Eccentric Training

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This is intended to be an informational outline of the most current available research on eccentric training techniques. Literature was compiled from numerous articles, databases and books. Due to the broad range of eccentric training application, this review focused only on techniques affecting the biceps brachii, triceps brachii, rotator cuff, lateral epicondylitis, and achilles tendon.

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Overview

The concept of an eccentric exercise program is based on increasing the strength of the tendon by gradually overloading it to promote an increase in tensile strength. The basic principles of the eccentric exercises are the length of the tendon, the load on the tendon, and speed of the exercise movement. Modifying these three factors lead to the development of a progressive eccentric exercise protocol. This paper will describe the physiological, biomechanical, and anatomical rationale behind using eccentric exercises in the treatment of tendonopathy. Parameters for its use as well as contraindications and precautions will also be presented.

History of Eccentric Training

Eccentric contractions are commonly associated with terms like muscle damage and muscle soreness. The implementation of eccentric exercises into a training protocol led to Theodore Hough developing the term delayed onset muscle soreness. Delayed onset muscle soreness (DOMS) was first described by Hough in 1902 after he found that exercise consisting of eccentric contractions caused athletes to develop very sore muscles.[13] Hough believed the eccentric exercise was causing "ruptures within the muscle".[13] However, considering the amount of time that musculature is subjected to eccentric contractions throughout daily movement the association of eccentrics with muscle damage can be misleading. Soreness may be a symptom of muscle damage, yet that damage is typically at the sub-cellular level and may not represent a true structural impairment. Furthermore, after performing an unaccustomed eccentric exercise and exhibiting soreness, the muscle quickly adapts and becomes accustomed to the increase in applied stress. As a result, not only is the soreness reduced, but other indicators of muscle damage are reduced. Muscles are designed to function eccentrically and to resist the mechanical strain placed upon them, as well as recover following an applied stress or strain.[7] This research can lead clinicians to develop

rehabilitation protocols aimed at increasing muscular function by regulating the amount of eccentric load placed on a particular muscle.

Tendonopathy

Tendon injuries fall into the classification known as overuse injuries.[1] There are different types of tendon pathologies including tendonopathy, tendonosis, and tenosynovitis. Tendonopathy is an aggravating soft-tissue lesion that is a common pathology in the athletic population. Tendonopathy injuries account for 30-50% of all sport injuries.[16, 17] Tendonopathy can be defined as inflammation of a tendon. Tendons are susceptible to multiple mechanisms of injury as they are associated with every muscle in the body. The most common sites of tendonopathy are at the calf, knee, and elbow. The pathology of tendonopathy is associated with chronic overuse and the repeated overloading of a tendon beyond its limit resulting in the development of structural damage.

Traditional Treatment

The various locations of tendonopathy, as well as the various etiologies associated with the condition result in a wide range of treatment techniques for tendonopathy.[41] Treatments for tendonopathy include rest, physical modalities (heat, electrical stimulation, ultrasound, and massage), drugs (oral and injection), stretching, and surgery.[41] While these treatment techniques have their benefits, they do not directly influence the strength and structure of the affected tendon.

Dr. H. Lamb & Nova Scotia Sports Medicine

Dr. Howard Lamb was a research fellow at the Nova Scotia Sports Medicine Clinic in 1978 and may be considered the founder of the eccentric exercise rehabilitation program. The clinic was disappointed with the outcomes of their patients with tendonopathy. They had been using treating patients using traditional treatment methods. Dr. Lamb reasoned that the reason for the

development of tendonopathy was an overloading of the tendon during activity which leads to micro ruptures which then causes inflammation and injury. Traditional treatment techniques were not directly addressing this issue of compromised tensile strength. Thus, Dr. Lamb introduced the idea of progressively overloading the tendon overtime which would then lead to an increase in tensile strength. The reason Dr. Lamb chose eccentric exercise instead of isometric or concentric was twofold: it simulates functional sports activity and produces more tensile force then other forms of contractions. The Nova Scotia Sports Medicine Clinic implemented Dr. Lamb's eccentric exercise program and later surveyed 200 of their patients to determine how effective they found the program to be. Nearly 90% of patients reported excellent or good results while using the Nova Scotia eccentric exercise program.[41]

Physiological Reasoning

All muscle contractions involve the actin and myosin filaments working together to migrate the muscle fibers creating movement at joints which allow the average person to function throughout a day. There are 3 types of contractions that a muscle can utilize, concentric, isometric, and eccentric. The easiest contraction to understand is concentric when the internal muscular force overcomes the external resistance shortening the muscle moving the object in the direction of muscle shortening. Actin and myosin slide over one another shortening the muscle fibers. This theory is commonly known as the sliding-filament theory. Isometric is very similar but there is no joint movement. The muscle attempts to shorten but the external resistance is held stationary. There is some muscle shortening to make up for muscular slack. Eccentric movements act in the opposite scheme of concentric. The muscle is contracting but lengthening simultaneously due to the internal force not being able to withstand the external resistance.[14] Current literature has found connections between eccentric loading and positive outcomes in tendonopathy patients.

Once a muscle fatigues the tendon accepts the kinetic forces hence the reason tendonopathy injuries are observed in overuse repetitive type athletes.[35] Main components comprising tendonopathy are angiofibroblastic hyperplasia which is an internal malignment of collagen fibers. Tendonopathy may be a deceiving word since it does not follow an exact inflammatory response as seen in other "-itis" type injuries but more of a degenerative type response. Initial healing response is to form new collagen in the degenerated tendon but the new collagen is Type III collagen and tendons are comprised mainly of Type I collagen. Each time the degenerative tendon is further worked it restarts the fibroplastic phase of healing lying down new Type III collagen further degenerating the components of a normal tendon. Another component of angiofibroplastic hyperplasia is a vascular portion. An increase in neovascularization is seen in damaged tendon but the neovessels lie haphazardly and not in a healing type fashion as seen in other damaged tissue. Neovessels lie perpendicular to the collage and do not benefit healing.[31] The final component of tendonopathy is a more commonly seen disruption of the current tissues' fibers. Eccentric loading exercises have been found to positively affect this blend of misfortune found in the tendon.

There are several theories to why eccentric exercise is effective in combating tendonopathies. The initial thoughts by Stanish and Curwin were that eccentrics would lengthen the musculo-tendonous structure relieving the tendon of constant stress.[42] Alfredson in 2003[1], had positive outcomes on patients with mid Achilles tendonopathy. One reason for positive outcomes could be the simple increase in tensile strengthening due to loading induced hypertrophy. Also, the decrease in pain may be a result from a lengthening of the musculo-tendonous junction creating less strain and allowing a greater range of motion to be achieved at the ankle. The third theory Alfredson postulated is the painful eccentric loading had an altering effect on pain perception around the tendon.[1] This particular theory has been further investigated by Ohberg in 2001[33]. Using gray-scale ultrasonography and color Doppler examination observed neovessels, which are increased in abundance surrounding the damaged tendon, surrounding the painful Achilles tendon

would disappear during the stretching phase (dorsiflexion) of the eccentric exercise and reappear upon shortened contraction (plantar flexion). This observation raises the question that the exercise may be damaging these neovessels and surrounding nerves decreasing the pain sensation around the tendon.[33] Another pilot study completed by Ohberg found 10 painful Achilles tendons that demonstrated a large amount of neovessels in the painful area and injected the area with a sclerosing agent. Patients were allowed function on a normal daily routine. At short term follow up, 8/10 patients were found to have completely depleted the neovessels surrounding the painful area and the 2 patients that pain returned were found to have remaining neovessels surrounding the painful tendon. After an average 3.8 year follow up, the tendon revealed a decrease in thickness and the overall structure appeared normal.[32, 34]

There are some precautions that need to be used while incorporating eccentric loading exercises into rehabilitation of a tendonopathy. One main theory is that repetitive overload could result in heat damage to the tendon. Since eccentric loading creates a great amount of stored elastic energy if this energy is not used it is released as heat and if the heat becomes greater than 42.5°C lesions are formed within the tendon which could in turn decrease the tendon's elasticity. There needs to be some guidelines on what constitutes too much eccentric training.[28]

Eccentric Training: Parameters of Application

There is debate as to how an eccentric exercise program should be designed regarding:

a. Whether it should contain only eccentric exercises, or a combination concentric and eccentric exercises
b. If it should allow for pain during and after exercise
c. The optimal number of repetitions in each session
d. The optimal frequency of repetitions in each session

I. **Principles of Eccentric Loading Regimen** [25]

a. Length of tendon

i. If a tendon is pre-stretched, its resting length is increased, thereby lessening the strain on the tendon during movement

b. Load
   i. Progressively increasing the load will increase the strength of the tendon
   ii. Load should be increased according to the patient's symptoms (load to point of mild discomfort, but not a degree of disabling pain),otherwise, the possibility of re-injury is high

c. Speed
   i. Increasing contraction speed will produce greater amount of force
   ii. Speed of eccentric training should be increased in every treatment session, thus increasing the load on the tendon
   iii. Other therapists claim that eccentric contractions should be performed at a slow velocity to avoid reinjury

d. Frequency [19, 22, 41, 43]
   i. 3 sets of 10-15 reps; 1-2 times per day for 10-12 weeks
   ii. 4 seconds[47] to 10 seconds per repetition[46]

II. Eccentrics: More than Strengthening

a. It is believed that eccentric exercises have underlying mechanisms other than improvement in muscle performance. The table below was specifically applied to the treatment of Achilles tendonopathy with an eccentric program[3], but it is plausible that the information can be applied to other site of tendonosis in the body. It provides justification that eccentric training programs serve as more than a strengthening program

Program Details (ex: heel drops)	**Generic strengthening hypertrophy**
Eccentric only	Few strengthening programs advocate eccentric-only repetitions. When they do, this is often built on a foundation of concentric training followed by a meson-cycle of so-called "negatives". Secondly, eccentric loading may be used specifically to induce changes in the peak force angle by adding sarcomeres
Three sets of 15 twice a day	Hypertrophy programs would normally utilize a lower number of repetitions (commonly 3) sessions per week) and would not prescribe sessions twice a day, 7 days a week for 10+ weeks
Two similar exercises done in sequence	Supersets are common in strength training programs and are designed to fatigue one element of a muscle prior to performing more resistance training on the whole movement patter. The usual eccentric load program does not require the sets to reach such levels of fatigue. [6]
Perform with some discomfort	Muscle hypertrophy-focused resistance training requires maximal activation. Pain response from passive structures such as

	tendon would not facilitate this type of training
Progress using velocity	Increasing velocity of the eccentric exercise is mostly reported in early publications[42], but if one uses velocity to increase the load it is likely to reduce the drive to the desired muscle group during the movements. It is also likely to increase the peak loading impact at the end-range. Therefore an eccentric training program affects the end-range passive structures rather than in mid-range where the muscle fibers area able to generate resistance

The parameters of application for the following eccentric training programs have been commonly used among the reported literature in the treatment of various types of tendonopathies. These studies showed to have beneficial outcomes for study participants for these pathologies including decreased pain, improved levels of function, and overall satisfaction with the outcomes of the interventions. Currently, there is limited evidence to support the use of eccentric exercise over other treatments; however, the listed application parameters have been widely utilized and accepted among the reported literature.

III. Achilles Tendonopathy

a. Exercise programs that incorporate an eccentric component have been shown effective [40]
    i. Concentric calf muscle training program (calf raises) did not prove to be as effective as an eccentric (heel-drop) training program [27]
    ii. A 12 week course of eccentric strengthening exercises was more effective than a traditional concentric strengthening program for treating Achilles tendonopathy [27]
        1. 82% of randomized eccentric strengthening protocol patients had improvement in pain levels compares to 36% in the concentric training group

b. Eccentric Training Program [2, 3, 9, 15, 21, 24, 26, 27, 37]

Exercise Parameter	**Program**
Warm-up	Bicycling 10 minutes[2] and Achilles stretch[26]
Repetitions	15
Sets	2 or 3 similar exercises of heel-drops (a & b below)
Exercises	Eccentric loading only; step up with non-affected leg, and lower with the affected

	leg a) knee straight (see Figure 6) b) knee bent
Frequency	2 times daily, 7 days per week
Duration	10-12 weeks
Intensity	Control parameter – discomfort/pain. Load to discomfort (especially first 2 weeks). Increase load by external loading

IV. Lateral Epicondyle Tendonopathy

a. Duration
   i. Studies vary between 4 and 12 week duration of an eccentric training program
   ii. Favorable outcomes from eccentric training after 4 weeks [46] which may be explained by collagen production and maturation [23] from normalized tendon morphology following eccentric training [34, 39]
   iii. Also found that a 12-week painful eccentric training program may influence pain by having a mechanical influence on the neural supply and allowing collagen development and maturation [29]

b. Eccentric Training Program [12, 18, 22, 41, 43, 45-47]

Exercise Parameter	**Program**
Warm-up[46]	A. Forearm extensor and flexor muscles with wrist movements without any load for 2-3 minutes B. Static stretch for 15-30 seconds; repeat 3-5 times
Repetitions	5-15
Sets	3
Exercises	A. Wrist extension* (see Figure 5) OR B. "Tyler Twist" with Thera-Band Flexbar
Frequency	1-2 times daily, 7 days per week
Duration	12 weeks
Intensity	Control parameter – discomfort/pain. Load to discomfort and increase load when patient no longer experiences minor pain/discomfort with free-weights or theraband

* Elbow fully supported in full extension with forearm in supination, wrist in extension, and hand hanging over the edge of support surface

V. Rotator Cuff Tendonopathy

a. Histological examinations of the rotator cuff (supraspinatus tendon) in patients with impingement syndrome have shown changes described as tendonosis, similar to what have been found in chronic painful Achilles and patellar tendonosis [11]
b. Currently, there is no randomized study on the effectiveness of eccentric exercises on rotator cuff tendonopathy
    i. 1 small uncontrolled pilot study showed benefits of eccentric exercises [5, 15]
        1. significant decreases in self reported shoulder pain and significant increases in self reported shoulder function
c. Three sets of 10 eccentric repetitions daily while progressing from slow to moderate to fast speed every other day and adding resistance weekly is recommending
    i. Theoretically loads the tendon in the matter in which it absorbs forces and has been proven beneficial clinically [12]
d. Eccentric Training Program [5, 15]

Exercise Parameter	**Program**
Warm-up[5]	A. Shoulder shrug B. Scapular retraction C. Upper trapezius stretch
Repetitions	15
Sets	3
Exercises	A. Supraspinatus; side-lying position B. Infraspinatus; side-lying position[5] (see Figure 1) OR C. Supraspinatus & Deltoid[15]; slowly lower arm from start position (30° HABD thumb pointing towards ground) with Ulla-Sling (see Figure 3)
Frequency	2 times daily; 7 days per week
Duration	12 weeks
Intensity	Control parameter – discomfort/pain. Exercise into pain, but pain level should remain acceptable, or not exceed a 5 on a 0-10 pain scale

Eccentric Training: Indications, Contraindications, and Precautions

Indications of Eccentric Training:

- Chronic, painful tendonosis[2, 15, 30]
- Overuse syndromes[1]
- No response to earlier conservative treatments[8]
- Overhead throwing or striking athlete rehabilitation[48]

Contraindications of Eccentric Training:

- Acute musculoskeletal injuries[4]
- Osteoarthritis[30, 44]
- Connective tissue disease[30]
- Diffuse pain syndrome, i.e. fibromyalgia[30]
- Unstable fractures[30]

Precautions of Eccentric Training:

- Eccentric loading on the tendon can be painful[2, 30]
- Progression should be monitored with evaluation of range of motion, strength, and sport specific functional tests[48]
- Eccentric training workload should not be increased by more than 10% per week[48]
- Swelling and prolonged loss in the ability of the muscle to generate force are possible[38]

Eccentric Training Exercises:

SHOULDER

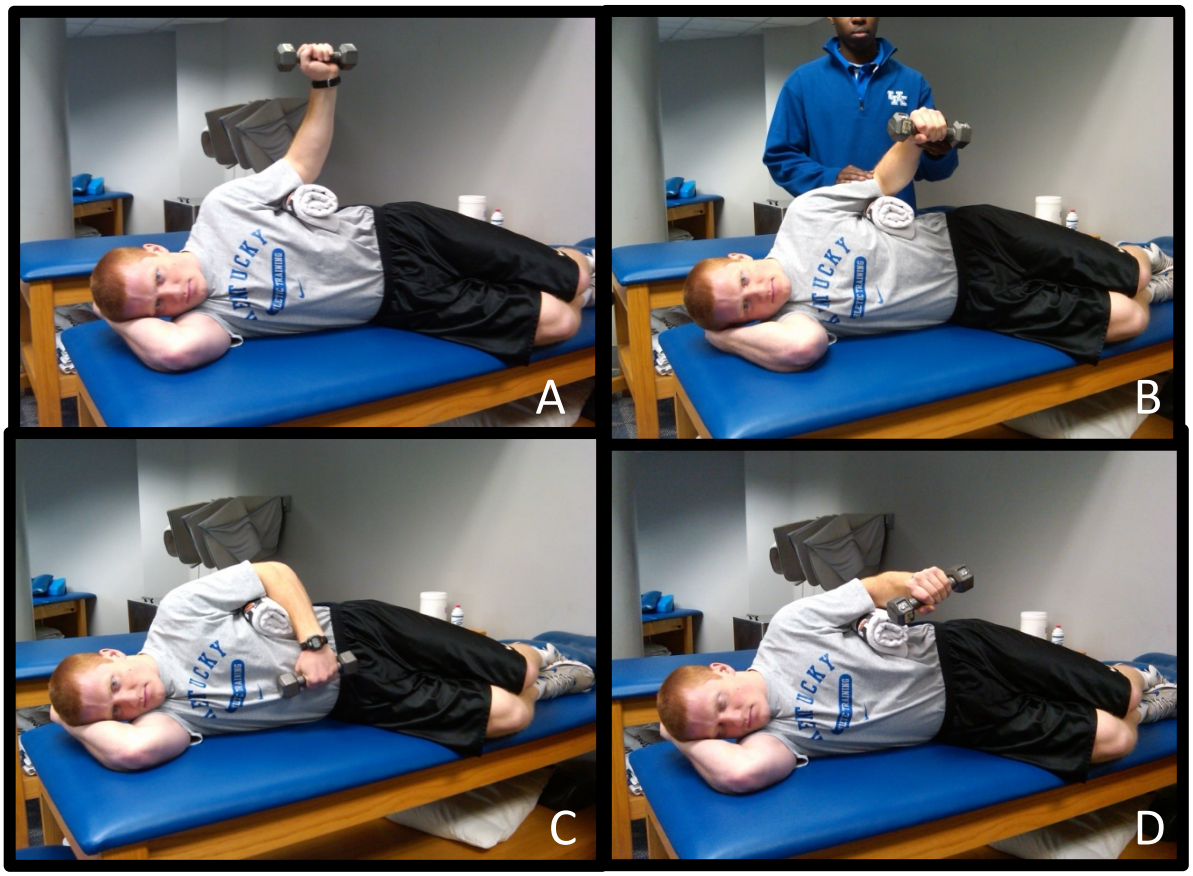
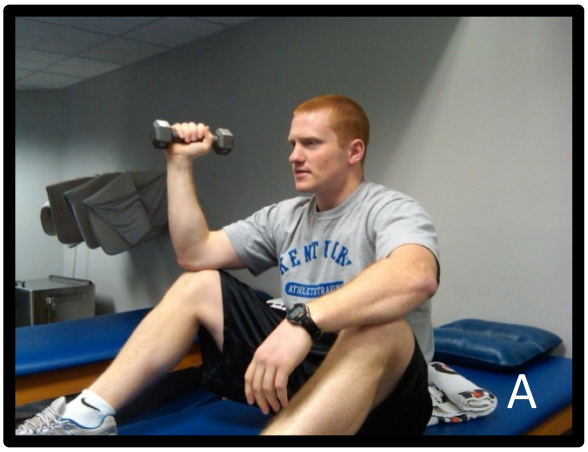


Figure 1

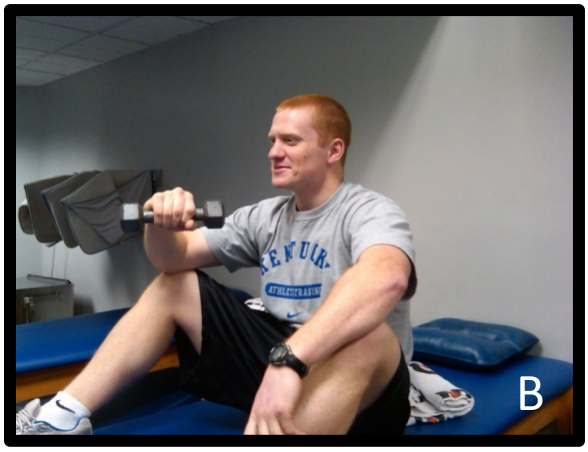
Bernhardsson et al utilized eccentric side lying external for the treatment of the rotator cuff for patients with subacromial impingement.[5] No description of the exercise was provided in the article. It is assumed that patients were positioned side-lying with the extremity being treated in full external rotation with a weight in hand. The weight is then slowly lowered towards the table, with the brachium remaining adducted to the body via a rolled up towel, until it reaches their body. A clinician then grasps the patient's wrist and returns then to the starting position. This is done so there is no concentric muscular contraction.

Video Link: http://www.youtube.com/watch?v=L3rRiepx_94

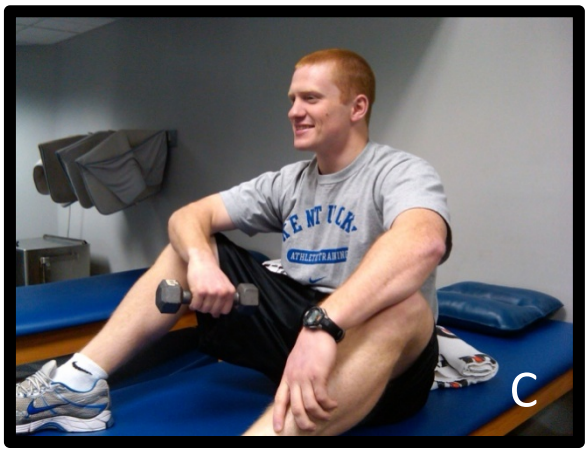
Variations to the side-lying eccentric external rotation



Begin in 90° of shoulder flexion and 90° of elbow flexion with the forearm perpendicular to the floor.



Lower the hand of the involved side towards the table.



Use the opposite hand of the uninvolved side to return the involved hand to the starting position.

Lower the hand all the way down until maximum internal rotation is reached.

Figure 2

Video Link: http://www.youtube.com/watch?v=XKU25ZQIYV8

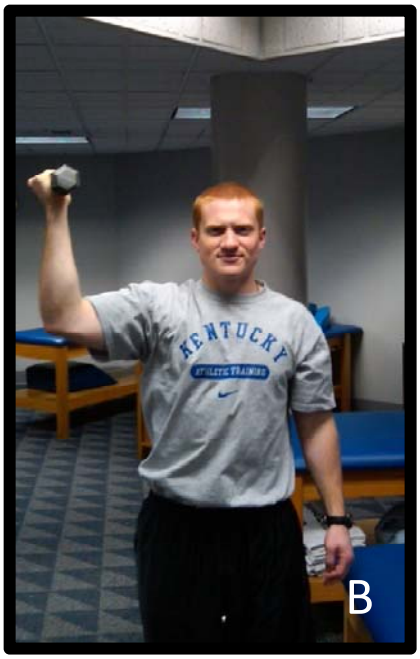
Pictured above is an eccentric arm lowering exercise described by Jonsson. The patient passive abducts their arm in the scapular plane with the use of a pulley. The patient is placed in the empty-can position and they slowly lower their arm to the ground without any help from the pulley. Weight may be added to this exercise as pictured here.[15]

Figure 3

Video Link: **http://www.youtube.com/watch?v=wlqkOE8HTQE**

Eccentric Exercise – Long Head Bicipital Tendonopathy

Patient is started in full flexion / abduction with the shoulder externally rotated.



Lower the extremity to the 90 / 90 position with the forearm fully supinated.

Slowly extend the elbow until full elbow extension is achieved.

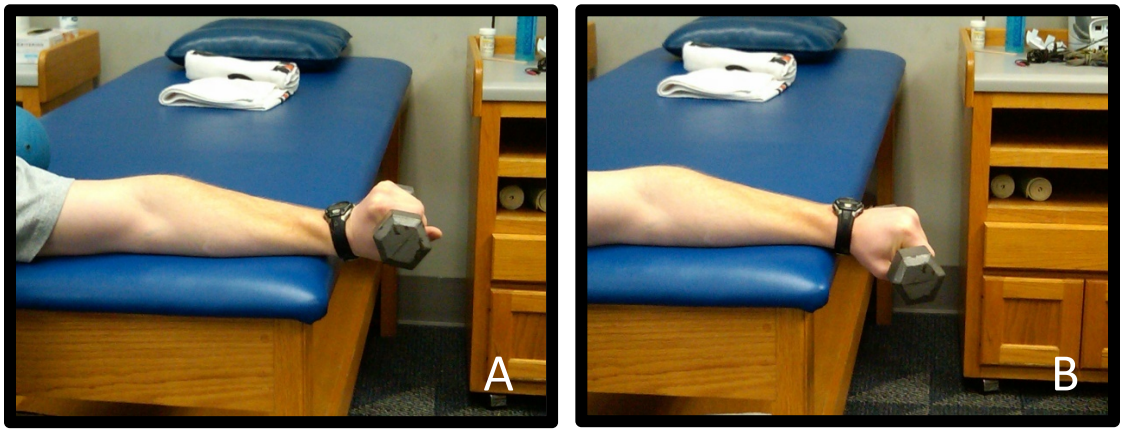
From position C, slowly lower the arm to a resting position

Use the uninvolved hand to return involved side to the starting position.

Figure 4

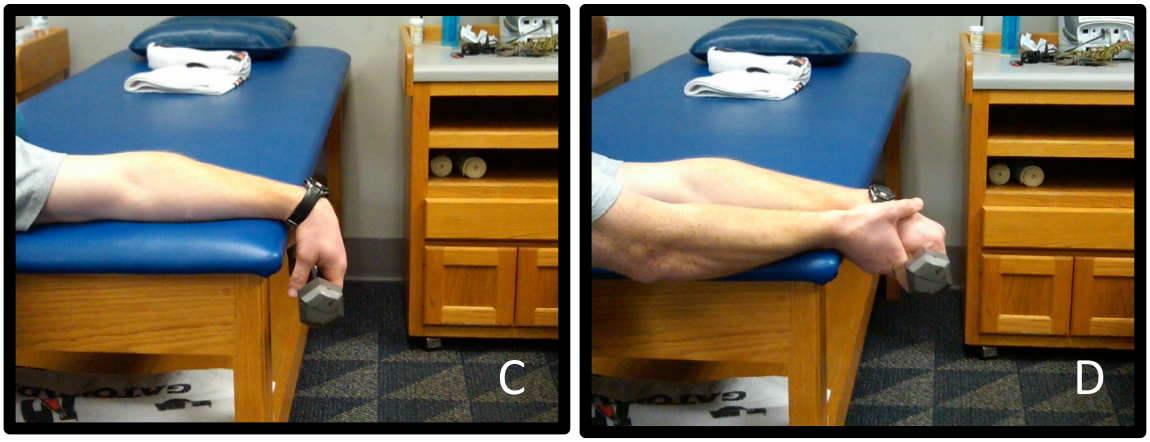
Video Link: http://www.youtube.com/watch?v=QTjXtFQO9qA

ELBOW



Begin with the wrist in full extension with a weight in hand.

Slowly lower the weight down towards the table.



Fully lower the weight into maximal wrist flexion as permitted by the table.

Use the other hand to return the hand of the involved elbow back to the starting position.

Figure 5

Video Link: http://www.youtube.com/watch?v=E7sWpDKsF_g

LOWER LEG

Begin with both feet on the platform.

Use both feet to get into full plantarflexion.

Remove the uninvolved side.

Slowly lower the heel towards the ground.

Lower the heel until maximum dorsiflexion is achieved. Then place the uninvolved side back on the platform and return to the starting position.

Figure 6

Video Link: **http://www.youtube.com/watch?v=gEgx0qJp3HM**

Eccentric Training: Literature Search

Eccentric training was defined as training including voluntary muscle contractions, while lengthening of muscle fibers occurred; this includes actions commonly used to decelerate the body or an object. Searches were performed in Medline, Pubmed, and Cinahl databases. All searches were limited to the English language. Search terms for this literature review included: eccentric training, rehabilitation, eccentric exercises, tendonopathy, tendonopathy, tendonosis, Achilles, lateral epicondylitis, shoulder, rotator cuff, biceps, and triceps.

Search Terms	**Results**	**Articles Used**
Eccentric training	960 results	Alfredson et al 1998[2]
		Alfredson 2003[1]
		Barroso et al 2010[4]
		Bernhardsson et al 2011[5]
		Croisier et al 2007[8]
		Fahlstrom et al 2003[9]
		Frohm & Saartok 2007[10]
		Jonsson et al 2006[15]
		Kingma et al 2007[20]
		Knobloch et al 2010[21]
		Langberg et al 2007[23]
		Maffulli et al 2008[26]
		Mafi et al 2001[27]
		Malliaras et al 2008[29]
		Martinez-Silvestrini et al 2005[30]
		Ohberg et al 2004[34]
		Ohberg & Alfredson 2004[32]
		Roos et al 2004[36]
		Sayana & Maffulli 2007[37]
		Shalabi et al 2004[39]
		Silbernagel et al 2001[40]
		Svernlov & Adolfsson 2001[46]
		Tyler et al 2010[47]
		Uhl & Madaleno 2001[48]

Search Terms	Results	Articles Used
Eccentric exercises	1842 results	Allison & Purdam 2009[3]
		Maffulli et al 2010[25]
		Rees et al 2009[35]
Eccentric exercise AND lateral epicondylitis	16 results	Stasinopoulos et al 2004[44]
		Stasinopoulos et al 2005[45]
Maffulli N	623 results	Maffulli 1998[24]
Hand searched articles		Butterfield 2010[7]
		Fukuda 2003[11]
		Fyfe & Stanish 1992[12]
		Hough 1902[13]
		Huxley 1957[14]
		Josza & Kannus 1997[16]
		Kannus 1997[17]
		Khan & Cook 2000[18]
		Khan et al 2000[19]
		Kraushaar et al 1999[22]
		Maganaris et al 2008[28]
		Nirschl & Ashman 2003[31]
		Ohberg et al 2001[33]
		Sayers et al 1999[38]
		Stanish et al 1986[42]
		Stanish et al 2000[41]
		Stasinopoulos & Johnson 2004[43]

Eccentric Training: Literature Review

Achilles Tendon Eccentric Training								
Author	**Study type and Level of Evidence***	**Purpose**	**Methods**	**Subjects**	**Treatment**	**Outcome Measures**	**Results**	**Author Conclusions**
Kingma et al, 2007[20]	Systematic review; OCEBM 1a	to review the effectiveness of eccentric overload training in patients with chronic Achilles tendonopathy.	systematic literature search; two researchers independently searched the electronic databases; First screening phase: selection criteria to titles and abstracts. Second screening phase: applied to full-text articles.	47 primary studies for possible inclusion; 28 excluded on basis of title/abstracts; remaining 19 studies included for the second phase of screening, in which 10 studies were excluded.	Scored for methodological quality with Delphi score; conclusive power of studies' conclusions was calculated; eccentric training evaluated.	Methodological quality: Dephi score; power of studies' conclusions calculated via grading system; eccentric training effect calculated for all studies.	Only moderate agreement for overall scores of methodological quality. Training duration 6 or 12 weeks. All studies reported pain reduction in eccentric overload group (mean pain reduction: 60%) and control group (mean pain reduction: 33%). All studies using a control group reported greater reductions in pain for the eccentric overload training group than control group except one.	Due to methodological shortcomings in included studies, no definite answer can be given to the question of whether tendonopathy has a beneficial effect on pain and function. The studies did show eccentric overload training resulted in decreased pain intensity in patients with chronic Achilles tendonopathy.
Mafi et al, 2001[27]	Randomized controlled trial; OCEBM 1b, PEDro 6/10	to compare two different treatment models (eccentric vs. concentric calf muscle training) in a randomized manner on patients with painful chronic Achilles tendonosis located at the 2--6 cm level in the tendon.	Randomized controlled trial, patients randomized to eccentric or concentric calf strengthening groups.	44 patients with severe Achilles tendon pain and who were referred to researchers as candidates for surgical treatment. Presence of tendonopathy established by clinical exam and ultrasonography. Pain in tendon 2--6 cm level from calcaneal insertion; mean average of 21 mo. of pain.	Eccentric training model same as used in Alfredson et al 1998. ECC training twice daily, 7 days/week, for 12 weeks; 3x15 sets/reps. CON training twice daily, 7 days/week, for 12 weeks. Jogging allowed if only mild discomfort or no pain felt.	VAS for pain; patient satisfaction	Treatment results with eccentric training were significantly better ($p<0.002$). In eccentric training regimen 82% of patients were satisfied and resumed previous level of activity, only 36% in concentric group were satisfied and returned to normal activity.	Treatment with eccentric calf muscle training in patients with painful chronic Achilles tendonosis yield good short-term clinical results and significantly better results than were achieved with concentric calf muscle training in a randomized prospective multi-center study comparing these two treatment models.

Author	Study type and Level of Evidence*	Purpose	Methods	Subjects	Treatment	Outcome Measures	Results	Author Conclusions
Silbernagel et al, 2001[40]	Prospective randomized controlled trial; OCEBM 1b; PEDro 6/10	to examine the reliability of measurement techniques used to evalute complaints of discomfort, range of motion, pain on palpation, jumping ability and muscular endurance for patients with pain from the Achilles tendon; also, to evaluate the effect of an exercise program with eccentric overload for patients with chronic pain from the Achilles tendon.	Patients randomly allocated to experimental group or control group, randomization technique not specified.	40 subjects with 57 involved Achilles tendons due to patients with bilateral pain. Inclusion: men/women above the age of 18, chronic proximal Achilles allodynia, pain of at least 3 months' duration. Exclusion: surgery of involved foot, rheumatoid arthritis, diabetes or any other illness.	Treatment protocol for experiment group included a progressive lower extremity range of motion, balance and gait training and toe-raise program, which incorporated concentric and eccentric exercises; Treatment protocol for control group included calf stretching, concentric/eccentric toe raises. Treatment lasted for 12 weeks.	VAS 0-10 for pain; range of motion test; jumping test; toe-raise test; pain and symptoms.	No significant differences between groups in pain, range of motion, jumping tests or toe-raise test before treatment, at three months or at six months. No differences between groups on pain with palpation (VAS), though experimental group had significant decrease in pain on palpation at three and six months compared with before treatment.	Pedagogical information and training with a controlled exercise programme for a longer time (12 weeks or longer with relatively high eccentric loads and somewhat over the pain limit) produce good results for chronic Achilles tendon pain.
Alfredson et al, 1998[2]	Prospective longitudinal cohort with retrospective control group comparison; OCEBM 2b, STROBE 17/22	to study the effect of heavy-load eccentric calf muscle training in recreational athletes who had chronic Achilles tendonosis with a long duration of symptoms despite conventional non-surgical treatment		15 rec athletes (12 men, 3 women; mean age 44.3 ± 7 yrs) with chronic Achilles tendonopathy	Eccentric exercises 2x daily, 7 days per week for 12 weeks. Exercises included calf raises on the edge of a step with the knee straight and then knee bent on involved leg only; patient returned to position through a concentric contraction of the contralateral leg.	Pain measured on a 100mm VAS at week 0 and week 12; isokinetic calf muscle strength at week 0 and week 12	After training, concentric plantar flexion strength and eccentric plantar flexion strength increased significantly, post-surgical group had significantly lower concentric/ecc plantar flexion strength 24 wks post-op.	The treatment model provided is a successful and easy method of treating Achilles tendonopathy and helping patients return to pre-injury activity level. Authors suggest this method be tried before doing surgery.
Maffulli et al, 2008 [26]	Prospective longitudinal cohort; OCEBM 2b, STROBE 17/22	to evaluate the effects of eccentric strengthening exercises in athletic patients with Achilles tendonopathy		45 athletic patients (29 men mean age 26 ± 12.8 yrs, 16 women mean age 28 ± 13.1) with a clinical diagnosis of unilateral tendonopathy of the main body of the Achilles tendon	Graded progressive eccentric calf strengthening exercise program for 12 weeks; eccentric heel drop starting on tiptoe, limb is lowered until heel is below step. Performed with knee straight and flexed. 3 x 15, one min. rest between sets, 2xdaily, 7days/wk for 12 wks. Ice massage 10-15 min after treatment.	VISA-A questionnaire; based on visual analog score, 10 questions, to assess pain and activity. Previous shown to be valid and reliable for Achilles tendonopathy.	Mean pre-management VISA-A scores of 36 improved to 52 at latest follow-up (p=0.001). 27/45 patients responded to eccentric exercises and discharged after 6 months. 18 patients did not improve with eccentrics. 10 had surgery; after surgery, VISA-A improved from 26 to 71 points (p=0.001)	60% of patients benefited from heavy load eccentric heel-drop exercise regimen alone. The VISA-A was used successfully to monitor clinical progress of Achilles tendonopathy.

Author	Study type and Level of Evidence*	Purpose	Methods	Subjects	Treatment	Outcome Measures	Results	Author Conclusions
Fahlstrom et al, 2003[9]	Prospective longitudinal cohort; OCEBM 2b, STROBE 18/22	to investigate if the previously achieved good clinicial results of treating Achilles tendonosis with eccentric exercises could be reproduced in a larger group of patients; also to investigate the effects of eccentric training in patients with chronic insertional Achilles tendon pain		78 recreational athletes with chronic painful Achilles tendonosis at the midportion of the tendon (55 patients with unilateral symptoms, 23 patients with bilateral symptoms); 30 recreational athletes with chronic painful Achilles tendonosis at the insertion of the tendon.	eccentric calf-muscle training for twice daily, seven days per week for 12 weeks; given a home exercise program and were taught exercises; a six-week follow-up was performed to ensure exercises were performed correctly	Baseline VAS scores were collected before training started and after Week 12; interview was also performed at the end of training and patients gave percentage of satisfaction; 0% = not satisfied; 100% = satisfied.	90 of 101 patients with Achilles tendonosis in the mid-portion returned to pre-injury activity after 12-week training; VAS change from before to after was highly significant. 10 of 30 patients with insertional Achilles tendonosis returned to pre-injury activity after 12-week training. VAS change from before to after was highly significant. Patients with chronic insertional tendonosis were significantly younger and had longer history of pain than patients with mid-portion tendonosis.	Treatment with eccentric calf muscle training can be recommended for patients with chronic mid-portion Achilles tendonosis. In patients with chronic insertional Achilles tendon pain, eccentric calf-muscle training was not shown to give good clinical results.
Knobloch et al, 2010[21]	Prospective longitudinal cohort; OCEBM 2b; STROBE 16/22	to evaluate the gender-specific response to painful eccentric training among symptomatic males and females suffering Achilles tendonopathy.		75 patients with midportion Achilles tendonopathy for at least 12 weeks. Inclusion: midportion Achilles tendon pain; pain in mid-portion area of Achilles tendon 2-6 cm proximal to insertion. Exclusion: prior Achilles tendon surgery; insertional tendonopathy; bilateral symptoms, among others.	3x15 repetitions on a single leg lasting with every position for 2 seconds were performed with straight knee only; twice a day. 12 weeks of training.	Pain measured on 0-10 scale; 5 items on FAOS determined for all patients; VISA-A score determined before and after intervention; laser Doppler and spectroscopy system for non-invasive microcirculatory assessment at 5 points in tendon.	After eccentric training, pain level decrease was significantly different between females and males (4.4 ± 2.6 vs. 3.0 ± 2.1). VISA-A score improved in males by 27% and by 20% in females. Pain reduction not significantly different among females younger or older than 50 years of age after training.	Females suffering Achilles tendonopathy do not benefit as much as symptomatic males from 12 weeks of eccentric training.

Author	Study type and Level of Evidence*	Purpose	Methods	Subjects	Treatment	Outcome Measures	Results	Author Conclusions
Roos et al, 2004[36]	Prospective randomized clinical trial; OCEBM 2b PEDro 4/10	to prospectively study the short- and long-term effects of eccentric exercises and prolonged stretching with the use of a night splint on pain and function because of Achilles tendonopathy in subjects recruited from primary care.	Subject randomization by pulling envelope from box; number was allocated to one of three treatment groups.	44 subjects. Inclusion: insidious onset of Achilles tendonopathy; moderate pain/problems when performing physical activities; duration of symptoms at least 4 weeks; pain 2-6 cm proximal to the insertion. Exclusion: insertional tendon pain.	Three groups provided treatment either via eccentric exercises, night splints or both. Eccentrics prescribed twice daily for 12 weeks. An anterior night splint was custom-made for each subject in 90 deg. of dorsiflexion and neutral plantigrade .	FAOS; physical activity level	No significant differences were found in pain between three groups at any point in time. At 12 weeks, 27% in eccentric group compared with 58% in the splint+eccentric group and 50% in splint group reported moderate to extreme difficulty during sporting activities.	Eccentric exercises seem to improve function and reduce pain because of Achilles tendonopathy in patients recruited from primary care.
Sayana & Maffulli, 2007[37]	Prospective cohort; OCEBM 2b; STROBE 17/22	to evaluate the response of the non-athletic population to conservative management of Achilles tendonopathy.	12 week prospective cohort with one treatment group performing eccentric exercises	34 sedentary patients. Inclusion: at least 18 yrs of age, unilateral Achilles tendonopathy 2-6 cm proximal to the insertion of the Achilles tendon on the calcaneus. Exclusion: athletes, participation in recreational sports, diagnosis of Achilles paratendonopathy or combination of Achilles tendonopathy and paratendonopathy, diagnosis of insertional tendonopathy, etc.	Exercise protocol included progressive eccentric heel drop exercises with knee straight and knee bent. Given as a home exercise program. Told to continue exercises through mild to moderate pain. Patients followed up every 2 weeks.	VISA-A questionnaire to address pain and activity	Mean pre-management VISA-A scores was 39±22.8 and improved to 50±26.5 at latest follow up. Mean difference between pre- and post-treatment scores was 11.5±18.8. 19 of 34 patients responded to eccentric exercises and were discharged after 6 month follow-up.	Less than 60% of our non-athletic patients benefited from an intensive, heavy load eccentric heel drop exercise regimen along. The VISA-A has been successfully used in our patients to monitor clinical progress of Achilles tendonopathy.
Shalabi et al, 2004[39]	Prospective cohort; OCEBM 2b; STROBE 18/22	to evaluate 25 patients with chronic painful Achilles tendinopaty, before and immediately after 3 months of daily eccentric calf muscle strength training, using MRI to evaluate tendon volume and intratendinous signal alterations,	12 week prospective cohort with one treatment group performing eccentric exercises	25 patients, 10 sports-related tendonopathies. Inclusion: pain and local tenderness at palpation of midportion of Achilles tendon, 2-7 cm proximal to tendon insertion.	Patients given home exercise program including eccentric calf exercises with the knee bent and straight. Told to continue through pain that was not disabling. At 12 weeks patients saw physical therapist for final follow-up appointment.	MRI of transverse and sagittal bilateral Achilles tendons with contrast; 6-point pain scale.	Eccentric training resulted in 14% (mean) decrease of tendon vlume evident on T1-weighted images and a 23% (mean) decrease of intratendinous signal in symptomatic Achilles tendons.	The tendon volume and intratendinous signal decreased after 3 months of eccentric calf muscle strength training. The reduced intratendinous signal correlated to diminished pain. MRI techniques can be used as an adjunct to clinical evaluation by monitoring morphologic effects.

Author	Study type and Level of Evidence*	Purpose	Methods	Subjects	Treatment	Outcome Measures	Results	Author Conclusions
Ohberg et al, 2004[34]	Prospective cohort; OCEBM 2b; STROBE 16/22	to study tendon thickness and tendon structure via ultrasonography in patients treated with eccentric calf muscle training for painful chronic Achilles tendonosis, localized at the 2-6 cm level.	12 week prospective cohort with one treatment group performing eccentric exercises	26 Achilles tendons with painful symptoms from the mid-portion (2-6 cm) of the Achilles tendon. Ultrasonography showed thickening of tendon, focal hypoechoic areas, and irregular tendon structure, corresponding to the painful area.	12 week eccentric calf muscle training, program or parameters not specified	Gray scale ultrasonography; questionnaire	There was a significant decrease in tendon thickness between the measurements before and after treatment.	Eccentric calf muscle training in patients with painful mid-portion chronic Achilles tendonosis has good short and mid-term clinical results. At ultrasonographic follow up, in most patients, tendon thickness is decreased.
Ohberg et al, 2001[33]	Prospective Cohort; OCEBM 2b, STROBE 15/22	To investigate the long-term clinical results and side-to-side differences in calf muscle strength after suurgical treatment of chronic Achilles tendonosis.	Inclusion criteria were unilateral pain in the Achilles pain and a duration of ≥6 months and all patients had localized changes in the painful area 2-6 cm from the tendon insertion into the calcaneus verified with US. Exclusion criteria included bilateral symptoms and restricted ankle ROM due to other pathology. Isokinetic strength was evaluated preoperatively, at 1 year, and at 5 years.	24 patients (17M/7F) who were surgically treated for chronic Achilles tendonosis.	Week 2-6 post-op: cast removed, dorsi/plantarflexion ROM 3x20 reps 4x/day, partial WB walking. Week 6-10: concentric dorsi/plantar theraband with light tband if ROM good. Week 10-12: heavier concentric and light eccentric started if ROM good. Week 13-16: increasing concentric and eccentric calf training with body weight as load Slow return to sport activity.	Isokinetic calf muscle strength. 3-5 submax concentric and 2-3 sub-max eccentric contractions were performed before testing. For concentric plantar flexion, 5 repetitions of at 90 deg/s and 10 repetitions at 225 deg/s were performed. For eccentric plantar flexion, 3 repetitions were performed at 90 deg/s.	At pre-op, injured side had significantly lower concentric PF peak torque at both speeds and eccentric PF peak torque. At one year, there were no significant increases over pre-op for any strength measure. Concentric PF was lower than the non injured side, but eccentric PF did not differ from the healthy side.	Deficits in concentric and eccentric PF strength seen in the injured side compared to the healthy side are observed pre-operatively and persist post-operatively despite a carefully controlled rehab protocol. The authors also conclude that, while statistically significant, the differences are small and may not be clinically significant.
Langberg et al, 2007[23]	Prospective case control; OCEBM 3b, STROBE 16/22	to investigate the effect of a 12-week eccentric rehabilitation program on local collagen turnover in the area surrounding the Achilles tendon in high-level soccer players with chronic Achilles tendon disorders, using a microdialysis technique.	12 week prospective case control study with six individuals performing eccentric calf muscle exercises	6 elite male soccer players with unilateral Achilles tendonosis; non-injured tendon served as control.	Performed standardized eccentric training program with two daily training sessions for 12 weeks. Exercises progressed through added load and knee bent and straight exercises.	Blood samples for Collagen Type I synthesis and degradation marker concentration before and after training; Microdialysis; VAS for pain.	After training, a significant increase in collagen synthesis was measured in the painful tendons, however this was not found in the healthy tendons. Collagen degradation was not induced by training in either injured or healthy tendons.	12 weeks of eccentric training stimulates collagen type I synthesis in chronically injured human Achilles tendons, and that this increased synthesis is accompanied by a significant reduction in pain in the tendon during loading.

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Lateral Epicondylitis Eccentric Training								
Author	**Study type and Level of Evidence***	**Purpose**	**Methods**	**Subjects**	**Treatment**	**Outcome Measures**	**Results**	**Author Conclusions**
Tyler, 2010	Randomized controlled trial OCEBM 1b , PEDro 6/10	To assess the efficacy of a novel eccentric wrist extensor strengthening exercise added to standard treatment for chronic lateral epicondylosis,	Two groups for eccentric and stretching protocols; all groups did standard lat. Epicondyle treatments, while one group added eccentrics and the other focused on stretching.	21 patients randomized into an eccentric group and a standard treatment group. Inclusion: symptoms greater than 6 weeks, 3 positive clinical tests. Exclusion: history of fracture, dislocation, surgery,bilateral elbow pain etc.	All received wrist extensor stretching, ultrasound, cross-friction massage, heat and ice; standard treatment group performed isotonic wrist extensor strengthening; eccentric group performed isolated eccentric wrist extensor strength hening (Tyler Twist). Also prescribed as home plan. 3x15 daily, 4 sec. each, with 30 sec. rest in between each set.	DASH; VAS; strength testing of wrist extension and middle finger extension. Tenderness assessed by a handheld dynamometer and probe technique.	Eccentric group had significantly better improvements in DASH score than standard treatment group. Improvement in VAS also significantly improved in ecc. group than standard group. Strength in ecc group improved. Tenderness reduced in ecc. group, but not in standard group.	Study provides further efficacy for use of eccentrics in lateral epicondylopathy.
Martinez-Silvestri et al, 2005[30]	RCT OCEBM 1b, PEDro 5/10	to evaluate the effectiveness of eccentric strengthening	Inclusion criteria: pain localized to lateral elbow, continual symptoms for more than 3 months, maximal tenderness localized to lateral epicondyle and pain with 2 tests. Exclusion criteria: substantial OA, RA or inflammatory arthropathy affecting elbow/wrist; connective tissue disease etc. Randomly allocated to groups.	completion rate: 28 of 33 in conservative stretching group; 26 of 30 subjects in concentric group; 27 of 31 subjects in eccentric group	6 weeks of treatment in either stretching, concentric strengthening or eccentric strengthening groups	Pain-free grip strength; Patient-rated Forearm Evaluation Questionnaire (PRFEQ); Disabilities of the Arm, Shoulder and Hand questionnaire (DASH); SF-36; and VAS.	No baseline measures were significantly different among treatment groups; at 6 wks, the within-treatment group improvement in PFG, VAS and DASH scores, as well as SF-36 subscales (pain and physical functioning) were significant for all group.	Significant gains were made in stretching, concentric strengthening, and eccentric strengthening at six weeks. Although there were no significant differences in outcome among the groups, eccentric strengthening did not cause subjects to worsen.
Svernlov & Adolfsson, 2001[46]	Prospective randomized controlled trial OCEBM 2b, PEDro 6/10	to evaluate the clinical results of this eccentric training regime in comparison with conventional stretching and also after 3.4 years in two groups of patients with different duration of symptoms.	12 weeks, one eccentric training group and the other stretching techniques. Inclusion: pain distinctly located on the lateral humeral epicondyle at palpation, pain over lateral epicondyle during 2 tests. Exclusion: presence of rheumatoid arthritis, fibromyalgia, previous surgery in the region, provocable pain from elbow joint, etc.	129 subjects with lateral humeral epicondylalgia, mean duration of symptoms 19.4 months.	Control group underwent contract-relax-stretch PNF program. Eccentric training group used a modified program from Curwin and Stanish (1984). Exercises to be pain free. Initial instruction by PT and then exercises carried out at home for 12 weeks. Used counterforce brace during activity and wrist support at night.	VAS for pain; grip strength	Significant improvements seen in all VAS recordings of pain. Significantly increased grip strength was observed. 54% of subjects considered themselves completely recovered.	The described conservative regime including eccentric training and static stretch, combined with forearm band and wrist support, is an effective tretament of lateral humeral epicondylalgia.

Author	Study type and Level of Evidence*	Purpose	Methods	Subjects	Treatment	Outcome Measures	Results	Author Conclusions
Stasinopoulos et al, 2004[44]	Case control OCEBM 3b, STROBE 17/22	to make a comparison of the effects of a home exercise program and a supervised exercise program for the treatment of lateral epicondylar tendonopathy.	Patients allocated to two groups by sequential allocation. One group was supervised 5 times a week by a physical therapist; the other group was given a home exercise program to do 5 times/week and saw PT once a week..	70 patients allocated to two groups. Patients with lateral epicondyle tendonopathy for ≥ four weeks. Inclusion: pain on lateral epicondyle; pain in at least two of the chosen four tests. Exclusion: one of more of following: dysfuction in shoulder, neck, thoracic region; local or generalized arthritis; neurological deficit etc.	Exercises consisted of slow progressive eccentric exercises for ECRB tendon. 3x12 repetitions of slow progressive eccentric exercises, 1 min. rest interval between each set. Told to continue exercises if experiencing mild pain. Told to stop if pain is disabling. Also included ECRB static stretching.	Pain measured on a VAS; function measured as a VAS; pain-free grip strength with handheld dynamometry; drop out rate used as indicator of treatment outcomes.	At week 12, VAS for pain significantly declined more in supervised group than home exercise group. At week 12, VAS for function rose significantly in the supervised program than the home exercise program when compared with baseline measures.	Supervised exercise program was superior to a home exercise program. Further well-designd trials are needed to confirm these results.
Croisier et al, 2007[8]	Prospective case-control OCEBM 3b, STROBE 16/22	to analyze the effectiveness of an eccentric isokinetic training program for chronic lateral epicondylar tendonopathy versus a passive intervention	Diagnostic ultrasound confirmed tendon injury; x-ray to determine presence of calcification. 46 patients assigned to non-eccentric control group and 46 age-, gender- and activity-matched patients were assigned to an eccentrically trained group.	92 patients (85 right-handed; 7 left-handed) suffering from long duration symptoms. Inclusion: pain/tenderness at lateral epicondyle and prox. Portion of extensor muscle mass, increased pain on selected special tests. Exclusion: pain over radial and posterior interosseous nerve; pain/tenderness over radiohumeral joint; exacerbation of pain on movement of neck , etc.	Control: non-strengthening rehab of ice, analgesis TENS, US, deep friction massage and stretching. ECC group: all above treatments, as well as isokinetic eccentric training of wrist extensors and forearm supinators. Began with low load/low velocity, which was increased as pain decreased. Treatment 3x/week, approx. 9 weeks duration.	VAS scale before rehab, after 4 weeks, after 7 weeks and at the end of treatment. Bilateral muscle strength asymmetries assessed at the end of treatment. Disability questionnaire used to determine degree of disability. Ultrasound on bilateral epicondylian tendons performed before and after treatment.	34 ECC group patients followed program strictly, 12 others delayed or unable to complete program due to pain. Pain reduction in ECC group compared to control was significant at 7 weeks. Significant decrease in scores on disability questionnaire in ECC group after treatment compared to control.	There were more marked reduction of pain in the eccentric group and an absence of strength deficits on the involved side. The results suggest the relevance of implementing isokinetic adapted eccentric training in the management of chronic lateral epicondylar tendonopathy.

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Rotator Cuff Eccentric Literature								
Author	**Study type and Level of Evidence***	**Purpose**	**Methods**	**Subjects**	**Treatment**	**Outcome Measures**	**Results**	**Author Conclusions**
P Jonsson et al, 2006[15]	Prospective pilot cohort OCEBM 2b STROBE 15/22	to investigate if treatment with painful eccentric supraspinatus and deltoideus muscle training was effective in patients with long duration of pain-sx related to subacromial impingement in shoulder	Diagnosis of impingement syndrome based on clinical exam, ultrasound and x-ray. Exclusion: Pts. With signs of arthrosis in AC joint or large calcifications in rotator cuff causing mechanical impingement during HABD.	9 subjects (5 males, 4 females) with chronic painful impingement syndrome, sx of mean 41 months and on waiting list for surgical treatment.	Ulla-sling used to elevate arm to starting position; patient slowly lowers the arm from 30 degrees of HABD with thumb pointing down. 3x15 repetitions, twice daily, 7 days/wk for 12 weeks. Load increased when exercise was no longer painful.	Constant score for shoulder function; VAS for pain during horizontal shoulder activity before tx, 12 wks after and 52 wks after tx; patient satisfaction "yes" (removed from surgery list) or "no" (remained on surgery list)	5 patients satisfied with treatment: Constant score 80, VAS 18. 4 patients not satisfied with treatment: Constant score 50, VAS 67.	In this small pilot study, a specially designed painful eccentric training model for the supraspinatus and deltoideus muscles showed promising short-term clinical results on a small group of patients with severe pain from shoulder impingement.
Bernhardsson et al, 2011[5]	Prospective case series, single-subject experimental design OCEBM 3b, STROBE 15/22	to evaluate the effect on pain intensity and function of an exercise concept including specific eccentric strength training with progressive loading of the supraspinatus and infraspinatus tendons in patients with subacromial impingement syndrome.	3-week baseline phase, 11 repeated measures of primary outcomes colleted; followed by 12 week treatment phase, 23 repeated measures of same primary outcomes collected. Secondary outcomes collected at start and end of each phase.	10 subjects. Inclusion: 3 positive tests, not included. Exclusion: complete tendon rupture, substantial radiating neck pain, history of chronic rheumatic or inflammatory disease, previous surgery of affected shoulder, shoulder instability, etc.	5 exercises in training program, including 2 warm-up/scapular stabilizing exercises, 1 stretching exercise, 2 eccentric strengthening exercises for supraspinatus and infraspinatus. Program performed in 3x15, twice a day, 7 days/week for 12 weeks. Instructed to exercise through "acceptable pain."	Primary: Pain intensity on VAS; function via numeric Patient-Specific Functional Scale. Secondary: Constant score, Western Ontario Rotator Cuff Index.	8 of 10 subjects demonstrated significantly reduced pain intensity in the intervention phase compared to the baseline phase. VAS showed decreasing trend for 6 subjects, no change in 3 subjects, and an increase in 1 subject. All subjects demonstrated significantly improved function.	A 3-month exercise programe emphasizing eccentric strength training may decrease pain intensity and imrpove function in patients with subacromial impingement syndrome; further studies are necessary.

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N/A: Not Available or Not Applicable; Tx: Treatment

General Muscle Eccentric Training								
Author	**Study type and Level of Evidence***	**Purpose**	**Methods**	**Subjects**	**Treatment**	**Outcome Measures**	**Results**	**Author Conclusions**
Barroso et al, 2010[4]	Case control; OCEBM 2b; STROBE 14/22	to examine fast and slow velocity eccentric exercise of the elbow flexors for changes in indirect markers of muscle damage following 3 exercise bouts performed every 2 weeks.	Subjects reported to lab for 5 consecutive days every other week for 3 weeks; bout of ECC exercise performed on first visit of each week, one at 60 deg/sec and the other at 180 deg/sec.	15 physically active men; previous experience in resistance training but hadn't engaged in training at least 6 months prior to the study; free from musculoskeletal injury.	30 maximal eccentric contractions of elbow flexors on isokinetic dynamometer at either 60 deg/sec or 180 deg/sec.	MVIC; ROM; soreness; plasma CK activity	No significant difference in total work during eccentric exercises between groups or between bouts. No significant changes in soreness seen between groups. Changes in plasma CK activity were not significantly different before exercise or post-exercise between groups or between bouts.	Eccentric contraction velocity has little effect on muscle damage or the repeated-bout effect.

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Tx: Treatment

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