SPINE Volume 31, Number 19, pp E707–E712


# Effect of Different Upright Sitting Postures on Spinal-Pelvic Curvature and Trunk Muscle Activation in a Pain-Free Population

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**Study Design.** A normative within-subjects single-group study.

**Objective.** To compare spinal-pelvic curvature and trunk muscle activation in 2 upright sitting postures ("thoracic" and "lumbo-pelvic") and slump sitting in a pain-free population.

**Summary of Background Data.** Clinical observations suggest that both upright and slump sitting postures can exacerbate low back pain. Little research has investigated the effects of different upright sitting postures on trunk muscle activation.

**Methods.** Spinal-pelvic curvature and surface electromyography of 6 trunk muscles were measured bilaterally in 2 upright (thoracic and lumbo-pelvic) sitting postures and slump sitting in 22 subjects.

**Results.** Thoracic, compared to lumbo-pelvic, upright sitting showed significantly greater thoracic extension ($P < 0.001$), with significantly less lumbar extension ($P < 0.001$) and anterior pelvic tilt ($P = 0.03$). Furthermore, there was significantly less superficial lumbar multifidus ($P < 0.001$) and internal oblique ($P = 0.03$) activity, with significantly higher thoracic erector spinae ($P < 0.001$) and external oblique ($P = 0.04$) activity in thoracic upright sitting. There was no significant difference in superficial lumbar multifidus activity between thoracic upright and slump sitting.

**Conclusions.** Different upright sitting postures resulted in altered trunk muscle activation. Thoracic when compared to lumbo-pelvic upright sitting involved less coactivation of the local spinal muscles, with greater coactivation of the global muscles. These results highlight the importance of postural training specificity when the aim is to activate the lumbo-pelvic stabilizing muscles in subjects with back pain.

**Key words:** trunk muscles, electromyography, lumbar spine, sitting posture. **Spine 2006;31:E707–E712**

The sedentary demands of modern life result in people spending more time sitting.[1] Epidemiologic studies have shown that occupations that involve prolonged sitting have a high incidence of low back pain (LBP).[2–4] Sitting has been reported to be a common aggravating factor for LBP disorders,[4] however, there is no conclusive evidence of increased risk.[5,6] Clinical observations suggest that both upright and slump sitting postures can be provocative for patients with LBP.[7] Despite previous research, there still appears to be little agreement in the literature on optimal sitting posture.[4,8,9]

Recent research suggests that the manner in which the spine is postured in sitting highly influences patterns of trunk muscle activity. O'Sullivan *et al*[10] reported that "lumbo-pelvic" upright sitting posture (defined as anterior rotation of the pelvis, lumbar lordosis, and relaxation of the thorax) resulted in tonic activity in the transverse portion of internal oblique, superficial lumbar multifidus, and, in some cases, thoracic erector spinae, suggesting a postural stabilizing role for these muscles. Activation of these muscles reduces in slump sitting, where it appears there is a transition of load from active stabilizing structures to passive spinal structures.[10,11] Snijders *et al*[12] reported similar findings when moving from unsupported sitting to cross-leg sitting. In contrast, Callaghan and Dunk[13] showed no reduction in lumbar erector spinae activation when moving from upright to slump sitting but rather a reduction in thoracic erector spinae activation. However, in their study, upright posture was not clearly defined.

O'Sullivan[7] described a subgroup of subjects with LBP that presented with pain associated with upright sitting postures involving a thoracolumbar lordosis. It was proposed that this "thoracic" upright posture was associated with inhibition of superficial lumbar multifidus and the transverse abdominal wall muscles with excessive activation of the global muscles, such as thoracic erector spinae and external oblique. To date and our knowledge, no studies have compared lumbo-pelvic and thoracic upright sitting postures with reference to differences in trunk muscle activation. Therefore, the purpose of this study was to investigate spinal-pelvic curvature, pelvic angle, and trunk muscle activation in these 2 upright sitting postures and compare these postures to slump sitting.

## Materials and Methods

**Subjects.** There were 22 subjects, including 13 males and 9 females, recruited from the Perth metropolitan region. Their

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Acknowledgment date: June 17, 2005. First revision date: January 31, 2006. Second revision date: April 7, 2006. Acceptance date: April 7, 2006.
The manuscript submitted does not contain information about medical device(s)/drug(s).
No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
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mean age was 32 years (standard deviation [SD] ±13), mean height 172 cm (SD ±10), and mean weight 71 kg (SD ±11). Ethical approval from the Curtin University Human Research Ethics committee and written informed consent were obtained. Subjects were excluded if they were pregnant, had any reports of LBP (requiring medication or consultation with a health professional and/or days off work within the last 2 years), had any known spine disorders, neurologic conditions, recent pelvic or abdominal surgery, had pain in the test postures, or had previous specific postural training.

**Experimental Protocol.** Before data collection, subjects sat unsupported on an adjustable stool with their hips and knees at 90°, their feet positioned shoulder width apart, and their arms relaxed at the side of their body. They were then instructed to view a designated point 1.5 m ahead at their eye level. To achieve thoracic upright sitting, subjects were instructed to sit with their shoulder blades slightly retracted and thoracolumbar spine extended (Figure 1A). This starting position was maintained for 5 seconds. They were then asked to relax into a slumped posture by relaxing the thoracolumbar spine and rotating their pelvis posteriorly, while looking straight ahead (Figure 1B). Subjects performed this transition of posture over a 5-second period, then the slump sitting posture was held for 5 seconds. To achieve the lumbo-pelvic upright sitting posture, subjects were instructed to rotate their pelvis anteriorly to obtain a neutral lordosis of the lumbar spine and relax their thorax (Figure 1C). They maintained this position for 5 seconds before returning to the slump sitting posture over a 5-second period. This position was again maintained for 5 seconds.

Timing for all trials was controlled using a metronome, and standardized instructions were given to position the participants. Before data collection, a familiarization session outlining all seated postures was held for all subjects. Subjects practiced all testing procedures until they could readily reproduce all postures.

**Data Collection and Analysis.** Synchronized spinal-pelvic curvature and trunk muscle activity were collected over 3 trials. Spinal-pelvic curvature was measured using the 3Space Fastrak motion tracking system (model 3SF0002; Polhemus Navigation Science Division, Kaiser Aerospace, VT), which consists of an electromagnetic source and sensors. Data were sampled at a frequency of 25 Hz. This system has been shown to be both reliable and valid for the measurement of lumbar spine movement, with a recorded accuracy of 0.2°.[14] Sensors were placed over the spinous processes of T6, T12, and S2 vertebrae to allow calculation of spinal-pelvic curvatures. To maintain integrity of the sensor positioning throughout testing and accommodate for skin movement, subjects were asked to bend forward slightly while the 3 sensors were taped securely in place. Flexion and extension angular values were then defined for the following spinal-pelvic regions: thoracic (T6 relative to T12), lumbar (T12 relative to S2), and pelvic angle (S2 relative to the magnetic source). Spinal-pelvic curvatures were calculated as described by Dankaerts *et al.*[15]

Before electromyogram (EMG) measurement, the skin was prepared to reduce skin impedance to below 5 kΩ by cleaning the site with alcohol, shaving the electrode site, and lightly abrading the skin with fine sandpaper. Pairs of self-adhesive disposable Ag/AgCl disc surface electrodes (3 M Red Dot; 3 M Health Care Products, London, Canada) with an electrical contact surface area of 1 $cm^2$ were placed unilaterally 2.5 cm apart and parallel to the following muscles on both sides: superficial lumbar multifidus (L5 level, parallel to a line connecting the posterior superior iliac spine and L1-L2 interspinous space);[16] iliocostalis lumborum pars thoracis (level of L1 spinous process, midway between the midline and lateral aspect of the participant's body);[17] thoracic erector spinae (5-cm lateral to the T9 spinous process);[13] external oblique (just below the rib cage, along a line connecting the most inferior costal margin and the contralateral pubic tubercle);[18] internal oblique (1-cm medial to the anterior superior iliac spine);[19] and rectus abdominis (1 cm above the umbilicus and 2-cm lateral to midline).[19] There were 2 common earth electrodes placed over the right iliac crest. Snap leads were used to connect the surface electrodes to the amplifiers, and the electrodes were taped securely to avoid excessive movement of the leads.

Surface EMG (SEMG) signals were recorded at a sampling frequency of 1000 Hz by 2 Octopus Cable Telemetric systems (Bortec Electronics Inc., Calgary, Canada). The EMG system bandwidth was 10–500 Hz, and the common mode rejection

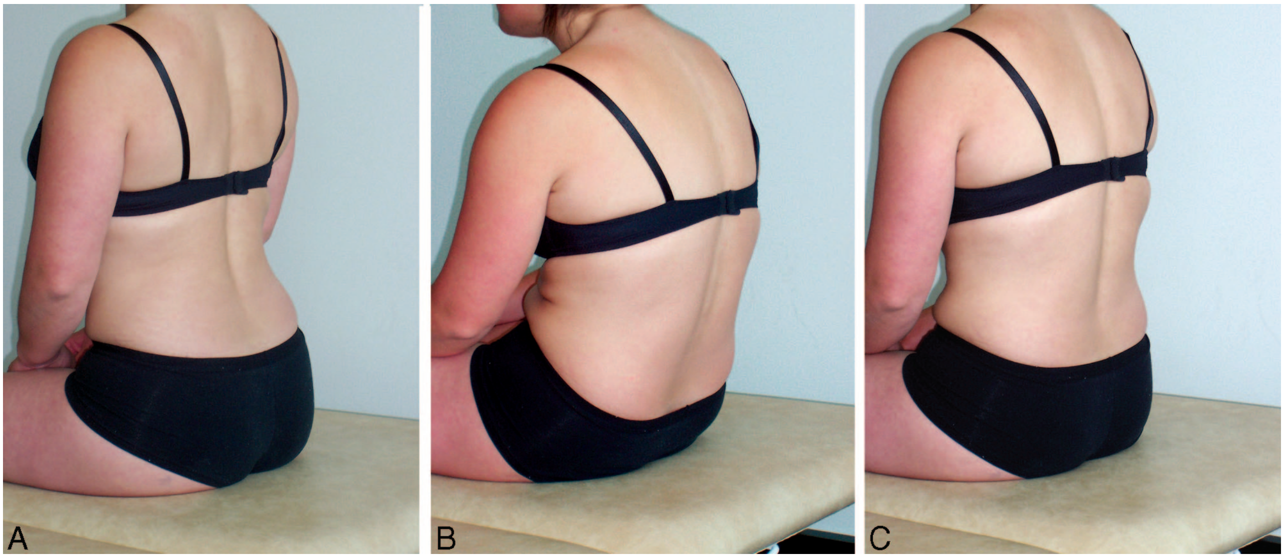


Figure 1. (**A**) Thoracic upright sitting. (**B**) Slump sitting. (**C**) Lumbo-pelvic upright sitting.

ratio was more than 115 dB at 60 Hz. All raw myoelectric signals were amplified with a gain of 2000. Data were collected and processed using the customized software program LabVIEW V7.0 (National Instruments, TX). The raw SEMG data were first visually checked for electrocardiac artifacts. Where it was observed that electrocardiac signal contaminated the SEMG signal, the artifact was manually removed and replaced with adjacent unaffected data of the same duration, using a customized program in LabVIEW. The raw data were demeaned, full wave rectified, and filtered using a fourth-order zero lag Butterworth filter,[20] with a cut off of 4 Hz to yield a linear envelope for each channel. Both the abdominal and back muscles were amplitude normalized to maximal voluntary isometric contraction (MVIC).

To generate MVIC for the abdominal muscles, 3 standardized tests were used.[15] First, the subject was positioned supine with the legs straight and strapped with a belt. A resisted curl-up with maximal manual isometric resistance applied in a symmetrical manner through the shoulders of the subject by the investigator (standing at the head end of the couch) was used for left and right rectus abdominis. A resisted crossed curl-up, with the right shoulder moving toward the left and maximal manual isometric resistance applied through the right shoulder by the investigator (standing at the left side) was used for left internal oblique and right external oblique muscles. For the right internal oblique and left external oblique, the same procedure was repeated on the opposite side. The highest generated contraction on any of the 3 abdominal tests was used as MVIC for that specific abdominal muscle.

One normalization technique was used for all 3 back muscles with the subject positioned prone, legs straight, and strapped with a belt.[21] The subject with hands on the neck was asked to lift the head, shoulders and elbows just off the examination table. Symmetrical maximal manual resistance was provided to the scapular region by the investigator (standing at the head of the subject).[21] There were 3 MVIC trials of 3 seconds duration each,[22] with a 3 minute rest period given between trials performed to avoid the cumulative effect of fatigue.[23] The mean MVIC value from the 3 trials was used as the measurement for each subject. These procedures have shown high levels of reliability.[17,18]

The middle 3 seconds of amplitude normalized EMG data, from the 5-second testing period, were analyzed. EMG data from the right and left sides were analyzed, and the average value was considered representative because of minimal side differences (<2% MVIC). Data from all 3 trials were analyzed.

**Statistical Analysis.** Statistical analysis was performed using SPSS statistical analysis software (version V11.0; SPSS, Inc., Chicago, IL). One-way analysis of variance with repeated measures was used to detect differences between the 3 sitting postures (slump, thoracic, and lumbo-pelvic) in spinal-pelvic curvature, pelvic angle, and trunk muscle activation. Within-subject contrasts were used to detect further differences.

## ■ Results

The mean and SD of spinal-pelvic curvature and pelvic angles (in degrees) and normalized trunk muscle activity (as a percentage of MVIC) comparing the 3 sitting postures are shown in Figures 2 and 3, respectively.

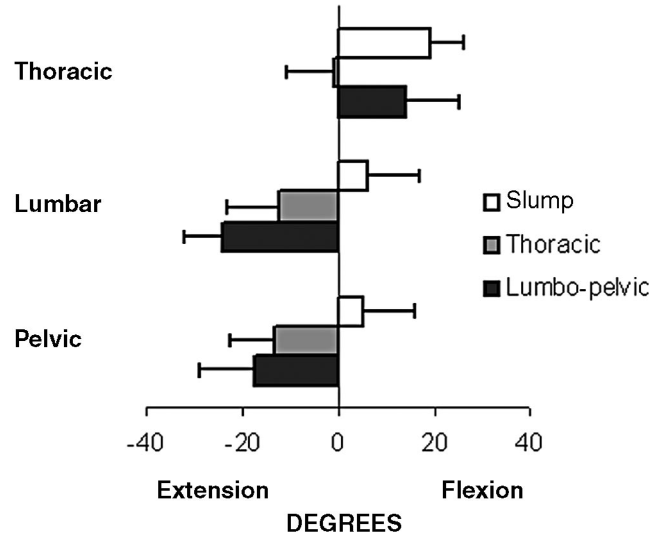


Figure 2. Comparison of thoracic, lumbar, and pelvic curvatures across 3 sitting postures: slump, thoracic upright, and lumbo-pelvic upright sitting. Error bars indicate SD.

### *Spinal-Pelvic Curvature*

There were significant differences ($P < 0.05$) evident between all 3 sitting postures for the 2 spinal-pelvic curvatures and the pelvic angle:

- When compared to lumbo-pelvic sitting, thoracic upright sitting involved significantly greater thoracic extension ($P < 0.001$), less lumbar extension ($P < 0.001$), and less anterior pelvic tilt ($P = 0.03$).
- When compared to slump sitting, thoracic upright sitting involved significantly greater thoracic extension ($P < 0.001$), lumbar extension ($P < 0.001$), and anterior pelvic tilt ($P < 0.001$).
- Lumbo-pelvic upright sitting, when compared to slump sitting, involved significantly greater thoracic

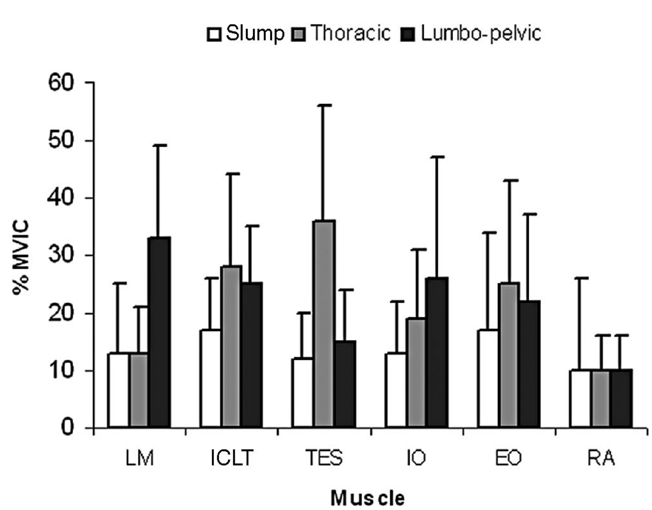


Figure 3. Comparison of muscle activity (percentage of MVIC) in 6 trunk muscles across 3 sitting postures: slump, thoracic, and lumbo-pelvic sitting. Error bars indicate SD. EO indicates external oblique; ICLT, iliocostalis lumborum pars thoracis; IO, internal oblique; LM, lumbar multifidus; RA, rectus abdominis; TES, thoracic erector spinae.

extension ($P = 0.002$), lumbar extension ($P < 0.001$), and anterior pelvic tilt ($P < 0.001$).

### *Trunk Muscle Activation*

There were a number of significant differences ($P < 0.05$) found among all 3 sitting postures for the trunk muscles analyzed in this study. The results are:

- Compared to lumbo-pelvic upright sitting, thoracic upright sitting was associated with significantly less muscle activity of superficial lumbar multifidus ($P < 0.001$) and internal oblique ($P = 0.03$), and significantly greater muscle activity of thoracic erector spinae ($P < 0.001$) and external oblique ($P = 0.04$). Neither rectus abdominis ($P = 0.07$) nor iliocostalis lumborum pars thoracis ($P = 0.214$) were significantly different between these 2 upright sitting postures.
- Compared to slump sitting, thoracic upright sitting was associated with significantly greater muscle activity of internal oblique ($P = 0.006$), external oblique ($P = 0.003$), thoracic erector spinae ($P < 0.001$), and iliocostalis lumborum pars thoracis ($P < 0.001$). Neither rectus abdominis ($P = 0.07$) nor superficial lumbar multifidus ($P = 0.785$) were significantly different between thoracic upright and slump sitting.
- Lumbo-pelvic upright sitting, compared to slump sitting, was associated with significantly greater muscle activity of superficial lumbar multifidus ($P < 0.001$), internal oblique ($P = 0.001$), and iliocostalis lumborum pars thoracis ($P < 0.001$). Neither rectus abdominis ($P = 0.4$), thoracic erector spinae ($P = 0.149$), nor external oblique ($P = 0.06$) were significantly different between lumbo-pelvic upright and slump sitting.

## ■ Discussion

The current study clearly shows that different upright sitting postures result in different trunk muscle activation patterns. When compared to lumbo-pelvic upright sitting, thoracic upright sitting was defined by increased thoracic lordosis, less lumbar lordosis, and less anterior pelvic tilt. In turn, this result was associated with greater activation of thoracic erector spinae and external oblique, and reduced superficial lumbar multifidus and internal oblique activation. Conversely, there was no difference in superficial lumbar multifidus activation between thoracic upright and slump sitting, or thoracic erector spinae activity between lumbo-pelvic upright and slump sitting. These findings support the hypothesis that the local (lumbar multifidus and internal oblique) and global (thoracic erector spinae and external oblique) muscles of the lumbo-pelvic region can be preferentially facilitated in different unsupported upright sitting postures with changes in spinal-pelvic curvature.[7]

An interesting finding of this study was that the same low level of superficial lumbar multifidus activity (13% MVIC) was observed during both slump sitting and thoracic upright sitting. It appears that superficial lumbar multifidus is relatively inhibited, both at end range flexion (slump sitting) as well as in upright postures with dominant activation of thoracic erector spinae. These findings support the suggestion[7] that the exact manner by which upright sitting posture is defined is critical to ensure activation of superficial lumbar multifidus. Specifically, anterior pelvic rotation with neutral lumbar lordosis and relaxation of the thoracic spine results in activation of superficial lumbar multifidus and concurrent relaxation of thoracic erector spinae, which seems logical when one considers that the action of superficial lumbar multifidus is that of a local lumbar lordoser.[24] Although thoracic upright sitting involved greater lumbar lordosis and anterior pelvic tilt than slump sitting, it resulted in activation of thoracic erector spinae without a change in superficial lumbar multifidus activity compared to slump sitting. This result suggests that a substitution pattern exists between these 2 muscles in the control of upright sitting in relation to controlling the extension moment of the spine.

Previous studies have compared trunk muscle activation in upright sitting and slump sitting.[10,13] O'Sullivan *et al*[10] reported flexion-relaxation of superficial lumbar multifidus when moving from upright to slump sitting, similar to the current study, when comparing lumbo-pelvic upright and slump sitting. This effect was not observed in the lumbar erector spinae by Callaghan and Dunk.[13] However, they did not clearly define how their upright sitting posture was achieved and measured lumbar erector spinae activation at the level of L3. The high levels of thoracic erector spinae activity in thoracic upright sitting in our study are similar to those reported by Callaghan and Dunk[13] in their upright sitting condition. These findings may suggest that the method used to define an upright sitting posture, and the exact muscles measured, may be critical to determine the different patterns of trunk muscle activation associated with upright sitting postures.

The low level of rectus abdominis activity was not significantly different across any of the 3 sitting postures, indicating that its role does not change in maintaining the different sitting postures as defined in this study. However, internal oblique and external oblique were more active in both upright postures compared to slump sitting, suggesting a degree of postural muscle activity for these muscles in the 2 upright sitting postures. This tonic oblique abdominal muscle activity observed in upright sitting may reflect the central nervous system's response to the balance of forces with the back muscles[25] as well as the requirement to maintain intra-abdominal pressure[26] in these postures. When compared to lumbo-pelvic upright sitting, thoracic upright sitting was associated with increased activity of external oblique and reduced internal oblique muscle activity.

Coactivation of trunk muscles is suggested to increase spinal stability and be necessary to maintain upright postures.[27] However, excessive stiffness and coactivation impose large load penalties on the joints and prevent motion.[28] Local spinal stabilizing muscles, such as superficial lumbar multifidus, may have mechanical advantages like translating their force to the spine without the high levels of compressive loading associated with multisegmental muscles.[29] In comparison, global spinal muscles, such as external oblique and thoracic erector spinae, although having a greater potential to enhance spinal stability, have a small efficiency ratio, suggesting that stability is provided but with a larger associated compressive penalty. This effect is supported by previous work suggesting that external oblique provided the greatest gains in stability at a cost of higher muscle fatigue and compressive load.[30] In contrast, internal oblique produced larger increases in spinal stability relative to muscle fatigue.

When optimal posture[31] is considered for sitting, lumbo-pelvic sitting appears to fulfill a number of criteria. It does not involve end range postures which minimize connective tissue strain.[32] Furthermore, it results in preferential activation of the local spinal stabilizing muscles, known to be fatigue resistant[30] and capable of providing a local stabilizing effect on the lumbo-pelvic region without a high compressive load being placed on the spine.[29]

In contrast, thoracic upright sitting results in high levels of coactivation of external oblique and thoracic erector spinae, which exert high compressive loads[29] on the spine. Meanwhile, slump sitting results in flexion-relaxation of the spinal stabilizing muscles,[10] with associated increases in intervertebral disc[33] and connective tissue loading.[32] Concepts regarding ideal posturing of the lumbo-pelvic region also need to be balanced against the known requirement of the spine for dynamic movement to facilitate fluid transfer and intervertebral disc nutrition.[34] Although there is growing clinical evidence to suggest that altered postural patterns in sitting are associated with LBP,[15,35] further research is required to determine whether lumbo-pelvic sitting reduces back pain in subjects for whom sitting is an aggravating factor.

In the current study, the SEMG data were normalized to MVIC rather than sub-MVIC. The main advantage of MVIC is that the data have greater physiologic meaning because they represent the level of muscle activity as a percentage of a person's maximum contraction.[36] This result allows comparison to other studies because normalizing to MVIC is the most common approach used in EMG research. However, it should be acknowledged that using MVIC is problematic in populations with LBP because maximal exertions in some cases are not possible to achieve because of pain and can be unreliable.[10,37] In a clinical setting, normalized EMG data to a sub-MVIC may be preferable.[15,18,37,38]

The findings of this study show that clinicians need to be highly specific when teaching upright sitting posture if the aim of the intervention is to facilitate the lumbo-pelvic stabilizing muscles. Furthermore, future research investigating motor responses in sitting must accurately measure and/or define spinal posture.

## ■ Conclusions

This study showed that different upright sitting postures result in altered trunk muscle activation. Compared to lumbo-pelvic upright, thoracic upright sitting involved less coactivation of the local spinal muscles, with greater coactivation of the global muscles. These results highlight the importance of postural training specificity when the aim is to activate the lumbo-pelvic stabilizing muscles.

### ■ Key Points

- Spinal-pelvic curvature and trunk muscle activation were measured in 2 upright sitting postures and compared to slump sitting.
- Thoracic upright sitting resulted in increased coactivation of thoracic erector spinae and external oblique.
- Lumbo-pelvic upright sitting resulted in increased coactivation of superficial lumbar multifidus and internal oblique.
- Slump sitting and thoracic upright sitting resulted in similar and lower levels of superficial lumbar multifidus activation.
- Findings suggest that differences in upright sitting posture greatly influence trunk muscle activation.

***Acknowledgment***

The authors thank Associate Professor Kathy Briffa, Bahman Jamaluddin, Randy Booth, Charlotte Carlson, Divir Chen, Adam Schultz, Gabriella Bargon, Niamh Moloney, Meredith Perry, Sharon Tsang, Paul Davey (research assistant), and Dr. Ritu Gupta (statistician) for their kind assistance with this study.

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