**INTRODUCTION:** The roles of antagonistic activation of abdominal muscles and of intra-abdominal pressurization (IAP) remain enigmatic, but are thought to be associated with both spinal unloading and spinal stabilization. Intra-abdominal pressurization associated with activation of abdominal wall muscles is thought to reduce compression force on the spine, and increase trunk stability, so training of these muscles is included in conservative management regimens. biomechanical analyses are required to explain the function of IAP because of the anatomical and physiological complexity, but prior analyses have been over-simplified. This paper reports a novel biomechanical analysis of the trunk, with the abdominal wall represented by three layers, each a curved mesh having contractile and elastic properties. The curved muscle paths of abdominal muscles are required to contain intra-abdominal pressure (IAP). The elastic components correspond to muscle series and parallel stiffness, transverse connection between contractile elements of muscle, and fascia. The model analyses were used to estimate the effects of raised intra-abdominal pressure on the compression loading of the spine in a range of tasks, and to identify the associated trunk muscular activity. These analyses were used to test whether increased intra-abdominal pressure was associated with reduced spinal compression forces for efforts that generated moments about each of the principal axis directions.  

**METHODS:** A published biomechanical model of the spine and its musculature [1] was modified by the addition of anatomically realistic curved abdominal musculature connected by fascia to the spine, and with radial elements connecting the contractile elements in a three-layer lattice (Figure 1). Published values of muscle cross-sectional areas and fascial thickness were used to estimate the stiffness of fascia and of muscle. It was assumed that the muscles were activated to achieve the maximum tension in the muscles, and that the tension was distributed evenly across the cross-section of each muscle. The model predicted a reduction in spinal compression forces of 21% for axial rotation moment of 60 Nm applied to the spine, along with IAP of 5 or 10 kPa (37.5 or 75 mmHg) and partial bodyweight (340 N) imposed on the spine. IAP values were in the physiological range [2]. Muscle forces and spinal compressive loads were calculated, consistent with static equilibrium and a 'cost function' that minimized the squares of both muscle and fascial strains. Also, sensitivities of the calculated spinal compression force were estimated to the activation of the different abdominal muscle layers, while respecting the curved muscle paths, and the stiffness properties of fascia and of muscles both longitudinal and transverse to the contractile direction.  

**RESULTS:** The analysis predicted a reduction in spinal compressive force with increase in IAP from 5 to 10 kPa in all four external moment (effort) directions, and over the range of external effort magnitudes (Figure 2). The reduction at 60 Nm external effort was 21% for extension effort, 18% for flexion effort, 29% for lateral bending and 31% for axial rotation (Table 1). The spinal compression force also decreased with increased IAP with zero external moment, corresponding to 'Valsalva' manoeuvre. The calculated activation of abdominal muscles was in the range 0 – 12% of maximum activation, similar to published reports. The calculated spinal compressive forces and muscle forces were relatively unchanged in the sensitivity studies, and the changes made in the sensitivity studies did not alter the overall finding of spinal 'unloading' by IAP.  

**DISCUSSION:** The analyses indicated that IAP has a spinal unloading effect in a range of external moment generating efforts of the trunk, with between 18% and 31% reduction in spinal compression force for different effort directions when pressure is increased from 5 to 10 kPa. The unloading results from an extension moment generated by the IAP that exceeds the flexion moment generated by the abdominal wall muscle activation forces. This model provides analytical estimates of the loading of the spine and trunk using different assumptions about the activation of the different abdominal muscle layers, while respecting the curved muscle paths, and the stiffness properties of fascia and of muscles both longitudinal and transverse to the contractile direction. It predicts that intra-abdominal pressure produces spinal unloading, and shows likely muscle activation patterns that achieve this.

**References:**


**Acknowledgements:** Supported by NIH R01 AR 40909.