[CLINICAL COMMENTARY]

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Eccentric or Concentric Exercises for the Treatment of Tendinopathies?

Tendon tissue plays an essential role in transmitting muscle contractile forces to produce movement and is therefore uniquely designed to withstand considerable loads. During locomotion, the Achilles and patellar tendons may see forces up to approximately 8 times body weight.[23,31,62] Repetitive loading of a tendon often results in overuse injuries, including tendinopathy, which is a clinical condition characterized by pain in the area of the tendon during activity, localized tenderness on palpation, local swelling of the tendon, and impaired performance.[45,60] Tendinopathy is a sizable problem in both elite and recreational athletes.[22,27,93] Specifically, the incidence of tendon injuries has been estimated to be as high as 30% to 50% of all sports injuries and 50% of injuries to elite endurance runners, and 6% of sedentary people will at some point experience a tendon injury.[52,58] Moreover, the symptoms and reduction in performance may last for an extended period, potentially years.[44,57] The exact injury mechanism remains elusive, but an understanding of how tendon tissue adapts to mechanical loading could be the key to understanding the pathogenesis of tendinopathy and thus provide the basis for prevention of overuse injuries.

Tendinopathy is the commonly accepted term for the clinical condition in and around overloaded tendons.[46] These injuries were previously considered to be the result of a prolonged inflammatory condition (chronic tendinitis).[90] However, more recently, the extent to which inflammation plays a role in chronic tendinopathy has been debated.[25,63,80] The slow, insidious onset of tendinopathy makes it difficult to identify the start of the condition in humans, and efforts to develop animal models to study the early events of the condition have been inconsistent.[32,35] Therefore, the definitive role of inflammation in the early stages of the condition remains difficult to investigate. Notwithstanding these limitations, it has been shown that tendon tissue from individuals with Achilles tendinopathy does not display an elevated expression of inflammatory markers after 1 hour of running.[77] Rather than inflamed, tendon tissue obtained from individuals with tendinopathy is typically more cellular than healthy tissue and displays both signs of general tissue degeneration, including collagen degeneration and necrosis, as well as signs of regeneration, including neovascularization, irregular fiber structure, and increased ground substance (see Fredberg and Stengaard-Pedersen[25]).

Tendinopathy is a substantial clinical challenge because it can severely limit sports participation for months and po-

● **SYNOPSIS:** Tendinopathy is a very common disorder in both recreational and elite athletes. Many individuals have recurrent symptoms that lead to chronic conditions and termination of sports activity. Exercise has become a popular and somewhat efficacious treatment regime, and isolated eccentric exercise has been particularly promoted. In this clinical commentary, we review the relevant evidence for different exercise regimes in tendinopathy rehabilitation, with particular focus on the applied loads that are experienced by the tendon and how the exercise regime may affect these applied loads. There is no convincing clinical evidence to demonstrate that isolated eccentric loading exercise improves clinical outcomes more than other loading therapies. However, the great variation and sometimes insufficient reporting of the details of treatment protocols may hamper the interpretation of what may be the optimal exercise regime with respect to parameters such as load magnitude, speed of movement, and recovery period between exercise sessions. Future studies should control for these loading parameters, evaluate various exercise dosages, and think beyond isolated eccentric exercises to arrive at firm recommendations regarding rehabilitation of individuals with tendinopathies. *J Orthop Sports Phys Ther 2015;45(11):853-863. Epub 14 Oct 2015. doi:10.2519/jospt.2015.5910*

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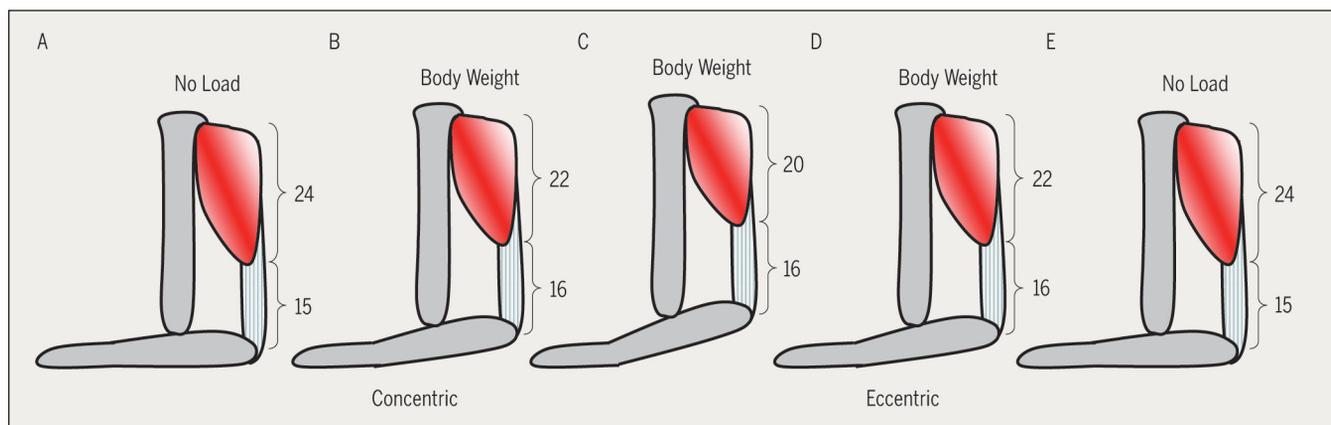
FIGURE 1. Schematic illustration of concentric and eccentric muscle contraction about the ankle joint. Numbers illustrate lengths (not to scale). (A) During concentric heel rise, the tendon and muscle are initially relaxed. (B) As muscle shortens, force is generated, causing the tendon to lengthen until sufficient force has been reached and the heel begins to rise. (C) While muscle shortens further, the heel continues to rise under approximately constant force and, due to the constant load, the length of tendon also remains constant. (D) In the eccentric phase, the heel drops as muscle lengthens, still at approximately constant force, and consequently tendon retains its length. (E) Finally, the muscle lengthens as it is relaxed and tendon shortens because load is removed. Note that across the schematics, tendon length is determined by the amount of load carried independent of muscle length.

tentially years.[4,44] The list of currently available interventions for this clinical condition is extensive and may include surgery, nonsteroidal anti-inflammatory drugs, corticosteroids, sclerosing injection, shockwave therapy, platelet-rich plasma injection, intratendinous hyperosmolar dextrose (prolotherapy) injection, high-volume injections of 10 mL 0.5% bupivacaine and 40 mL normal saline into the paratenon, Kinesio Tape, and therapeutic ultrasound, just to mention a few.[81,92] Although these and other treatment options are described in the literature, various loading interventions have predominated in the treatment of tendinopathies.[64] It seems that loading paradigms yield positive clinical,[2,61,88] structural,[50] and biochemical outcomes.[49]

Much of the attention on loading programs as a treatment paradigm for these challenging injuries originated from an article published by Stanish et al[90] in 1986. In this article, the loading regime was described as a stretch-shortening exercise, that is, an eccentric component rapidly followed by a concentric component. For example, in the case of the patellar tendon, "The patient, from a standing position, flexes the knees and drops to a squatting position abruptly, then recoils to the standing position."[90]

The progression of the exercise protocol, with abating symptoms, was described as increasing the speed of the movement, and thereafter an external load was added for additional progression.[90]

Approximately a decade later, it was suggested that isolated eccentric contraction alone, without the accompanying concentric component of a stretch-shortening cycle, provided good clinical results for patients with tendinopathy.[4] This isolated eccentric loading paradigm has since gained considerable popularity and is now widely regarded as the treatment of choice, although there is a lack of convincing evidence that it is the most effective exercise regime.[64] More recently, new loading-based exercise regimes, such as isolated concentric training,[61] heavy slow resistance training,[9,49] and concentric/eccentric progressing to eccentric training,[88,89] have emerged. This article focuses on the underlying rationale of these various loading paradigms.

Response of Healthy Tendon to Load

It is well established that exercise in general can affect both skeletal muscle[38] and tendon.[48] In tendon, there is an acute increase in blood flow and collagen synthesis,[54,55] and long-term effects lead to tissue hypertrophy and altered material properties.[12,85,98] The magnitude and type of adaptation likely depend on the exercise regime, including the magnitude of the load, range of motion performed, contraction mode (eccentric lengthening/concentric shortening), movement speed, number of repetitions, and rest periods between the exercise sessions. By varying these components, a wide range of exercise programs can be constructed, from endurance (low load, high speed, many repetitions) to strength (high load, low speed, few repetitions) programs, with myriad combinations in between. The response of tendon to the various exercise parameters will be discussed in the following sections, though knowledge on several matters remains limited.

It is well known that the tendon cells (fibroblasts) respond to mechanical stimuli in the form of strain,[42,66,96] and that depriving them of strain (relative tissue deformation) leads to degeneration and apoptosis (cell death).[7,17,99] However, the dose response to strain magnitude is still not well established. Cell-culture experiments suggest that there is an increased response (increased collagen expression, reduced matrix metalloproteinase expression, and increased matrix stiffness) with increased strain,[56,101] but there may be an optimal strain, beyond which the

stretching becomes detrimental.[41,68] The absolute values of strain used in cell-culture stimulation vary greatly, and it is uncertain how much of a given strain the cells will experience in vivo, because the surrounding matrix may provide shielding. In vivo, in healthy human Achilles tendons, it has been reported that with equal exercise volume, working at 90% of maximum voluntary contraction (MVC), which causes approximately 5% tendon strain, yields increased stiffness and cross-sectional area compared to working at 55% MVC, which causes approximately 3% tendon strain.[5]

Speed and/or duration of loading during exercise also appear to be important for tendon adaptation.[6,41,51,56] At the cellular level, most,[30,41,97] but not all,[21] studies have found that the adaptive response of fibroblasts to dynamic load is superior to that of static load (zero speed). Though the response to different dynamic load regimes is complex due to the interaction of the parameters, overall, the evidence suggests that increased time under load, increased number of load cycles, and increased loading rate result in a positive adaptive response (increased matrix strength and stiffness and decreased matrix metalloproteinase expression) in cultured fibroblasts.[41,56,100] The response appears to be a bit different in vivo, where it has been reported that the stiffness and size (cross-sectional area) of human Achilles tendon were more responsive to a low number of loads of long duration (6-second cycle) than to a high number of faster loads (2-second cycle) when the total exercise volume was kept constant.[5,6] This finding is corroborated somewhat by another study showing that isometric contractions of long duration (20 seconds) yielded greater patellar tendon adaptation (increased stiffness) than rapid (1-second) contractions at equal exercise volume.[51] In the latter study, muscle strength and volume adaptation were unaffected by contraction duration.

It is unknown whether tendon cells experience some form of fatigue as a result of repeated load cycles. Tendon cells have a low metabolic rate and probably do not require rest for the purpose of restoring energy deposits. However, the anabolic response to loading is sustained in tendon for up to several days following an exercise bout,[55,65] which could indicate the need for a postexercise recovery period.[63] But, conversely, studies on cell culture have performed continuous stimulation of fibroblasts for up to 24 hours per day without detrimental effects,[41,59] and most exercise protocols for tendinopathy management are performed every day without recovery periods.[4,67,89] Overall, there is a lack of studies specifically addressing the effects of recovery and how it affects tendon adaptation.

The majority of the tendon is composed of extracellular matrix (ECM), which is a passive structure and, unlike the cells, does not actively respond to load, though it may still be differentially affected by exercise parameters. It has been suggested that accumulation of microdamage may be involved in the etiology of tendinopathy[87] and, because the turnover in tendons is slow,[34] ECM damage could accumulate. Microdamage is difficult to measure, and its clinical relevance is therefore unclear. However, if it does play a role, it would be an argument in favor of recovery periods. Mechanical studies have shown that both overloading and mechanical fatigue can cause damage to tendon ECM,[43,72] which could play a role in tendinopathy. The tendon ECM is also a viscoelastic material, which means that slower loading regimes can yield greater strains than faster loading regimes, as the tendon has more time to creep.[74] Creep also appears to be associated with greater relative fibril slippage,[24] which may generate local shear strains sensed by the cells. Slow loading may therefore produce particularly strong cell stimuli that can be beneficial to the tendon if the strain is sufficient, but could be detrimental if strain is excessive. This viscoelastic behavior depends on the amount of time the tendon is under load and is therefore unaffected by the mode of muscle contraction (eccentric or concentric).
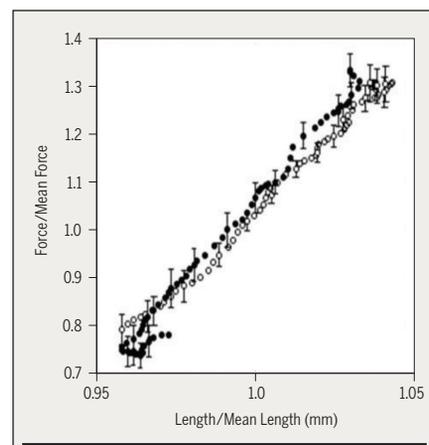

FIGURE 2. Achilles tendon force versus Achilles tendon length. Eccentric data are shown as open circles, whereas concentric data are filled circles. Reprinted with permission from Chaudhry S, Morrissey D, Woledge RC, Bader DL, Screen HR. Eccentric and concentric loading of the triceps surae: an in vivo study of dynamic muscle and tendon biomechanical parameters. *J Appl Biomech.* 2015;31:69-78. ©Human Kinetics, Inc.

In summary, tendon is responsive to loading and will respond more strongly to greater loads, although there is likely an optimum beyond which load becomes detrimental. Slower loading regimes may be superior to rapid loading, while the importance of recovery between loading sessions is unclear.

Tendon Under Eccentric and Concentric Muscle Contractions

Although isolated eccentric loading regimes for tendinopathy have been widely accepted as the treatment of choice,[92] the potential mechanisms behind this intervention remain unclear. In the following section, we discuss some of the proposed mechanisms and their potential applications in light of existing evidence.

Strictly speaking, the descriptions "concentric" and "eccentric" only apply to muscle, which actively contracts. Tendon is a mechanically passive structure that lengthens when load increases and shortens when load is reduced (**FIGURE 1**). It is therefore questionable whether the mode of muscle contraction for a given load and range of motion would have a differential effect on tendon tissue. The fact that

muscles can produce greater maximal force eccentrically than concentrically would suggest a potential for greater mechanical stimulation from eccentric than from concentric exercise.[18,37] Accordingly, it has been suggested that the tendon may stretch more during eccentric loading than concentric loading.[1,90] However, while there is a potential for greater tendon load and, consequently, stretch with eccentric exercise, this potential is rarely utilized because rehabilitation exercises seldom approach concentric 1-repetition maximum. It has been shown that Achilles tendon load and stretch are identical during the concentric and eccentric components of a heel rise/drop against body weight (**FIGURE 2**), a typical load used in rehabilitation.[11,79] The 2 most commonly used eccentric exercises for tendinopathy are squats for the patellar tendon and standing heel lowering for the Achilles tendon, and both movements are typically performed to a 15-repetition maximum.[4,103]

TABLES 1 and **2** list the number of weekly repetitions and estimated loads used in several eccentric exercise regimes published in the literature. It should be noted that several studies have used an individualized load progression, but they seldom report the actual amount achieved, only the starting load. It is also worth noting that most studies do not include a control group, which is likely due to ethical concerns; therefore, it is uncertain whether the provided treatment was in fact superior to a "wait and see" approach. However, most of these studies included patients with chronic symptoms, suggesting that time alone would not have improved their condition.

A few theoretical mechanisms have been suggested to explain how eccentric loading may differentially influence tendon. For example, during heel-lowering/raising tasks, the ground reaction force may fluctuate at a higher frequency (approximately 10 Hz) during the eccentric phase.[36,79,84] While tendon cells could potentially register this modulation, the magnitude of the modulation is quite small compared to the total load (approximately 10%). It has also been proposed that motor unit activation differs between concentric and eccentric exercises,[18] which may produce a difference in load distribution and shear within the tendon, although such a mechanism is unlikely to be a factor for the patellar tendon, in which load is distributed via the patella. Finally, secreted signaling molecules from the muscle (myokines), such as interleukin 6 (IL-6),[75] could potentially affect the nearby tendon, and myokine expression may differ between concentric and eccentric exercise, although the effects are currently unclear.[73,94]

In contrast to these hypothetical considerations, there is evidence to suggest that eccentric and concentric muscle contractions do not yield a differential response of the tendon. In animal models, it has been shown that concentric or eccentric contraction to the same force level does not influence the expression of collagen at the cellular level.[29] In fact, even if the eccentric muscular contraction force were greater than concentric contraction force, both contraction modes would yield

TABLE 1	EXERCISE PROGRAMS USED IN STUDIES FOR ACHILLES TENDINOPATHY	
Study/Group	**Load***	**Pain Improvement†**
Alfredson et al[4]		
Isolated ECC	1260 (100%)‡§	VAS, 94%
Croisier et al[13]		
Isolated ECC	135 (130%)‖	VAS, 73% (10 wk)
Alfredson and Lorentzon[3]		
Isolated ECC	1260 (100%)‡§	VAS, 75%
Öhberg and Alfredson[70]		
Isolated ECC	1260 (100%)‡§	Pain during activity: reduced, 88%
Roos et al[83]		
Isolated ECC	1260 (100%)‡§	Foot and Ankle Outcome Score, 36%
Shalabi et al[86]		
Isolated ECC	1260 (100%)‡§	6-point pain scale, 40%
de Vos et al[16]		
Isolated ECC	1260 (100%)‡§	VISA-A, 78%
Langberg et al[53]		
Isolated ECC	1260 (120%)‡§	VAS, 71%
Petersen et al[76]		
Isolated ECC	1890 (100%)‡§	VAS, 60%
Yelland et al[102]		
Isolated ECC	1260 (100%)‡§	VISA-A, 38%
Silbernagel et al[88]		
Isolated ECC plus mixed ECC + CON plus other exercises	Mixed, 840 (50%)‡ Mixed, 945 (100%)‡§ ECC, 630 (100%)‡§	VISA-A, 60%
Rompe et al[82]		
Isolated ECC	1260 (100%)‡§	VISA-A, 49% (16 wk)¶
Wait and see	0 (0%)	VISA-A, 14% (16 wk)

TABLE 1	EXERCISE PROGRAMS USED IN STUDIES FOR ACHILLES TENDINOPATHY (CONTINUED)	
Study/Group	**Load***	**Pain Improvement†**
Nørregaard et al[69]		
Isolated ECC	1260 (100%)‡§	Modified KOOS-score: improved, 25%
Stretching	Stretching	Modified KOOS-score: improved, 25%
Beyer et al[9]		
Isolated ECC	1260 (100%)‡§	VISA-A, 24% VAS, 59%
Heavy slow resistance (ECC + CON)	144 (130%)‡	VISA-A, 41% VAS, 69%
Mafi et al[61]		
Isolated ECC	1260 (100%)‡§	Satisfied, 82%¶ VAS of satisfied, 83%
Isolated CON plus jump plus rope skipping	1260 (100%)‡	Satisfied, 32% VAS of satisfied, 86%
Niesen-Vertommen et al[67]		
Isolated ECC	300 (55%)§	VAS, 78%¶
Mixed ECC + CON	300 (25%)§‖	VAS, 46%
Silbernagel et al[89]		
Isolated ECC plus mixed ECC + CON plus other exercises	Mixed, 840 (50%)‡ Mixed, 945 (100%)‡§ ECC, 630 (100%)‡§	Pain during activity: reduced, 57%
Mixed ECC + CON	1260 (50%) or 315 (100%)§	Pain during activity: reduced, 80%

Abbreviations: CON, concentric; ECC, eccentric; KOOS, Knee injury Osteoarthritis Outcome Score; VAS, visual analog scale; VISA-A, Victorian Institute of Sport Assessment-Achilles.
*Load reported as weekly repetitions and estimated load as percentage of body weight (50% body weight is 2 legged and 100% is 1 legged). In general, peak load is listed, but for studies with load progression that did not report the achieved progress, only the load before progression is listed. No attempt was made to evaluate load in stretching exercises.
†Unless otherwise stated, all studies had 12 weeks of intervention.
‡Pain accepted.
§Study included unreported progression beyond what is listed.
‖Estimated percent body weight from maximal voluntary contraction or other external load.
¶Improvement in ECC group significantly greater than in comparator.

similar expressions of collagen.[33] These animal findings imply that given a sufficiently high force (and resulting strain on the fibroblast), the contraction mode is inconsequential for the tendon cellular response. A recent study examined the effect of contraction mode on tendon (and muscle) hypertrophy in healthy human subjects.[20] The 12-week resistance training consisted of isolated concentric knee extensions on one side and eccentric knee extensions on the contralateral side. The sets, repetitions, and time of loading were similar between sides, but the loading for the eccentric side was 120% that of the concentric side. The results showed that resistance training with either concentric or eccentric contraction produced a similar magnitude of tendon hypertrophy.[20] These findings reinforce the notion that the cellular and tissue response in healthy tendon is independent of contraction mode.

In summary, there are a number of mechanisms that could theoretically differentiate the effect of eccentric from concentric exercise on tendon, but there is no evidence that these mechanisms actually play a role or are beneficial. In contrast, there is evidence from animal and human studies that suggests a lack of differential effect of eccentric versus concentric exercises.

The Effects of Muscle Contraction Regimes on Tendinopathy

Both elite and recreational athletes are frequently afflicted by Achilles and/or patellar tendinopathy.[52,57] The clinical literature has mainly focused on use of eccentric loading exercise in the treatment of these tendinopathies, and therefore the following sections on Achilles and patellar tendinopathy will first cover the clinical studies that have investigated the effects of eccentric loading, followed by studies that have investigated the effects of other types of loading exercises. **TABLES 1** and **2** cover the clinical studies on Achilles and patellar tendinopathy, with load reported as weekly repetitions and estimated load as a percentage of body weight.

The Effect of Eccentric Muscle Contraction on Achilles Tendon It has been shown that eccentric-loading regimens for Achilles tendinopathy can provide clinical improvements, including reduction in pain and improved function.[15,47,88,92] Several studies[3,13] have employed the isolated eccentric-loading paradigm initially introduced by Alfredson et al.[4] When this exercise model is performed as unilateral heel drop, the force placed on the tendon is a function of body weight, and the force can be modulated with additional weight placed in a backpack worn by the patient. In addition to improvements in pain and function, it appears that structural features observed with ultrasound and magnetic resonance imaging are altered following isolated eccentric loading in some,[28,70,71,86] but not all, studies.[14,69,76,82] It has also been shown that in addition to decreasing pain, isolated eccentric loading can result in increased synthesis of type I collagen.[53] Thus, isolated eccentric loading appears to influence biochemical and biomechanical parameters and improve clinical outcomes. The beneficial effects of isolated eccentric loading with body weight appear to be reduced if the pain is located toward the tendon inser-

tion[19]; however, this might be remedied by avoiding ankle dorsiflexion below horizontal to avoid compression of the distal end of the tendon against the posterior aspect of the calcaneus.[40]

Several studies have compared isolated eccentric loading with body weight to other types of nonloading therapy (eg, prolotherapy, cryotherapy, splints).[16,76,83,102] Most of these studies report significant clinical improvements with eccentric exercise,[16,76,83,102] although the effect relative to the alternative treatment varies (eg, eccentric loading regimes have greater effect than cryotherapy, but similar effect compared to shockwave therapy and heel brace).[92]

Collectively, these studies demonstrate positive clinical benefits from eccentric loading, but because none of these studies has a comparison group using an alternative muscle contraction mode (concentric or isometric), they are unable to show whether the actual muscle contraction mode plays a role in the outcome.

The Effect of Eccentric Muscle Contraction Compared to Other Contraction Regimes for Achilles Tendinopathy A limited number of studies have investigated the effect of isolated eccentric exercise relative to other loading regimes for Achilles tendinopathy.[9,61,67,69,89] It has been shown that fast heel-drop exercises with a high eccentric load were more effective in reducing overall pain than isotonic concentric/eccentric exercises at lower loads.[67] Others have compared isolated eccentric and concentric loading and demonstrated similar pain reduction with both regimes, with the load on the tendon being greater in the eccentric (body weight plus backpack) than in the concentric (less or equal body weight) group (**TABLE 1**).[61] A more extensive rehabilitation program that included concentric/eccentric loading with body weight yielded better self-reported outcomes (questionnaire on function and pain) than a concentric program of a lesser total loading volume not at 6 weeks but at 1-year follow-up.[89] Isolated eccentric loading with body weight has also been compared to static

stretching, which places a low-magnitude load on the tendon for an extended period, and the results showed that the interventions yielded a similar clinical outcome.[69] It was recently demonstrated that heavy slow resistance training 3 times per week was equally effective in reducing symptoms compared to the traditional eccentric regimen performed 7 days per week in patients with Achilles tendinopathy.[9] These data indicate that different muscle contraction loading regimes can accomplish the same clinical improvement in patients with Achilles tendinopathy. Thus, it seems that loading confers some clinical improvements to Achilles tendinopathy, but, based on the available literature, it is not possible to delineate the role of contraction mode (eccentric or concentric) from that of load magnitude, number of repetitions and sets, contraction speed, and recovery time between sessions.

The Effects of Eccentric Muscle Contraction on Patellar Tendon Similar to Achilles tendinopathy, it has been suggested that eccentric-loading regimes for patellar tendinopathy may provide clinical improvements.[8,13,39,78] Patients typically eccentrically load the affected patellar tendon while performing a partial squat on the affected limb, and then return to the starting position by concentrically loading the nonaffected tendon. One study compared isolated eccentric loading with body weight to nonloading therapy with ultrasound or transverse friction massage.[91] The authors reported that as few as 3 weekly sessions (each session consisting of 3 sets of 15 repetitions) of isolated eccentric squats for 4 weeks yielded significant clinical improvements, which were far greater than with nonloading therapy.[91] It has also been shown that eccentric loading can result

TABLE 2	EXERCISE PROGRAMS USED IN STUDIES FOR PATELLAR TENDINOPATHY

Study/Group	Load*	Pain Improvement†
Bahr et al[8]		
Isolated ECC	630 (100%)‡§	VISA-P, 73%
Croisier et al[13]		
Isolated ECC	135 (130%)‖	VAS, 71%
Purdam et al[78]		
Isolated ECC	630 (100%)‡§	VAS, 62%
Stasinopoulos and Stasinopoulos[91]		
Isolated ECC	135 (100%)‡§	5-point scale, 80% (4 wk)
Visnes et al[95]		
Isolated ECC + competitive volleyball	630 (100%)‡§	No improvement
Competitive volleyball (control)	0 (0%)	No improvement
Young et al[103]		
Isolated ECC on 25° decline board	630 (100%)‡§	VISA-P, 25% VAS, 51%
Isolated ECC on horizontal step	630 (100%)	VISA-P, 18% VAS, 53%
Jonsson and Alfredson[39]		
Isolated ECC	630 (100%)‡§	VISA-P, 102%¶ VAS, 69%¶
Isolated CON (n = 4)	630 (100%)‡§	VISA-P, −9% VAS, 8%

TABLE 2	Exercise Programs Used in Studies for Patellar Tendinopathy (continued)	
Study/Group	**Load***	**Pain Improvement†**
Kongsgaard et al[49]		
Isolated ECC	630 (100%)‡	VISA-P, 42%
Heavy slow resistance (ECC + CON)	288 (130%)‡	VISA-P, 39%
Kongsgaard et al[50]		
No ECC	...	...
Heavy slow resistance (ECC + CON)	288 (130%)‡	VISA-P, 27%
Frohm et al[26]		
Isolated ECC	315 (100%)‡§	VISA-P, 108%
Isolated ECC overload	32 (170%)‡‖	VISA-P, 76%
Cannell et al[10]		
ECC drop squats	300 (60%)‡§	VAS, 55%
Mixed ECC + CON, focused on CON	150 (CON, 125%)§‖ (ECC, 63%)‖	VAS, 31%

Abbreviations: CON, concentric; ECC, eccentric; VAS, visual analog scale; VISA-P, Victorian Institute of Sport Assessment-patella.
*Load reported as weekly repetitions and estimated load as percentage of body weight (50% body weight is 2 legged and 100% is 1 legged). In general, peak load is listed, but for studies with load progression that did not report the achieved progress, only the load before progression is listed. No attempt was made to evaluate load in stretching exercises.
†Unless otherwise stated, all studies had 12 weeks of intervention.
‡Pain accepted.
§Study included unreported progression beyond what is listed.
‖Estimated percent body weight from maximal voluntary contraction or other external load.
¶Improvement in ECC group significantly greater than in comparator.

in clinical improvement when patients were instructed to refrain from sports activity during the intervention period.[39,91] However, in elite volleyball players with patellar tendinopathy, adding 8 weeks of isolated eccentric loading to the already existing activity during the season did not confer any pain relief.[95] In contrast, in Achilles tendinopathy, it has been shown that moderate physical activity during the treatment period was not detrimental to the benefits of eccentric exercise.[88] The apparent difference between activity at an elite level and more moderate activity may be related to insufficient recovery time or possibly the total load volume of sports activity and the added eccentric-loading exercises,[63] although this requires further investigation. Ultrasonography has been used to investigate structural changes (tendon thickness and Doppler activity) in patellar tendinopathy following eccentric exercise, but has not demonstrated significant effects.[49] Collectively, the above studies show that eccentric loading may provide clinical benefits in patellar tendinopathy treatment, but, again, whether the actual direction of muscle contraction plays a role in the outcome or clinical benefits are instead related to the absolute magnitude of loading is unclear, as none of these studies had a similar comparison group. **The Effect of Eccentric Muscle Contraction Compared to Other Contraction Regimes for Patellar Tendinopathy** For patellar tendinopathy, only 1 study has compared isolated eccentric loading with an identical concentric-loading regime at equal load magnitude, volume, and speed.[39] The authors[39] concluded that eccentric loading was more effective in reducing pain than concentric loading; however, due to a high number of dropouts, only 4 of 7 partici-

pants remained in the concentric group, hampering any meaningful comparison and firm conclusion.

Other studies have compared loading regimes without matching the load (**TABLE 2**). Isolated eccentric squats on a decline board have been compared to mixed concentric/eccentric squats on a flat surface in elite volleyball players: both groups performed exercises on only the affected extremity for 12 weeks before starting the competitive season.[103] Both protocols resulted in reduced pain and increased function, without a difference between the groups. Twelve weeks of isolated heavy eccentric training using few repetitions of high load (100% MVC, approximately 170% body weight) has been compared with isolated eccentric squats on a decline board using a larger number of repetitions at lower load (100% body weight, approximately 60% MVC).[26] Both groups markedly improved in pain and function but without a difference between the groups. Another study compared eccentric drop squats landing on 2 feet (60 repetitions per session) with knee flexion/extension exercise (30 repetitions per session), with the aim of creating a high concentric load component (75%-80% MVC).[10] Both groups trained with progressive loads 5 times weekly and had reduced tendon pain after 12 weeks, but outcomes were no different between groups. Only 1 study has investigated biochemical outcomes: the efficacy of isolated eccentric squats compared to mixed concentric/eccentric heavy slow resistance training.[49] Both exercise regimes resulted in reduced pain and improved function, but biochemical changes (increased collagen content and reduced glycation) were only evident with heavy slow resistance training. In addition, heavy slow resistance training was associated with structural changes.[50] Therefore, collectively, there is no firm evidence to support the notion that eccentric loading is more efficient than concentric or other loading regimes for patellar tendinopathy. Most studies have not matched for other parameters, such

as load, speed, frequency, and rest periods,[10,26,39] and it is therefore still unclear what specific load magnitude, frequency, or total load volume per session should be used to provide meaningful clinical and structural improvements in patients with patellar tendinopathy.

Clinical Implications and Future Directions

Tendinopathies are a common ailment among athletes, and there is currently an incomplete picture of the etiology. Although there are several suggested treatment options, loading regimes appear to have good clinical results. Early works have shown an exercise program with isolated eccentric contraction to have good clinical outcomes, which promoted the paradigm of eccentric loading for tendinopathy. However, as outlined in this review, there is little evidence for isolating the eccentric component of a loading-based regime. The basic mechanisms that are likely to influence tendon adaptations appear to be related mainly to tendon load/strain magnitude and duration, and there is no theoretical basis for greater tendon loads in eccentric exercises at a given force (body weight or external load).

There is a paucity of clinical trials directly comparing different exercise regimes and different exercise dosages, but the available evidence provides little support for the superiority of isolated eccentrics. It is worth noting that studies rarely use comparable load magnitude when comparing eccentric to other load regimes. To delineate the effects of mode and load magnitude, future work should compare isolated eccentric and concentric action under equal load at various exercise dosages in individuals with tendinopathy. The focus on eccentric exercise has overshadowed other aspects of tendinopathy rehabilitation, and acknowledgement of the limited evidence may prompt a broader approach, including the use of heavy load and low speed, which has some support from both basic science and clinical trials. ◉

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