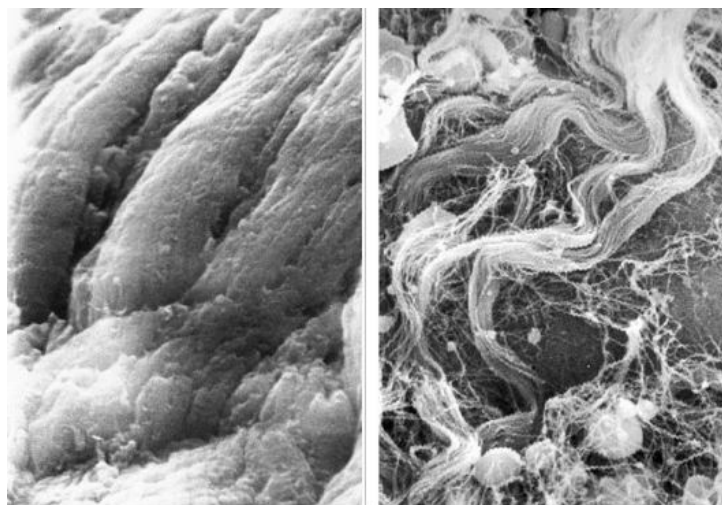


Tendon changes with aging & how to reduce the chance of Injury

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Collagen Bundles from a Young (L) and Old Tendon (R)

This post is quite heavy on physiology. I decided to break up this topic and will provide more practical posts in the future on how to best manage tendon training and what to look out for when starting a new conditioning routine.

TENDONS & CELLULAR CHANGES WITH AGE

Tendons are densely packed connective tissues that transmit forces from muscle to bone. Mature tendons are mainly composed of type I collagen fibers (collagen that provides strength & elasticity to tissues), which are tightly packaged into parallel fascicles that glide on one another when force is applied, giving tendons high tensile strength [1]. When at rest, tendons display a crimping pattern at intervals throughout their length, giving them elasticity during loading.

Age-related changes in vasculature and composition may predispose older tendons to injury as they lose the ability to repair themselves over time. As a tendon ages, Type II collagen fibres (collagen typically found in cartilage) spreads throughout the tendon reducing its elasticity and tensile strength.

Tendon aging is associated with a decreased potential for cell proliferation and a reduction in the number of stem/progenitor-like cells (Tenocytes). Mechanically, aging appears to be associated with a reduction in modulus (A measure of the rigidity or stiffness of a material) and strength.

Tendon growth and significant mechanical adaptation seems only to occur during maturation after which there is limited changes in the collagen content of a tendon.

Because of the low tendon turnover in adults, it has been suggested that exercise prior to skeletal maturity may yield a stronger tendon that is more resistant to injury.

Areas of reduced blood flow correlate with the classical sites of tendon rupture, particularly those of the Achilles tendon.

With increasing age, a decrease in the number of elastic fibers & contractile proteins decrease the tendon's ability to tolerate repeated & excessive loads. as well as many morphological changes have been observed .

TENDON BIOMECHANICAL CHANGES WITH AGE

The main role of any tendon is to decelerate the body and limbs with the muscles lengthening actively to dissipate energy. During rapid energy-dissipating events, tendons buffer the work done on muscle by storing elastic energy temporarily, then releasing this energy to do work on the muscle. This elastic mechanism may reduce the risk of muscle damage by reducing peak forces and lengthening rates of active muscle. It follows that changes in tendon properties (that which occurs through aging) may affect muscle–tendon interaction and energy dissipation in the Muscle Tendon Unit increasing this region to strain injury.

The most drastic biomechanical change of tendon aging is decreased tensile strength . An increase in collagen crosslinking widely alters the mechanical properties of the tendon as there can be found a decrease in ultimate strain, ultimate load, modulus of elasticity, and tensile strength, and an increase in mechanical stiffness. The increased rigidity of collagen fibers (mechanical stiffness) results in a decrease in the tensile strength of a tendon .

It appears that there is an ideal amount of stabilized crosslinks beyond which more crosslinking stabilization becomes a maladaptive adjustment . Other biomechanical tendon variables altered by aging are those associated with tissue viscosity . With age, the relative collagen content of a tendon increases, but the elastin and proteoglycan matrix decrease, suggesting less elasticity .

On the other hand, If a tendon is too compliant (lacks stiffness) it will result in a reduced ability of the muscle to generate force. The property of a tendon is dependent on its stress and strain characteristics where stress is defined as force divided by cross-sectional area and strain is defined as the change in length divided by its resting length. Modulus of elasticity helps describe the relationship between stress and strain. For example, a stiff tendon can accept high loads (stress) and experience very low deformation (strain). There is evidence suggesting that tendon stiffness and hypertrophy increases following resistance training.

The resident cell population composing tendon tissue is mechanosensitive, given that the cells are able to alter the extracellular matrix in response to modifications of the local loading environment. One factor in the reduced capacity of older tendons to tolerate increasing stress and strain is the reduced activity levels (and associated tendon loading) of people as they age.

Altogether, the above-noted changes make the tendon weaker than its younger counterpart and more likely to tear or suffer from overuse injury when subjected to increased stress and strain .

TENDON CHANGES TO EXERCISE



Moreover, resistance training in humans appear to result in increases in tendon cross-sectional area , and it has been shown that subjects with a side-to-side difference (22%) in knee extensor strength as a result of habitual sport-specific high loading have a greater tendon cross-sectional area (20%) on the stronger side .

Collectively, these studies support the notion that tendons hypertrophy in response to increased loading. If the hypertrophy represents tensile bearing components, i.e., principally collagen fibrils, the larger cross-section means that the stress across the tendon is reduced, which may play a role in injury prevention.

However, a possible caveat is that exercise-induced hypertrophy could represent increased water content and not an actual accrual of collagen matrix.

Any such growth seems to contradict the earlier statement that post maturation there is limited tendon growth. A possible explanation is that loading-induced tendon growth takes place at the very periphery of the tendon.

It can be speculated that tendon growth occurs through the addition of new external "layers" of collagenous matrix, comparable with the growth rings of a tree.

Whilst the actual collagen fibrils of the tendon seem to be largely unaffected by exercise, there can be some hypertrophy of the whole tendon as outlined above. In older tendons, it appears that resistance training can yield increased stiffness and modulus of the tendon, which may help mitigate the risk of injury.

Overall, tendons reduce in their stiffness and capacity to rapidly respond to loading and this reduction in tendon stiffness by aging has at least two important functional implications.

An older tendon would stretch more during a muscle contraction, thus causing the muscle's sarcomeres to shorten more than it would do if attached to a younger, less extensible tendon. A reduction in muscle contractile force would be expected owing to a change in sarcomere working length to a new length corresponding to less optimal myofilament overlap. A more compliant

tendon would require a longer time to be stretched than a stiffer tendon . This would mean that older tendons are less capable than younger tendons of transmitting fast forces from muscles to bones.

Eccentric type tendon injuries are very common in older participants who partake in regular exercise. This could be due to the increased pliability of the tendon and its attachment to the muscle. For example:

If an older tendon is more pliable during a contraction, in particular an eccentric contraction (for example the achilles/calf musculotendinous complex during ground contact during running) then a longer eccentric stretch at the musculotendinous junction would result in the muscles' actin/myosin crossbridges extending beyond their functional length placing the remaining eccentric load onto the connective tissues resulting in injury.

Typically, strength training (which lacks rapid eccentric tendon loading) rarely leads to tendon injury.

If we take the Achilles Tendon as an example of a 'problematic' tendon in the aging exercising population – the following has been found:

The aging Achilles Tendon appears to be capable of increasing its stiffness in response to mechanical loading exercise by changing both its material and dimensional properties. Continuing exercise seems to maintain, but not cause further adaptive changes in tendons, suggesting that the adaptive time–response relationship of aging tendons subjected to mechanical loading is nonlinear. (In other words, training can lead to early adaptations which quickly plateau (~3-months) regardless of continued tendon loading).

The implications suggest that whilst there is potentially limited long term conditioning improvement to be had with the Achilles tendon (in particular post maturation), progressive tendon loading has been shown to increase the tendon's ability to tolerate increased load strain. This improved tolerance will potentially reduce the tendon's potential for injury when performing dynamic activities such as rapid eccentric loading movements (eg jumping & running).

ROLE OF EXERCISE AND TENDON HEALTH - SUMMARY

1. With respect to exercise, tendon cells respond by increasing collagen synthesis in humans, which likely reflects synthesis at the very periphery of the tendon rather than the core. It seems that resistance training can yield increased stiffness and modulus of the tendon and may reduce the amount of glycation (reduces the sliding function of tendon fibres). Exercise thereby tends to counteract the effects of aging.
2. It would appear that while maturing tendons can respond to the mechanical forces applied to it during growth, there is no evidence that it can do so after skeletal maturity. Appropriate exercise regimes early in life may help to improve the quality of a growing tendon, thereby reducing the incidence of injury during ageing or subsequent athletic career .
3. Repetitive tendon overloading is largely responsible for age related tendinopathies – Appropriate volume/load planning (Periodization) is key to minimising the chance of developing tendon issues with exercise and increasing age.

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