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Is the lumbodorsal fascia necessary?

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Summary The role of the lumbodorsal fascia is generally neglected in spine biomechanics. Yet it is perhaps the most important structure insuring the integrity of the spinal machinery. The viscoelastic property of its collagen has a direct impact on the way the muscles are used and forces are channeled from the ground to the upper extremities. As a controller of the forces distribution between muscles and fascia, lordosis is the prime candidate for rehabilitation in the event of injury.

The lumbodorsal fascia was described in remarkable details by the anatomists of the renaissance, but its role in the function of the spine was not clarified until the 1970s when Harry Farfan (1975) proposed that the fascia had to channel forces from the powerful gluteus maximus to the upper extremities.

His idea was simple but accurate: when comparing the cross sections of the legs muscles to that of the erectors spinae, it is obvious that the power produced by the legs muscles could not possibly be channeled up by the much smaller erectors.

That elementary consideration was too simple to be acceptable to the gurus of the time. The opposition crystallized around the work of Bartelink (1957) who developed a model that correctly predicted that the back muscles were too small to do heavy lifting. But instead of looking for a neighboring anatomical structure that could supplement the action of the erectors, Bartelink introduced a concept that changed everything for the following 40 years, and counting.

Indeed, Bartelink proposed that the missing force preventing the collapse of the trunk during heavy lifting would come from an increase in the internal abdominal pressure (IAP). That pressure would push on the diaphragm and, presto, the trunk will resist the loads.

The idea in itself is good but does not resist analysis. It can be calculated that the IAP would have to rise 20 times over the blood pressure to permit a 250 kg lift. Regrettably, few people were bothered by the prospect of an exploding patient and the myth of the IAP survived into the 21st century.

The work of Bartelink was subsequently refined (Gracovetsky et al., 1977). It was realized that there were an infinite number of ways by which a task can be executed or posture can be maintained. That redundancy in the anatomy was felt at the time

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to be bothersome since somehow, the opposing concept of a single best posture was taking hold. Some method had to be found to determine that "best" posture. That was done by introducing the optimization techniques that proved to be invaluable in calculating the best flight to the moon. The problem was formulated by determining the muscle firing strategy that will do the task while maintaining a minimum amount of compressive stress at the intervertebral joint.

Unfortunately, solving the redundancy of the spine musculature by optimization techniques created another problem since the "best" mathematical solution required some muscles to be negative (that is pushing rather than pulling), a physiological impossibility. Never mind; the gurus of the time overcame that riddle by introducing a mathematical artificial constraint that forced the muscles to pull. Et voila!

No one at the time was unduly concerned by either the reason for which evolution resulted in the design of animals with such a large redundancy of the spinal musculature, or the fact that the best calculated unconstrained solution required negative muscles. I began having some serious doubts in the late 1970s since it did not make sense to have a complex biological system working in such a constrained environment. Clearly the animal should have evolved to remove the constraints for the sake of energy efficiency. But how?

The answer was buried in the mathematics. In short a matrix characterizing the model of the spine had to be made positive definite. To force that matrix to be positive definitely required introducing specific terms in the equations. These new elements were then mapped back to the anatomy and found to represent links between the pelvic crest and the spinous processes. That was how the deep layer of the lumbodorsal fascia came to my attention.

Proper modeling of the spinal anatomy with all layers of the fascia demonstrated the key role that this collagen structure has in the spine function. For instance, the maximum load that the erectors spinae muscles can support is about 50 kg which is well below what can be achieved by strong men. A 250 kg lift requires the fascia to support four times what the spine musculature can do. Clearly, the loss of the fascia will severely weaken the spinal machinery resulting in an abnormal increase in spine compression and torsion, the primary sources of injury of the intervertebral joint.

The importance of the lumbodorsal fascia can also be demonstrated by the well-known "muscle relaxation" phenomenon in which the entire erectors spinae muscle shuts down when the trunk is sufficiently flexed, even while holding significant loads. Relaxation is possible because the tightened fascia takes on the lion share of the forces transmitted from the legs to the upper extremities. It is only when the trunk returning to the erect stance crosses a threshold of about 45° of flexion that the fascia begins to slacken forcing the erectors' spinae to contribute to the lift. When this switchover happens, the most difficult part of the lift has already been done and the erectors have enough residual power to take control of the posture in the near erect stance.

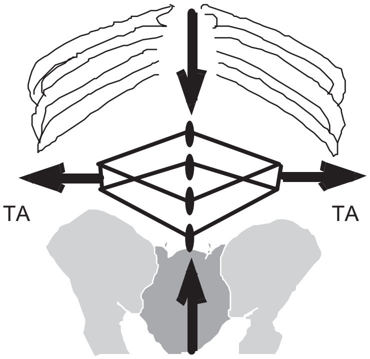

Figure 1 A pull of transversus abdominis on the lateral raphe of the lumbodorsal fascia induces a force that brings together the tips of the spinous processes. The ratio of the raphe displacement to the spinous processes displacement is called the Poisson's ratio. It is about one. This mechanism is effective when the fascia is flat, that is when the internal abdominal pressure is sufficiently high to maintain a round belly.

The superficial layer of the fascia also contributes to trunk extension in a very peculiar way. Figure 1 demonstrates that the superficial layers can be effective for any trunk angle since their contribution to the spine extension depends mainly on the action of transversus.

There is a caveat though. Collagen is viscoelastic with a fairly short (1/3 s) time constant. This means that any attempt to "freeze" the motion of the trunk while lifting a heavy load will (1) stretch the fascia thereby disabling the most important structural component of the spine, (2) dramatically increase the compressive stress on the intervertebral joint, and (3) force the lifter to abort the lift by dropping the load. The strengthening of the viscoelastic fascia resulting from the trunk velocity far outstrips the added penalty imposed by the inertia forces.

It is the viscoelastic property of collagen that requires muscle redundancy since it is not possible to continuously load collagen material. To circumvent the problem of collagen stretching, a cyclic mechanism of alternatively loading and unloading

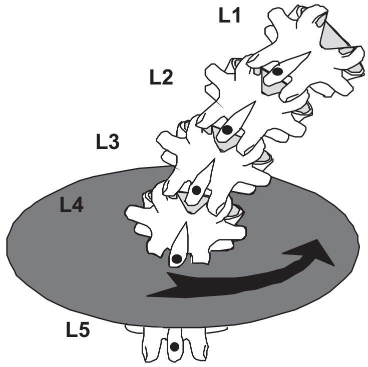

Figure 2 A lateral bend to the left induces a counter clockwise motion of the pelvis.

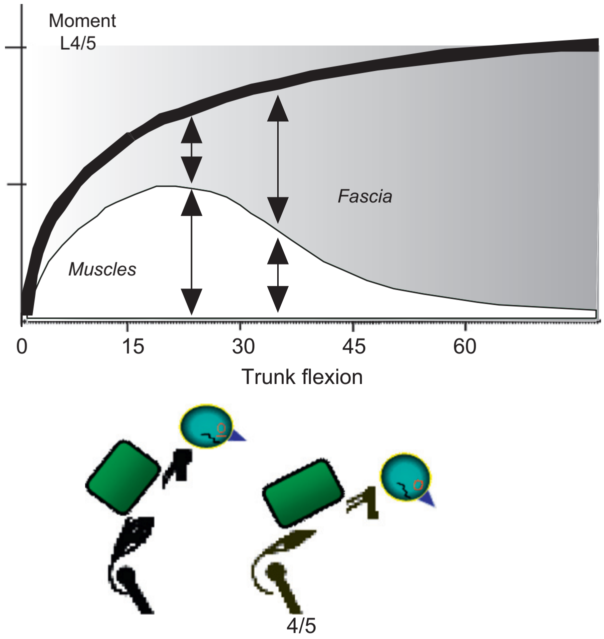

Figure 3 The combination of trunk flexion and pelvic tilt modifies the distribution of forces through the fascia and erectors spinae. This oscillation occurs at each step and delays the onset of fatigue.

collagen and muscle must be implemented. Such an oscillation permits tissues to sequentially rest, recover and maintain core stability. Rehabilitation must therefore return the function of these many combinations of muscles and ligaments. No single exercise will do, and a well thought out training program is a must to help the patient.

The calculations also demonstrated that lordosis was the single most important parameter controlling the distribution of forces between fascia and muscles. Consequently, restoring the control of lordosis should be the first priority in any rehabilitation program. That is true for lifting as well as walking.

Figure 4 Both postures are best in the sense that both result in the task being executed at minimum stress for the spinal structures. Note the significant differences in lordosis. This strategy increases the chances of survival of the individual by minimizing the probability of musculoskeletal injury.

Indeed, Lovett (1903) discovered the so called coupled motion of the spine (Figure 2). Panjabi (1977) formally studied how lordosis affects the conversion of a lateral bending torque into an axial torque. In short, lordosis controls how the primitive lateral bending inherited from our fish ancestors is converted into an axial torque driving the pelvis (Gracovetsky, 1988).

It follows that the search for pelvic stability cannot be restricted to its interaction with the motion of the legs, but first and foremost, with that of the spinal structures above it.

Since both trunk flexion and pelvic tilt can modify the lumbar lordosis, it can be appreciated that during walking, the combination of trunk and pelvic oscillations will continuously redirect the flow of forces passing from the legs to the upper extremities (Figure 3).

Since no structure is being continuously loaded, walking can be sustained for very long periods of time.

The need to dynamically alter lordosis is rooted in the necessity of executing task while maximizing the chances of survival. From a mechanical standpoint this means adopting whatever musculoskeletal posture so that the stress supported by the spine remains at all times as low as can be. It can be shown that the maximum stress level that is voluntarily supported does not exceed two-thirds of the ultimate that the tissues can support. Nature has cleverly built a safety margin which can be exceptionally overridden by the central nervous system with excessive fear or artificial drugs.

Hence, a geometrical "best" posture does not exist. The term "best posture" must be defined with respect to the objective to be achieved (Figure 4). That definition is independent of the anatomical perfection of the individual. People with deformities can still have their own "best posture" since they will adopt a geometry minimizing the stress within their available structures. Forcing a deformed child to adopt the posture of a normal one may not be a constructive form of rehabilitation, and may very well damage the deformed structures that will then be unduly stressed.

Conclusion

There is no such thing as a geometrical best posture and the attempts at forcing individuals into fixed patterns may be well meant but have dubious scientific foundations. The overriding consideration of the musculoskeletal system is to survive the everyday tasks that must be accomplished. Minimizing the stress within the spine requires a healthy lumbodorsal fascia controlled by lordosis. Loss of either lordosis control or the structural integrity of the fascia increases the stress on the spine, and as a corollary, increases the amount of energy needed to accomplish any task. Not only will the individual exhaust himself faster, but his musculoskeletal system is now at risk of injury.

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