Fascia as a Sensory Organ:
A Literature Review of the Sensory Innervation of Muscular Fascia

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BACKGROUND & APPROACH

A proprioceptive as well as potential nociceptive capacity of fascia has been postulated (5). However, the current understanding of the sensory innervation of fascial tissues has been insufficient.

A related literature review was performed. Database files of Medline, ScienceDirect, Google Scholar, and Embase were searched for the key words ‘fascia’ and ‘innervation’.

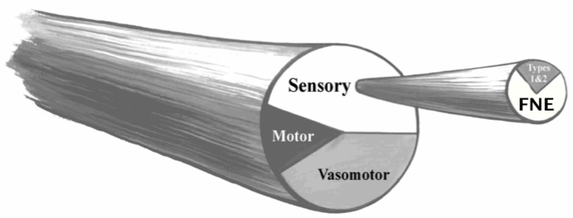

Fig.1: Neuron type distribution.
Within a typical nerve supplying a myofascial region the sensory axons make up the majority of individual neurons (here shown for the nerve supplying soleus & lat. gastrocnemius in the cat). Among these the nerves which terminate in free nerve endings (FNE) make up approximately 80% (4).

Nerve ending	Neuron type	Prefered location
Muscle spindle receptors  primary & secondary	I	Endomysium
Golgi 	I	Highest density in myotendinous junctions
Pacini & Paciniform 	II	Inner layer of joint capsules Spinal ligaments Retinaculi and similar fascial bands with a high proprioceptive function
Golgi-Mazzoni 	II	Inner layer of joint capsules Periosteum
Ruffini 	II	Outer layer of joint capsules Retinaculi and similar fascial bands with a high proprioceptive function
Free nerve endings 	III, IV	Highest density in periosteum Vicinity of blood vessels in perimysium

Table 1: Sensory receptors found in fascial tissues.
Shown here are the receptors, as well as their related neuron types, according to their conventional classification. However, histological distinction between Golgi organs and Ruffini receptors is sometimes difficult, as well as between Pacini and Golgi-Mazzoni corpuscles. It is possible, that their typology relates to a histological continuum rather than a distinct expression pattern.

RESULTS

21 research papers from 1940 to 2011 were identified. Of these, 13 had investigated human fasciae, six fascia from rats, and four from other animals (three examined multiple species). The superficial layer of the lumbar fascia was most frequently examined. While eight papers were published later then 2005, all other were published within the last century (eight papers in 1940-1974, and five in 1988-1996). Only the nine most recent studies employed immunohistochemical identification with modern neuronal antibodies (such as PGP 9.6, CGRP, or S100). At least half of the studies, particularly the older ones, are of poor methodological quality when judged by contemporary standards.

In 20 studies sensory nerves were found in fascial tissues. In all of these small unmyelinated nerves were identified. However, among them only the four most recent studies reported evidence of a termination of these nerves within the fascia (3,11); whereas the previous studies did not mention clear measures to exclude a mere passing of those neurons through the tissue. The majority of studies also report the presence of fascial Pacini and Golgi receptors. Ruffini receptors were clearly identified in six studies only.

Only one study failed to find any sensory nerves (1). This study had examined the dense superficial layer of the human lumbar fascia in chronic back pain patience. This finding contrasts with the most recent study (11), which reports the presence of nociceptive nerve endings when examining the same tissue layer in three low back pain patients.

Newer studies report strong indications for a proprioceptive capacity of at least some of the nerve endings, suggested by their particular distribution pattern within the fascial membranes of the limbs (9).

A clear nociceptive capacity has been demonstrated from the lumbar fascia of humans and rats (11).

Interestingly, newer examinations report the highest density of sensory endings in the loose connective tissue layer located superficial to the dense fascia profunda layer (9,11).

Study	Tisue source /Method	Nerve or nerve endings found
Strasmann et al. 1990	Fasciae of lateral elbow region in rats (n=16) EM: staining with acetylcholinestase in toto	Golgi, Pacini, FNE*. Majority of Golgi attached to septal membranes. Four kinds of FNEs: (1) Without a perineural sheath. (2) With displayed axonal swellings. (3) With a perineural sheath. (4) With perineural sheath and a primitive lamellated corpuscle.
Yahia et al. 1992	Human lumbar fascia (n=7) IH: neurofilament protein and S-1 00 protein	FNE*, Ruffini, Pacini.
Bednar et al 1995	Human lumbar fascia (n=12) IH: neuron-specific enolase	No terminal nerves found. *
Staubesand & Li 1996	Human fascia cruris (from 24 healthy donors and 27 with venous insufficiency) EM: staining with glutaraldehyd	Type II, III and IV nerve fibers, often accompanying intrafascial venes *
Stecco et al. 2007	Deep fascia of human upper limbs (20 limbs from 13 cadavers) IH: S-100	FNE*, Ruffini, Pacini, plus some Golgi-Mazzoni
Stecco et al. 2009a	Pectoral fascia and fascia lata (6 human cadavers) IH: S-100	Some small nerve fibers. No specific differences between f. lata and pect.f. in terms of density or type of innervation.
van der Wal 2009	Fasciae of lateral elbow region in rats (n=15?) EM: staining with acetylcholinestase in toto	FNE*, Golgi & Pacini
Stecco et al. 2009b	Crural fascia (10 legs from 5 human cadavers) IH: S-100	*“Nerve fibres are found in all specimens. They are particularly numerous around vessels, but are also distributed throughout the fibrous components of the fascia.”*
Stecco et al. 2010	Deep fascia of human ankle region (27 legs from 15 bodies, including 3 amputated legs) IH: S-100	Nerve fibers were particularly numerous around vessels, “*although they were also distributed homogeneously throughout the fibrous components of the fascia. Some Ruffini, Pacini and rare Golgi-Mazzoni corpuscles were also highlighted, mainly in the retinacula”.*
Corey et al. 2011	Rats (n=5) 3-D reconstructions of thick (30–80µm) tissue sections IH: PGP9.5, CGRP, fast blue	CGRP positive FNE.
Tesarz et al. 2011	Rat (n=8), human (n=3) IH: PGP 9.5, TH, CGRP, SP	Rich innervation with terminal nerves. Most nerve fibers located in the outer layer and in the SCT.
Benetazzo et al. 2011	Human (n=2) 3D reconstruction of serial sections. IH: S100	Study did not investigate nerve terminations. Small nerves (mean diameter 15 µm) found, flowing from the superficial sub-layer into the adjacent SCT. No nerves visible in intermediate and deep sub-layers.

Table 2: Comparison of innervation studies with modest and good methodological standards. Excluded in this table are older studies, which used light microscopy only. Abbreviations: EM: electronmicroscopy. IH: immunohistochemical analysis. FNE: free nerve ending. SCT: subcutaneous loose connective tissue. SCT: subcutaneous connectiv tissue. *Method of identification of termination of small nerves not mentioned.

CONCLUSIONS

- The majority of studies was performed in the last century, and these are of poor methodological quality.
- Recent publications suggest a proprioceptive innervation of fascial tissues, particularly with Golgi and Pacini receptors.
- There are also strong indications for a nociceptive capacity in the human lumbar fascia.
- Two recent studies indicate a particularly dense innervation of the loose connective tissue superficial to the fascia profunda.

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