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Fascia: a morphological description and classification system based on a literature review

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Fascia is virtually inseparable from all structures in the body and acts to create continuity amongst tissues to enhance function and support. In the past fascia has been difficult to study leading to ambiguities in nomenclature, which have only recently been addressed. Through review of the available literature, advances in fascia research were compiled, and issues related to terminology, descriptions, and clinical relevance of fascia were addressed. Our multimodal search strategy was conducted in Medline and PubMed databases, with other targeted searches in Google Scholar and by hand, utilizing reference lists and conference proceedings.

In an effort to organize nomenclature for fascial structures provided by the Federative International Committee on Anatomical Terminology (FICAT), we developed a functional classification system which includes four categories of fascia: i) linking, ii) fascicular, iii) compression, and iv) separating fasciae. Each category was developed from descriptions in the literature on gross anatomy, histology, and biomechanics; the category names reflect the function of the fascia.

An up-to-date definition of fascia is provided, as well as descriptions of its function and clinical features. Our

Le fascia est pratiquement inséparable de toutes les structures du corps, et il sert à créer une continuité entre les tissus afin d'en améliorer la fonction et le soutien. Il a déjà été difficile d'étudier le fascia, ce qui a donné lieu à des ambiguïtés dans la nomenclature, qui n'ont été abordées que récemment. Grâce à un examen de la documentation disponible, les avancées dans la recherche sur le fascia ont été compilées, et les problèmes relevant de la terminologie, des descriptions et de la pertinence clinique du fascia ont été traités. Nous avons adopté une stratégie de recherche multimodale pour nos recherches dans les bases de données Medline et PubMed, avec des recherches ciblées dans Google Scholar et manuelles, au moyen de listes de références et de comptes rendus de congrès.

Dans le but d'organiser la nomenclature des structures du fascia fournie par le Federative International Committee on Anatomical Terminology (FICAT, traduction libre : comité fédératif international de terminologie anatomique), nous avons mis au point un système de classification fonctionnel qui comprend quatre catégories de fascia : les fascias i) de liaison, ii) fasciculaire, iii) de compression et iv) de séparation. Chaque catégorie a été élaborée à partir de descriptions se trouvant dans la littérature portant sur l'anatomie macroscopique, l'histologie et la biomécanique. Le nom de chaque catégorie se rapporte à la fonction du fascia.

Une définition à jour du fascia est fournie, ainsi que des descriptions de ses fonctions et caractéristiques cliniques. Notre classification emploie la terminologie

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classification demonstrates the use of internationally accepted terminology in an ontology which can improve understanding of major terms in each category of fascia. (JCCA 2012;56(3):179-191)

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acceptée à l'échelle internationale dans le cadre d'une ontologie qui peut améliorer la compréhension des termes importants dans chaque catégorie de fascia. (JCCA 2012;56(3):179-191)

MOTS CLÉS : fascia, tissu conjonctif, classification, anatomie, histologie, terminologie, innervations, thérapeutique manuelle

Introduction

Fascia is an uninterrupted viscoelastic tissue which forms a functional 3-dimensional collagen matrix.[1-3] It surrounds and penetrates all structures of the body extending from head to toe, thus making it difficult to isolate and develop its nomenclature.[1] The Federative International Committee on Anatomical Terminology (FICAT), in the 1998 edition of Terminologia Anatomica, points out significant flaws in the nomenclature system for fascia, largely stemming from the anglocentric nature of the terms used, and lack of formal international applicability.[4] The usage of the terms *superficial fascia* and *deep fascia* is considered incorrect by the FICAT because histological terminology referring to layers of the connective tissue varies too much internationally to be generalized by these two terms.[4] Common names of certain fascia are also considered to be inaccurate, e.g., *Scarpa's*, *Camper's*, and *Colles'*. It is suggested that they be replaced with *subcutaneous tissue of abdomen membranous layer*, *subcutaneous tissue of abdomen fatty layer* and *membranous layer of perineum*, respectively.[4] Terminologia Anatomica gives a long list of terms related to their definition of fascia, and attempts to offer a system for grouping various fasciae based on embryological origins and modes of development. However, clear details on the groupings and justification for this strategy are not given, and it remains difficult to organize and properly use the multiple fascial terms. Furthermore, the application of these terms for communication in research, education, and clinical practice remains difficult and impractical. In light of the contribution made by the FICAT on fascial terminology, it is important to utilize their work on terminology and suggest how it may be further arranged and used in practice. Indeed, a number of experts have called for further development on the description and nomenclature of all fasciae and have made significant contributions of their own.[5-7]

Recent advances in research within the fields of biomechanics, gross anatomy, and histology, provide the international research community with an opportunity to improve the terminology associated with fascia, thereby improving intra- and inter-professional communications.[5,8-10] However, discrepancies still exist concerning the official definition, terminology, classification and clinical significance of fascia.[5-6]

For example, the FICAT broadly defines fascia as sheaths, sheets or other dissectible connective tissue aggregations. The First International Fascia Research Congress (2007) formulated a comprehensive definition of fascia as the soft tissue component of the connective tissue system, emphasizing its uninterrupted, three-dimensional web-like extensions and highlighting its functional attributes.[1,4] The Congress went on to include joint and organ capsules, muscular septa, ligaments, retinacula, aponeuroses, tendons, myofascia, neurofascia and other fibrous collagenous tissues as forms of fascia, inseparable from surrounding connective tissues.[1] The broad nature of these two definitions is controversial, and not all of the tissues have been widely accepted into common usage. Thus, a consistent terminology to classify and categorize fascia has not been formally established and accepted internationally.[5-6] Gray's textbook approach to naming fascia regionally based on the adjacent or overlaying structures is a practical approach, however, this suggests fascia has a beginning and an end, which is not true to its form.[11-12] Thus, the topographical approach is important when identifying regional fascia, but it is not used consistently in practice internationally, nor does it help to describe the functional role of the regional fascia.

A more recent ontology highlights the importance of two functional forms of fascia, *connecting* and *disconnecting*, for which fiber orientation and descriptions of fascia's role in proprioception are key justifications for each category.[7] In support of this principle, there is an extensive body of work demonstrating that significant amounts of force are transmitted amongst multiple antagonist and synergistic muscle groups across joint capsules through various sections of extra- and intramuscular fascia.[7-8,13-15]

Although the recent ontologies grounded in fascial function represent an advance in classification, the complexities of fascia make it necessary to expand on these two categories (*connecting* and *disconnecting*) to further sort and describe all groups of fascia according to their attributes reported recently in the literature.[7] These additional attributes include: collagen type ratio, extracellular matrix proteins, nerve fiber types, myofascial force transmitting potential, details on fiber orientation, and influence on the circulatory system.[8,16-21]

Lack of consistent terminology has a negative effect on communication within health professions, and impedes collaborations in research.[22] Since fascia represents a topic of growing interest worldwide, it should be a priority to reduce ambiguity in fundamental terms so that this field of research can properly advance. For example, the lack of common definitions and nomenclature hinders communication between those involved in the process of diagnosis and treatment of pelvic pathologies in everyday practice.[23] One study revealed this by comparing the unofficial/common terms being used in the field and the terms provided by the Terminologia Anatomica, demonstrating how this text can be used to improve consistency in the nomenclature. While we do accept the validity of a topographical approach in naming fascia, it does not take into account the fact that fascia doesn't have a beginning and end like muscle, nor does a topographical approach account for fascia's microscopic features, or diversity of its functional characteristics.[5-7,12]

Purpose

The aim of the present study is to develop a classification system for fascial structures, based primarily on their functional properties, but also incorporating morphological characteristics identified in the literature, and utilizing internationally accepted terminology from the FICAT.[4,24]

Methods:

A review of the literature on fascia was conducted with electronic searches of EBSCO databases, PubMed, and Google Scholar, along with hand searches of proceedings from the past two International Fascia Research Congresses (2007, 2009). Search strategies in EBSCO and PubMed consisted of individual and combined MeSH term searches for "Fascia" and "Connective Tissue" using specific limiters for our topic to emphasize anatomy. These search terms were also paired separately with various keywords – "terminology", "extracellular matrix", "collagen", and "function". Results were limited to English, full text peer reviewed journal articles, conference proceedings, and textbooks. Inclusion was limited to articles with abstracts related to morphology, terminology, and/or clinical aspects of fascia. Information was then used to help organize fascia terminology, utilizing terms from two texts: Terminologia Anatomica and Terminologia Histologica.[4,24]

Results

In section A below, we present the results of our literature review, discussing the anatomical, histological, and biomechanical features of fascia, and its innervation. Then in section B, we outline our resulting proposal for a new classification system (Table 1) incorporating these features of fascia. It is important to first understand the key characteristics and the divergent classifications of fascia at gross anatomical, histological, and biomechanical perspectives before outlining the details of these four categories.

A. Literature Review

I. Overview

The range of research advances revealed in the literature includes observations on imaging, advanced dissection and staining techniques, as well as modeling of tissue deformation, and in vitro cellular processes.[10,12,25-30] Areas of interest at the past two (2009, 2010) Fascia Research Congresses have included: biomechanics, innervation, vascularisation, molecular structure, clinical relevance, and terminology.[31] Upon review of the advances in fascia research, we see that fascia is not a passive structure, but a functional organ of stability and motion, virtually inseparable from all surrounding tissue.

II. Gross Anatomy

Gross anatomical studies of fascia demonstrate an array of characteristics based on location, density, fiber direction, and fascia's relationship to surrounding structures.[19,26-27] Based on location, the FICAT describes the following fasciae: i) in relation to the body regions: fascia of head and neck, fascia of trunk, and fascia of limbs, ii) in relation to the surrounding structures: subcutaneous fascia, fascia of muscles, visceral fascia, parietal fascia, and fascia extraserosalis which represents any other fascia which lies inside the parietal fascia and outside the visceral fascia.[4]

Fascia's key characteristic, continuity, helps explain concepts such as myofascial force transmission.[3] Hunjing describes biomechanical features of extramuscular and intramuscular force transmission in rat specimens where surrounding connective tissues are seen to influence force potential and connect muscle groups.[13-15] Dissectional observations of the intramuscular connective tissue (IMCT) show this fascia to influence length of sarcomeres to improve force production.[15] Other morphological descriptions of fascia characterize it as being optimally designed to take up tensional forces in the musculoskeletal system.

In the past, classical dissection techniques have essentially ignored fascia , simply removing it to get to muscle and deeper structures.[5] Subsequently, it was revealed through careful dissection that fascia commonly occurs as an undulating layered system of different connective tissue types.[19,28-29] Three-dimensional models of the crural and thoracolumbar fasciae demonstrate that the "deep fasciae" are formed of three sub-layers of connective tissue with different densities and orientations.[19,29] It was discovered that in each sub-layer the collagen fibers are parallel to each other, whereas the orientation between the fibers of adjacent layers changes, forming an angle of approximately 70-80 degrees with each other.[29] This allows denser fascial sheets to slide freely over underlying layers, without significant friction, and enhances fascia's ability to take up strain in virtually all directions.[29]

It is difficult to gain an appreciation for the true appearance of fascia, aside from basic structure, in embalmed cadavers. Direct observation of fascia's appearance and behavior in a living, hydrated body, has been conducted with recent fluoroscopic imaging under the skin of the dorsal forearm, shedding new light on how this sliding collagenous system works.[32-33] These observations demonstrate that fascia incorporates a water dense vacuolar system able to slide independent of the rate of contraction in muscle around it and able to conduct structures like capillaries throughout sections of myofascia.[32-33] The viscoelastic nature of fascia can only be observed in hydrated tissue, and in embalmed tissue we are only observing an artifact of the living tissue. A better appreciation for the true gross appearance of fascia can be gained through fresh body dissections, and in vivo via direct imaging techniques.[34]

Pathological changes in fascia have been observed with special imaging techniques, such as ultrasonic elastography that displays deformation and the elasticity of soft tissues.[34] This technology allows a non-invasive estimation of tissues stiffness based on the fact that soft tissue has greater tissue displacement than hard tissue when externally compressed.[10] By further quantifying the properties of the soft tissues, as with recent 3-D mathematical models of fascial deformation, insight will be gained into the effects of manual treatments beneath the skin and how the body responds to various forces.[30,35-36]

III. Histology

Fascia has specific cells, ground substance, and fiber types that make it a form of connective tissue proper.[16,37-38] A better understanding of fascia at the cellular level gives insight into its functional properties.[39] Clear changes to the extracellular matrix (ECM) in the form of adhesive sites between microscopic filaments have been studied in "scarred" fascia.[40-41] Collagen types have also been shown to vary with mechanical forces and strains.[39] We hypothesize that the functional properties of fascia are reliant on the composition of the ECM, specific cells, and filaments, including but not limited to the ratio of collagen types.

Collagen, a triple helix glycoprotein, is the key structural fiber that gives connective tissue its ability to resist tension.[17,37-38] There are twenty five distinct collagen types recognized in the Ross histology textbook and atlas, and twenty eight collagen types recognized in the latest review by Gordon.[16,37] Although, type I collagen is the main type accounting for 90% of the human body's collagen, fascia contains an array of collagen type combinations including, but not limited to, types I, III, IV, V, VI, XI, XII, XIV, XXI.[16-17,37-38] Collagen provides resistance to tension and stretch, which commonly occur in fascial tissues, such as ligaments, tendons, sheaths, muscular fascia and deeper fascial sub-layers.[37]

Collagen type III, also known as reticular fiber, is involved in forming the scaffolding for the cells of the loose connective tissues related to the endoneurium, vascular walls, and smooth muscle.[1-2,17]A collagen fibril needs the support of not only fibrillar collagen types, but also a mix of non-fibrillar forms known as fibril-associated collagens with interrupted triple helices (FACITs).[16] The functions of FACITs include: i) anchoring to the basement membrane, ii) regulating the diameter of fibrils, iii) forming lattice networks, and iv) acting as transmembrane structures.[16] These fibrils are important to the integrity and function of fascia within the ECM. Elastic fibers within the ground substance give fascia its characteristic stretch.[29,37-38,42]

A combination of multiple types of collagen within the extracellular matrix forms a unique structure, like a blueprint that reflects the function and compliance of fascia in various regions.[16-17] Without a characteristic fiber arrangement and composition for each fascial region, it is likely that fascia would not withstand stresses or have the same function.

The cells within fascia include fibrocytes (fibroblasts, myofibroblasts), adipocytes, and various migrating white blood cells.[27,41-42] Fibroblasts are highly adaptable to their environment, and show a capacity to remodel in response to the direction of various mechanical stimuli, producing biochemical responses.[29,41,43-45] If function changes, as with increased mechanical stress, or prolonged immobilization, deoxyribonucleic acid (DNA) transcription of pro-collagen in the fibroblasts will change types (e.g., collagen type I into collagen type III), or undifferentiated cell types may adapt towards a more functionally appropriate lineage (e.g., chondrocyte).[42,45-48]

Benjamin et al, studied the morphological changes observable in various tendons and ligaments in response to biomechanical stresses.[46] It was established that the tissue structure and the molecular composition of ECM are directly correlated with the local mechanical forces.[46,47] Under significant states of compression, tissue once populated with fibroblasts, becomes invested predominately with chondrocytes and forms specialized connective tissue, cartilage, with further solid mineral deposition.[46,47] These adaptations have been demonstrated in the supraspinatus tendon, transverse acetabular ligament, transverse ligament of atlas, as well as various other ligaments and tendons throughout the body.[47,48]

Myofibroblasts within fascia demonstrate contractile properties and contain actin-myosin filaments typically seen in smooth muscle.[49-51] The significance of these contractile properties remains unclear, however in-vitro observations of autonomous contraction of myofibroblasts harvested from porcine and rat fascia when stimulated with various pharmacological agents (i.e., mepyramine, angiotensine, glyceryltrinitrate) have been repeated in different labratories.[52-53] An estimation of tension created by contraction of myofibroblasts when extrapolated to a large fascial sheet (i.e., thoracolumbar fascia) may produce tension within the musculoskeletal system between 30-40N.[51] The significance of this contractile property remains hypothetical and reproduction of these contractile forces in-vivo in response to efferent neural stimulus is yet to be done.

Increased concentration of myofibroblasts in pathological fascia has been observed, suspected to create tissue contractures in clinical conditions like palmar fascial fibromatosis (Dupuytren's disease), plantar fascial fibromatosis (Ledderhose's disease), and adhesive capsulitis (frozen shoulder).[49,54-56] Fascia is also susceptible to the actions of typical cells of inflammation influencing communication, growth, and function.[37,38]

Fiber orientation in fascia is important to its overall structure and function, and can be viewed with the unaided eye, polarized light, or various microscopic techniques.[18,27,57] It is a consistent observation that the fibers are oriented parallel to predicted force vectors, and are likely to resist tension.[18,27,57] Based on certain common characteristics, including the fiber arrangement, connective tissue proper is classified by the Terminologia Histologica as loose connective tissue and dense connective tissue.[24] The dense connective tissue is sub-categorized as: i) unidirectional parallel ordered dense connective tissue, ii) multidirectional parallel ordered dense connective tissue, iii) woven connective tissue, iv) irregular fusocellular connective tissue.[24]

IV. Mechanotransduction

Mechanotransduction entails significant cellular change that occurs in response to biomechanical tension and compression. These stimuli exert their effects within the cells through filaments of the ECM, and so mechanical stimulation leads to a cascade of events which eventually influences the activity in the nucleus.[48,58,59] Mechanotransduction is produced as cells convert a diversity of mechanical stimuli, transmitted throughout the ECM, into chemical activity to regulate morphology and function of tissues.[60-61] The cellular responses include the release of interleukins, adhesion kinases and other biochemicals.[61-62]

Local injury in a tissue can have widespread consequences via mechanotransduction's role in stimulating quiescent cells to form active fibroblasts.[62] This mechanism of cellular activation via mechanical force has been hypothesized to play a role in embryological development as part of the induction process of mesenchymal cells throughout the mesoderm.[63] Clinically, the effects of mechanotransduction have been observed with the intervention of acupuncture.[64] There is evidence to suggest that the insertion of acupuncture needles into the fascia stimulates the activity of fibroblasts, presumably through physical strain exerted on the transmembranous microfilaments in the ECM.[65-66] Needles will also cause displacement of that tissue, and twisting of the needle once it is inserted can cause further displacement of the fascia as measured with ultrasonic elastomyography.[35] Simple manual pressure has also been demonstrated, through deformation, to cause alterations in the viscoelasticity of tissue.[30,36] These cellular and filamentous responses may provide a theoretical framework for the therapeutic mechanisms of soft tissue therapies.[36,67-68] An understanding of mechanotransduction reveals that for healing and injury it is not only the gross observable reaction of tissues that is of interest, but also the biomechanical response of the ECM within fascia.

V. Innervation

Electron microscopy and special staining procedures demonstrate that fascia is populated by sensory neural fibers, suggesting that fascia contributes to proprioception and nociception, and may be responsive to manual pressure, temperature, and vibration.[18,26,69,70] Some receptors found within fascia may be responsive to, and influence some autonomic responses, such as lowering blood pressure.[71-72]

On a structural basis, two classes of sensory receptors are recognized: free nerve endings as terminal branches of the axons, and encapsulated endings with distinctive arrangements of non-neuronal cells that completely enclose the terminal parts of the axons.[73] Some of these receptors function as both a mechanoreceptor and a nociceptor (types III and IV receptors).[73] Pain that arises in muscles, tendons, ligaments, and bones is detected by these receptors. There have been conflicting results in the research, but most recent evidence has revealed small diameter free nerve endings in the thoracolumbar fascia of rats and humans.[69] One investigation has revealed the presence of these fibers on electronmicroscopy[18], meanwhile another group has demonstrated calcitonin gene-related peptide (CGRP) and substance P (SP) within the same fibers, suggesting afferent function, including nociception.[69] Further work must be done on human specimens as currently the best evidence is heavily reliant on animal models.

Langevin et al, developed a pathophysiological model of low back pain based on connective tissue nociception, after demonstrating on ultrasound the structural alterations of the low back connective tissues.[34,70] Fascial connections within different motor units, and different functional synergists, can provide an alternative explanation for referred pain distributions, which often do not follow either nerve pathways or the morphology of a single muscle.[74]

Many encapsulated endings found in fascia are mechanoreceptors that respond to mechanical pressure or deformation, and include Golgi receptors, Pacinian corpuscles, and Ruffini's corpuscles.[18,26,75-76] Different techniques of tissue manipulation may stimulate the above receptors: the high-velocity thrust manipulations and vibratory techniques likely stimulate Pacinian receptors, while slow, deep soft tissue techniques likely target Ruffini's bodies.[75-76] Knowing what receptors are more significantly concentrated in a particular target tissue can help a manual practitioner choose the method of stimulus and technique (e.g., deep pressure, light stroke, stretch, tension, or vibration).[75-76] Understanding that certain types of fascia are more densely populated with certain particular receptors can aid in the overall understanding of the body and creating more effective approaches to manual treatments.

B. Classification System

In an effort to organize nomenclature for fascia provided by the FICAT, we developed a functional classification system which includes four categories of fascia: i) *linking*, ii) *fascicular*, iii) *compression*, and iv) *separating* fasciae.

All fascia-related terminology provided in the Terminologia Anatomica can be subsumed within these four categories (Table 1).[4] This system is not meant to be a reductionist approach to the fascial system, but a mode of exploring and better understanding the complex interaction of functions that exist within the system. Each region of the body contains multiple categories, suggesting that every region of the body has a complex mixture of different fascial types. To illustrate this concept, the thigh is an example of a body region which contains all four fascial categories: Illiotibial band (*Linking*), perimysium of the quadriceps femoris muscle (*Fascicular*), fascia lata (*Compression*), and subcutaneous tissue (*Separating*).

I. Linking Fascia

The *linking* category is predominantly dense regular parallel ordered unidirectional connective tissue proper with a significant amount of collagen type I.[16,24] This includes fasciae of muscles, fasciae of regions (head & neck, trunk, limbs), aponeuroses, tendinous arches and neurovascular sheaths.[4]

This category is subdivided into dynamic and passive divisions. The dynamic division includes major fascial groups more significantly related to movement and joint stability, and characterized by higher concentrations of contractile and proprioceptive fibers**.** The dynamic division is composed of fasciae of muscles (investing layer, fascia of individual muscle), and fasciae of the trunk.[4] The innervation of dynamic linking fascia functionally differentiates it from other categories, permitting it to contribute to nociception and proprioception. For example, the thoracolumbar fascia (TLF) contributes to spinal stability and makes firm connections between the trunk and limbs.[77] It is also densely innervated by free nerve endings and Paciniform corpuscles which respond to rapid pressure and vibration.[2,18,73,78]

The passive division is acted on by other extramuscular tissues to maintain continuity throughout the body or form tunnels and sheaths.[7] The passive division incorporates fasciae of muscles (muscle sheaths), fasciae of the head and neck, fasciae of limbs, aponeuroses, tendinous arches, and retinaculae.[4] This group can act as muscular insertion points, such as the epicranial aponeurosis, and as joint linkages and tendinous arches ultimately providing proprioceptive information when tension is exerted.[7] The passive *linking* fasciae can only transmit force when they are stretched and loaded, while *dynamic* fasciae can theoretically contract more autonomously like smooth muscle, thereby affecting tension in the musculoskeletal system, but not significant enough to be the primary mover of limbs.[51]

II. Fascicular Fascia

Fascicular fascia forms adaptable tunnels which bundle vessels as well as fascicles within muscle, tendon, bone and nerves. *Fascicular* fascia plays an important role in organization, transport, strength and locomotion.[39] This category is organized as a mixture of both loose and dense regular multidirectional connective tissues.[24] Types I and III collagen are the major components of these tissues with lesser amounts of Types V, VI, XII, and XIV.[16,39,79]

Fascicular fascia of the muscle comprises three distinct layers of IMCT: epimysium surrounding whole muscles, perimysium separating fascicles or bundles of muscle fibers within the muscle, and endomysium covering the individual muscle fibers.[39] Forming the muscle architecture, this network of collagen fibers can be seen as an extensive matrix of tunnels that connects and dissipates force within muscle, provides intramuscular pathways and mechanical support for large and small nerves, blood vessels and lymphatics.[32,39,79] The *fascicular* fascia of the muscle converges into a dense regular connective tissue link at the myotendinous junction to become *fascicular* fascia of the tendon, comprising endotendon, peritendon and epitendon.[5,7,79] At this junction, *fascicular* fascia is richly innervated by Golgi tendon organs which are stimulated by muscle contraction.[37,38] Tension in the tendon results in a reflex decrease in tonus in contiguous striated muscle fibers.[70]

IMCT is essential for myofascial force transmission (as outlined in Results section A I), enhancing the forces produced by muscles.[8] *Fascicular* fasciae allow forces to be transferred from within muscle to synergistic muscles, and also, via the extramuscular pathway, through the *linking* fascia, to antagonistic muscles.[8,13-14] The *fascicular* fascia forms the connective tissue envelope for nerve fascicles and whole peripheral nerves: perineurium and epineurium, respectively.[37,38] The perineurium serves as a metabolically active diffusion barrier that contributes to

Table 1 *Fascial categories: function, terms, and histological features*

Fascial category		Function	(Examples) Terminologia Anatomica[4]	Terminologia Histologica[24]	Histological features[16,37]
Linking	Dynamic	– role in movement and stability – critical to myofascial force transmission – creates significant pretension in musculature	**Fasciae of muscles (investing layer) & fasciae of individual muscles:** Pectoral fascia Supraspinatus fascia Deltoid fascia **Fasciae of trunk:** Thoracolumbar fascia Diaphragmatic fascia Iliopsoas fascia **Fasciae of limbs/membrorum** Iliotibial tract Axillary fascia	Dense regular parallel ordered unidirectional connective tissue proper	Collagen types: I, XII, XIV Actin-myosin filaments Pacinian corpsules, Free nerve endings
	Passive	– maintains continuity, passive force transmission – proprioceptive communication throughout the body	**Fasciae of muscles (muscle sheath)** Rectus sheath **Head & Neck** Cervical fascia Carotid sheath Ligamentum nuchae Ligamentum flavum **Fasciae of limbs/membrorum** Intermuscular septae Anterior talofibular ligament **Aponeuroses** Erector spinae aponeurosis Bicipital aponeurosis Plantar aponeurosis **Tendinous arches** Muscular & vascular spaces/lacunae Iliopectineal arch Tendinous arch of soleus	Dense regular woven connective tissue Multidirectional parallel ordered connective tissue	Collagen types: I, III, XII, XIV Elastin Golgi tendon organs, Pacinian & Ruffini's corpuscles
Fascicular		– provides myofascial force transmission & proprioceptive feedback for movement control – maintains protection for nerves and vessels – allows vascular sheaths to be in continuity with adventitia	**Intramuscular & extramuscular fasciae. Neurovascular sheaths** Endomysium Perimysium Epimysium Endotendon Peritendon Paratendon Perichondrium Endosteum Periosteum Endoneurium Perineurium Epineurium	Loose connective tissue Dense regular multidirectional parallel ordered connective tissue Dense irregular connective tissue	Collagen types: I, III, IV, V, XII, XIV Golgi tendon organs

Table 1 *(Continued)*

Fascial category	Function	(Examples) Terminologia Anatomica[4]	Terminologia Histologica[24]	Histological features[16,37]
Compression	– provides stocking, compression and tension compartmental effects – influences venous return – enhances proprioception, muscular efficiency and coordination	**Fasciae of limbs/membrorum** Brachial fascia Antebrachial fascia Dorsal fascia of hand Fascia lata Crural fascia Dorsal fascia of foot	Dense regular woven connective tissue Multidirectional parallel ordered connective tissue	Collagen type I Elastin Ruffini's corpuscles
Separating	– compartmentalizes organs and body regions to maintain structural functions – promotes sliding and reduces friction during motion – responds to stretch and distention – provides physical support and shock absorption – limits the spread of infection	**Parietal Fascia** Parietal pleura Fibrous pericardium Endothoracic fascia Parietal peritoneum Endoabdominal fascia Endopelvic fascia **Visceral fascia** Meninges Visceral pleura Serous pericardium Visceral peritoneum Visceral abdominal fascia Visceral pelvic fascia **Extraserosal fascia** Sternopericardial ligaments Bronchopericardial membrane Pulmonary ligaments Extraperitoneal fascia **Investing fascia** Subcutaneous tissue of abdomen Membranous layer of perineum	Loose connective tissue Dense irregular fusocellular connective tissue	Collagen types: III, V, VII Extracellular matrix: reticular and elastic fibers Reticular fibers provide a cellular framework Elastin Pacinian and Ruffini's corpuscles

the formation of a blood-nerve barrier.[80] The blood vessels that supply the nerves travel in the epineurium.[80] These two layers of the *fascicular* fascia are innervated by the nervi nervorum, which can evoke nociception through the release of CGRP and may create neurogenic inflammation.[81] An inflammation of the nervi nervorum causes the inflammatory reaction of the nerve's fascial envelopes to induce the mechanical sensitivity, which can manifest as local, radicular, or neuropathic pain.[75,82,83]

III. Compression Fascia

Compression fascia is a mixture of dense regular woven and multidirectional parallel ordered connective tissue layers that ensheath whole limbs to create a stocking effect.[24,84] This fascial category plays an important role in locomotion and venous return due to its influence on compartmental pressure, muscle contraction and force distribution.[20,29,84] For example, the crural fascia is composed of two or three layers of parallel ordered collagenous fiber bundles, each layer being separated by a thin layer of loose connective tissue.[19,29] The spatial orientation of the collagen fibers changes from layer to layer within the *compression* fascia.[29] The presence of loose connective tissue interposed between adjacent layers permits local sliding, allowing the single layers to respond more effectively.[29]

Examples of this type of fascia are observed in the limbs and are observed as fascia lata, crural fascia, brachial fascia, and antebrachial fascia. While there are proprioceptors embedded in this fascia, its role as a sensory organ is less significant than that of the *linking,* or *fascicular* categories.

IV. Separating Fascia

Separating fascia is generally loose connective tissue and dense irregular fusocellular connective tissue.[24] The reticular Type III collagen fibers and elastic fibers are the major components of the ECM of *separating* fascia, with small amounts of collagen Types V, VII.[16-17] While the reticular fibers provide a supporting framework for the cellular constituents, the elastic fibers form a three-dimensional network to allow *separating* fascia to respond to stretch and distention.[28,37] *Separating* fascia divides the body in visible sheets and layers of varying fibers allowing it to take up forces and friction in all directions. While its major function is to allow more efficient sliding of tissues over one another, it may still form adhesions from faulty movement patterns or injury.[54]

FICAT's terms for *separating* fascia include: parietal fascia, visceral fascia, extraserosal fascia, investing/subcutaneous fascia, formerly known as fascia superficialis.[4] This category also includes synovial sheaths and fasciae of limbs.[4] Parietal fascia lies outside the parietal layer of serosa such as pericardium, pleura and peritoneum, and lines the wall of a body cavity.[4] Visceral fascia lies immediately outside the visceral layer of the serosa and surrounds the viscera.[4,85] Extraserosal fascia lies within the space between the visceral and parietal fasciae.[4]

This fascia class is a complex connective tissue matrix, ensheathing everything from body cavities to individual organs. It separates, supports, and compartmentalizes organs and regions in order to maintain proper structural and functional relationships throughout the body. This group of fascia has a unique appearance and texture upon observation, ranging from transparent woven sheets to a fuzzy cotton-like consistency.[28]

The innervation of *separating* fascia serves primarily to sense distension and compression of tissues. More detailed histological analyses are necessary to reveal with certainty the fascial innervations of these deep layers. However, concentrations of Pacinian corpuscles (detecting deep pressure) and Ruffini's corpuscles, which responding slowly to sustained pressure and tangential forces, are thought to be present in much of *separating* fascia, for example, in subcutaneous tissue.[28,70,86] Deep sustained pressure may be necessary for manual practitioners to affect this fascial tissue.

Conclusion

Through this article, we have reviewed advances in fascia research and addressed issues related to terminology and classification of fascia. The literature supports defining fascia as an innervated, continuous, functional organ of stability and motion that is formed by 3-dimensional collagen matrices. In an effort to organize the nomenclature of fascia, we devised a functional classification system which includes four categories of fascia: i) *linking*, ii) *fascicular*, iii) *compression*, and iv) *separating* fasciae.

These categories were developed based primarily on the functional properties of fasciae, with further observations from the literature on gross anatomical, histological and biomechanical features, and terms unique to each category. Such a classification system based on functional properties of fasciae may have more relevance to the clinical experiences of manual therapists.

All fascial related terminology provided in the Terminologia Anatomica[4] can be subsumed within these four fascial categories (Table 1).

Each region of the body contains multiple categories. This suggests that the complex interaction of different fascial types improves the musculoskeletal system's efficiency. It is our hope that this classification system will add clarity, improve diagnostic precision and contribute to manual therapists' understanding of fascia as a target of pathology and treatment.

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