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Fascia and Tensegrity The Quintessence of a Unified Systems Conception

Research Article

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Abstract

The heterogeneous connective tissue fascia is constructed upon a tensegrity-based architecture providing cells and organism's with stability coupled with mobility. A term coined by Sharkey and Avison "Fasciategrity" used for the first time at the British Fascia Symposium 2018, speaks of the relationship of balance and integrity within the fascial net. Tensegrity construction principles provide an opportunity to deliver, to medical trainees and post-graduate medical specialists, a unified systems conception of living form and function. In this the 21st century anatomists are ready to move away from a mechanical view of the human corpus based on a 17th century model of parts and levers. A new emphasis is required to integrate current models and theories that substantiate fascia as the connected, unifying, continuous universal singularity that permeates the entire soma. Such models and theories are complex, however, with increased cross talk between experts and professionals in fields of specialty, within scientific disciplines, a new paradigm is emerging. This new unified systems approach to human anatomy and physiology has the potential to impact global healthcare. A unified systems model of human anatomy (with a special focus on the architecture of fascia) is one that is predicated upon a specific 'nature inspired' tensegrity architecture utilizing soft matter as the building material during embryonic self-construction. Self-construction leads to emerging transformations that are driven by both genetic and epigenetic stresses [i.e., biochemical and biophysicalcues] embracing collective behaviour with emerging small world networks that utilize non-linear dynamics. Time is a key component as self-organization occurs in a hierarchical time-dependent/temporal sequalae. This short paper focuses on the essential architectural characteristics of cells and multi-cellular organisms that supports a living unified system. While the human body is a true reflection of infinity and continuity it also possesses virtual boarders, boundaries and compartmentalization's. Such virtual borders and boundaries are self-constructed connections, disconnections and compartments necessary for physiology, metabolism and autoimmune responses reflecting evolutionary contingency.

Keywords: Fascia; Tensegrity; Continuity; Unified Systems; Biotensegrity; Stability; Embryology.

Introduction

Embedded in the philosophy of human biomechanics is man as machine [1]. The erroneous nature of man as machine is self-evident. Machines are man-made. Living constructs are self-developed, self-constructed, self-emerging, self-stressed, unified systems maintaining constancy through an ever-changing internal environment providing allostatic balance [2]. Machines are constructed from hard matter constituents which are Hookean materials following Hooke's law, therefore, reflecting the fallacy of biomechanics [3, 4]. Living constructs are composed of soft matter material that naturally express non-linear behaviour [i.e., non-linear stress/strain curves] and therefore have no valid Young's modulus or Poison's ratio [4]. Recent research [5, 6] has confirmed what some experts viewed as a surprising mechanical characteristic in human and animal tendons known as auxeticity where by tissue does not shrink but rather expands transverse to the direction of extension when stretched. Auxeticity and thixotropy are characteristics expressed in the physical properties of soft matter [5]. For example, Francisco Torrent-Guasp's anatomical dissection revealinga helical heart, a result of spiral folding [Fig 1 a and b], has brought to a reasonable conclusion, the elusive ambitions of Erasistratus, Leonardo da Vinci, Galen and other great pantheons of anatomy who, having attempted to unravel the heart, could not reveal its true helical nature [7]. Erasistratus and Galen were among the first to note that blood was sucked into the heart when filling [i.e., diastole] and that the heart muscle got wider, reflecting the auxetic and tensegral nature of the myocardium, during the contraction phase [i.e., systole] [7]. Any disagreement among

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anatomists and cardiologists concerning the accuracy of the helical ventricular myocardial band (HVMB) would benefit with the inclusion of tensegrity architectural principles and the concept of living tissue as soft matter containing liquid crystals [3]. All liquid crystals operate on a spectrum of hardness to softness, without straying from their fundamental category of soft matter. All liquid in the human body (with the exception of urine) is bound. Bones begin as cartilaginous placeholders and "crystalize" into harder cases, containing soft matter within their more crystalline arrangements [9].

Tensegrity - The Model Of Cellular Architecture And Force Transfer

Tensegrity is a compression of the words, tension and integrity, a term created by designer, inventor and futurist R. Buckminster Fuller. It is not a true noun but an invented word/term to help explain a model of living architecture [3]. "My tensegrity" and "Islands of compression inside an ocean of tension" are descriptions Fuller used as part of a patent submission Fuller made in 1962 (10). Fuller also referred to "tensional integrity" while renowned contemporary sculptor and photographer Kenneth Snelson preferred to define tensegrity as "floating compression" (10). Human beings follow the same rules of soft-matter physics as do all living organisms in a vast variety of morphological expressions. The laws governing tensegrity have been established as applying to the organism, thus, they also apply to fascia and the extra-cellular matrix at all developmental stages of embryology [31]. While physical laws concerning forces and force transmission do not change, the nature of the self-developmental forming processes go through variations (12).

Due to the singular nature of fascia, proposals have been previously put forward, with supporting evidence, arguing that bone is fascia and therefore a change in the taxonomy of bone has been proposed [8,9]. The microscopic left and right-handed epithelium, the helically constructed collagen of blood vessels with the spiral configurations contained within the myocardium, contain a tensegrity architecture which is the basis of form for all fascial structures [10]. A tensegrity structure comprises pre-stressed elements balanced between tensional and compressional members resulting in emergent properties ranging from rigidity to mobility with stability, otherwise known as "pre-stress stability" or "super stability"[11]. Evidence that tensegrity expressed cellular architecture [i.e., biotensegrity] provides the vital pre-stress required for cellular shape integrity, physiology and metabolism, by means of molecular microfilaments and microtubules, was established as early as 1983 [12].

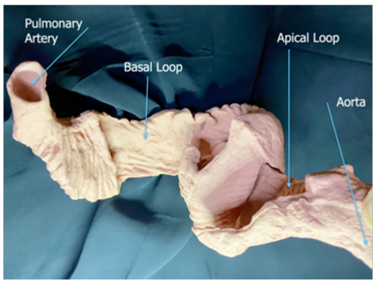
As a pre-stressed tensegrity structure, cells dissipate local stresses translating forces on a local and global basis via mechanical exchanges through integrins and other transmembranous molecules [13].

The human body is organized in nested tensegrity networks [Fig 2] formedmicro to macro and constructed of systems within systems [14]. All constituent proteins, fats and carbohydrates [i.e., proteoglycans, muscle fibers, lipid membranes] constituting bone, myofascia, blood vessels and nerves are tensegrity based, inhomogeneous, anisotropic structures at all scale sizes [15]. Biotensegrity is a model of the binding geometries by which forces transmit through all aspects of all living soft-matter forms and cannot be selectively applied to certain stages of the form, or to certain items within that form. In its fullest expression biotensegrity is a model of wholeness with the tensegrity-icosahedron being the basic form that acts invariably as a liquid crystal due to the geometric constraints of close packing in living volumetric forms [10].

No other platonic volumes can demonstrate these attributes and exhibit phase-change throughout the matrix as an expression of life [10]. Researcher Donald Ingber has described tensegrity as

Figure 1. a and b. Torrent Guasp Band. The biventricular myocardial band. Images: Sharkey, J 2020. Francisco Torrent-Guasp's anatomical dissection revealing the helical ventricular myocardial band (HVMB), a result of spiral folding, bringing to a reasonable conclusion, the elusive ambitions of Erasistratus, Leonardo da Vinci, Galen and other great pantheons of anatomy who, having attempted to unravel the heart, could not reveal its true helical nature, a feat deserving the noble prize.

(a)



(b)

a model for explaining how mechanical forces regulate cellular activity [15].

As a living tensegrity construct this architectural blueprint uniquely includes 'self-generated stress'utilized at all scales and in all tissues including bone, myocardial tissue, liver, spleenand nerve [16]. Levin has described how bones and myofascial structures, from the micro to the macro level, act as tensegrities providing balance and stability in a closed multi-bar kinematic system [17]. Cellular tensegrity architecture, comprised of biopolymers, including active contractile cytoskeletal microfilaments and passive osmotic elements combine to convert interconnected mechanical forces via the extracellular matrix and cytoskeletal networks into biochemical physiology, metabolism and motion [18]. Tensegrity thus provides a model dependent reality of continuity [Fig 3] from the cellular and intracellular ranks to the higher ranking of a unified system [i.e., organism]. Myofascial force transmission, including involvement of septa, tendons and ligaments, all tensegrity-based structures, function as mechanosensitive signaling networks on a body-wide basis [19,20,21,22]. These structures have been identified as important site-specific fascia tuning pegs providing appropriate tuning specific tension necessary for the integrity of the fascial net [i.e., Fasciategrity] [23].

Contra-arguments have been madeconcerning the risks of biotechnologies used in agriculture due to a lack of understanding concerning cellular dynamics [24]. Such research is an example of information from disparate fields of specialty, yet allied scientific disciplines, that can inform discussion in anatomy and medicine. Altieri's findings highlight alack of understanding concerning genetic function without appreciating that cells operate in acollaborative synergistic co-operativewithin cellular networks, a first principle of living tensegrity [24].

This takes us in an opposite direction from the currently accepted model [i.e., biomechanics] where by the whole is equal to the sum of its parts representing a bottom-up approach for explaining complexity [25]. Patterns of genetic activity change moment to moment in response to the intra and extracellular matrix in which they are entrenched [30]. Organisms are constituted from many specialized interacting components that lead to enhanced complexity and greater integration [26,30]. Complexity generatesunexpected emergent properties demonstrating thatcomplex unified systems are more than the sum of their parts and represent a wholistic top-down approach and a model of 'form follows force' [26,27]. According to research from Stopak and Harris [Fig 4] undifferentiated extracellular matrix assembles itself, dependent on the stresses acting upon it, resulting in bone, cartilage, blood vessels, muscle fibers, lymphatic tissue and other [28]. Discussion regarding force transfer focuses our attention on the local and global model of mechanotransduction whereby cells respond to forces and translate such stressors to cue physiological, metabolic, and movement responses [29,30].

The scientific evidence cited in this article points to a body that is connected from the inner most intra-cellular matrices via the cytoskeleton to the outermost unified somatic systems reflecting increasing complexity [31]. A focus on chemical cues as a result of combining forces may hold the key to the vision of human embryology, differentiation, growth, topography, anatomy, physiology and behaviour [32]. This points to a reality whereby the very nature of biochemical activity has a physicality at the heart of molecular gene expression influenced by environmental and various anthropological influences [33]. At the heart of this physicality lies tensegrity icosahedronbasedarchitecture, present on a ubiquitous scale, via the extracellular matrix required for force generation and translation [12].

Oscillatory Contributions To Living Kinematics

The word biomechanics is clear in its intension to describe the combined inner workings that result in living motion as a result of movement around a fixed axis. Bio, referring to living constructs and mechanics or mechanical, from the Greek 'mēchanikē', meaning to study the mechanical theories and principles of living organisms [3]. Mechanical constructs require a screw or pin to stabilize and fixate separate components to support operation as a whole and therefore falls short of a satisfactory explanation for human movement [3]. Nature has had the required time to work out the most ephemeral way, combined with self-emergence via self-development, to provide a continuous anatomy, unbroken and uninterrupted, necessary for energy efficient motion [3]. Inappropriate oscillations, a result of strong winds, created a sway that destroyed the Tacoma Narrows Bridge in 1940. Every human cell oscillates at its own specific frequency ensuring differentiation and healthy physiology [34]. Embryologically, motion occurs before consciousness, and it is believed that movement may be the precursor to, and generator of, consciousness based on frequency specific oscillations/resonance [35]. A centrally originating oscillation/resonance in the 10 Hz range has been shown to modulate slow digital movements and pre-emptive smooth eye movements [36]. The human construct avails of nested tensegrities providing

Figure 2. The human body is organized in nested tensegrity networks formed micro to macro and constructed of systems within systems. This image shows a tensegrity nested within a tensegrity as a visual representation of an architecture that is scale free. Image: Sharkey, J. 2020.

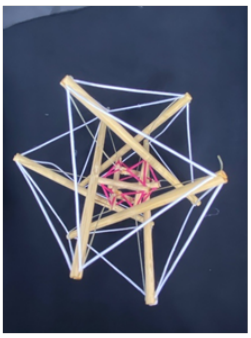
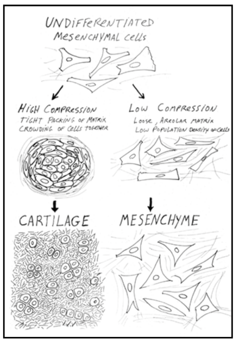


Figure 3. Tensegrity provides a model dependent reality of continuity from the cellular and intracellular ranks to the higher ranking of a unified system [i.e., organism]. Myofascial force transmission, involving septa, tendons and ligaments, all tensegrity-based structures, function as mechanosensitive signaling networks on a body-wide basis. In this image the haemostat is placed beneath the anti-brachial fascia to highlight the continuity of the fascial net. Image: Sharkey, J 2019.

Figure 4. Undifferentiated extracellular matrix constructs itself dependent on the forces acting upon it.



non-linear, synchronous, frequency specific resonant oscillations [Fig2]. Such oscillations are translated via mechanotransduction into metabolism and nutritious or detrimental motion, or undesired vibration, similar to the events at Tacoma Narrows Bridge [37]. Rather than a system of parts, a system of continuity and connectedness with appropriate frequency specific resonance is the proposed vision of anatomy in this the 21st century [38].

Conclusion

The teaching of anatomy by dissection is regarded, by many medical students and post-graduate medical professionals, as the most effective way to learn anatomy. Clinical relevance is critical to the practicing surgeon, general medical practitioners and other specialists. The topic of fascia is scarcely included within the medical anatomy curriculum and one would be hard pushed to find even a paragraph devoted to fascia in any anatomy or embryology textbook. Increased interest in fascia research undeniably attests to the ubiquitous nature of fascia while embryology provides a rich hunting ground for bloodless plains essential during surgery to ensure minimally invasive disruption and subsequent scarring.

The tensegrity model provides a modern alternative to the current biomechanics of one muscle one action, origins and insertions, offering a new vision of living constructs as self-developed, self-constructed, self-emerging, self-stressed, unified systems maintaining constancy through an ever-changing internal environment providing allostatic balance. The tensegrity model encourages a move away from a "musculoskeletal system" whereby muscles "hang off" or are "attached to" bone and moves us towards a unified systems, continuous, soft matter construct that naturally expresses non-linear behaviour and where disruption to one location can impact locally and globally. It is hoped that this paper will encourage interest and discussion among members of various anatomical societies and medical educational authorities to consider the inclusion of tensegrity in the medical curriculum while broadening the topic of fascia and its clinical relevance. The combining of fascia science and tensegrity principles has been promoted as "Fasciategrity", a useful term in helping learners appreciate the inter-dependency of fascia and tensegrity.

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