Fascial Dysfunction as origin of myo-skeletal pain

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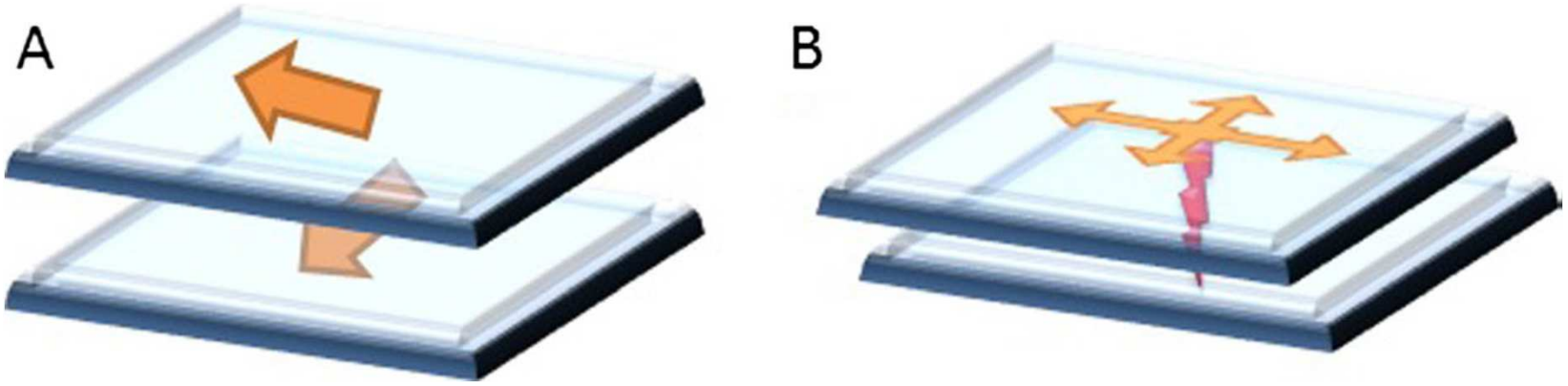
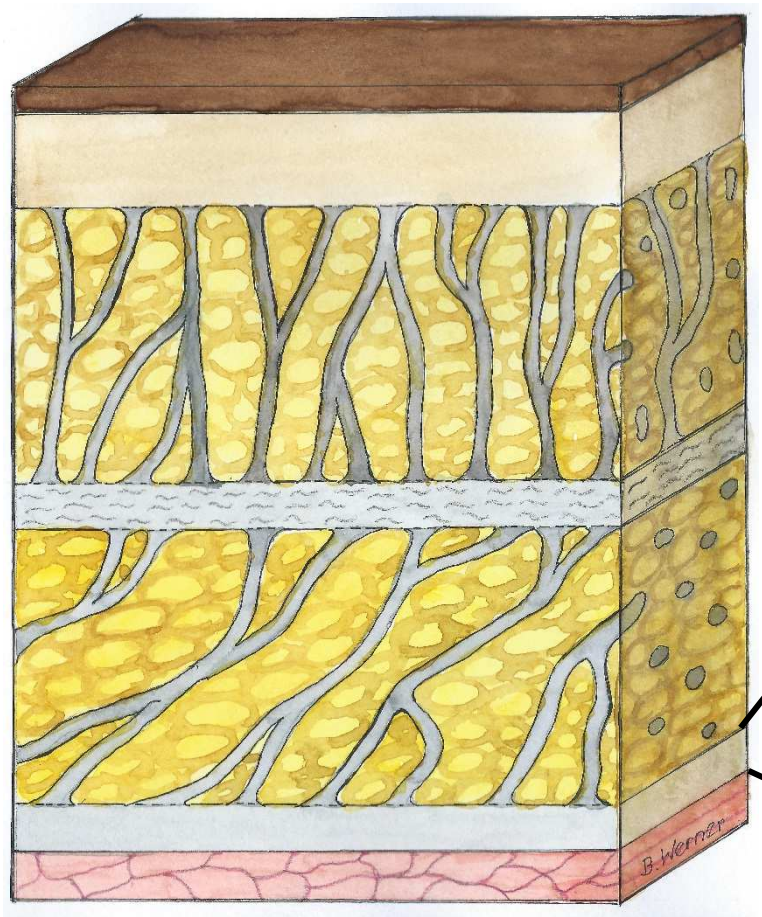
Fibrosis or Densification?

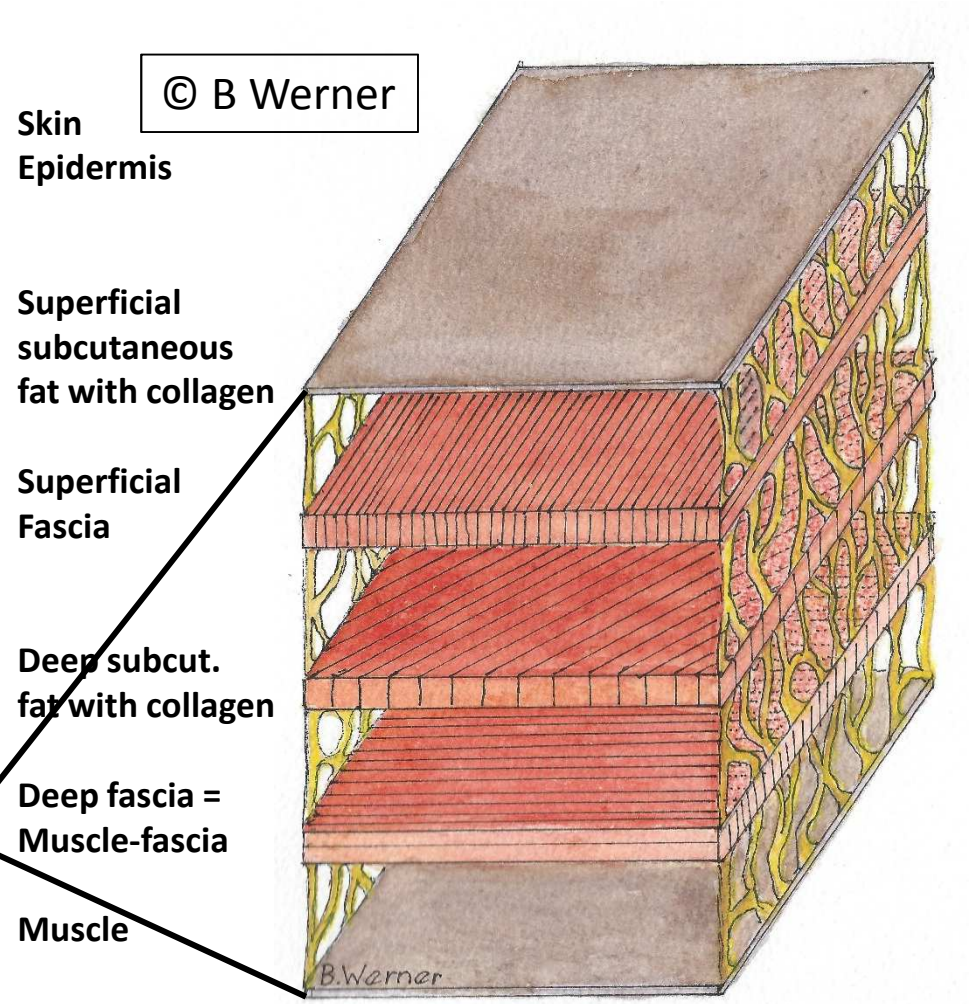
- The deep fascia is a complex structure formed by at least two components:
  - Two or three layers of collagen fiber bundles
  - Loose connective tissue interposed (A)
- An alteration of the collagen tissue will give a fascial fibrosis
- An alteration of the loose connective tissue will produce a fascial densification (B)



Anatomy of fascia

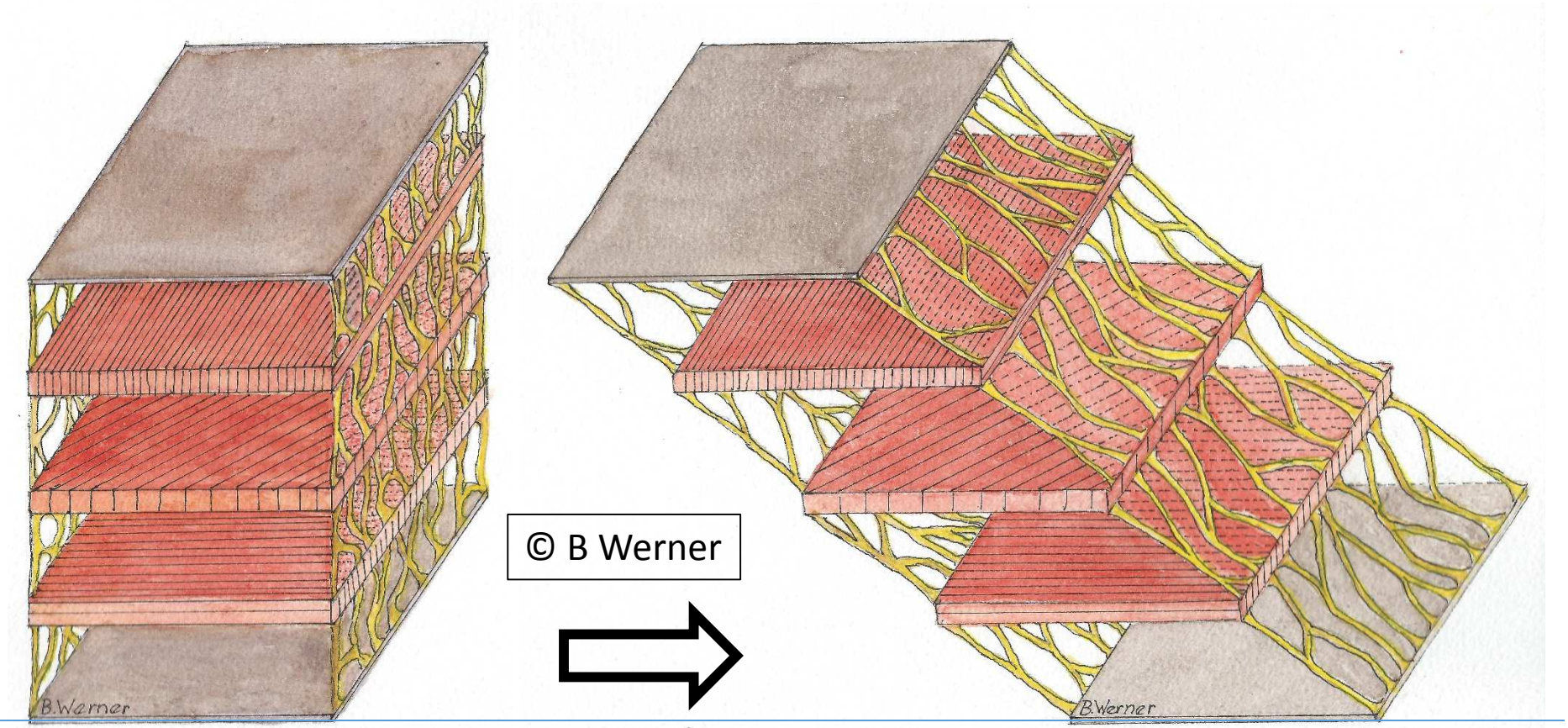


Skin, fat, superficial and deep fascia



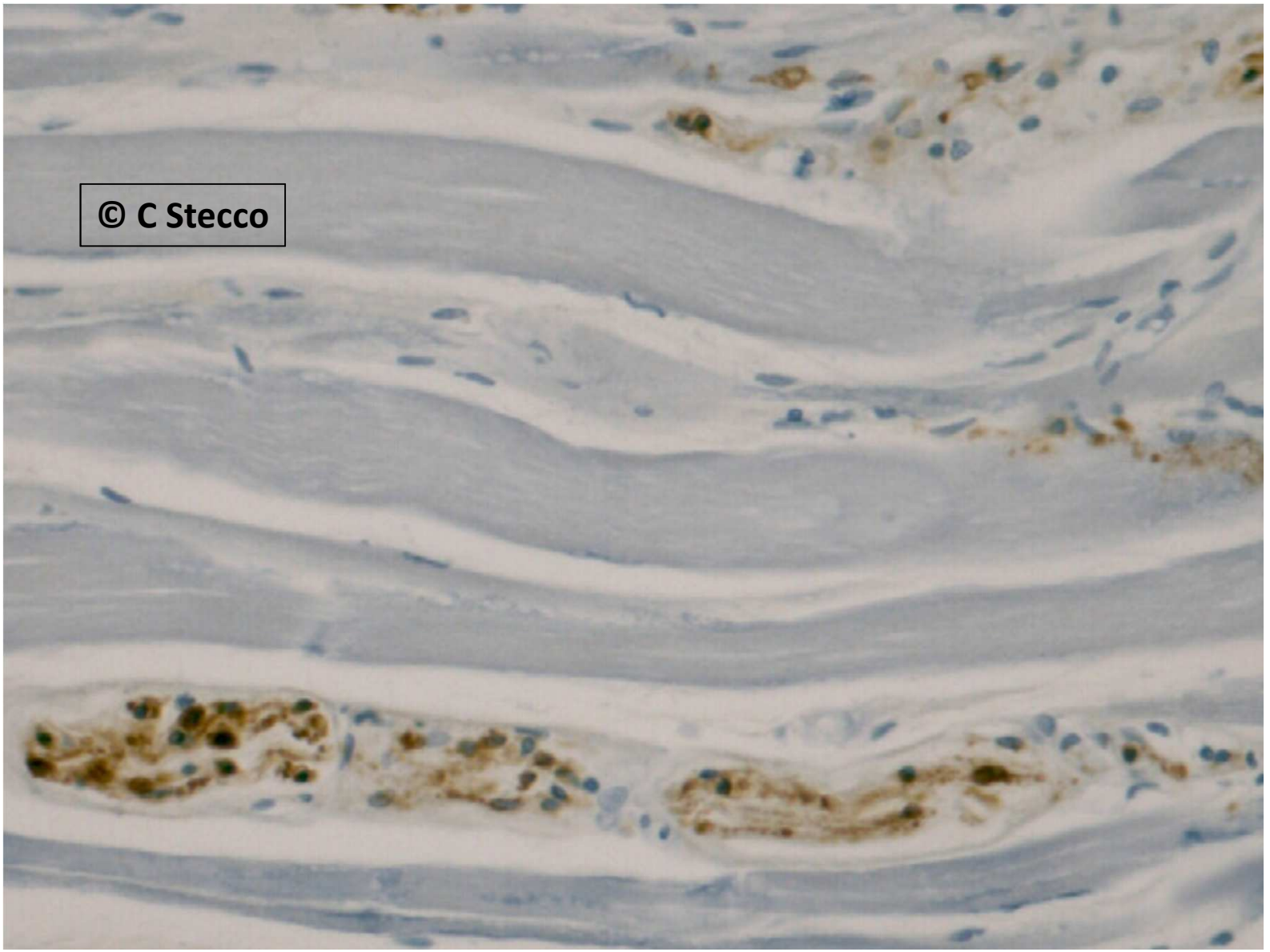
Layers of deep fascia: collagen & CT

Gliding of the fascia



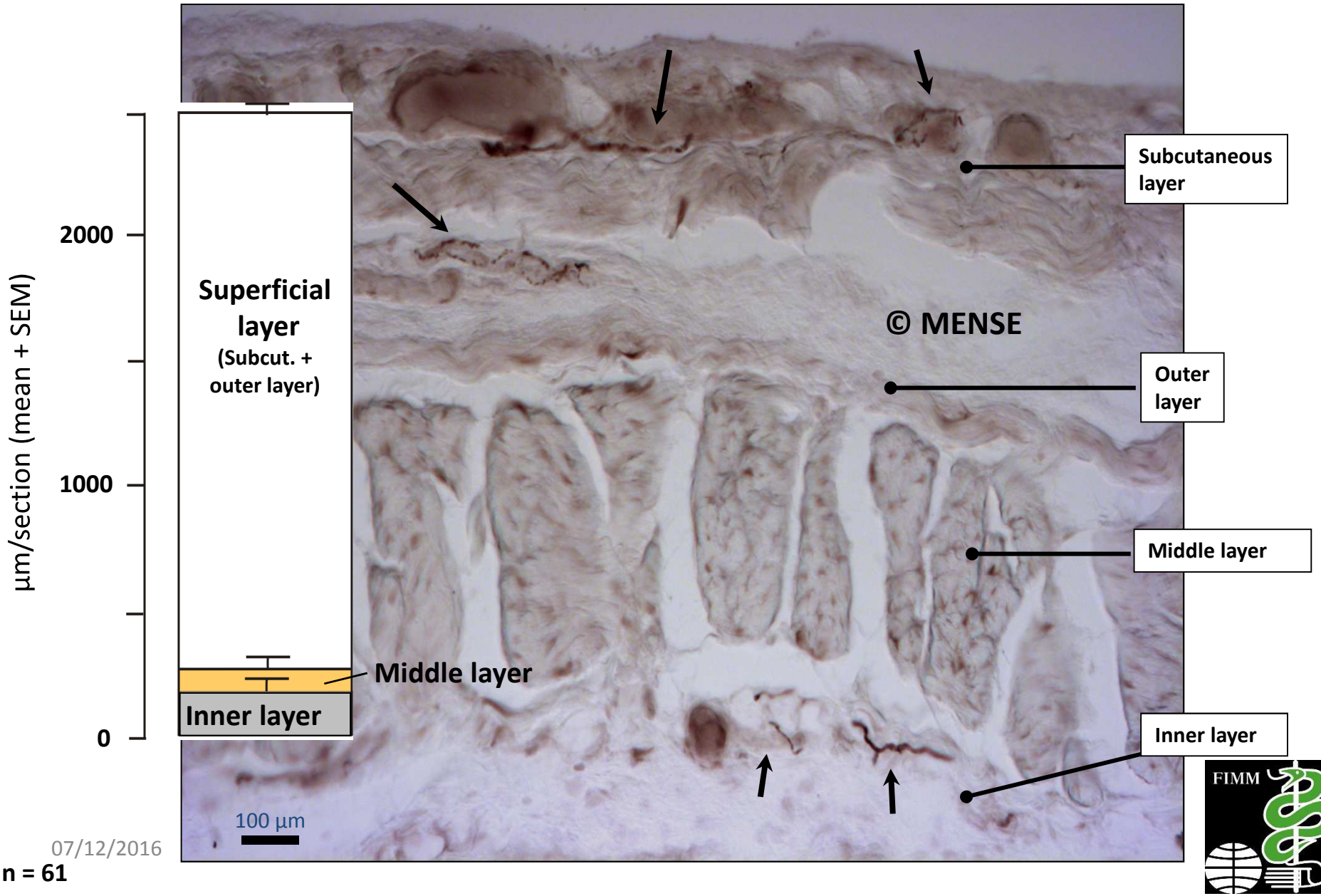
Dysfunction of the connective tissue will decrease the capacity of gliding: “densification”

Nerve fibers on/in the fascia

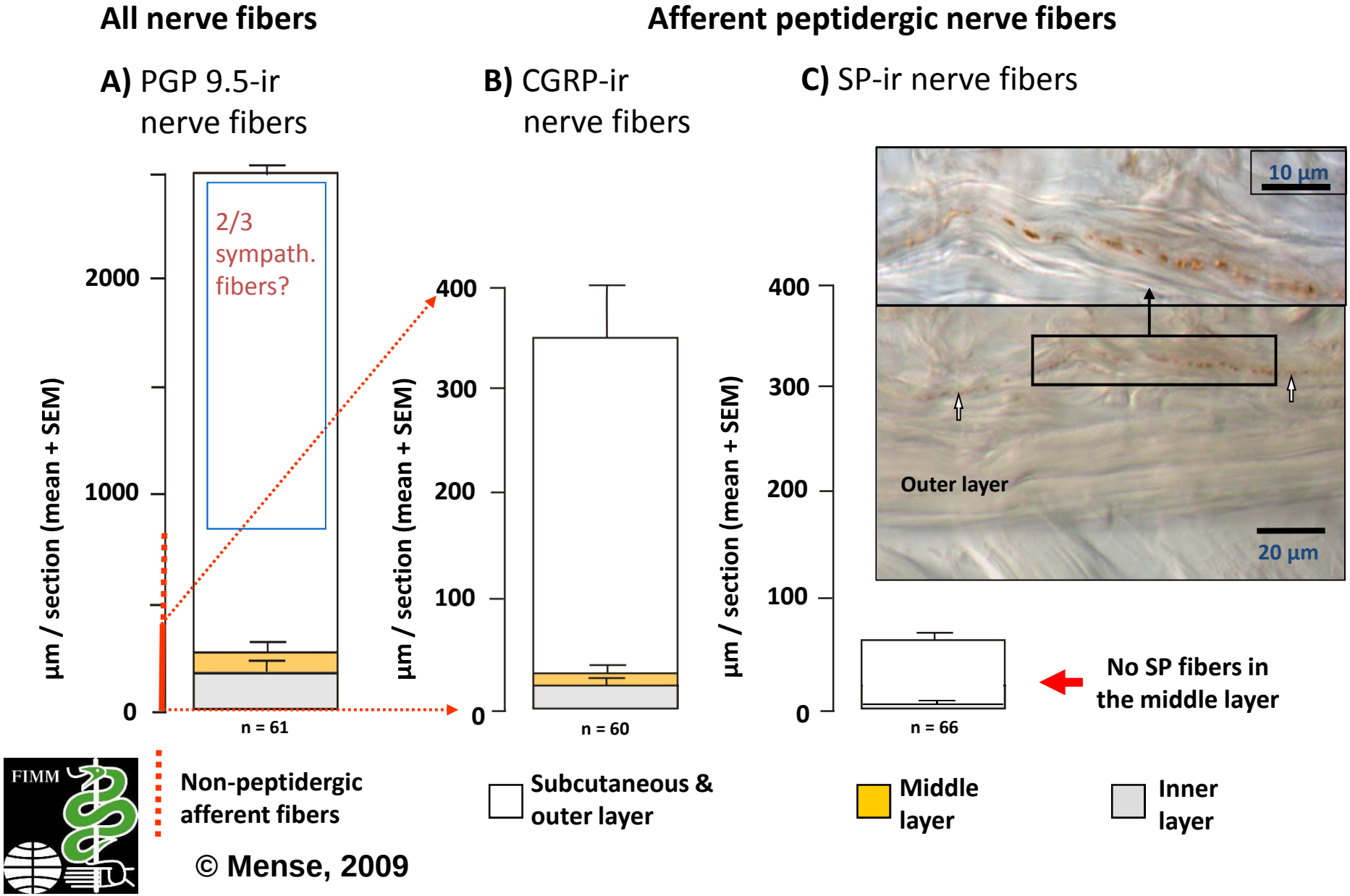


PGP 9.5-POSITIVE NERVE FIBERS

© MENSE



Distribution of sensory nerve fibers in fascial layers (rat)



Fibrosis or densification?

Fibrosis is similar to the process of scarring, with the deposition of excessive amounts of fibrous connective tissue, reflecting a reparative or reactive process. It can obliterate the architecture and function of the involved tissue.

Densification indicates an increase of density of the fascia. By this means the mechanical properties of the fascia will be modified, but without a change of its general structure.

vs.

Fibrosis or densification?

Fibrosis:

- Dupuytren's disease and eosinophil fasciitis can be considered as typical examples of fascial fibrosis.

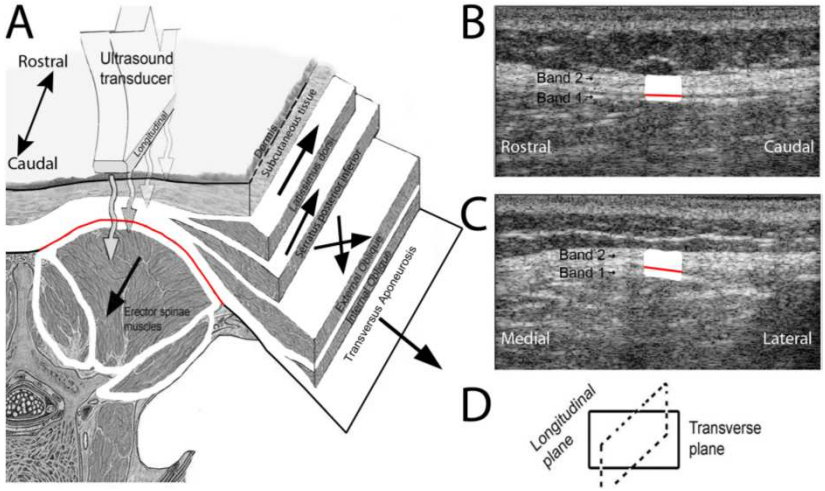
Densification:

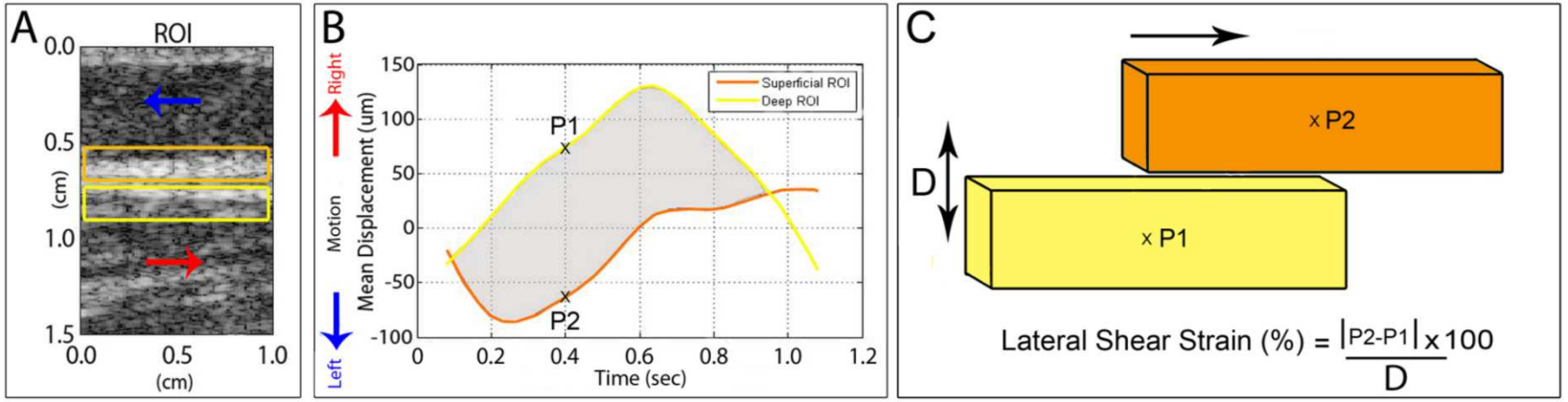
- Chronic non specific neck pain seems to be associated with fascial densification.

In reality, for the majority of cases it is not clear whether fascial densification or fascial fibrosis is involved. This lack of certainty causes not only confusion in terminology, but it also implies that quite different treatment modalities can be used successfully to release fascial pain.

The TLF is a prime candidate for chronic non specific LBP…

Thoraco-lumbar fascia shear strain was ~20% lower in human subjects with chronic LBP. This reduction of shear plane motion may be due to abnormal trunk movement patterns and/or intrinsic connective tissue pathology.

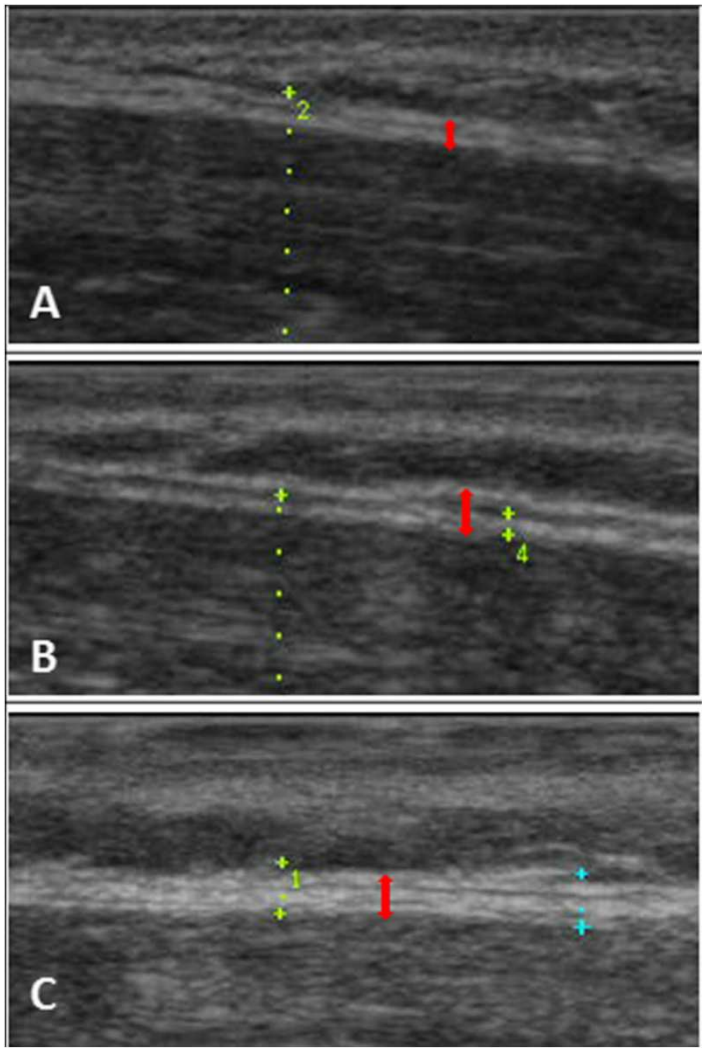




Langevin et al. (2011) Reduced thoracolumbar fascia shear strain in human chronic low back pain. BMC Musculoskeletal Disorders; 12:203-14

Neck fascia is a candidate for chronic neck pain (CNP)…

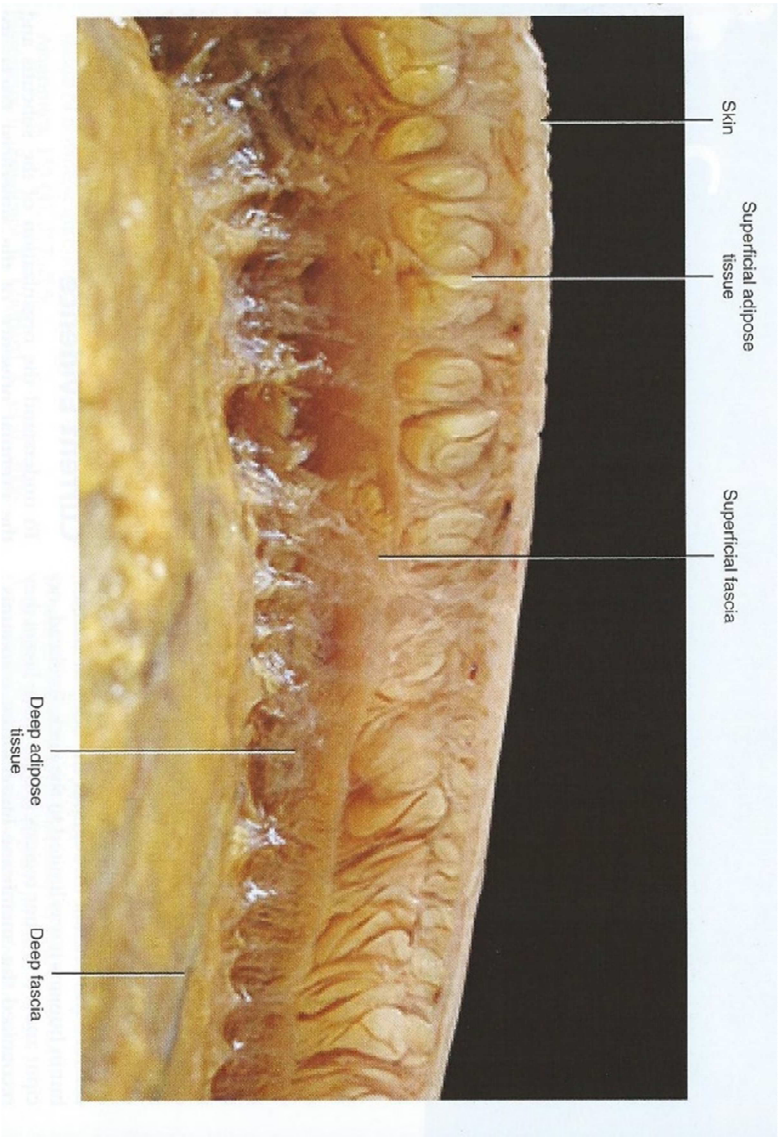
Loose connective tissue within the fascia may play a significant role in the development of CNP. The value of 15 mm of the SCM fascia is considered as a cut-off value to make a diagnosis of myofascial disease in a subject with CNP.



Pavan PG, Stecco et al. (2014) Painful Connections: Densification Versus Fibrosis of Fascia. Curr Pain Headache Rep; 18:441-4

Fascial densification – the role of the water

- Water is the key component of loose connective tissue
- Water is linked to glucosaminoglycans, above all hyaluronan
- GAGs, depending on their chemistry, can glue layers together, when water is missing
- If a fascia is dry, it has much higher risk for a tear or a rupture



Causes of densification: strenuous exercises

- Piehl-Aulin et al. (1985) demonstrate a transient accumulation of hyaluronan following exercise
- Tadmor et al. (2002) show that when hyaluronan is organized in layers, viscosity increases considerably with increasing distance between surfaces

The increased viscosity of the loose connective tissue in side the fascia may be perceived by the patients a s an increase in myofascial stiffness.

Tadmor R, Chen N, Israelachvili JN (2002)
Thin film rheology and lubricity of hyaluronic acid solutions at a normal physiological concentration.
J Biomed Mater Res; 61:514-23

Causes of densification: Lactate

- Pippelzadeh (1998) demonstrated that, when super fused with lactic acid, the contractions of the myofibroblasts of the superficial fascia of rats was significantly higher
- Trabold et al. (2003) demonstrated that lactate stimulates collagen synthesis

Lactate induces also an increase of the fibrosis as well as of the fascial densification (= fascial stiffness)

Pipelzadeh MH, Naylor IL (1998) The in vitro enhancement of rat myofibroblast contractility by alterations to the pH of the physiological solution. Eur J Pharmacol; 357:257-9

Trabold O, Wagner S et al. (2003) Lactate and oxygen constitute a fundamental regulatory mechanism in wound healing. Wound Repair Regen; 11:504-9

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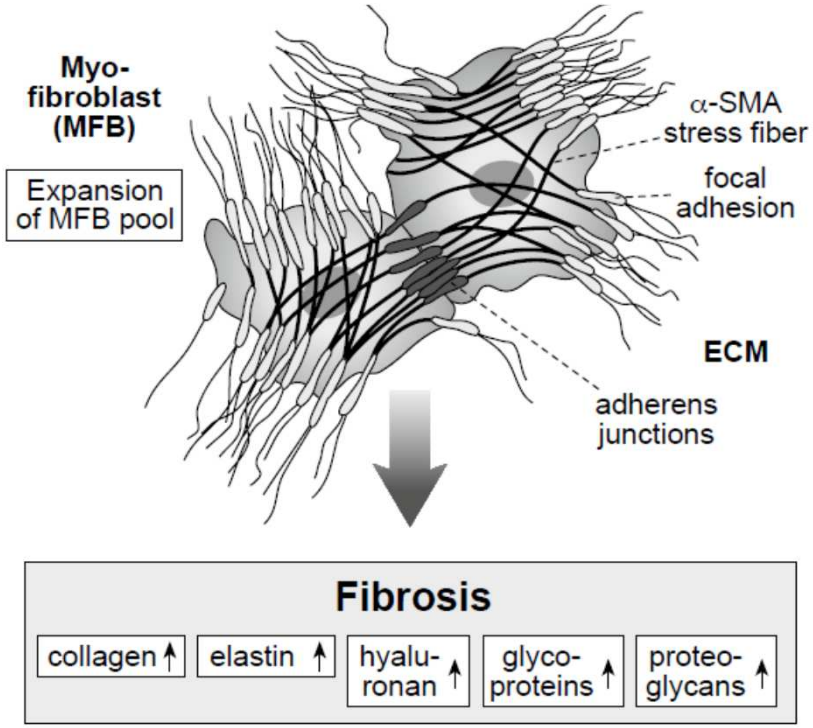

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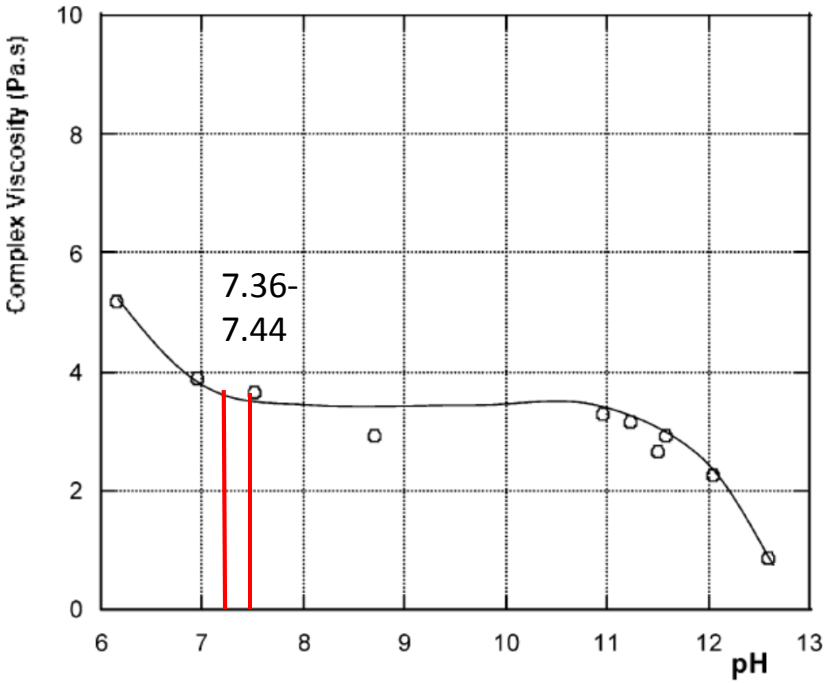
Trabold O, Wagner S et al. (2003) Lactate and oxygen constitute a fundamental regulatory mechanism in wound healing. Wound Repair Regen; 11:504-9

Klingler et al. (2012) The role of fibrosis in Duchenne muscular dystrophy. Acta Myologica. 31: 184-195

Causes of densification:
Low pH

- Hyaluronic acid shows stable condition in alkaline solution, but in acid solution its viscosity increases dramatically
- After strenuous exercise the muscle pH can reach a value of 6.6 which increases the HA viscosity by ~20%
- This may be perceived by patients as an increase of fascial stiffness

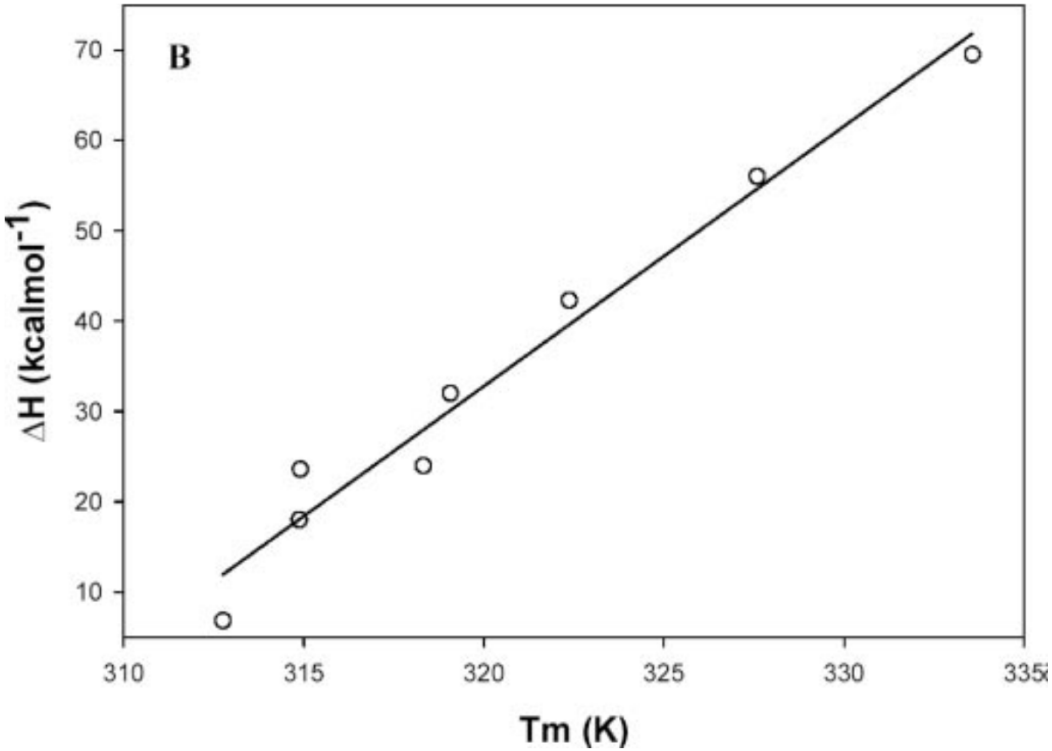


Complex HA viscosity as a function of The pH in basic conditions

Gatej I, Popa M, Rinaudo M (2005) Role of the pH on hyaluronan behavior in aqueous solution. Biomacromolecules; 6:61-7

Causes of densification: Low temperature

The large hydrodynamic volume of HA chains depends on the stiffness of the chain, which is due to steric hindrance to rotation about the linkages between sugar residues, and to the dynamically forming and breaking hydrogen bonds across those linkages. With increasing temperature, rotations about the linkages are easier, and the chains gain flexibility. This shrinks the molecular volume, and consequently reduces the viscosity.



Temperature dependence of hyaluronic acid: low temperature causes high viscosity.

Jha BK, Mitras N et al. (2004) pH and Cation-induced Thermodynamic Stability of Human Hyaluronan Binding Protein 1 Regulates Its Hyaluronan Affinity. J Biol Chem. 279: 23061-72

Causes of densification: Immobilization

Hyaluronan is a thixotropic substance. Dintenfass (1966) demonstrates that synovial fluid has thixotropic and elastic (instantaneous dilating) properties. He finds that its viscosity decreases with an increase of shear rate, but it is pressure resistant under sudden impacts.

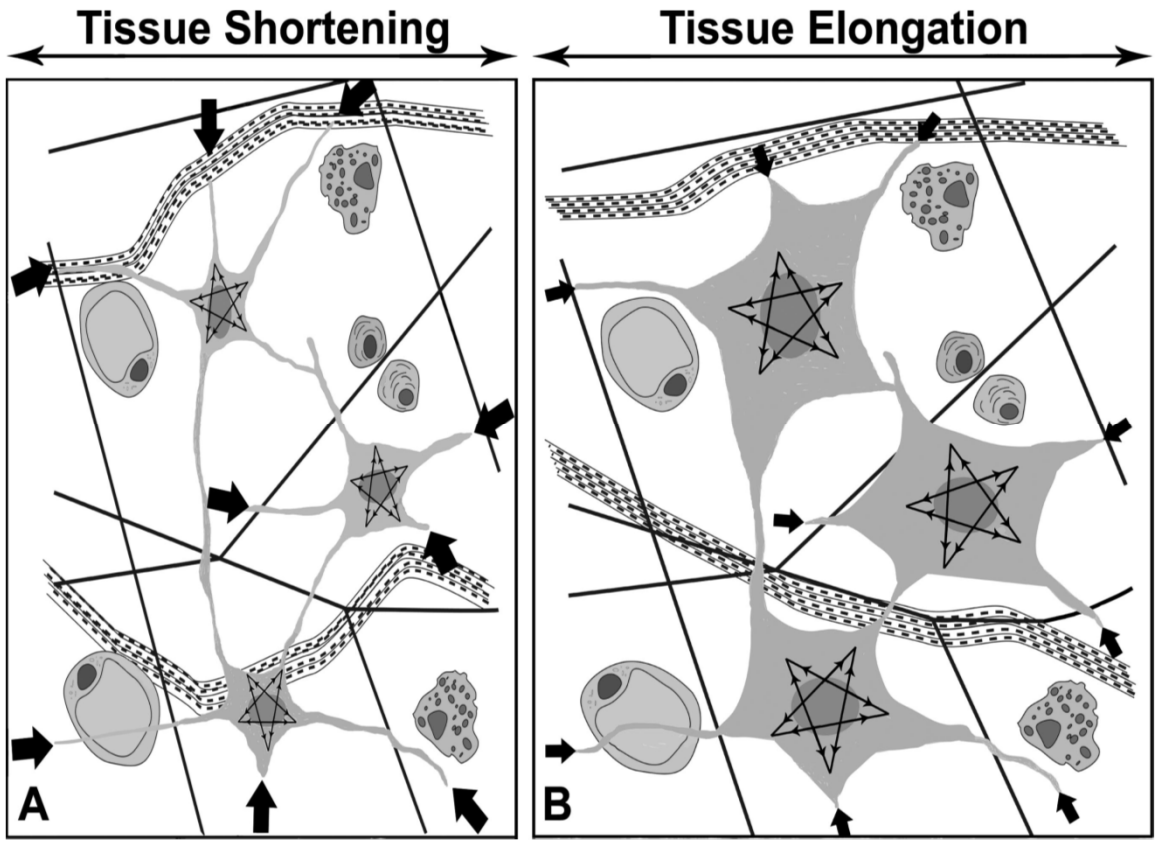
This property can also be assumed for the key element of the fascial loose connective tissue and explains why immobility reduces fascial gliding and consequently the range of motion. Besides, movements and massages can reduce its viscosity.

Dintenfass L (1966) Rheology of complex fluids and some observations on joint lubrication. Fed Proc; 25:1054-60

Alterations of fascial fibrous components

Collagen fiber turnover: 300 – 500 days

- Stretching fibroblasts increases turnover by secretion of collagenase an enzyme for degradation of collagen fibers
- Stretching or compressing make an immediate and proportional deformation of fibroblasts, but after 15-20 min the cell morphology readapts, causing a loss of biological activation
- Cyclical stretching is more effective than continuous



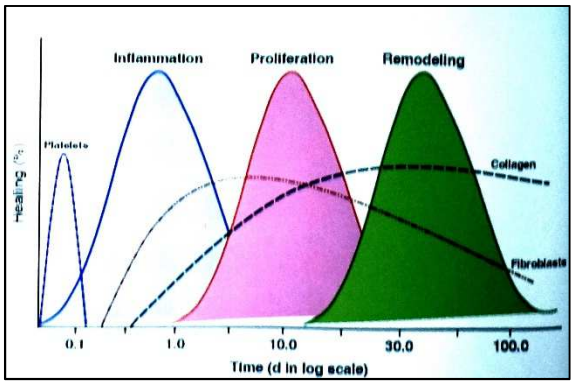
Carano A, Siciliani G (1996) Effects of continuous and intermittent forces on human fibroblasts in vitro. European Journal of Orthodontics; 18:19-26

Langevin HM, Bouffard NA et al. (2005) Dynamic fibroblast cytoskeletal response to subcutaneous tissue stretch ex vivo and in vivo. Am J Physiol Cell Physiol; 288:747–56

Causes of alterations in the fibrous component: Trauma or Surgery

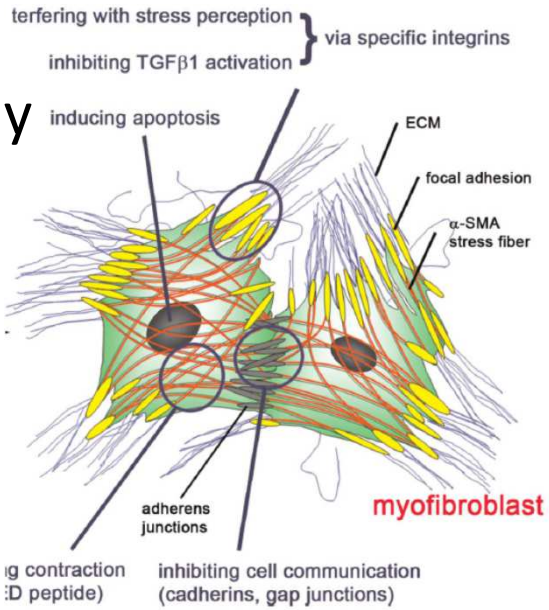
Fascial damage always causes an inflammatory reaction that promotes the healing process. Three sequential, yet overlapping phases of this healing process occur:

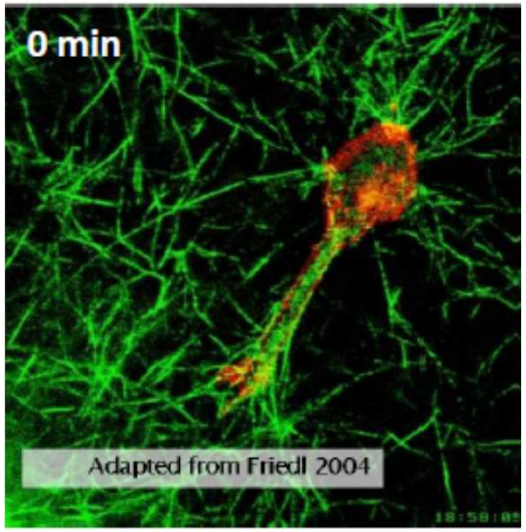
1. **Inflammation (0 – 1 day)**
2. **Proliferation (1 – 30d)**: fibroblasts grow and form a new provisional ECM by collagen II and then type I. In this phase the collagen forms an irregular connective tissue with the main function of closing the wound.
3. **Remodeling (20 – 100d)**: correct healing requires essentially that collagen fibers remodel and realign according to local tensile stress. Only now the connective tissue can transmit forces at a distance.



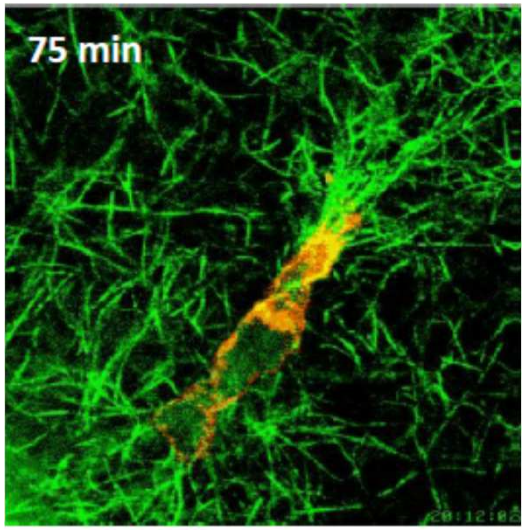
Inflammation provokes fibroblasts

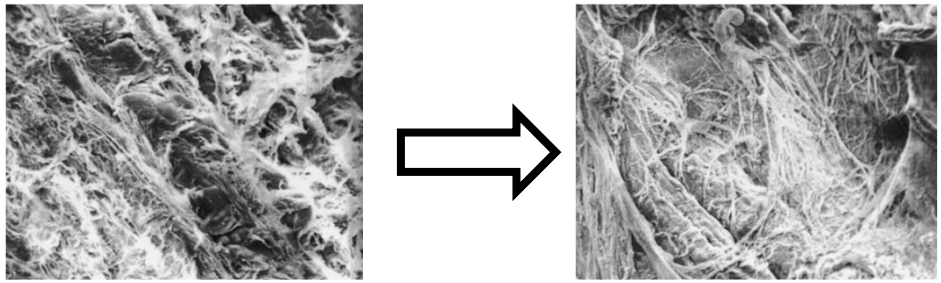
In tissue inflammation fibroblasts that exist only isolated all over the fascia will transform into myo-fibrocytes. They can move very slowly through the fascia and concentrate around a localized inflammation.





Without treatment these myo- fibrocytes will produce much collagen II and III and transform that part of fascia into a fibrotic scar.



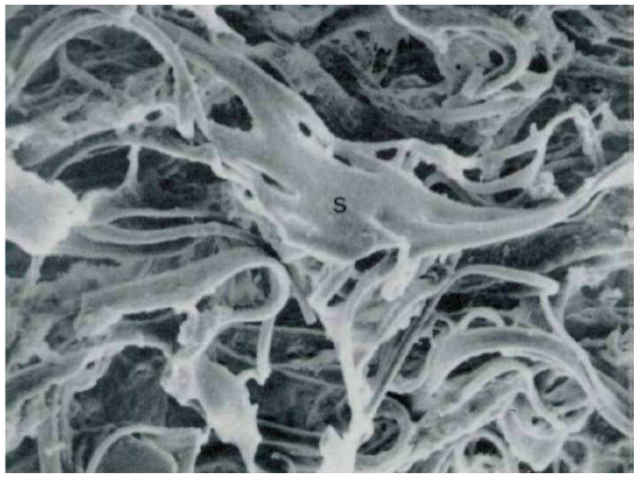


Remodeling of the fascial fibrous component

Remodeling is a fragile process and susceptible to interruption or failure.

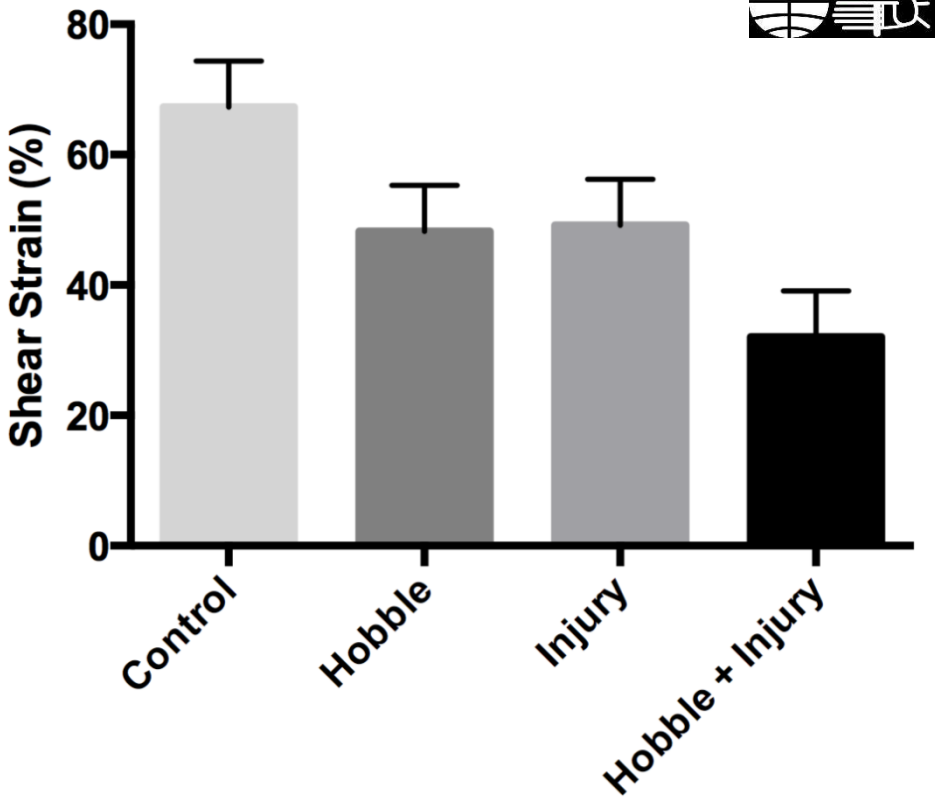
A fundamental role is played by the mechanical stress acting on the injury site, that guides the neuro-inflammatory process.

If the tissue was previously in an unbalanced condition or is immobilized, the remodeling process will not lead to a physiological spatial reconstitution, but instead causes random deposition of unorganized collagen fiber material.



Immobilization (post-traumatic) decreases fascial gliding

Injury caused increase in fascial thickness (.007) and decrease in fascial shear on the non-injured side (.027). Movement restriction did not change fascia thickness, but decrease the shear on the non-hobble side (.024). The combination of injury and movement restriction had additive effects with a 52% reduction in shear strain compared with controls and a 28% reduction compared to movement restriction alone.



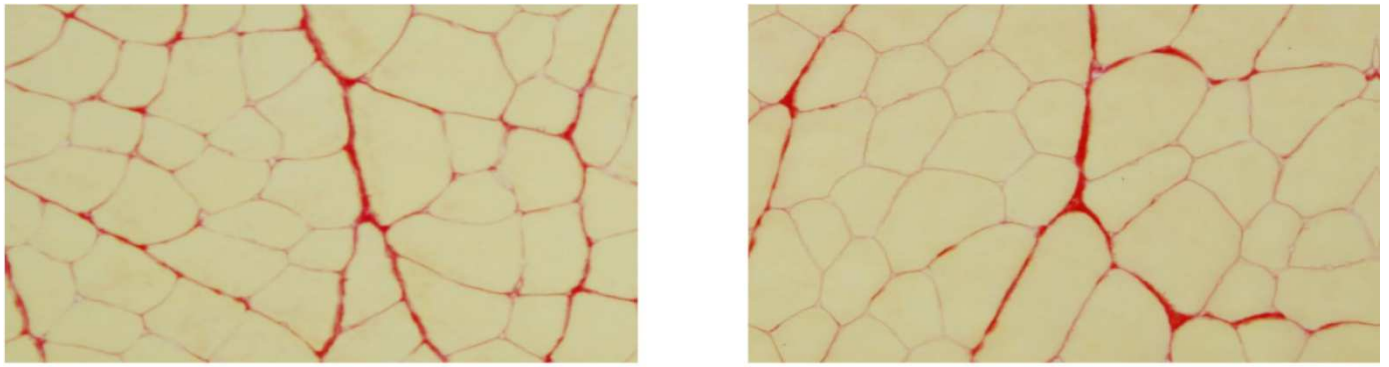
Bishop JH, Fox JR et al. (2016) Ultrasound Evaluation of the Combined Effects of Thoracolumbar Fascia Injury and Movement Restriction in a Porcine Model. PLoS ONE 11(1): e0147393

Causes of alterations in the fibrous component: Immobilization

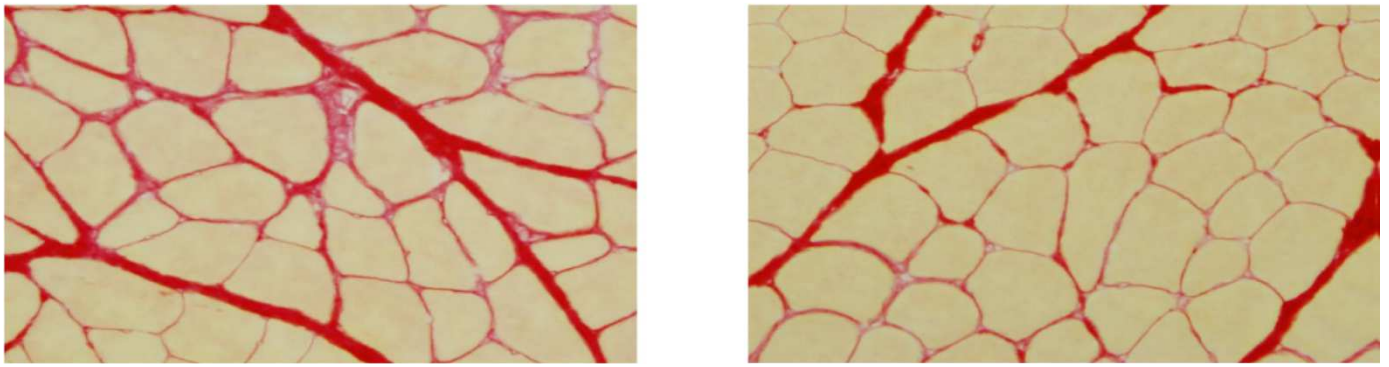
Slimani et al. (2012) demonstrated that immobilization causes pronounced muscle connective tissue thickening.

During early recovery there are sustained increased expression of markers of CT remodeling and increased nuclear apoptosis

Control

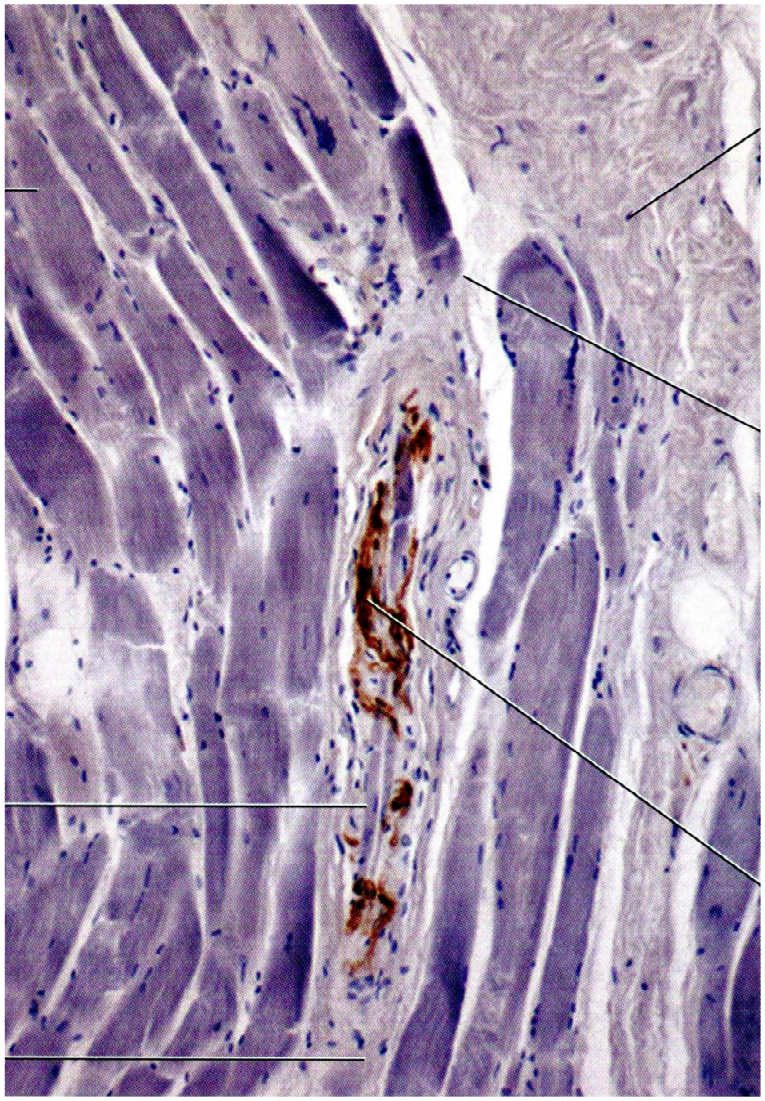


Immobilized



Causes of alterations in the fibrous component: Immobilization

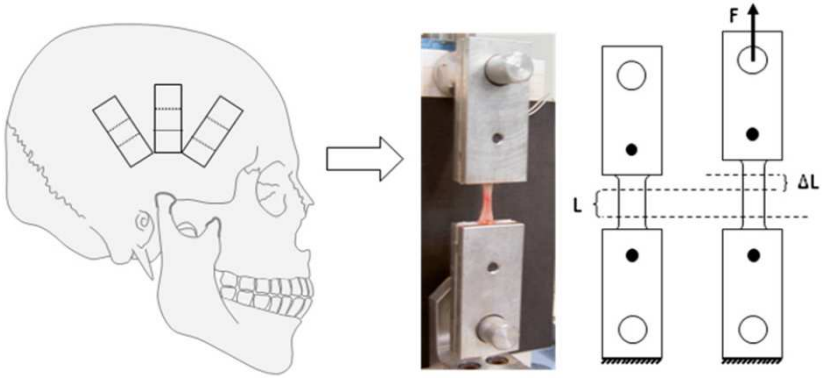
- The capsule of muscle spindles are in continuity with the perimysium of the muscles
- The thickening of the perimysium can alter the muscle spindles activation and consequently the muscle contraction
- The threshold of muscle spindle corresponds to a tension of 3 grams

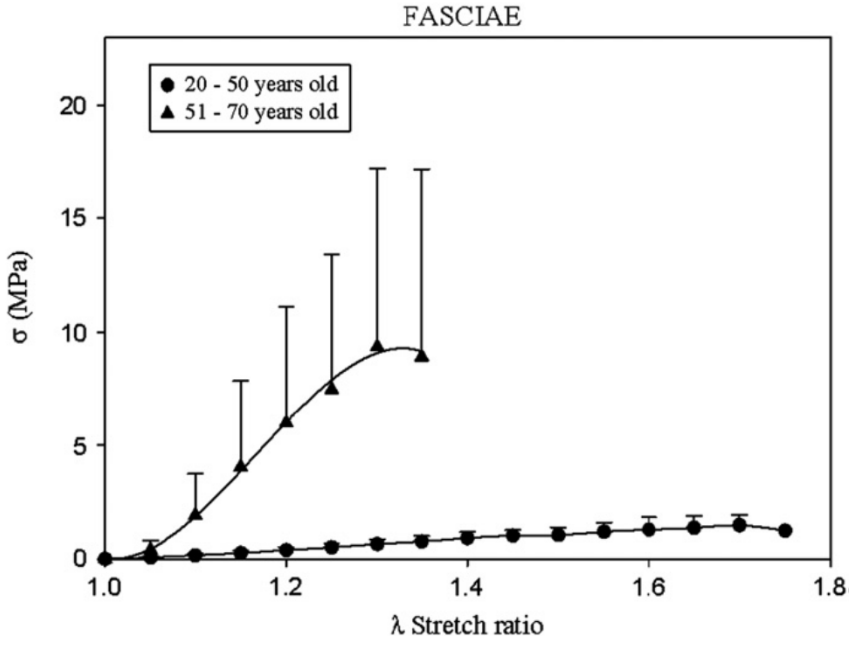


Causes of alterations in the fibrous component: <u>Aging</u>

Trindade et al. (2012) demonstrate that the human deep temporal fascia is stiffer in older than in younger persons

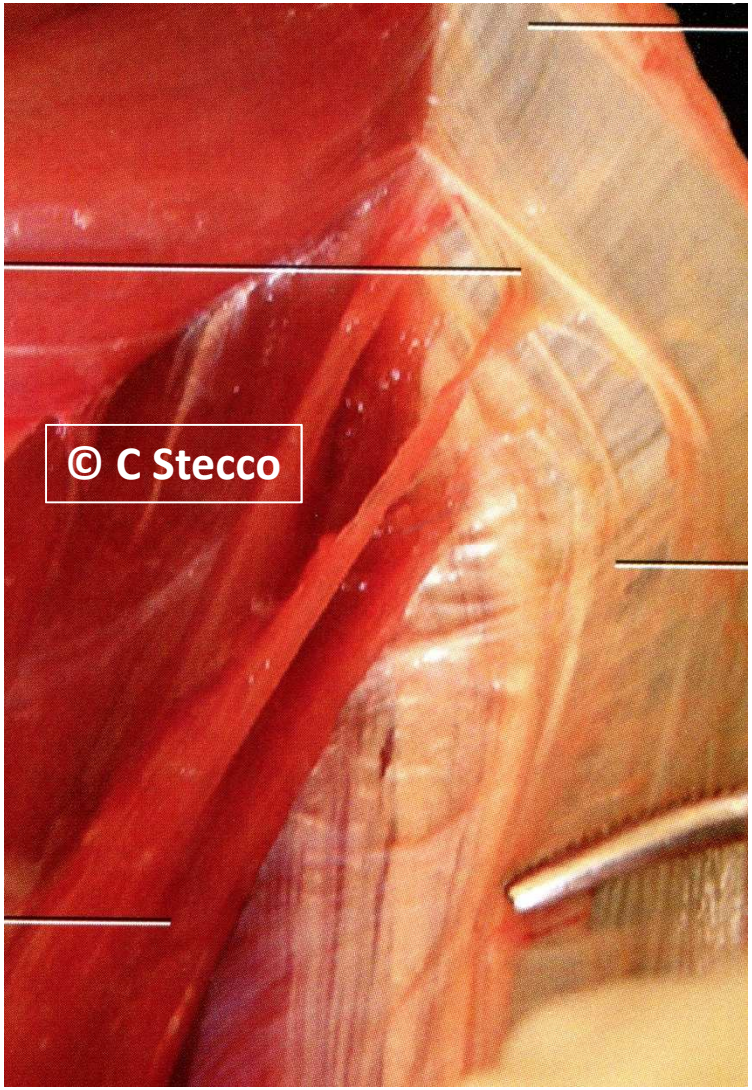
Woytysiak (2013) showed that in newborn pigs the perimuscular collagen fibrils of the m. longissimus lumborum have a wavy disposition and form a loose network. Only with increasing age do the arrangement of collagen fibrils becomes denser and more regular





Causes of alterations in the fibrous component: Overuse

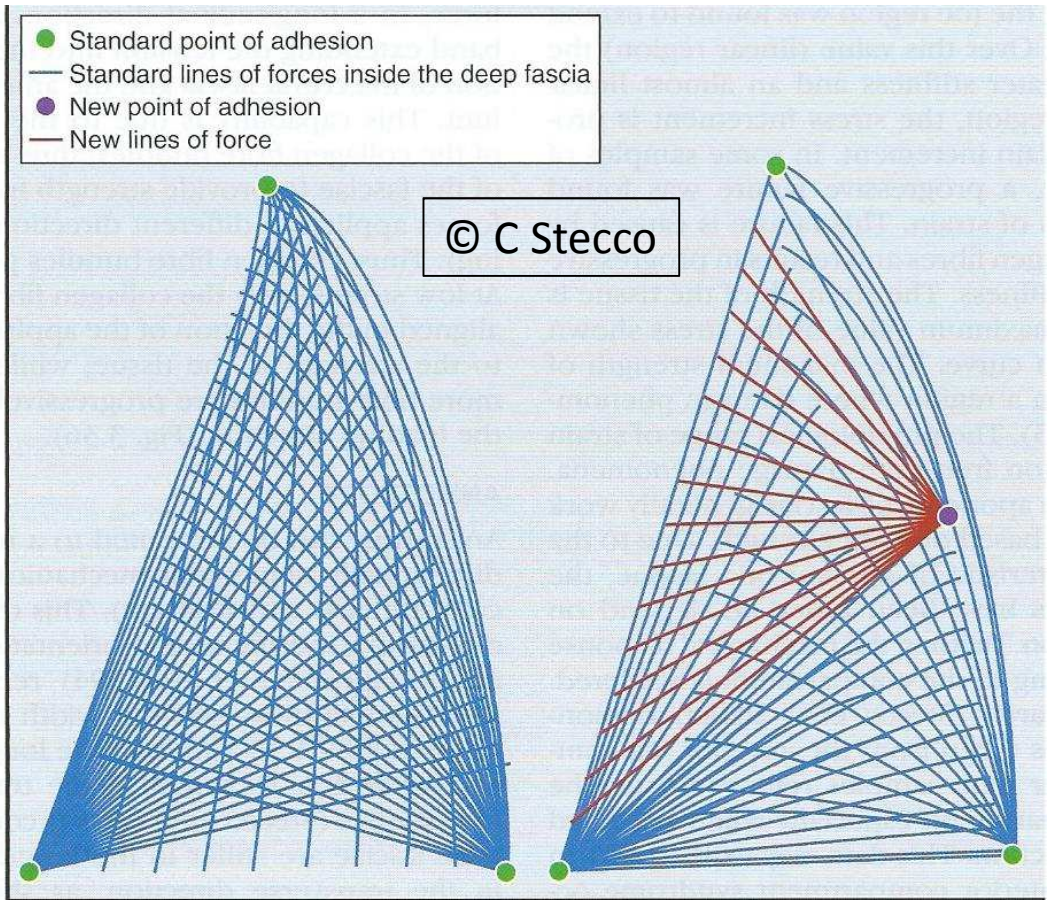
- Connective tissues exhibit adaptive responses to conditions of increased loading and disuse
- If the adaptive response is adequate, the fascia hoard local alterations that change the distribution of the lines of force inside the fascia



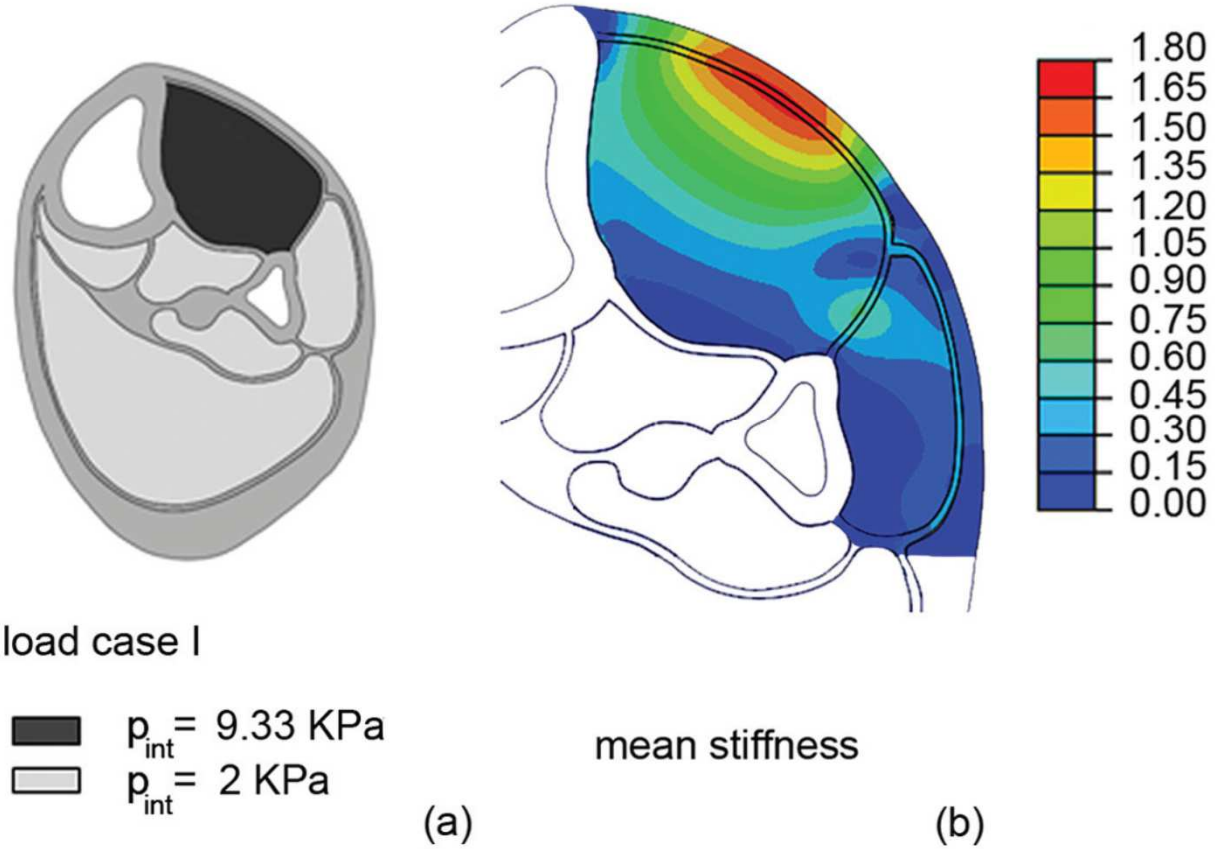
Retinacula and the lines of forces

Retinacula are defined by the forces acting to the deep fascia. In this way fascia remains a light and flexible tissue, but at the same time highly resistant – like a sail.

In case of an injury the resistance will decrease as the lines of forces change.



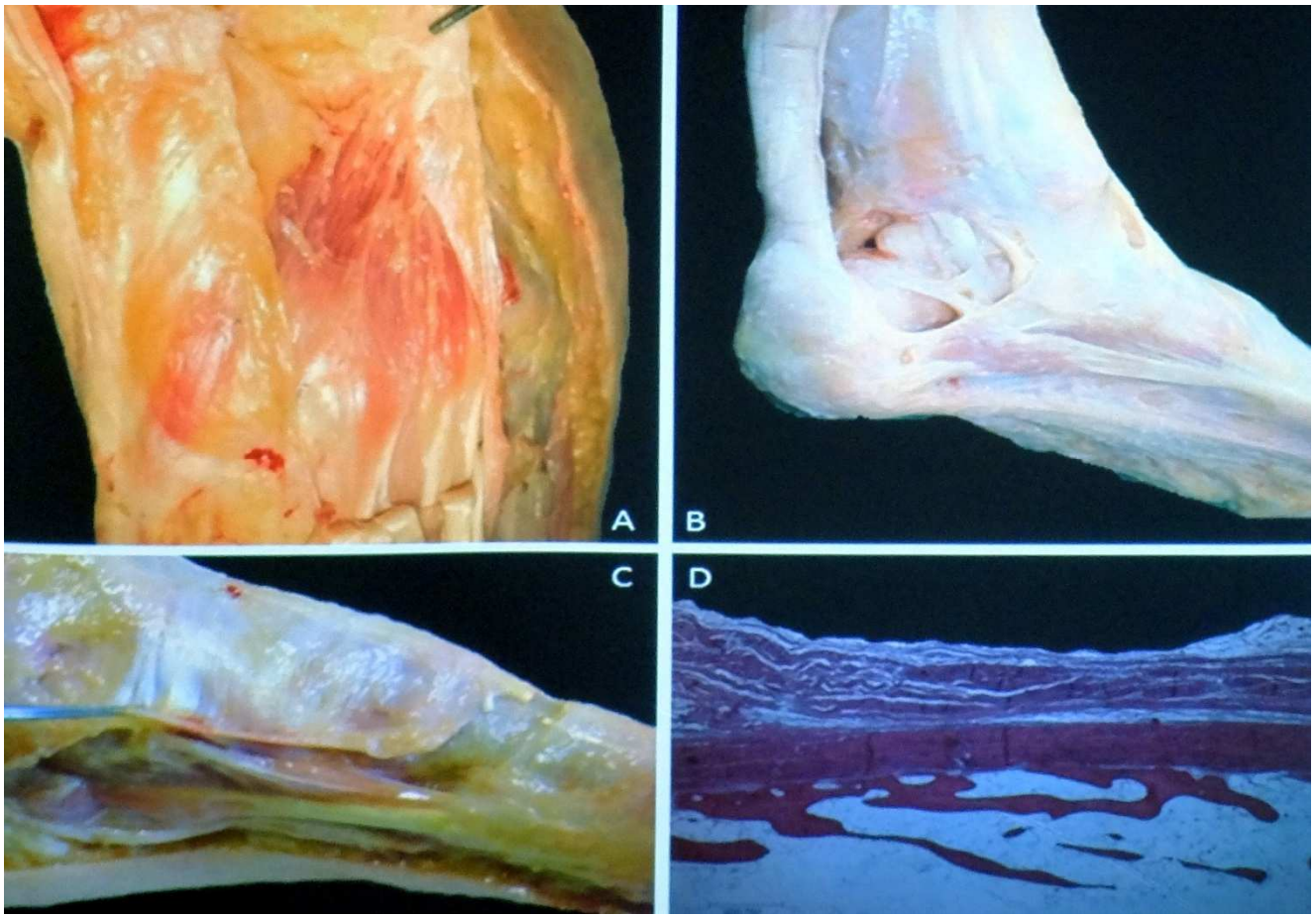
The fascial stiffness can affect the compartment pressure…



Numerical analysis of the effects of a fascial stiffness in compartment pressure. Different pre-stain levels of the crural fascia in the proximal-distal direction changes in the internal pressure in muscular compartments

Pavan PG, Pachera P, Natali AN (2015) Numerical modelling of crural fascia mechanical interaction with muscular compartments. Proc Inst Mech Eng H. 229(5):395-402.

Muscle and bone insertions into retinacula



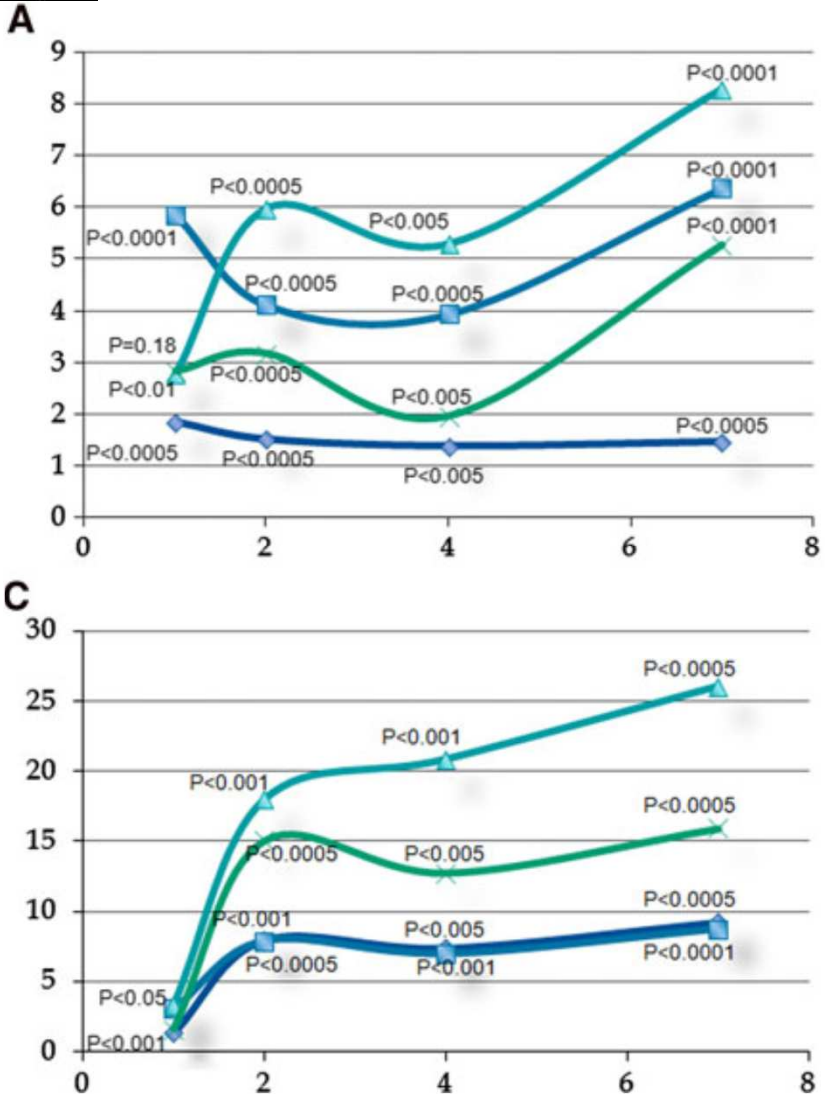
A: extensor digitorum: insertion in inferior retinaculum

B: abductor hallucis brevis: insertion in flexor retinaculum & calcaneus

C: abductor hallucis brevis: insertion in inferior extensor retinaculum

D: connection superior extensor retinaculum to periosteum of fibula

Retinacula damage is related to altered proprioception



A damage of ankle retinacula visible in MRI corresponds to alteration in proprioception seen in static posturography and clinical examination.

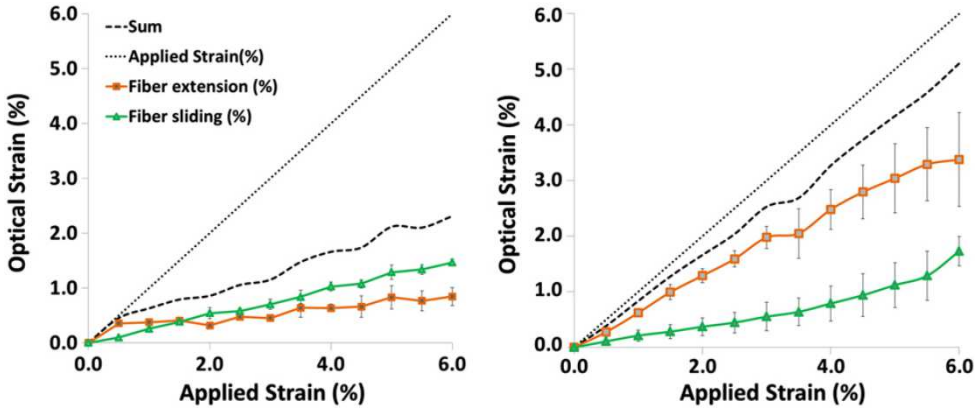
Restoring the normal tension in the fascia will recover the functional stability of the ankle

Stecco A, Stecco C et al. (2011) RMI study and clinical correlations of ankle retinacula damage and outcomes of ankle sprain. Surg Radiol Anat 33: 881–90

Causes of alterations in the fibrous component: Diabetes

- In diabetic subjects there is an increased synthesis of type III and IV collagen, and a concomitant decreased synthesis of type I collagen (Arkkila et al., 2001)
- Patients with type I diabetes have a significantly thicker plantar fascia compared with normal controls (Duffin et al., 2002)

- Diabetes alters the mechanical properties of fibrous tissue, reducing fiber-gliding with a compensatory increase in fiber-stretch (Li et al., 2013)

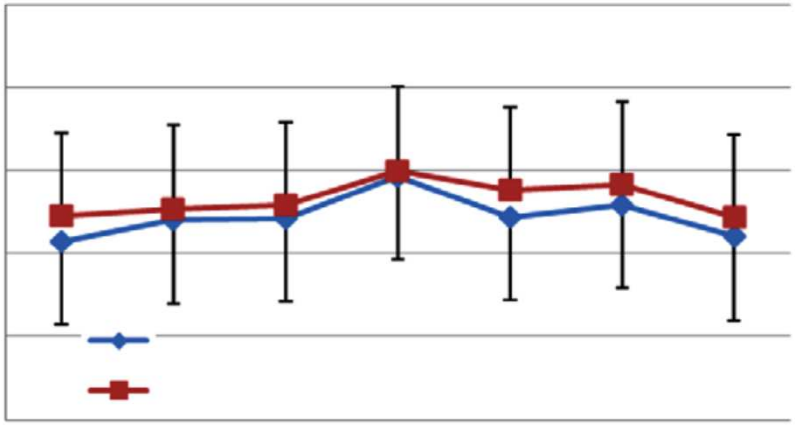


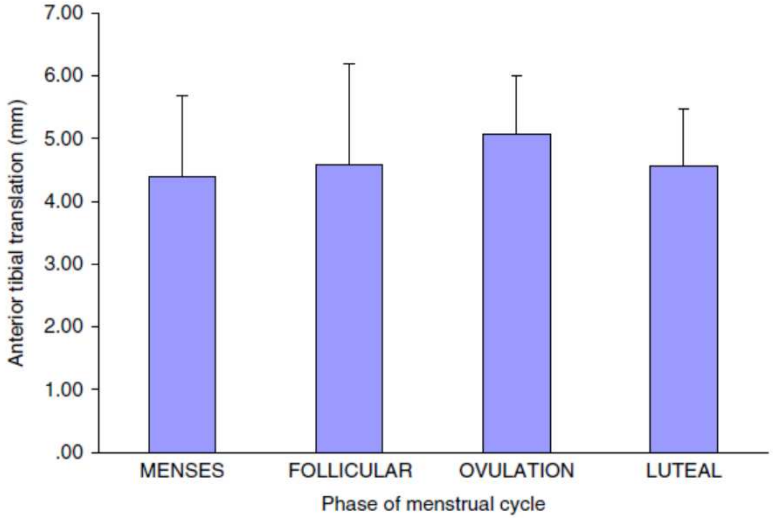
These findings could have important implications for fascial remodeling and mechanically regulated cell signaling.

Causes of alterations in the fibrous component: Hormones

Human CT has receptors for various hormones, such as estrogen receptor β

- Lee et al.(2013): the ACL elasticity changes during the menstrual cycle
- Eiling et al.(2007): musculotendinous stiffness is 5-10% lower in ovulatory phase

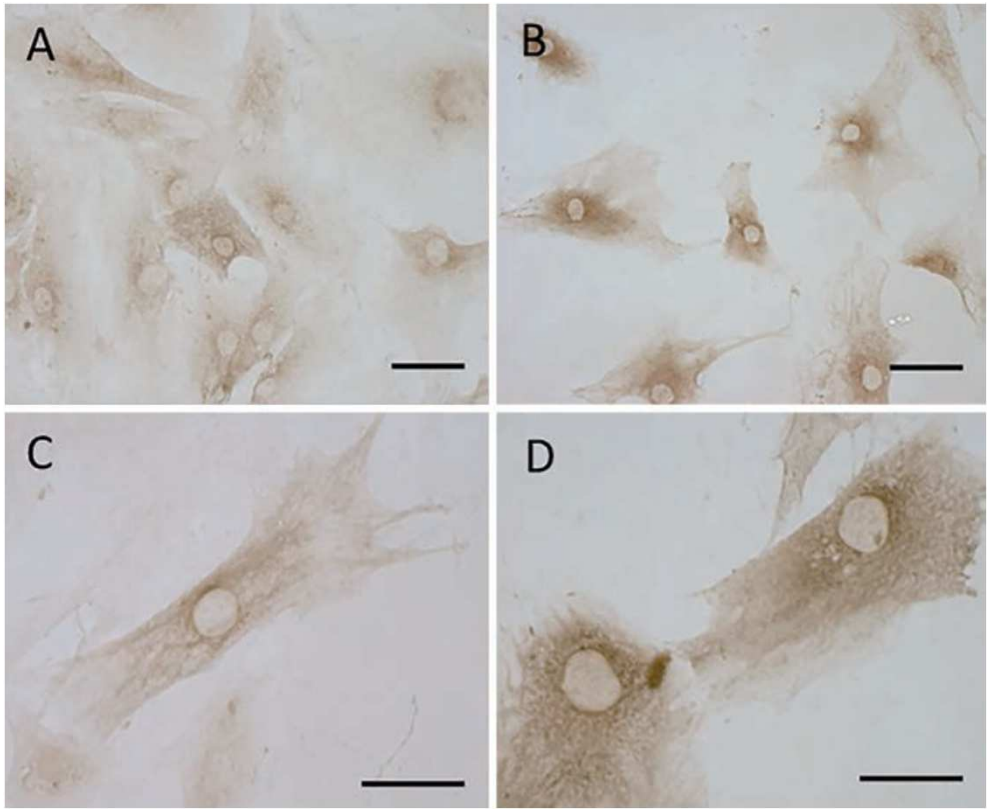




Lee H, Petrofsky JS et al. (2013) Anterior cruciate ligament elasticity and force for flexion during the menstrual cycle. Med Sci Monit. 19:1080-8.
Eiling E, Bryant AL et al. (2007) Effects of menstrual-cycle hormone fluctuations on musculotendinous stiffness and knee joint laxity. Knee Surg Sports Traumatol Arthrosc; 15:126-32

Endocannabinoid receptors in the fascia – A possibility for medication?

- CB1 and CB2 receptors are expressed in human fascia and in human fascial fibroblast culture cells
- The CB receptors of fascial fibroblasts con contribute to modulate the fascial fibrosis and inflammation
- The presence of these receptors could help to explain the role of fascia in pain and the action of cannabinoid drugs in myofascial pain



CB-1 receptors CB-2 receptors

Fede C, Albertin G et al. (2016) Expression of the endocannabinoid receptors in human fascial tissue. Eur J Histochem. 60:130-4

How can we cure a fascial dysfunction ?

Densification:

It is easily curable by increasing temperature, pH, idratation, or increasing the local strain with a controlled mechanical stimulus

Fibrosis:

This alteration is difficult to modify because it is necessary to destroy the pathologic collagen fibers and permit the deposition of new collagen fibers (by inflammation)

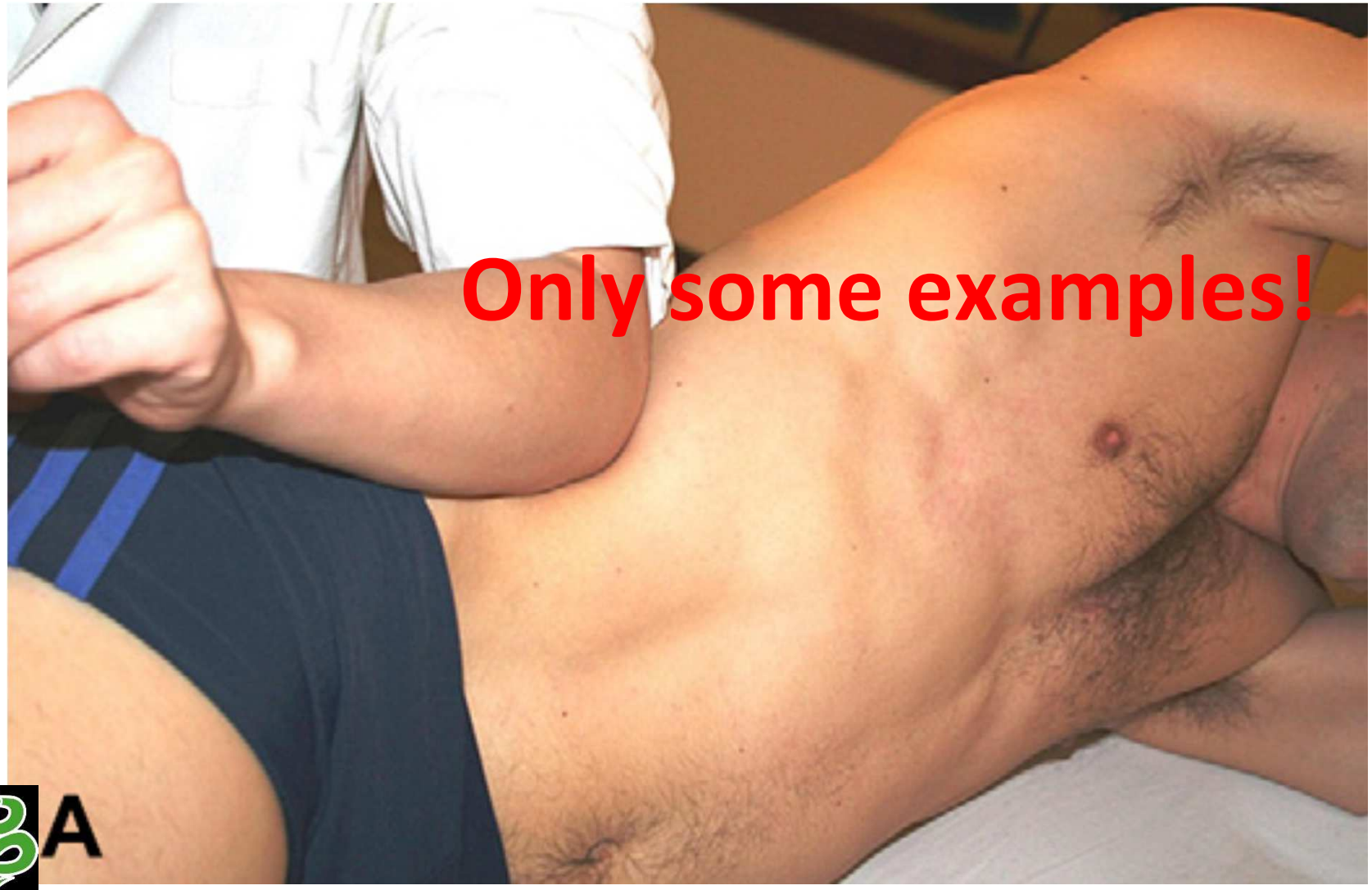
The two alterations are not incompatible:
a chronic altered gliding modifies the distribution of the forces inside the fibrous layers

Fascial Manipulation® – time-consuming, painful, but effective

Only some examples!

Borgini E, Stecco A et al. (2010) How much time is required to modify a fascial fibrosis? J Body Move Th. 14: 318-25

Fascial Manipulation® – time-consuming, painful, but effective



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Thank you for your attention!