
Left LES–right LES	0.38 (.003)
Left LES–right RA	0.44 (<.001)
Left RA–right LES	0.33 (.01)
Right EO–right LES	0.33 (.01)
Right LES–right RA	0.46 (<.001)
Lateral bend	
Left EO–right LES	0.35 (.01)
Left IO–right EO	0.29 (.02)
Left IO–right LES	0.33 (.01)
Left LES–right LES	0.28 (.03)
Left RA–right LES	0.32 (.01)
Right EO–right IO	0.30 (.02)
Right EO–right LES	0.32 (.01)
Right IO–right LES	0.38 (.003)
Right LES–right RA	0.37 (.003)
Axial twist	
Left EO–right LES	0.35 (.01)
Left IO–right EO	0.29 (.02)
Left IO–right LES	0.33 (.01)

EO, external oblique; *IO*, internal oblique; *LES*, lumbar erector spinae; *RA*, rectus abdominis.

Limitations

Methodologically, the study was limited by the sample of participants, who constituted a relatively homogeneous group of young individuals asymptomatic for back pain. However, it is well established in the literature that muscle activation patterns differ between asymptomatic individuals and those with LBP.[10,14,23-25] Therefore, the results may not generalize to individuals with LBP, and future work should aim to clarify thoracic-lumbar interactions in this population. Further, the thoracic movement tasks may have been relatively novel for participants. Although these types of movements are relatively common during activities of daily living, it is likely that individuals would not consciously target those body positions, but instead use the movements as a means of accomplishing an outcome task. This novelty may have affected the performance of these tasks relative to upright standing or the maximum trunk range-of-motion tasks. In addition, the lumbar position was not externally constrained during the thoracic movement tasks, resulting in small amounts of lumbar movement in the same direction as the thoracic spine. Our study design did not allow for delineation between the co-contraction resulting from the thoracic movement versus that required to maintain lumbar spine posture; future work may aim to distinguish between these 2 sources of co-contraction.

Conclusion

Lumbar muscle co-contraction differed between upright standing and thoracic movement tasks, with average increases of 67% (ThorFlex), 45% (ThorBend), and 55% (ThorTwist) from upright. These results suggest an interaction between the 2 spine regions during thoracic spine movement when the lumbar spine is held in a neutral position, and that thoracic spine posture should be accounted for during the investigation of lumbar spine mechanics.

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Contributorship Information

Concept development (provided idea for the research): A.S.-I., J.D.M.D.

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Data collection/processing (responsible for experiments, patient management, organization, or reporting data): A.S.-I., J.D.M.D.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): A.S.-I., J.D.M.D.
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Writing (responsible for writing a substantive part of the manuscript): A.S.-I., J.D.M.D.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): J.D.M.D.

Practical Applications

- The thoracic and lumbar spine regions interact when performing tasks with thoracic movement and a neutral lumbar spine posture.
- Thoracic spine posture should be considered when investigating lumbar spine mechanics.
- Potentially, exposure to tasks with thoracic movement and a neutral lumbar spine posture should be limited, as these movements increased lumbar co-contraction even while the low back remained in a neutral position.

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