PHYSIOLOGY OF THE FASCIA

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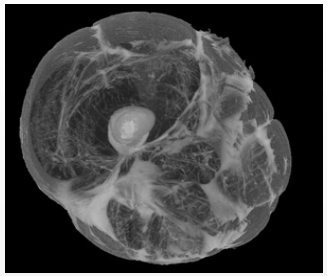
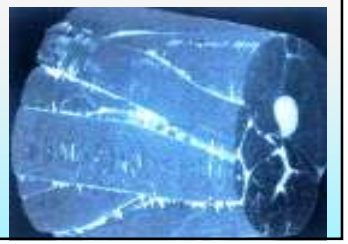
Introduction

Patel and Lieber (1997) and Huijing (1999) have shown that:

- 70% of the transmission of muscle tension is directed (in series) through tendons
- 30% of muscle force is transmitted through the connective structures in parallel

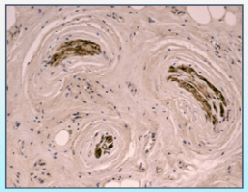




Innervation of the deep fascia

In the last years several researches have demonstrated the presence of many free and encapsulated nerve terminations, particularly Ruffini and Pacini corpuscles, inside the fasciae

Ruffini corpuscles (S100, 200x)



Pacini corpuscles (S100, 100x)

ORIGINAL ARTICLE

Anatomy of the deep fascia of the upper limb. Second part: study of innervation

C. Stecco[a], G. Gagey[b], A. Delmas[c], A. Pozzuoli[d], A. Porzionato[e], V. Macchi[f], R. Aldegheri[g], R. De Caro[h,*], V. Delmas[c]

Innervation of the deep fascia

- Nervous elements were present in all of the specimens, although differences existed according to zones and subjects:
  - Free nerve endining were revealed in all specimens, whereas Ruffini and Pacini corpuscles were present only in some.
  - The flexor retinaculum was the most innervated structure, while lacertus fibrosus was the less innervated

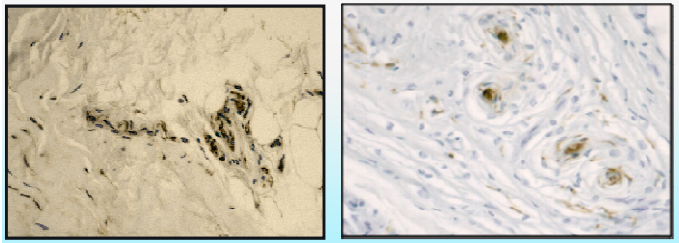
	Brachial fascia	Lacertus fibrosus	Antibrachial fascia	Flexor retinaculum
Nerve	48.57	27.36	44.37	53.55
Pacini Corpuscle	0.43	0.26	0.26	0.66
Ruffini Corpuscle	0.29	0.1	0.26	0.55

Number and types of mechanoreceptors in 1 cm^2

Relationships between nerves and fascia

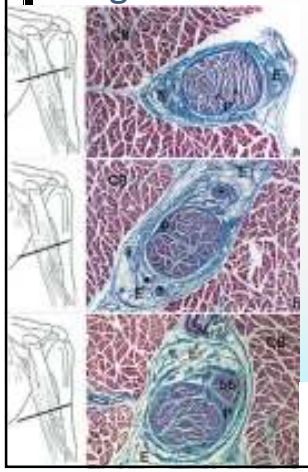
The capsules of the corpuscles and the free nerve endings are connected to the surrounding collagen fibres

Stretching of the deep fascia activates these receptors



S-100 immunohistochemical stain

Large nerve fibres and deep fascia

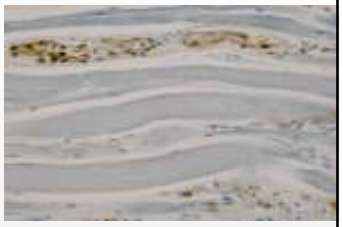


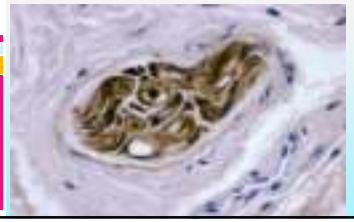
The larger nerve fibres are often surrounded by different layers of loose connective tissue that preserve the nerve from traction to which the fascia is subjected.

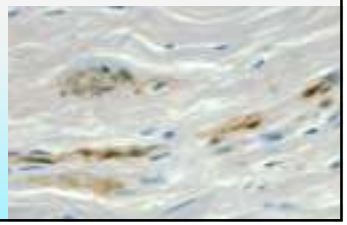
Musculocutaneous Nerve: Histotopographic Study and Clinical Implications

Fascia and proprioception

Could the nerve terminations within the fascia perceive the state of contraction of the underlying muscles?







In the trunk:

Intimate relation between fascia and underlying muscles

The fascia is immediately stretched by the contraction of the underlying muscle

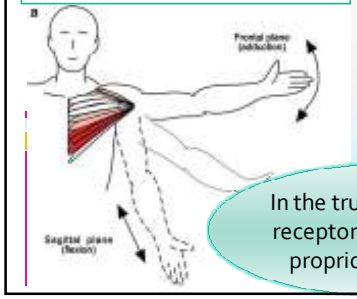
Activation of specific patterns of receptors within the fascia

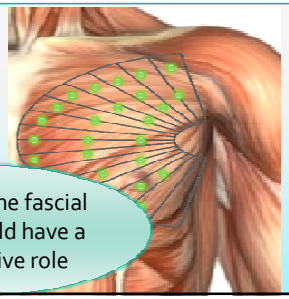
Gluteus maximus and its fascia

Sectorial activation

The muscle is activated in single sectors , stretching specific portions of the corresponding deep fascia

Different pattern of receptors are activated according to the degree of joint movement



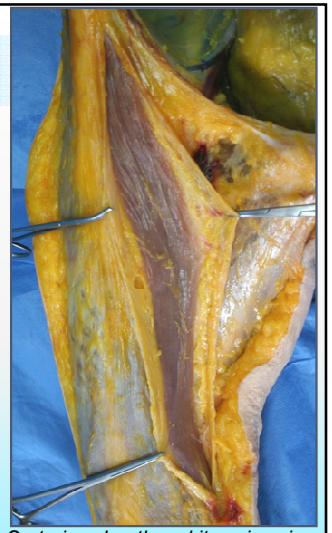


In the trunk, the fascial receptors could have a proprioceptive role

In the limbs:

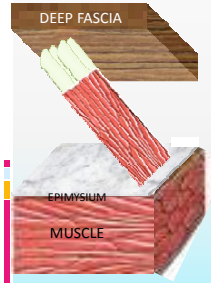
The fascia is relatively separated from the underlying muscles

Could the deep fascia of the limbs have a proprioceptive role?

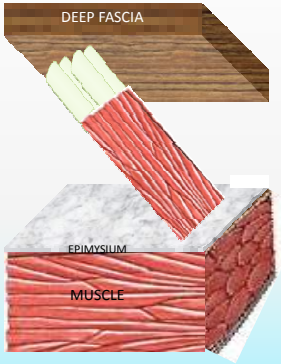


Sartorius sheath and its epimysium

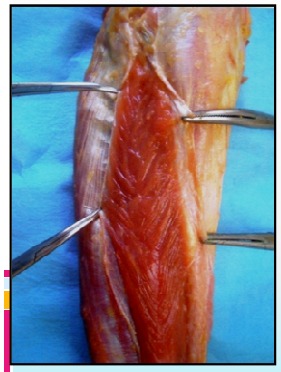
Crural fascia posterior region



Lateral portion of crural fascia



Insertion of muscles into deep fascia



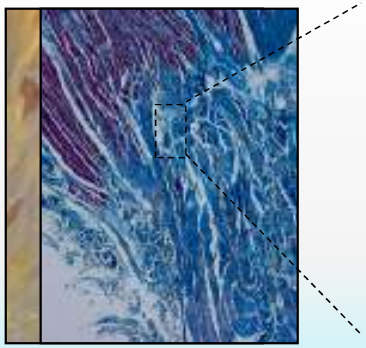
Insertion of the extensor carpi ulnaris at the antebrachial fascia

Insertion of the flexor carpi ulnaris at the antebrachial fascia

Origin of muscular fibers from the deep fascia that presents a thickening in correspondence with these insertions .

13

Continuity between muscular fibres and fascia



The deltoid muscle has some muscular fibers that distally tapers into a fascial insertion. In particular, we can see here the endomysium and epimysium of the muscle that merge with the brachial fascia.

The myofascial expansions

Many muscles have myofascial expansions. When these muscles contract, they also stretch the deep fascia connected with the expansion.

Lacertus fibrosus (aponeurosis) continues from the biceps tendon and merges with the antebrachial fascia

Specific spatial organization

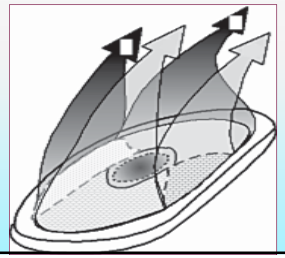
(Stecco et al, CTO, 2008)

The relationships between the expansions of the pectoral girdle muscles (i.e. pectoralis major, latissimus dorsi and deltoid) and brachial fascia were analyzed

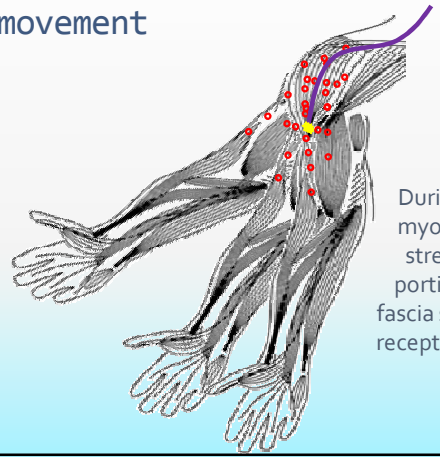
16

From myofascial connections to the perception of direction of movement

During various movements of the arm, these expansions stretch selective portions of the brachial fascia, with possible activation of specific patterns of fascial proprioceptors



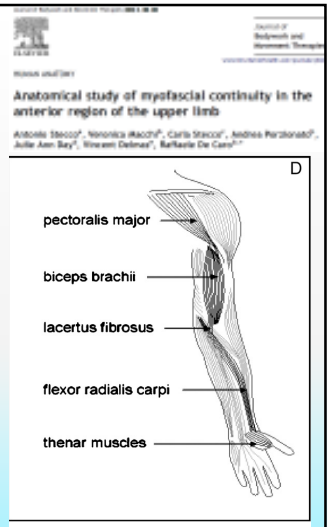
Model of the perception of the movement



During abduction the myofascial expansion stretches the lateral portion of the brachial fascia stimulating specific receptors localized in that region

Myokinetic Chains

- This spatial organization of the myofascial expansions could be also recognized along the limbs, connecting the different segments.
- This organization could guarantee a perceptive continuity along the entire limb, probably representing the anatomical base of the myokinetic chains.



Antemotion sequence

Fascia and proprioception

Fascia is rich in proprioceptive nerve endings

↓

Each movement could activate a specific pattern of receptors

↓

The deep fascia could have a role in proprioception

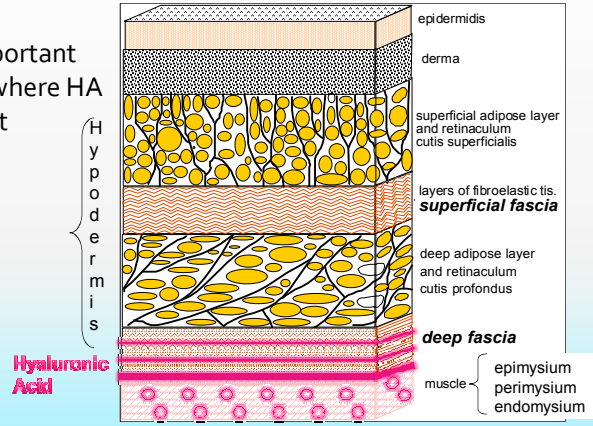
Sliding system

"A plane of potential movement exists in the form of the areolar tissue layer, and this appears to be lined with a lubricant, hyaluronic acid".

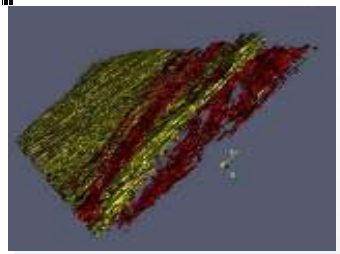
D. McCOMBE, et al; THE HISTOCHEMICAL STRUCTURE OF THE DEEP FASCIA AND ITS STRUCTURAL RESPONSE TO SURGERY; THE JOURNAL OF HAND SURGERY VOL. 26B No. 2 APRIL 2001

Distribution of Hyaluronic acid

Most important regions where HA is present



Structure of the fascia



Benetazzo L, Bizzego A, De Caro R, Frigo G, Guidolin D, Stecco C. 3D reconstruction of the crural and thoracolumbar fasciae. Surg Radiol Anat. 2011 Jan 4.

Hyaluronic acid is one of the chief components of the extracellular matrix.

Frasher, J.R.E ; *Laurent, T. C.; Laurent, U. B. G. (1997). "Hyaluronan: its nature, distribution, functions and turnover".* Journal of Internal Medicine *242: 27–33.*

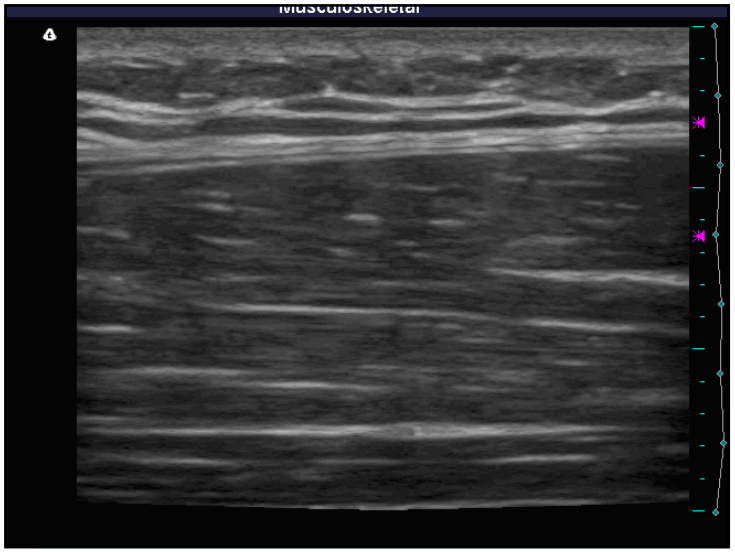
Could hyaluronic acid's alteration change the physiology of the fascia?

Haluronic acid

Between muscles fibres

Under the deep fascia (50X)

Over the muscle

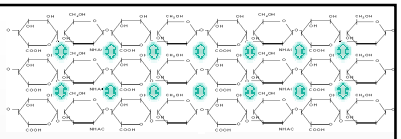


Etiology: overuse syndrome

"The retention of HA after exercise, as well as its endomysial location, is in accordance with the concept that HA is a substance that is present to lubricate and facilitate the movements between the muscle fibers".

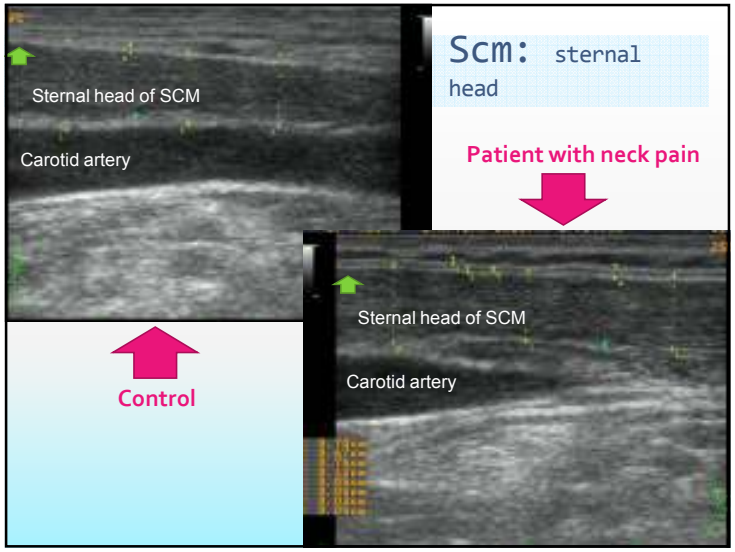
Piehl-Aulin K et al; Hyaluronan in human skeletal muscle of lower extremity: concentration, distribution, and effect of exercise. J Appl Physiol. 1991 Dec;71(6):2493-8.

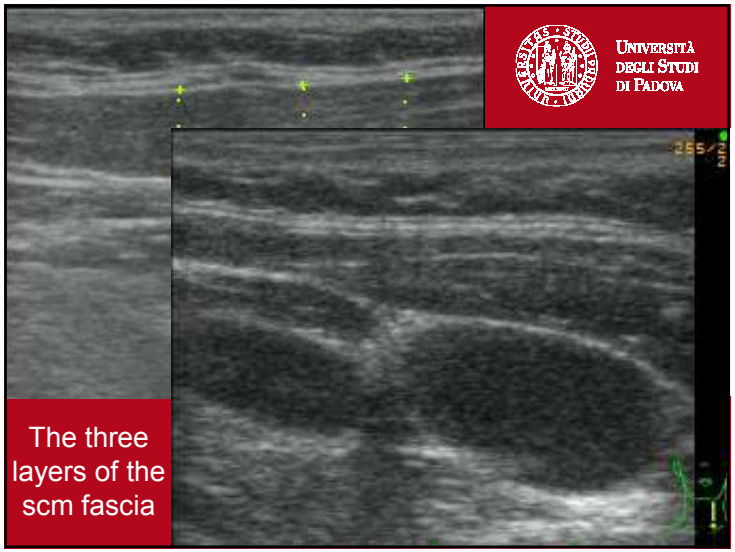
Etiopathology



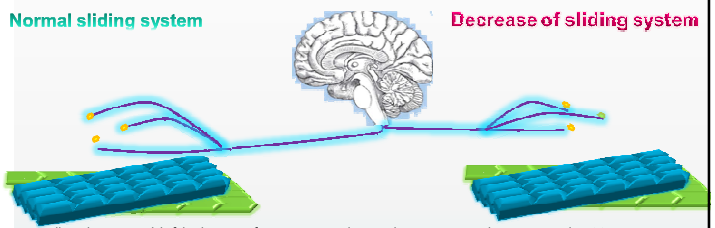
- "Evidence of HA aggregation has also been reported: short HA segments have been demonstrated to self-associate in physiological solution, while a variety of intermolecular aggregates were observed when HA was spread on surfaces".
- "By increasing the concentration of HA, HA chains begin to entangle conferring to the solution distinctive hydrodynamic properties: the viscoelasticity is dramatically increased".

Matteini P et al;Structural behavior of highly concentrated hyaluronan; Biomacromolecules. 2009 Jun 8;10(6):1516-22.





Tissue viscoelasticity shape the dynamic response of mechanoreceptors



- Bell J, Holmes M. Model of the dynamics of receptor potential in a mechanoreceptor.;Math Biosci. 1992 Jul;110(2):139-74.
- Damiano RE; Late onset regression after myopic keratomileusis.;J Refract Surg. 1999 Mar-Apr;15(2):160
- Loewenstein WR Skalak R; Mechanical transmission in a Pacinian corpuscle. An analysis and a theory.;J Physiol.1966 Jan;182(2):346-78.
- Swerup C, Rydqvist B. A mathematical model of the crustacean stretch receptor neuron. Biomechanics of the receptor muscle, mechanosensitive ion channels, and macrotransducer properties. J Neurophysiol. 1996 Oct;76(4):2211-20.
- Husmark I, Ottoson D.;The contribution of mechanical factors to the early adaptation of the spindle response.;J Physiol. 1971 Feb;212(3):577-92.
- Wilkinson RS, Fukami Y.; Responses of isolated Golgi tendon organs of cat to sinusoidal stretch. J Neurophysiol.; 1983 Apr;49(4):976-88.

Gate control

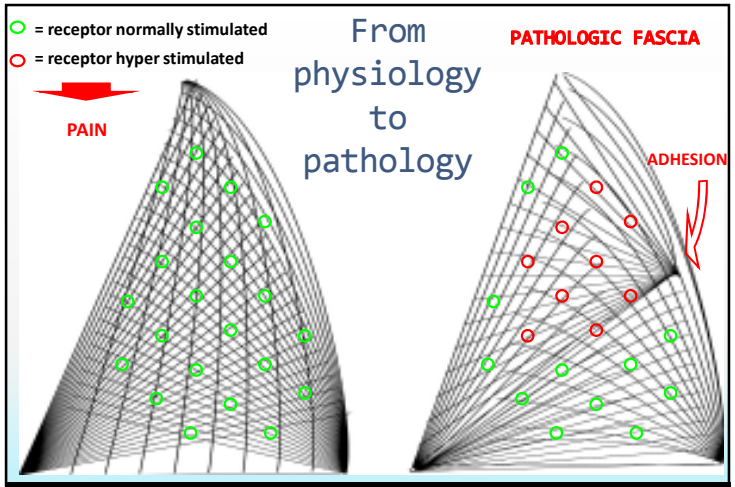
The adaptation of the fascia is possible within certain limits

This mechanism allows a sort of "gate control" on the normal activation of the intrafascial receptors

Beyond this level the nerve terminations are activated

If the fascia's sliding system is altered, the receptors could send a message of pain from stretching that is within the physiological range

From physiology to pathology



The adhesion alters the distribution of lines of force within the fascia and so the surrounding mechanoreceptors send a message of pain

Therapy:

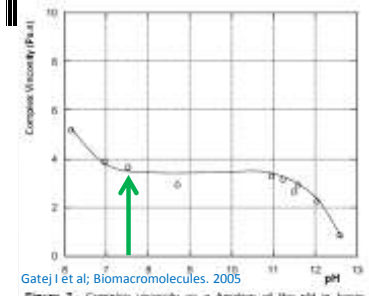
"These chain-chain interactions were reported to be reversibly disaggregated by :"

- "an increase in temperature"
- "alkalinization"

Matteini P et al;Structural behavior of highly concentrated hyaluronan; Biomacromolecules. 2009 Jun 8;10(6):1516-22.

Scott JE, Heatley F;Biological properties of hyaluronan in aqueous solution are controlled and sequestered by reversible tertiary structures, defined by NMR spectroscopy; Biomacromolecules. 2002 May-Jun;3(3):547-53.

Therapy: alkalinization



Gatej I et al; Biomacromolecules. 2005

Figure 7. Complex viscosity as a function of the pH in basic conditions. T = 20 °C, polymer concentration C_p = 10 g/L, and frequency is 1 rad/s.

- At the extenuation, the muscular pH was 6.82 +/-0.05 in the training leg and 6.69 +/-0.04 in the un-training leg.

  Juel C, et al; Am J Physiol Endocrinol Metab. 2004
- During the muscular exercise the pH decrease until 6.69 +/-0.04 (training leg) and until 6.82 +/-0.05 (un-trainig leg)

  Nielsen JJ, et al; J Physiol. 2004.
- The muscular pH decrease from 7.14 at rest until 6.71 (range 6.50-6.87) at the extenuation.

  Juel C, et al; Acta Physiol Sca 1990 Oct

exercise → Increase of HA → Decrease of pH → Increase of viscosity → stiffness

Therapy: increase in temperature

Matteini P et al;Structural behavior of highly concentrated hyaluronan; Biomacromolecules. 2009 Jun 8;10(6):1516-22.

1518 *Biomacromolecules, Vol. 10, No. 6, 2009*

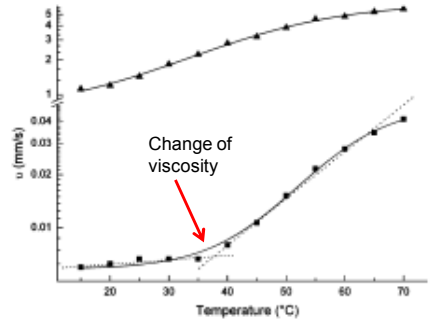


Figure 2. Mean velocity (v; log scale) of a 0.5 mm tungsten carbide ball inside a 100 mg/mL (squares) or a 10 mg/mL (triangles) HA solution in physiological saline as a function of the temperature.

"This water-mediated supramolecular assembly was shown to break down progressively when the temperature was increased to over ~40 °C".

Transition

"The Differential Scanning Calorimetry (DSC) curve enables the detection of an exothermic and an endothermic transition at 25-35 °C and at 45-60 °C, respectively. The latter was ascribed to a gel-like to fluid-like transition".

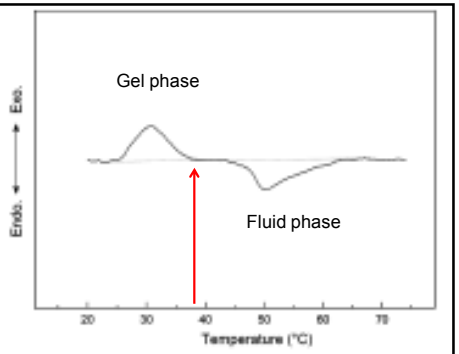
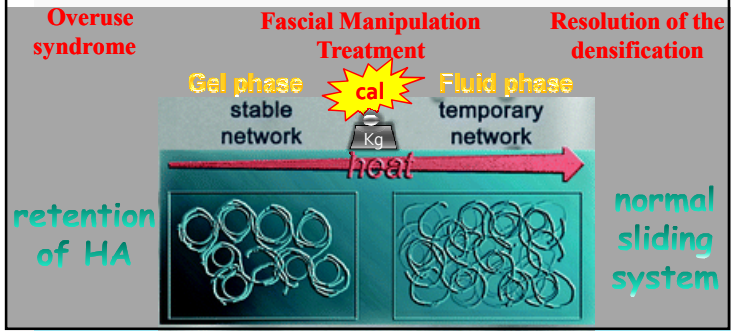


Figure 9. DSC curve (second run measurement) of 100 mg/mL HA in physiological saline recorded at a 5 °C/min scanning rate.

"These values are compatible with weak noncovalent interactions like those characteristic of van der Waals and hydrophobic forces, which are frequently responsible for the structuring of polysaccharide systems".

Densification: gel-like phase

"DSC pointed out the existence of a gel-like to fluid-like transition, while it excluded any involvement of strong intermolecular interactions".



A possible effect of all superficial heating modalities?

But what are the particular effects of Fascial Manipulation?

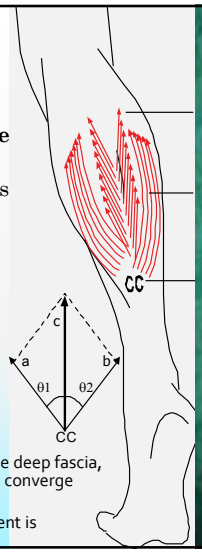
1. We work on the area where there is a densification and not where the symptoms are!
2. An inflammatory reaction lasting for 48 hours appears after the treatment.

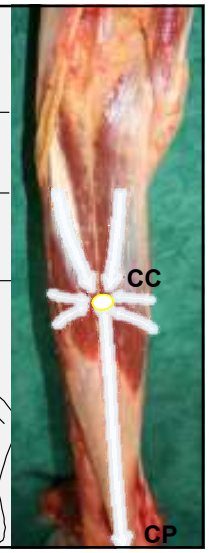
Function of the myofascial unit

The CC of the RE-TA unit corresponds to the **centre of the vectors** formed by:

1. Tractions of the muscle fibers of that motor unit;
2. Tension of the endo- peri- epimysium;
3. Tension of the local segment of deep fascia

A physiological sliding system in the CC is necessary to create a correct final vector

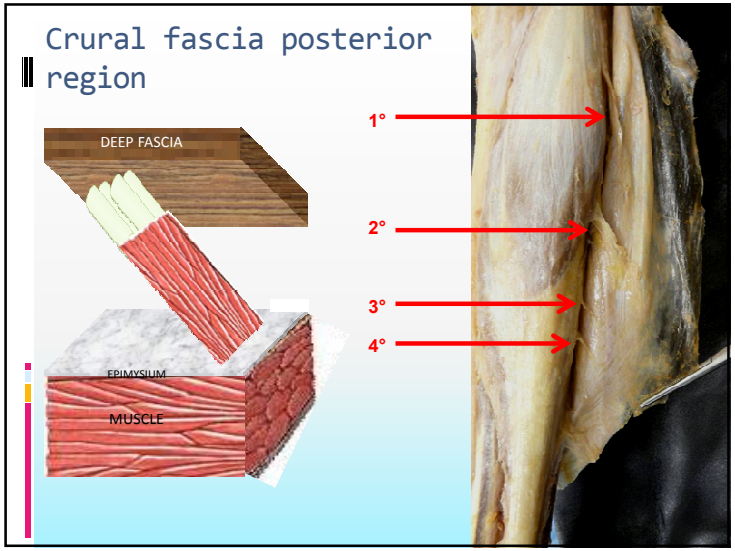




Centre of Coordination (CC) is situated in the deep fascia, where vectors from muscle fibre contraction converge together

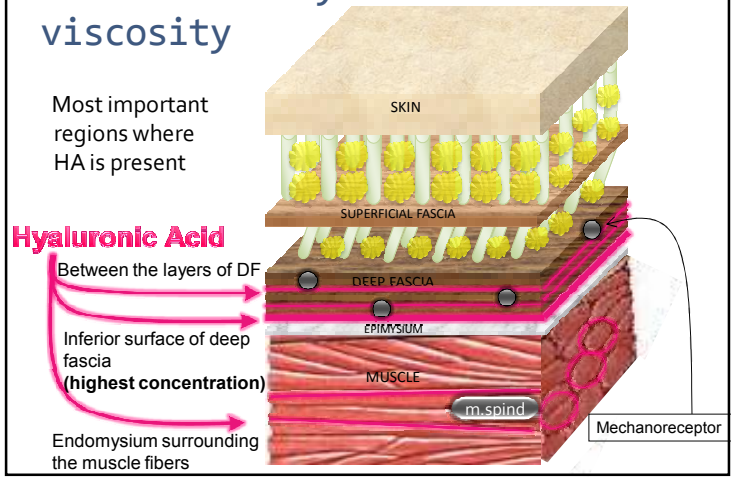
Centre of Perception (CP) is where movement is perceived when the MF Unit is activated

Crural fascia posterior region



Increase of Hyaluronic acid's viscosity

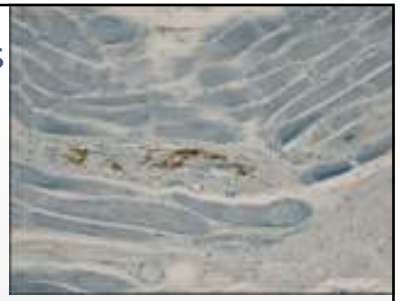
Most important regions where HA is present



Muscle spindles

"The capsule of the muscle spindles is either attached to the perimysium, or to fascial septae, or fine connective tissue threads on in the intramuscular spaces". *Baldissera*

Boyd-Clark LC, Briggs CA, Galea MP. Muscle spindle distribution, morphology,and density in longus colli and multifidus muscles of the cervical spine. Spine(Phila Pa 1976). 2002 Apr 1;27(7):694-701.



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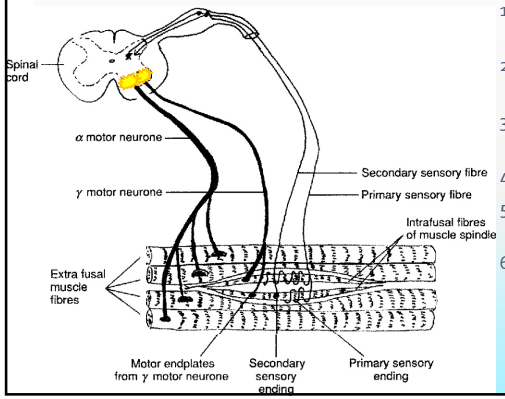
FUNCTIONS: a)Responses during fusimotor action; b)Passive responses

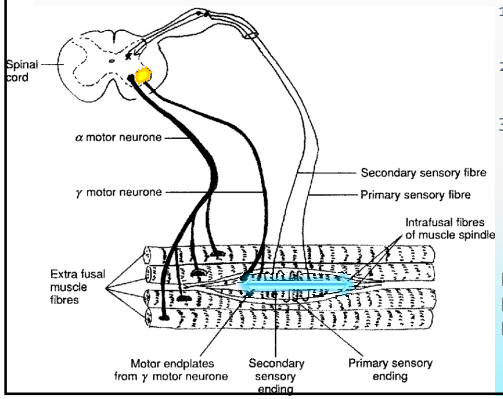
1. Controls and maintains muscle tone
2. Activates the dynamic stretch reflex mechanism
3. Maintains muscle contraction against the constant force of gravity
4. Controls fine motor movements.

Physiology of muscle spindles



1. Gamma motoneuron becomes active
2. Contraction of intrafusal fiber
3. Stretching of annulospiral ring
4. Ia afferent fibre
5. Stimulation of alfa motor neuron
6. Contraction of extrafusal muscle fibres

Pathology of muscle spindles



1. Gamma motoneuron becomes active
2. Contraction of intrafusal fiber
3. The alteration of the capsule doesn't permit the stretching of the annulospiral ring

NO CONTRACTION OF EXTRAFUSAL MUSCLE FIBRES

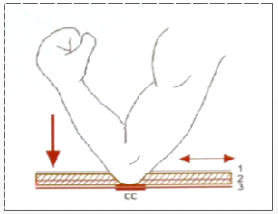
Dysfunction:

- Increase of the viscosity of HA in the Centre of Coordination
- ⇓
- Decrease of the sliding system in the CC
- ⇓
- Decrease activation of muscle spindles
- ⇓
- Improper recruitment of muscle fibres
- ⇓
- The resulting vector becomes faulty
- ⇓
- Mechanical incoordination in the articulation
- ⇓
- Phase of compensation
- ⇓
- Symptoms in the Centre of Perception

The symptoms appear only if the HA's gel phase is present also in the CC!

- HA aggregation
- Viscoelasticity is dramatically increased
  - The location is also in the CC → Dysfunction: symptoms
  - The location is NOT in the CC → NO symptoms

Effect of Fascial Manipulation treatment



Pressure + Friction × Time = Increase of temperature + Stress

Effect of Fascial Manipulation:

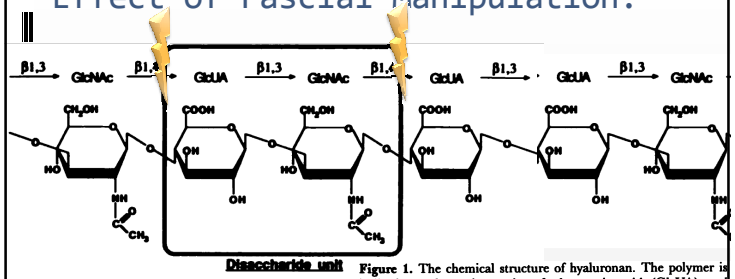


Figure 1. The chemical structure of hyaluronan. The polymer is built from alternating units of glucuronic acid (GlcUA) and N-acetylglucosamine (GlcNAc).

"Under conditions of stress hyaluronan becomes depolymerized and lower molecular mass polymers are generated"

Paul W. Noble; Hyaluronan and its catabolic products in tissue injury and repair; Matrix Biology 21 ,2002. 2529

Stern R et al; Hyaluronan fragments: an information-rich system. Eur J Cell Biol. 2006 Aug;85(8):699-715.

Post Fascial Manipulation effects:

- 0-15 min: Start of the inflammatory reaction
- 15min-12h: Increase in signs and symptoms of inflammatory reaction:
  - *pain, swelling, decrease of function*
- 12h-24h: Peak of inflammatory reaction
- 24h-48h: Resolution of the inflammatory reaction and of the symptoms

"The smallest products of the HA catabolic cascade can turn about and suppress the action of larger predecessors, and thereby mollifying their effects."

Stern R et al; Hyaluronan fragments: an information-rich system. Eur J Cell Biol. 2006 Aug;85(8):699-715.

Thanks