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A Critical Review on Tendon Structure and Load Remodeling

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SUMMARY

Introduction. As mechanic tendon structures enhancer, muscle-tendon load remodeling has recently been touted as potential strain, force-elongation, and energy storage capacity at both contraction actions and resistance modes. The tendon mechanism has been associated with enhanced stiffness and strain energy to muscle-tendon length complex, however it might be more far-reaching as either force-elongation relationship may be improved or ATP production are poorly understood.

Objective. To determine tendon structure and load remodeling improves muscle-tendon complex via increased tendon activation and muscle contraction. To date, tendon load remodeling on either muscle-tendon performance or tendon force are most common approach, which has produced equivocal outcomes. Tendon performance may be difficult to improve in athletes and individuals with the effectiveness of tendon mechanic properties among physical individual and athletes.

Materials and methods. Critic review literature research was conducted in two electronic databases like PubMed and Web of Science. Resolution for disparity, in conclusion, seem to be due to load remodeling different such as exercise protocols, muscle actions potential and high-quality protocols.

Results. Exploration of the optimal tendon strain, stiffness and force-elongation relationship are required including quantification of load remodeling following optimal resistance and contraction actions. Similarly, further evaluation of muscle contraction studies using high isometric action protocols with tendon load components is required to evaluate mechanism associated with load remodeling.

Conclusions. Until such studies are completed, the efficiency of tendon load remodeling to improve tendon strain energy storage and force-elongation performance remains ambiguous.

KEY WORDS

Tendon elongation; strain; energy storage; stiffness; isometric action.

INTRODUCTION

Considerable research applied has been recently placed on load remodeling of resistance, muscle action and potential energy capacity with tendon structure, its load remodeling explained based on tendon properties (1-3). Increasing on tendon development ratio through low and high force energy of tendon-aponeurosis may improve muscle actions and change muscle transit exercise performances (4, 5). Typical perspectives to increase tendon force energy capacity include the effectiveness of angular speed of maximal based tendon load, muscle-tendon unit and translation fibrils in parallel number increase of cross-sectional area (CSA) (6, 7). Indeed, translation fibrils and transition aponeurosis in turn orthogonal longitudinal-uniaxial shaping tendon force notified to be more than a perfect reflection by energy generation of lengthening linked to isometric tendon arm production and resistance load (3, 5). However, more recently this condition touted tendon load remodeling, composed of tendon elongation, strain and energy storage to force generation by optimal muscle lengthening (8, 9). The mechanism of tendon structure might be more far-reaching as a result, both the muscle contraction actions and force generation metabolism of adenosine triphosphate (ATP) energy (10). It has been required muscle strength or tendon stiffness development, that allows for the precise prescription of tendon loads to optimize tendon adaptation (8). Since the early one work has primarily focused on the force-elongation relationship potential energy effects of load remodeling on jumping performance (11). Indeed, a tendon-aponeurosis performance of sprinter and endurance runners muscle strength increases to load remodeling of tendon strain was observed to energy production at applied tendon strain (11). The fascicular tendon-aponeurosis structures, due to increased tendon loads, produce strain energy (1). However, in the other athletes, as applications of tendon strain is limitation as well as general bias focused on isometric maximal voluntary actions, jumping and running (12, 13). Recent works have addressed these limitations and investigated tendon strain associated with simply tendon energy effects on isometric maximal voluntary contraction that encompasses large force generation and stiffness in trained and untrained individuals (8, 14). Tendon strain, force-elongation relationships in the load patterns of tendon structure in the athlete population is scarce that should be investigated further (9). To date, complex responses to tendon structure have been reported, the potential for performance improvement is unclear (15). Additionally, there were studies reported that low-intense exercises were generally unable to adaptively induce tendon strain and stiffness (16, 17). Specifically, tendon loads on energy generation of resistance training and muscle actions may be an important application for athletes who may have the energy storage capacity of changes tendon load remodeling (18). However, the athletes can protect muscle performance, such as energy storage and tendon stiffness by the way load elongation relationship and strain for training performance improvement (8). This review, therefore, discussed the efficacy of tendon structure to improve training and load remodeling performance, followed by a discussion of research findings to date in respect of muscle-tendon load factors, that study has reported tendon strain energy, elongation, stiffness and load goal strategy.

STRAIN AND STIFFNESS ON TENDON LOAD REMODELING

Active muscle length has effective tendon activation against load remodeling conditioning called strain in any active and passive resistance by muscle-tendon strain complex (1, 2). Mechanism of tendon strain were originally prescribed to enhance tendon elongation and stiffness transformation. Its energy is built from isometric voluntary contraction and active lengthening of muscle stretch reflex, resulting from fascial lengths or titin activation that produce optimal force (3, 19). Positive effects of both muscle and tendon properties as a spring caused by resistance training, increased tendon-aponeurosis stiffness and contractile strength; both mechanical possess on stress-strain relationship to tendons properties can be determined by simple isolated elastic models (12, 20). A comprehensive investigating of tendon strain from training has displayed an altered tendon stiffness in different muscle actions and load remodeling (21, 22). The authors reported that, take into account understanding of tendon structure function to load remodeling during isometric actions, had an impact on tendon elongation, in this conditioning formed isometric high protocol to tendon development in physical individual and athletes (17). The purpose mechanism for the development of the elongation feature of tendon may be due to tension in isometric joint moment arm production and tendon moment lengthening of isometric ramp increased gradually in ratio-dependent mechanism. Indeed, tendon elongation showed that during a countermovement jump there is a production strain, but an isometric actions improve fascicle lengthening during final stage of take-off (12). In this case, isometric condition is anatomic mass expressing into force, the explained proportional section of a muscle-tendon complex length associated with energy strain generation by performing individual maximum tendon load condition (8, 22). Nonetheless, in another study outside of angular speed strategy was performed other tendon motion patterns to strain, therefore, the mechanic properties have been required to evaluate through same movement way (13). The alternative tendon length mechanism applied to strain on muscle actions had an effect within active or passive lengthening during submaximal and maximal angular explosive power movements. Indeed, minimum 100° and maximum 250° isometric lengthening highest energy generation is reflected in tendon load conditioning (12). Another alternative mechanism reported that tendons use stiffness to transmit and maintain forces production from muscular mechanical loadings (14). Tendon strain and stiffness explain tendons can enhance force and power generation through tendon strain energy (23). In particular, tendons improve muscle performance and stiffness during SCC activities, such as jumping and sprinting create a mechanical power pool at high joint moments (21). Most studies investigate the estimated active stiffness associated with tendon strain and elongation in submaximal isometric ramp action. One report has shown tendon structures to stiffness generation with ramp protocol high angular velocity ratios are thought to conduct more effective force capacity (3). Thus, tendon elongation had positive high strain rates were obtained, however the reports determined that isometric actions improved both tendon elongation and stiffness (3). However, following tendon strain of lower compartment muscle-tendon complex, both sprinter and long-distance runners were significantly reduced passive lengthening vastus lateralis within sprinters, and active lengthening was increasing within long-distance runners (9). The applications of these findings may apply to other athletes, as they are likely to undertake active lengthening of tendon and more routine strain of maximal voluntary contraction compared to other contraction. These potential quality control issues are an important functional role in the tendon stiffness (9). Considering studies to date have only used force strain relationship related to tendon and aponeurosis of sprinter and endurance runners that requires further investigation in muscle actions. It is worth noting, however, higher stiffness may be considered between tendon force and strain potential energy generation (11). A common issue with plyometric and isometric training is tendon properties during ramp and ballistic protocol, whereby tendon stiffness under passive and active conditions; *i.e.*, fascicle lengthening of plantar flexors have been reported following submaximal isometric contractions such as passive stiffness, and tendon strain did not change for plyometrics and isometrics (16). Notably, active muscle stiffness reported significantly increased with plyometric. This study showed that unlike previous plyometrics and stretch-shortening-cycle (SSC) than isometric contractions can produce more significant elongation and tensile force in tendon strain (12, 16). These differences could be related to different elongations of tendon structures, such that they can perform from tendon stiffness of isometric knee extension and plantar flexion. Comparison of sprinters and untrained individuals are more compliant and therefore lower tendon stiffness (15).

LOAD ELONGATION CONDITIONING

The most commonly employed fascicular of tendon-aponeurosis show dynamic elastic properties due to increased load effectively, which appears to reflect muscle ultimate load ratios during contraction actions, and time-dependent strain using quickly external loads (1). Load-elongation linear curve determines increased load-related development and response to stiffness-strain rate. This may theory in the tendon structure that can enhance both energy storage depending on force provided by gradually slow contraction at constant lengthening (13). In this case, this investigation reported on the spring nature of tendons after load remodeling, running and jumping affects maximum strain. Based on tendon stiffness and CSA using tendon ability in different sport branches and tendon capacity have reported between energy storage and tendon stiffness to find similar strain energy values (1, 13). The authors explained that tendon force is low in the speeds of movement, but a difficult comparison can be done, in fact the force development rate occurred angular speed of movement, which was explained by an external load (11, 12).

Another work showed the maximal ankle plantarflexion moment for the tendon force-elongation relationship during loading phase may be effective by increasing the tendon stiffness at performing isometric actions (14). Isometric protocols are mostly used for tendon elongation, however, muscle strength increases are only for being more efficient in isometric extension-flexion (43). Indeed, tendons are applied to transmit force derived from external joint torque by the muscle moment arm and it is showing important formation for the triceps surae in the plantar flexors (24). These conditions should be thought to depend on decreased tendon strain and muscle shortening (14, 20). In one research a load-elongation mechanism of muscle strain energy generation was reported on tibialis muscle-tendon complex during tetanic maximum isometric strain values observed at 0.8 to 2.5% dor muscle load modeling (25). However, tendon strain may exert its force transition and energy storage effects through this mechanism by load-elongation relationship during isometric actions, and elongation of tendon-aponeurosis changes can elevate muscle force levels at maximal voluntary contraction followed by isometric ramp (26). As a results, increases in the transfer relationship between muscle force and tendon elongation during decreasing phase ascending as the stiffness of tendon structures. Nonetheless, muscle actions works reported that tendon elongation-force enhancements by SSC effect increased at eccentric action than isometric action (27). Again, a work by reported light and heavy tendon strain, depending on intensity load respectively power and force transducer increased changes, had an effect on stiffness and force transducers during SSC movement (28). These findings have been shown under some conditions, tendon elongations become tendon strain increase during multi-joint sprinting and jumping (15). Based on tendon activities supported in efficient operation technique should have works the potential to create loads remodeling due to tendon strain morphological deformation (29). Importantly, dynamic tendon loads are necessary for evaluating the tendon viscoelastic structure, however muscle actions must include chronic muscle performance works and CSA evaluation for contraction and ballistic mode (7, 16). Based on the benefit, inducing tendon strain to metabolic stress on muscle performance should have been the continuous variability of load volumes (30), however, it is likely the potential tendon structure is important to use by athletes in practice. These tendon sections must be explained by the anatomical CSA (31). The effect of tendon strain on muscle-tendon shortness associated with the load intense outcomes have been previously investigated, however, limited results have been obtained on anatomic elongation tendon-aponeurosis (11). Specifically, muscle-tendon units and CSA facilitate the production of lengthening during angular changes of such as foot and leg joints. In turn, these tendon structures optimize load changes velocity to ATP energy generation of skeletal muscles (30). A recent work has investigated force generation, however many force activation increased walking and running at different speed exercises reached due to tendon lengthening mechanisms (6). Indeed, one research that investigated tendon structures in dynamic motions, as seen for load remodeling to walking and running, shows variance obtained from tendon-aponeurosis structures by force-length performance. Thus, few investigations examined the loading ratios of muscle action associated with maximal voluntary contraction (MVC) at high load, ramp maximum force at low load, submaximal isometric plantarflexion action, and maximal tendon force at sustained actions (32). However, sustained action results indicated that there may be negative loading rate effects on tendon mechanical properties. Lastly, considering the works to date only performed an isometric action not performed trained athletes (3), the safety of tendon elasticity long term of isometric exercises must be further investigated in terms of load remodeling. It is worth noting, however, generally angular elongations of dynamic movements are considered safe for applications (26).

TENDON ENERGY GENERATION WITH LOAD REMODELING

Contractile filaments and tendon structures were originally prescribed to enhance the stress-strain and load towards contraction energy storage; therefore, positional energy storage tendons produce large force based on strain of load and sometimes caused a loss of energy (19, 33). Furthermore, the viscoelastic tendon structure creates a reservoir that returns the energy storage associated with stress and strain in load remodeling (13). Tendon transmits the force contributes to energy capacity and enhances the force-elongation relationship and mechanical strain energy (23).

Initial investigations have demonstrated that tendons performed mechanism of energy storage at resistance training, jumping and other power activities based on spring-like properties can enhance mechanical energy production during eccentric, concentric and isometric actions (13, 34). Similarly, elastic energy of muscle-tendon complex or unit enhance SSC and power output in mechanical efficiency (9). Energy release, which is loaded into a tendon, but tendon loading system to explain energy storage at jump load mechanics occurred the highest power at peak isometric reaching with the elastic mechanism (35). Additionally, tendon strain energy higher jumping sport branch than other applied power activities for athletes (13). However, the tendon capacity of some athletes depends on maintaining the spring properties continuously depending on the limb muscle-tendon unit. Considering that continuing process, the strength and power loads use the elastic capacity of passive tendon structures that tendon energy storage accumulation on elongation with less energy expenditure during concentric action than eccentric action (27, 36). Indeed, a work evaluating muscle-tendon force previously reported that tendons show strain and stiffness energy in submaximal and maximal exercises in athletes and physical individuals (15). However, this work reported that energy storage of submaximal and maximal running performance improves through tendon strain and elongation capacity. To date, different responses to tendon mechanical work have been reported, which makes by series-elastic elements at running and walking speed loads, revealed that run transition speed more muscular fiber work. These results support previous mechanical energy expenditure (37). Nonetheless, a contemporary work (2) reported that tendon structure and spring properties can organize elastic energy storage at landing and jumping. The positive effect was observed 34% higher energy in high load within stiffness. Load remodeling, therefore, shows tendon storage energy to return energy through stiffness and tendon strain (13). A work reported that tendon stiffness and strain changes in energy storage of elastic properties occur to a greater degree in the high load flexors than in the low-stress extensors (38). One of the most critical controls of the tendon distal region at the active stiffness phase compared to the passive proximal region show stress in load remodeling, however, the force energy had greater active stiffness (3). An alternative mechanism works on ATP hydrolysis contraction energy produced mechanical load remodeling movement in concentric action than eccentric action for low response muscle contraction. Alternatively, passive elements are limited ATP hydrolysis while the high potential shows in eccentric actions (18). Performance responses have been replicated in tendon mechanics with concentric and eccentric load transition. Furthermore, in an investigation, by increasing tendon dynamics in contraction strategies of isometric and dynamic eccentric or concentric phases that cause changes in different muscle performance energy, should be seen as muscle behavior in maintaining storage of compartment muscles (39). The strategy of supported stiffness and tendon structure is energy formation in working modes, the available of contractile mechanical force in metabolic control, and is influenced by mechano-chemicals. Muscles use potential energy, pre-end of elastic elements in mechano-chemical warming intervals. If the change of mechano-chemicals in strengthening active muscle and tendon structure is explained, synthesis for energetic systems (ATP/mmol/nm) for elastic stores are affected in stress formation and muscle actions (40). For this reason, energy formations differ in muscle actions and a single fibril shows ATP hydrolysis in the tendon elongation distance. ATP synthesis has direct stability in isometric actions or other muscle actions, but must show potential energy with polarization for the energies of tendon structures that lack stability (41). In contrast, sublocation muscle maximum performance for exercise metabolic energy output was evaluated on high rate of ATP production of muscle elongation or lengthening in strain on time. However, for the muscle-tendon load condition, not only the type of contractions but also muscle lengthening and ATP-resynthesis rate and energy activations are required for force generation energy (10). Indeed, a study investigated that the metabolic stores at negative work increase energy source no different for these reasons, however, ATP hydrolysis actions against energies resistance loaded only the development of strain or SSC (42).

CONCLUSIONS AND FUTURE DIRECTIONS

The lack of studies investigating its effects in athletes from tendon strain and load-elongation force relationship within the existing literature is due to a number of factors, including the tendon loads and exercise protocols. Indeed, this diversity adds a level of critical outcomes to our ability to draw firm conclusions about the tendon structure of load remodeling on exercise and contraction modes. Nevertheless, from the available evidence, an active length may increase tendon strain and stiffness in the linear relationship (**figures 1-3**). This is supported by a recent review conducted at the time of writing this review, which also reported similar benefits (8). Little evidence of muscle-tendon elongation relationship used production of maintenance of power, strength, jump, walking and running for supporting strain and load remodling by energy generation capacity (**table I**). However, as the stiffness is examined in tendon properties, the studies on the evaluation of the force formation and energy capacity of the theories related to the changes in tendon strain and elongation are limited, and it was deemed necessary to examine more comprehensively at future studies. A critical point of view is that the load and elongation of tendon structures are based on high loading and angle change in isometric actions. In studies, force and elastic energies were more pronounced in sprinters than endurance athletes, as a result of more tendon load changes. Further research should focus on the strength and power increases to be obtained from the tendon strain energy in the force-elongation relationship in the load modeling of the tendon. Lastly, similar effects of tendon structure, strain, and elongation relationships on strength and energy capacity should be investigated in specialized power and strength training models of different athletes.

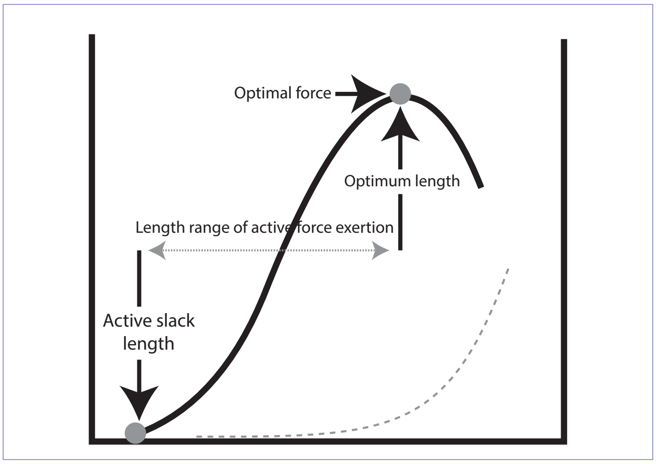

Figure 1. A linear curve representation of tendon strain changes associated with active lengthening and force response to show gradually energy storage forms tendon elongation relationship to optimal force.

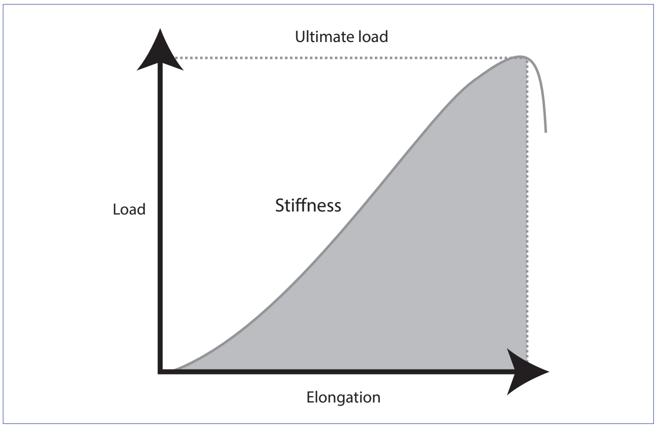

Figure 2. A linear curve representation of load-elongation changes in tendon structure displayed tendon elongation increase due to strain based on load and elastic energy storage.

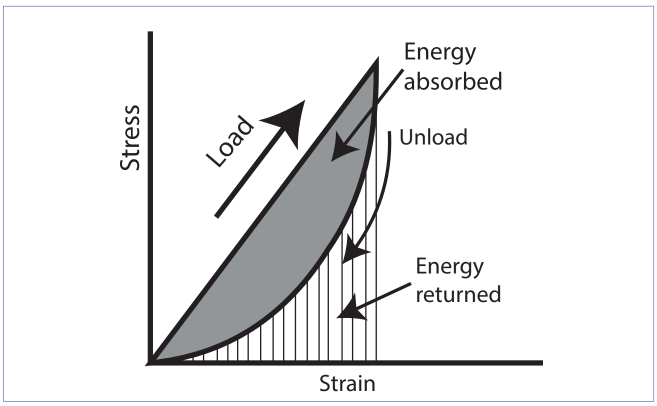

Figure 3. A stress-strain relationship linear representation associated with increased energy return due to the mechanical load remodeling.

Table I. Tendon performance on load remodeling.

Author (year)	Population	Experimental method	Exercise protocol	Main Outcomes	Conclusion
Kubo *et al.* (3)	Sprinters (n = 50) Untrained men (n = 18) Age: 20.4 ± 0.9; 22.2 ± 1.8 years	2 or 3 MVC protocol at a 100-deg ankle angle of medial gastrocnemius	A dynamometer was used to measure active muscle stiffness at peak angular velocities of 100, 200, 300, 500, and 600 degrees·s-1 during a ramp and ballistic contractions	Active muscle stiffness of submaximal isometric contractions at 500 and 600 deg.s-1 was greater in sprinters	A increase in active stiffness at high angular velocities was higher in sprinters due to tendon elongation
Miyamoto *et al.* (9)	Sprinters (n = 22), Long-distance runners (n = 22)	Highest maximal voluntary contraction (50% MVC) with the hip and knee flexed at 80° and 90° of vastus lateralis	A dynamometer was used to evaluate active and passive speed	Tendon stiffness of vastus lateralis at active speed was highest in long distance runners than sprinters	Active and passive stiffness resulted in locomotion speed
Arampatzis *et al.* (11)	Sprinters (n = 28) Endurance runners young male (n = 28) Age: 26.7 ± 5 years	2-3 min submaximal isometric contractions, and 3 maximal isometric force ramp MVC on ankle plantar flexion	A ultrasound was used to tendinous tissue elongation and at MVC maximum tendon force	The sprinters showed higher normalized stiffness of the triceps surae tendon and aponeurosis in the relationship between tendon force and tendon strain	High tendon force increase in sprinters
Wiesinger *et al.* (13)	Ski jumpers (n = 10) Endurance runners (n = 10) Water polo (n = 9) Non-physical active individual (n = 10) Age: 22.2 ± 2.9; 31.5 ± 4.6; 24.2 ± 3.2; 31.0 ± 5.1 years	Submaximal intensity of 1.5 W/kg and a caddence ~70 rpm after 10 min	Lower leg strength was performed on isokinetic dynamometer, muscle CSA at ultrasonography of gastrocnemius medialis, vastus lateralis and rectus femoris, and patellar and achilles tendon length	Tendon strain energy of the patellar tendon was higher in ski jumpers than in water polo players and for the Achilles higher in ski jumpers than runners	No significant difference in tendon energy storage

Author (year)	Population	Experimental method	Exercise protocol	Main Outcomes	Conclusion
Karamanidis and Erpro *et al.* (14)	Elite track and fieldjumpers (n = 67) Recreationally active individual (n = 24) Age: 23 ± 4; 24 ± 3 years	Submaximal 3 MVC protocol with 30, 50, and 80 of maximal joint arm for ankle plantar flexors stiffness and strain	Triceps surae muscle-tendon unit measured through dynamometry and ultrasonography	Jumpers had higher tendon stiffness	Increasing tendon stiffness
Kubo *et al.* (15)	Sprinters (n = 15) Untrained men (n = 15) Age: 20.8 ± 1.0; 0.7 ± 1.8 years	Isometric torque at maximal isometric contraction MVC for knee extension and plantar flexion	MVC, tendon elongation, 100 m race	Tendon stiffness of sprinter was lower than the untrained individual for knee extensor	There is a positive correlation between 100m sprint performance and tendon elongation
Kubo *et al.* (16)	Untrained men (n = 11) Age: 22.5 ± 3.2 years	Isometric and plyometric training (12-weeks) on tendon properties of plantarflexion	1RM, MVC, plyometrics (hopping and drop jumps) on a sledge apparatus, isometric (unilateral isometric plantar flexion)	Tendon stiffness during ramp and ballistic contractions increasing for isometric than plyometric	Ballistic contraction of plyometric training has developed tendon structure
Albracht and Arampatzis (20)	Recreational long distance runners (n = 26) Age: 27 ± 5 years	14 weeks, 5 set, 4 repetition isometric plantarflexion contraction with the ankle joint dorsiflexed	4 repetitions (MVC 90%) for tendon-aponeurosis elongation and stiffness at a dynamometer	Plantarflexion muscle strength 7% and tendon-aponeurosis stiffness 16 % increase	The combined tendon stiffness and muscle strength maintain a high economy of force generation
Epro *et al.* (21)	Track and field athletes (n = 67) Male (n = 35) Female (n = 32) Age: 23 ± 4; 24 ± 4 years	2 or 3 maximal and submaximal MVC at 30, 50, 80% of maximal joint moment arm	The triceps surae muscle strength and tendon stiffness measured in dynamometry and ultrasonography	Increasing tendon stiffness (8.1 ± 11.5%)	Jumping discipline showed a significantly higher triceps surae muscle strength and tendon stiffness
Pentidis *et al.* (22)	Artistic gymnastic athletes (n = 10) Non-athletes (n = 11) Age: 9.2 ± 1.6; 9.0 ± 1.7 years	SJ, CMJ, plantarflexion muscle strength	A force plate, dynamometer, ultrasound for tendon stiffness	No Achilles tendon stiffness	Higher 8.5% strain in athletes

Author (year)	Population	Experimental method	Exercise protocol	Main Outcomes	Conclusion
Mersmann *et al.* (23)	Volleyball athletes (n = 21) Untrained individuals (n = 24) Age: 16.7 ± 1 years	MVC with knee joint angle 60°, 70° and 75°	MVC on a dynamometer for muscle strength evaluation and patellar tendon mechanical properties by ultrasound method	Tendon stiffness is higher in athletes at 86.0 ± 27.1 kN/strain	Higher tendon strain during maximum contractions.
Holzer *et al.* (24)	Men individuals (n = 14) Age: 29 ± 6 years	MVCs were performed at 20° and 10° plantarflexion and 5°, 10°, 15°, 20°, 25°, and 30° dorsiflexion for each trial analyzed peak torque	Maximum voluntary plantarflexion contraction MVC of the right leg with an isokinetic dynamometer	Triceps muscle-tendon unit force increased based on isometric moment torque arm.	Contraction tendon load increased remodeling magnitude.
Maganaris and Paul (25)	Healthy men individuals (n = 5) Age: 22 ± 4 years	Percutaneous tetanic electrical stimulation bipolar wave pulses with a duration of 100 ms were applied at a frequency of 100 Hz for 1 s	20, 40, 60, 80 and 100 % of maximum isometric dorsiflexion moment measured with an isokinetic dynamometer	Tendon strain values increased with load	Increased strain values revealed via the function of dorsiflexion load
Kubo *et al.* (26)	Healthy men individuals (n = 7) Age: 25.3 ± 1.4 years	Ankle static stretching passively flexed to 35° of dorsiflexion for 10 min	An ultrasound was used to measure tendon elongation of medial gastrocnemius muscle at MVC ramp isometric plantar flexion protocol	Tendon elongation and muscle force relationship increased stiffness	Static stretching increased the elasticity of the tendon structures
Fukutani *et al.* (27)	Healthy men individuals (n = 12) Age: 24.2 ± 3.2 years	Concentric at 60°/s following preliminary isometric contraction and eccentric at 90°/s	A dynamometer measured the plantar flexion with knee and hip joints flexed at 0° and 80°, ultrasound measurement included fascicle length, tendon elongation, and pennation angle	Eccentric contraction without preliminary isometric contraction produced preactivation SSC effect	Active tendon elongation-force mechanisms contributed SSC effect

Author (year)	Population	Experimental method	Exercise protocol	Main Outcomes	Conclusion
Earp *et al.* (28)	Physical active men (n = 9) Physical active women (n = 9) Age: 25.8 ± 2.8 years	Single-leg, maximum intensity SCC knee extension at 20, 60, 90% loads of 1RM	3 leg extensions at each load of 1RM with the fastest concentric joint velocity	Vastus lateralis fascicle length, velocity and tendinous length measured by ultrasound	The tendon lengthened significantly less at the end of the eccentric phase. Tendon strain decreased during an SSC movement at loading intensity increases.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

YK: design, writing.

CONFLICT OF INTERESTS

The author declares that she has no conflict of interests.

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