Impact of the Quadratus Lumborum Muscle on the Lumbar Spine Joint Effort via a Parametrized Model

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Introduction

- Activity of deep muscles is difficult to record experimentally.
- Activity of deep muscles can be parametrized in order to study their impact on body structures (bones, ligaments, etc.).
- This study focused on the impact of the quadratus lumborum (QL) muscle on the lumbar spine joint efforts.

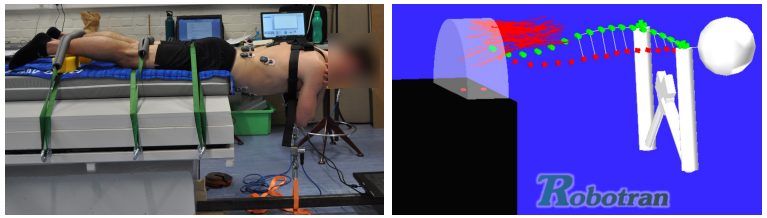

Figure: Sorensen test experiment and model adapted from [1] for a 25-year-old man (height 175 cm and mass 78 kg).

Methods

- A fully thoracolumbar spine and rib cage model [2] was used and modified to develop in the Robotran multibody software [3] the trunk model with lumbar (LP), dorsal paravertebral (DP) muscles and the QL muscle.
- The studied motion was a prone back extension exercise carried out in the Sorensen test posture [4].
- Finding a unique mathematical solution was ensured thanks to a deterministic muscle distribution based on maximal isometric forces available in [2].

Parametric study

- The parameter was the activated QL fraction, modulated from 0 to 40%.
- Its impact at each intervertebral disc (IVD) level in the lumbar (Lx) spine was evaluated thanks to the computation of compressive forces, shear forces and bending moments.

Results

Given activated QL fraction

- Compressive forces increase when coming closer to the pelvis due to the greater number of muscle fascicles in the lower area of the lumbar spine, which induces a larger force resultant.
- Shear are mainly found at L5/L4 level. Shear stresses at L5/L4 for a 12-cm^2 disc vary from 0.7 to 1.2 MPa which are close to values reported in the literature for forward flexion when standing [5].
- Bending moments reflect how internal fibers in each IVD are loaded. For a QL fraction below 20%, the positive bending moment at L5/L4 level indicates that IVD posterior fibers are in compression while anterior fibers are in traction. The negative bending moment at all the other levels reveals the opposite trend. Indeed, most of muscles acted at L5/L4 level, pulling L4 upwards. Above L5/L4 level, each segment might be seen as a cantilevered beam.

Increasing activated QL fraction

- Compressive forces increase in all IVD levels due to the larger force resultant from the QL muscle, itself due to shorter level arms of QL fascicles.
- Shear forces increase in most of IVD levels for the same reason.
- Bending moments decrease in cantilevered segments which results in less force in IVD internal fibers. The positive bending moment at L5/L4 level is reinforced, involving greater forces in IVD fibers.

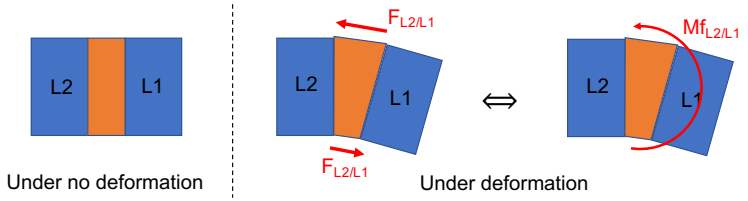

Figure: Orientation of IVD internal fibers. V is for vertebra and represented efforts act from the inferior level on the superior level.

References

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[5] Wilke et al. (1999). Spine, 24: 755-762.

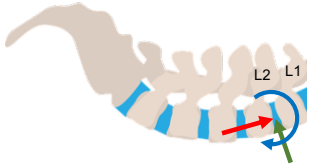

Figure: IVD resultant efforts – compressive force in red, shear in green and bending moment in blue – from L2 to L1. Drawn arrows define positive values.

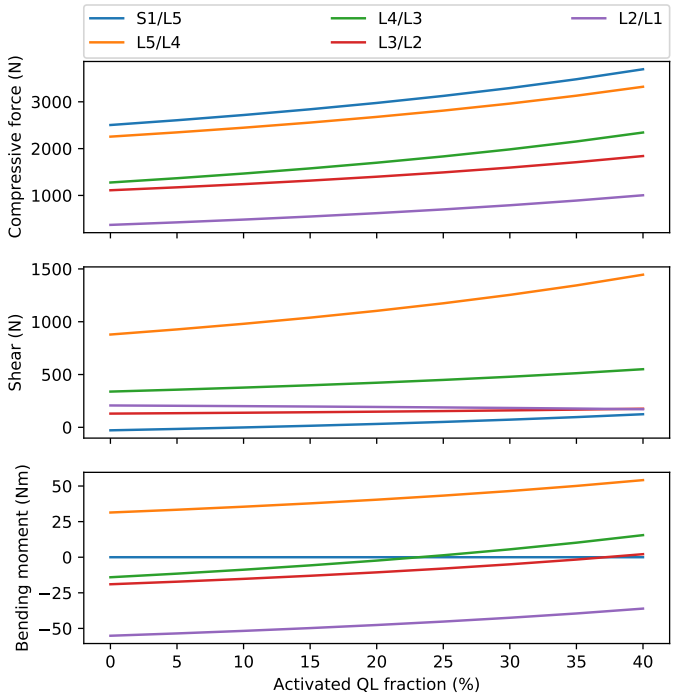

Figure: Efforts at each IVD in the lumbar spine.

Conclusion

- The QL muscle has a significative contribution on intervertebral efforts in the lumbar spine.
- Parametrized models could be used to analyze individual strategies.