

## Review Article

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# Lateral epicondylitis: A review of the literature

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**Abstract.** Lateral epicondylitis (Tennis Elbow) is the most frequent type of myotendinosis and can be responsible for substantial pain and loss of function of the affected limb. Muscular biomechanics characteristics and equipment are important in preventing the conditions. This article present on overview of the current knowledge on lateral Epicondylitis and focuses on Etiology, Diagnosis and treatment strategies, conservative treatment are discussed and recent surgical techniques are outlined. This information should assist health care practitioners who treat patients with this disorder.

**Keywords:** Lateral epicondylitis (tennis elbow), diagnosis, conservative treatment

## 1. Introduction

Lateral epicondylitis (Tennis Elbow) is a common soft tissue condition, treated by many physical therapists in a variety of clinical setting. The purpose of this paper is to review the relevant anatomy, clinical examination, diagnosis, neurochemical changes, conservative care and surgical treatment for patients with tennis elbow.

Lateral epicondylitis is a painful condition affecting the tendinous tissue of the lateral epicondyle of the humerus, leading to loss of function of the affected limb. Therefore it can have a major impact on the patient's social and personal life [84].

## 2. Anatomy

The elbow joint is provided by the bony anatomy and the ligaments, which are actually specialized thickening of the joint capsules [48]. The radial collateral lig-

ament is commonly described as originating from the lateral epicondyle and terminating diffusely in the annular ligament [33]. McVay [48] and Wadsworth [88] have described the lateral collateral ligamentous structures as a single complex. The lateral ulnar collateral ligament arises posterior to the radial collateral ligament and passes superficial to the annular ligament to attach to discrete bony tubercle to the ulna.

The anterior joint capsule inserts proximally above the coronoid and radial fossae. Distally, the capsule attaches to the anterior margin of the coronoid (medially) as well as to the annular ligament (laterally). The anterior portion is taut in extension and become lax with flexion. The posterior portion of the capsule is attached proximally just above the olecranon fossa and along the medial and lateral margin of the trochlea. Distally, attachment is along the medial and lateral articulation margin of the sigmoid notch, and laterally along the lateral aspect of the sigmoid notch to form the confluence with the annular ligament [50].

### 2.1. Bursae

The literature varies greatly on the number and importance of bursae located about the elbow [40,48,50,

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88]. Lanz and Wachsmuth [40] describes seven bursae, including three associated with the triceps. The best known and consistent is the superficial olecranon bursa located between the olecranon process and the subcutaneous tissue. The radiohumeral, or subextensor carpi radialis brevis, bursa lies deep to the common extensor tendon, below the brevis and superficial to the radiohumeral joint capsule.

This bursa has been recognized and implicated by several authors [13] in the etiology of lateral epicondylitis. McVay [48] indicated that radioulnar bursitis may occur from the irritation of repeated or violent extension of the wrist with the forearm pronated. Goldie et al. [29], however found no involvement of the bursae in elbows examined. His investigation identified the presence of a subtendinous space near the extensor carpi radialis brevis attachment to the lateral epicondyle that was filled with granulation of the muscle tissue, hypervascularized and edematous in patients with tennis elbow [29].

## 2.2. Musculotendinous structure

The extensor carpi radialis longus originates from the supracondylar ridge below the origin of the brachioradialis. This attachment is between the brachialis medially and the extensor carpi radialis brevis infero-laterally [91]. The extensor carpi radialis longus crosses the elbow and carpal joint to insert onto the dorsal base of the second metacarpal and is covered by the brachioradialis over most of the forearm. Its function is that of wrist extension, radial deviation, and possibly elbows flexion.

Originating from the lateral inferior aspect of the lateral epicondyle, the extensor carpi radialis brevis origin is the most extensor group. The extensor carpi radialis brevis is covered by the extensor carpi radialis longus and its fibers are almost indistinguishable from those of the extensor carpi radialis longus and extensor digitorum communis in most cases. The extensor carpi radialis brevis muscle also has additional attachment to the radial collateral ligament and the intermuscular septa between it and common extensor muscle [78]. The extensor carpi radialis brevis tendon inserts to the dorsal surface of the base of the metacarpal bone. Pure wrist extension with some assistance in radial deviation are the main functions of the extensor carpi radialis brevis.

The extensor digitorum communis originates from the anterior distal aspect of the lateral epicondyle and accounts for most of the contour of the extensor surface.

Parts of the extensor digitorum communis are also attached to the septum and tendon from which the extensor carpi radialis brevis arises [78]. The extensor digitorum communis insertion contributes to the extensor mechanism for the index, long, ring, and little fingers. In addition to the extension of the wrist and the digits. Wright et al. [91], suggests that the extensor digitorum communis may assist with elbow flexion when the arm is pronated.

## 3. Epidemiology

The incidence of lateral epicondylitis varies from approximately 1% to 3% in the general population to more than 50% among amateur tennis players [32]. However, tennis players' account for only about 5% of all sufferers of lateral epicondylitis [52]. Hence, "tennis elbow" is a misnomer [57]. Lateral epicondylitis is equally common among men and women, occurs more frequently among whites and in the dominant arm, and increases with age, peaking between the ages of 30 and 50 [19], with a mean age 42 [9]. It seems to occur equally among blue-collar and white-collar workers and among socioeconomic classes [19].

The natural course of the condition seems to be favourable, with spontaneous recovery within 1–2 years in 80–90% of the patients; however there is very little scientific data available on the natural history of the disease [28].

It is often caused by overuse or repetitive strain caused by repeated extension (bending back) of the wrist against resistance. This may be from activities such as tennis, badminton or squash but is also common after periods of excessive wrist use in day-to-day life and it may be caused through

- A poor backhand technique in tennis.
- A racket grip that is too small.
- Strings that are too tight.
- Playing with wet, heavy balls.
- Repetitive activities such as using a screwdriver, painting or typing.

## 4. Pathophysiology

Pain around the lateral epicondyle is known by a variety of names, and was described as periostitis, extensor carpi radialis brevis (ECRB) tendinosis and epicondylagia. The most commonly used names are "tennis elbow" and "lateral epicondylitis". The use of term

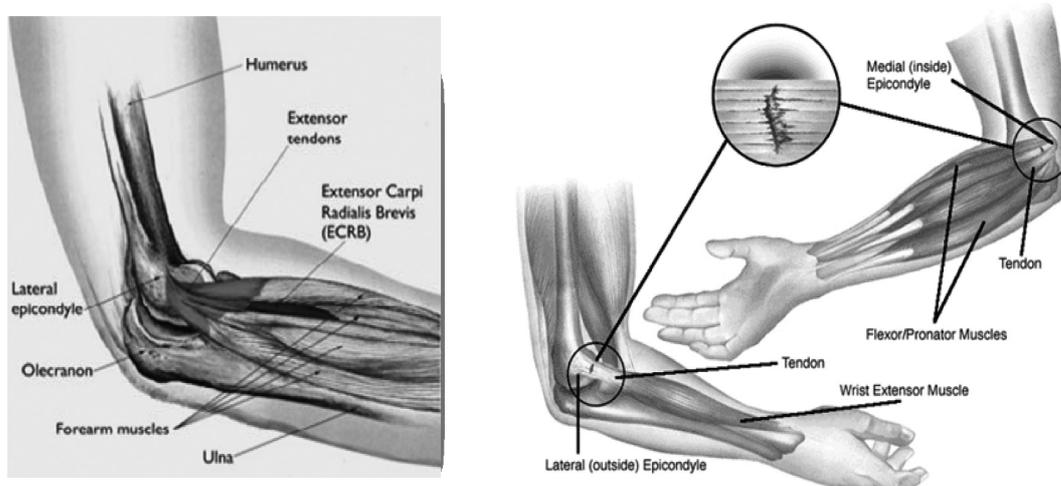


Fig. 1. Anterior-lateral view of elbow joint.

“periostitis” and “epicondylitis” was questioned over time, as histological studies failed to show inflammatory cells (macrophages, lymphocytes and neutrophils) in the affected tissues.

Microscopically, studies by Nirschl et al., showed mainly fibroblastic tissue and vascular invasion that led him to describe the condition in 1999 as “angiofibroblastic tendinosis” [34]. These findings led the researchers to conclude that a more appropriate term for the condition is “lateral elbow tendinosis” which defines a degenerative process characterized by an abundance of fibroblasts, vascular hyperplasia and unstructured collagen. The term tendinosis or tendinopathy implies the absence of chemical inflammation [3]. It has been postulated that tendinosis or tendinopathy is acquired by overuse of a hypovascular zone, which leads to subsequent neovascularisation [63].

Kraushaar and Nirschl [58] described tendinosis as a tennis elbow condition characterized by degenerative changes of the common extensor tendon tissue. Tissue studies conducted via immunohistochemical analysis have revealed degenerative changes involving fibroblasts, blood vessels and collagen. Tendinosis is confirmed with the presence of angiofibroblastic hyperplasia and the absence of cell type involved in inflammation. Kraushaar and Nirschl described four stages of tendinosis that may assist the therapist in determining what type of intervention to provide the patient [58]. Stage 1 is described as a peritendinous inflammation. This stage is actually what most clinicians refer to as tendinitis. Crepitus is usually palpable over the common extensor tendon. Stages 2, 3 and 4 refer to the

presence of angiofibroblastic degeneration, with stage 4 being the most severe. Due to fibrosis, stage may lead to tendon rupture and stage 4 to calcification [58].

Despite the absence of inflammatory cells the condition is painful. Recent studies showed sensory fibers containing substance-P and CGRP (Calcitonin gene-related peptide) - like immunoreactivity in the origin of the ECRB. The presence of these neuropeptides, which is limited to a subgroup of small vessels, implies the possibility of neurogenic inflammation as a cause of the perceived pain.

## 5. Neurochemical response

Despite the absence of inflammation, patients with tennis elbow complain of pain, particularly with abusive or aggravating activity. Two tissue studies have identified the presence of neurochemicals with the tendon of the ECRB [2,45]. Significant levels of substance-P and Calcitonin gene related peptide were reported within the ECRB tendon in patients with chronic tennis elbow with an average duration of symptoms of 22.7 months [45]. Alfredson, Ljung, Thorsen and Lorentzon investigated the use of microdialysis technique also used on the Achilles tendon [5] and patellar tendon [1] to determine the local concentration of glutamate, an excitatory neurotransmitter for pain and prostaglandin E2 and inflammatory mediator in the ECRB [2] tendon of patients with tennis elbow for at least six months. The result of the study yielded statistically significant difference in mean concentration lev-

els of glutamate in the tennis elbow patients compared to the control subjects. No significant differences were noted in prostaglandin levels between groups. Glutamate via NMDAR1, a glutamate receptor, immunoreactivity has been observed within neural structure of excised Achilles tendons and patellar tendons in patients with respective chronic tendinopathies [1]. The presence of significant levels of glutamate substance-P and CGRP in tendinosis may provide an alternative mechanism for pain mediation in tennis elbow as well as other chronic tendinopathies.

We don't know if the neurochemical response present in tendinopathy with duration of symptoms of six months or less and if there are recurrent inflammation or degenerative changes within the tendon since the human subjects studies were only performed on tendon of patients with chronic tendinopathies at the time of surgery in cases where the symptoms were longer more than six months. Animal models must be used to determine if there is an early neurochemical response associated with tennis elbow and other tendinopathies. A chemically induced experimental model of tennis elbow in Sprague-Dawley rats were used to investigate the involvement of sensory and sympathetic nerve fibers in pain mediation of tennis elbow [30]. Following irritation using Carrageenan and Freund adjuvans, chemical used to induce inflammatory injury, samples of ECRB muscle perfusates taken two, six and 24 hrs following injection of these irritants indicate that substance-P is abundant during an acute inflammatory response compared to similar tissue samples in the control group. Messer et al. examined immunoreactivity for substance-P in the tendon and paratenon tissues in the hind limb triceps muscle following repetitive eccentric muscle contractions in a controlled kicking rat model. Neurofilament labeling was evident within epitenon and paratenon of the trained tendons, but only sparsely apparent in the controlled tendons. Immunoreactivity for substance-P was intensive in the experimental limb of the trained animals and in sparse in the contralateral limbs of the trained animals and control animal limbs. Substance-P immunoreactivity was determined by using bioquantification techniques in volitional rat model of repetitive forceful motion. Substance-P increases in peritendon tissue in forelimb tendons have been exposed to highly repetitive and forceful tasks. The response is also dependent on task exposure, with the greatest response at 12 wks. The observation in these animal studies [23, 30,49] suggests that at least substance-P is present in acute overuse tendon conditions such as tennis elbow.

## 6. Signs and symptoms

The onset of pain is usually gradual. The force generated by muscle contraction may not produce pain until healing has begun and there is some adhesion between the tendon and the inflamed periosteum [62]. With repeated microtrauma, an inflammatory condition of the periosteum may develop, which can lead to formation of granulation tissue and adhesion. Swelling or ecchymosis is rare, except in cases of external trauma. The arm is painless at rest and during passive range of motion. Granulation tissue contains a large number of free nerve ending which may be responsible for increased tenderness on palpation [20,57,87]. Tenderness is most notable at the anterior aspect of the lateral epicondyle and the lateral forearm. Palpation of the radial collateral ligament may elicit exquisite tenderness and is usually increased with varus stress to the elbow. Grip strength may be decreased, but the articular and neurological signs are normal. In severe cases, pain at rest occurs along with varying decreases of motion at the extremes of flexion and extension.

In most cases, the lesion will involve the junctional tissue at the common extensors muscle origin of the lateral epicondyle, specifically the extensor carpi radialis brevis [8,20,27,38,39,41,54,57,71,87].

If the extensor carpi radialis brevis is involved, extension of the wrist will be more painful if resistance given at the heads of the metacarpals rather than at the fingertips [20]. Radial extension will more specifically indicate extensor carpi radialis brevis or extensor carpi radialis longus. Pain with resisted extension of the middle finger is present when the extensor carpi radialis brevis is involved [87]. Tenderness above the epicondyle will indicate that the extensor carpi radialis longus is involved, while anterolateral tenderness would arise from extensor carpi radialis brevis tissue inflammation. Ulnar extension will provoke the extensor carpi ulnaris. Radial and ulnar extensions involve the extensor digitorum communis, but most authors agree that involvement of the extensor digitorum communis and extensor carpi ulnaris is rare [8,20].

## 7. Physical examination/ diagnosis

First and foremost, how can therapist determine the histological status of the ECRB tendon in a patient with tennis elbow? The use of the clinical examination alone presents a challenge, but is unlikely that all patients with tennis elbow, if any, are likely to have a biopsy of his

or her common extensor tendon. It seems reasonable that the patient's history may provide the most useful data. The duration of the symptoms and the number of recurrences may suggest either an acute injury or condition consistent with a peritendinous inflammation or early stage tendinosis. A more long standing or chronic condition would increase the likelihood of advanced stage tendinosis. Generally if the symptoms of duration is 3 months or less this is considered an acute condition and chronic condition would be consistent with duration of symptoms greater than three months [47]. A history of previous occurrence of tennis elbow also suggests tendinosis.

Imaging techniques such as magnetic resonance imaging or diagnostic ultrasound are useful to identify the calcification, tears or ruptures of the ECRB [61, 64]. Therapist would not likely be able to determine the presence of these histopathological changes without imaging studies, keeping in mind that an intact ECRL tendon would certainly mask a complete rupture of ECRB tendon. Although imaging studies are described in the tennis elbow literature, they are typically not performed unless the patient fails conservative management and surgery is being considered [16, 47]. Imaging studies are the only noninvasive manner to provide some evidence of tissue changes.

Palpation may also be used during the clinical examination. Special test such as the tennis elbow test or Cozen's test, Mill's test, and variation in grip strength measures are commonly used during the physical examination [11,58,23]. The validity, specifically sensitivity and specificity of the Cozen's test and Mill's test has not been determined. Tissue observation noted by imaging may serve as the standard for determining the validity of the special tests; certainly is an area wide open for research. Pain free grip strength [82] and the patient related tennis elbow evaluation [47] are used to study the effects of the clinical intervention. Further investigation of these measures is needed to determine if there are differences in initial scores that may correlate with histopathological finding such as peritendinous inflammation, tendinosis, or ECRB tendon rupture.

### 7.1. Musculoskeletal diagnostic ultrasound for lateral epicondylitis

In lateral epicondylitis, the tendon origin appears thickened and hypoechoic on ultrasound. There may be hypoechoic linear clefts within the tendon, representing intrasubstance tears – a common occurrence in tendinopathy. As seen in Fig. 2, chronic epicondylitis

is associated with tendon thickening, calcification, and cortical irregularity, or spur formation of the epicondyle.

### 7.2. Magnetic resonance imaging (MRI) for lateral epicondylitis

The MRI appearance of lateral epicondylitis is also analogous to that of rotator cuff injuries, except that "magic-angle phenomenon" (see Advances in Musculoskeletal MRI) is generally not a problem. Thickening and/or increased signal intensity in the common extensor tendon can be seen on T2-weighted spinecho, T2\*-weighted gradientecho or STIR images in the coronal plane. Fat-suppressed Fast spinecho sequences are particularly useful as they can combine heavy T2 weighting with high-resolution matrixes.

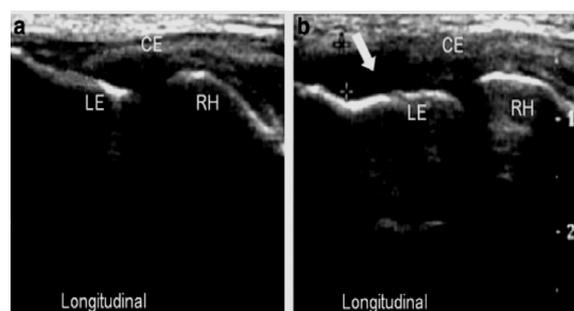


Fig. 2. Common extensor origin. (a) Normal longitudinal scan of the common extensor tendon, with a parallel echogenic fibrillar pattern. (b) Lateral epicondylitis. Abnormal focal swelling and hypoechogenicity (arrow) were seen at the tendon insertion site. LE, lateral epicondyle; RH, radial head; CE, common extensor tendon.

## 8. Therapeutical management for lateral epicondylitis

Many treatments are recommended for lateral epicondylitis; unfortunately there is little objective evidence that they help. Undoubtedly, this lack of evidence reflects in part the disagreement about the causes underlying this condition. In addition, it is likely that the dynamic nature of the lesion, wherein the disorder at the lateral epicondyle evolves with time, precludes establishing a clear starting point for therapy. Unfortunately, no controlled, double blind, and randomized clinical studies demonstrate the efficacy of any particular conservative or surgical intervention for treating lateral epicondylitis. Therapy can be a single modality; a combination of treatment; or some form of stepped

care approach, influenced by severity and chronicity of the problems, likelihood of a particular patient's compliance with a specific treatment regimen, the patient's occupational risks and potential for side effects from treatment.

Successful conservative treatment of lateral epicondylitis generally includes five distinct means of intervention to relieve pain, control inflammation, promote healing, improve local and general fitness and control force loads [56].

### 8.1. Pain

The treatment of the patient's pain can be accomplished through a variety of therapeutic modalities. Cold application, either with ice massage, ice packs or ethyl chloride spray, is widely advocated during both acute and chronic phases of lateral epicondylitis [39,57]. Heating modalities such as hot packs, whirlpool, and ultrasound have been used in subacute and chronic phases [37,54,57]. Shortwave and microwave diathermy are considered ineffective in treatment of overuse injuries such as lateral epicondylitis. Electrical stimulation with transcutaneous electrical nerve stimulation units can assist patients with their pain control. One of the most commonly used types of electrical stimulators in the treatment of lateral epicondylitis is the high voltage galvanic stimulator. Nirschl et al. report that this modality is more useful than ultrasound and second only to ice in effectiveness [54,56].

Extracorporeal Shock Wave Therapy (ESWT) has shown controversial results. But it provides little or no benefit in terms of pain and functions [32].

*The lack of positive evidence regarding its effectiveness doesn't support the use of ESWT for tennis elbow.*

Several studies evaluated the effect of Acupuncture. Acupuncture has shown the marked improvement in tennis elbow patients [10].

The efficacy of LASER therapy was studied in two recent review papers. But no evidence of a beneficial effect of laser treatment was found, in either the short or long term [51].

### 8.2. Inflammation

Physical therapists often use ice and electrical stimulation in an attempt to diminish the inflammatory response associated with this condition. Nonsteroidal

and anti-inflammatory are usually prescribed for 2–3 weeks [41]. No particular medication has been found to be superior, and selection of the medication and its dosage will vary according to the patient's response [41, 54]. Steroid injections are often used if treatment by oral medication and therapeutic modalities has failed to reduce the patient's pain and inflammation [41,54]. Halle et al. [31], conducted a study comparing the response of patients to four different treatments including ultrasound, ultrasound with hydrocortisone phonophoresis, transcutaneous electrical stimulation, and steroid injection all accompanied by the same home program of bracing, ice and painful task avoidance. The result from the study showed no significant difference in the treatment outcome [21].

### 8.3. Tissue healing

Patients should be encouraged to not overuse their extremity during the acute tissue healing phase and to avoid activities that aggravate their symptoms. Patients are reminded that avoidance of pain doesn't necessitate complete immobilization and that gentle and controlled stresses are important for the appropriate alignment of connective tissue as it heals. This concept is particularly important if the treatment involves the use of manipulative maneuvers such as Mill's or Cyriax's techniques [87]. Transverse or deep frictional massage is often used by physical therapists for treating lateral epicondylitis [81,90]. Cyriax believed that this helped to prevent random binding of newly formed collagen fibers.

### 8.4. Muscular conditioning

Leach and Miller [41] reported that the involved extremity will often demonstrate a reduction in passive flexion of 10–15 degree when compared with uninvolved side. If such a reduction in flexion is identified, stretching exercises designed to improve the flexibility of the wrist extensor group should be instituted and continued until wrist range of motion is equal to uninvolved side. The usual method of instituting strengthening exercises is a means of an intensity graded protocol according to the patient's tolerance. These exercise programmes should be started early in the treatment to assist with appropriate tissue remodeling. It is probably appropriate that early strength training should focus on low load, high-repetition training programs to avoid symptom aggravation.

## 9. Exercise programmes

The literature on this subject suggests that strengthening and stretching exercises are the main components of exercise programmes because tendons must not only be strong but also flexible [36,67,68].

The treatment regimen of home exercise programmes for other tendinopathies similar to LET is usually once or twice daily for at least 3 months [4, 46,58,62,67,70]. The treatment regimen of supervised exercise programmes is not known with certainty, but our experience suggests that such programmes should be administered at least three times per week for 4 weeks [18]. The most likely explanations for this difference in the treatment regimen of exercise programmes may be the compliance of patients and/or the clinical route/routine.

### 9.1. Stretching exercises

In the case of LET, static stretching should be performed for the ECRB tendon, the site most commonly affected by LET [36,37,75]. The best stretching position result for the ECRB tendon is achieved with the elbow in extension, Lateral elbow tendinopathy forearm in pronation, and wrist in flexion and with ulnar deviation, according to the patient's tolerance [68]. Recommendations for the optimal time for holding this stretching position vary, ranging from as little as 3 s to as much as 60 s [6]. Therapists believe that a stretch for 30–45 s is most effective for increasing tendon flexibility [6,25, 67–69,76].

A static stretch should be repeated several times per treatment session, although the first stretch repetition results in the greatest increase in muscle-tendon unit length [8,68,69]. Taylor et al. [83] report that more than 80% of a muscle-tendon unit length can be obtained after the fourth repetition of a static stretch. Stanish et al. [73,75], Fyfe and Stanish [25], claim that six repetitions of static stretching exercises should be performed in each treatment session, divided into an equal number of repetitions, with three before and three after eccentric training. Clinicians suggest a 15–45 s rest interval between each repetition [69]. However, there is no information concerning the treatment regimen for static stretching exercises. As was described in the eccentric exercises section, this information is available for home exercise programmes based on other tendinopathies similar to LET and for a supervised exercise programme based on the authors' experience.

Logically, it would seem that increasing tissue temperature before stretching would increase the flexibility of the muscletendon unit; however, many therapists believe that stretching with or without a warm up yields the same results [69].

#### 9.1.1. Recommendations for the application of static stretching exercises for the treatment of LET

Based on the previously reported evaluation, static stretching exercises for LET should be applied slowly with the elbow in extension, forearm in pronation, wrist in flexion and with ulnar deviation according to the patient's tolerance, in order to achieve the best stretching position result for the ECRB tendon, which is the injured tendon in LET. This position should be held for 30–45 s, three times before and three times after the eccentric exercises during each treatment session with a 30 s rest interval between each procedure. No literature was found to establish the treatment regimen of static stretching exercises for exercise programmes. The static stretching exercises will be individualised by the patient's description of the discomfort and pain experienced during the procedure.

### 9.2. Strengthening exercises

There are essentially three forms of musculotendinous contractions that strengthen soft tissue structures such as tendons: (i) isometric (ii) concentric (iii) eccentric [25,75,77]. Most therapists agree that eccentric contractions appear to have the most beneficial effects for the treatment of LET [17,36,37,67,68,75,76]. Moreover, eccentric exercises only for the injured tendon and not for all tendons in the relevant anatomical region. In the case of LET, eccentric training should be performed for the extensor tendons of the wrist, including the ECRB tendon which LET most commonly affects [25,36,67,68,75].

### 9.3. Eccentric exercises

The three principles of eccentric exercises are: (i) load (resistance) (ii) speed (velocity) (iii) frequency of contractions.

#### 9.3.1. Load (resistance)

One of the main principles of eccentric exercises is increasing the load (resistance) on the tendon. In-

creasing the load clearly subjects the tendon to greater stress and forms the basis for the progression of the programme. Indeed, this principle of progressive overloading forms the basis of all physical training programmes. The load of eccentric exercises should be increased according to the patient's symptoms; otherwise the possibility of re-injury is high [36,37,67,68,75,76]. The rate of increase of the load cannot be standardized among patients during the treatment period although anecdotal evidence in the form of discussion with therapists suggested that they did not have a protocol to account for how the injured tendon, which is loaded eccentrically, returns to a starting position without experiencing concentric loading. Concentric loading has no or little effect on the management of the injured tendon, but, in order to demonstrate the real effects of eccentric exercise, clinicians would need ways to avoid concentric loading of the tendon.

#### 9.3.2. Speed (velocity)

Another basic principle of successful eccentric exercises is the speed (velocity) of contractions. Stanish et al. [75,76], and Stanish et al. [76], state that the speed of eccentric training should be increased in every treatment session, thus increasing the load on the tendon to better simulate the mechanism of injury, which usually occurs at relatively high velocities. However, other therapists claim that eccentric contractions should be performed at a slow velocity to avoid the possibility of reinjury [36,37,67,68]. We concur with this latter opinion because, in contrast to traumatic events which produce rapid eccentric forces, low velocity eccentric loading presumably does not exceed the elastic limit of the tendon and generates less injurious heat within the tendon [1]. The most likely explanation for this lack of definition is the therapists' claim that in order to avoid pain, patients perform the eccentric exercises slowly anyway. Nevertheless, when an exercise programme treatment protocol is developed, the slowness of eccentric exercises should be defined. Failure to do so will make it difficult for therapists to replicate the exercise programme and put it into practice.

#### 9.3.3. Frequency of contractions

The third principle of eccentric exercises is the frequency of contractions. Sets and repetitions can vary in the literature, but therapists claim that three sets of ten repetitions, with the elbow in full extension, forearm in pronation and with the arm supported, can normally be performed without overloading the injured tendon,

as determined by the patient's tolerance [25,67,68,75,76].

If the affected arm is not supported, our experience has shown that patients complain of pain in other anatomical areas distant from elbow joint, such as the shoulder, neck, and scapula. Furthermore, elbow has to be in full extension and the forearm in pronation because, in this position, the best strengthening effect for the extensor tendons of the wrist is achieved [68].

#### 9.4. Recommendations for the application of eccentric exercises for the treatment of LET

Based on the above evaluation, eccentric exercises for LET should be performed on a bed with the elbow supported on the bed in full extension, forearm in pronation, wrist in extended position (as high as possible), and the hand hanging over the edge of the bed. In this position, patients should flex their wrist slowly until full flexion is achieved, and then return to the starting position. Patients are instructed to continue with the exercise even if they experience mild pain. However, they are instructed to stop the exercise if the pain becomes disabling. They should perform three sets of 10 repetitions at each treatment session, with at least a 1 min rest interval between each set. When patients are able to perform the eccentric exercises without experiencing any minor pain or discomfort, the load is increased using free weights or therabands. However, no literature was retrieved that explained the following three issues: (i) how the injured tendon, which is loaded eccentrically, returns to the starting position without experiencing concentric loading; (ii) the treatment regimen of the eccentric exercises; and (iii) how the slowness of eccentric exercises should be defined. All these issues should be answered so a complete treatment protocol for exercise programmes can be established. The starting and final positions of eccentric exercises, the increase in the load, and the degree of mild or disabling pain cannot properly be standardised because all these are individualised by patients' descriptions of pain experienced during the procedure.

#### 9.5. How exercise programmes work?

How an exercise programme relieves pain remains uncertain. It is claimed that eccentric training results in tendon strengthening by stimulating mechanoreceptors in tenocytes to produce collagen, which is probably the key cellular mechanism that determines recovery from tendon injuries [36,37,58]. In addition,

eccentric training may induce a response that normalizes the high concentrations of glycosaminoglycans. It may also improve collagen alignment of the tendon and stimulate collagen cross-linkage formation, both of which improve tensile strength [36,37,58] as supported by experimental studies on animals. It has also been proposed that the positive effects of exercise programmes for tendon injuries may be attributable to either the effect of stretching, with a lengthening of the muscle-tendon unit and consequently less strain experienced during joint motion, or the effects of loading within the muscle-tendon unit, with hypertrophy and increased tensile strength in the tendon [4]. Ohberg et al. [58] believe that, during eccentric training, the blood flow is stopped in the area of damage and this leads to neovascularisation, the formation of new blood vessels, which improves blood flow and healing in the long term. Exercise programmes appear to reduce pain and improve function, reversing the pathology of LET although there is a lack of good quality evidence to confirm that physiological effects translate into clinically meaningful outcomes.

#### 9.6. Controlling force loading

Controlling force loading will be vital both in the early and late treatment of lateral epicondylitis and is an important factor when considering preventive measures. Tennis patient with lateral epicondylitis should be encouraged to use a racquet with a mid to large size head, a lighter weight, and reduced string tension by 3–5 lbs [43]. The hand grip should also be the right size [56]. A handle with too small of a diameter will require increased grasp effort, thus presumably increasing the stress upon the wrist extensor muscle attachment. The injured player should also play with new tennis balls, since old tennis balls require more stroke force to achieve the same velocity.

In the occupational setting, an ergonomics analysis of task requirements is usually beneficial in determining which job may be likely to cause increased stress of the wrist extensor mechanism [21]. Assessment of playing technique and ergonomic analysis are important not only for treatment of injured client but also for preventing repetitive overuse injuries as well.

#### 9.7. Bracing and protective equipment

Bracing is commonly used form of intervention to assist with pain control. The commonly used brace is a simple cock-up splint during the acute stage [18,20,

38]. The purpose of the cock-up splint is to put the wrist extensor mechanism at rest. The most frequently used brace is probably the tennis elbow strap or “counterforce armband” [24]. This type of brace is advocated for controlling the force at the tennis lesion site [40,41]. Forearm supports braces are used throughout the acute and chronic phases of the disease, and their mechanism of function is thought to result from counterforce control [56]. In study by Wadsworth et al. [86] application of counterforce armband was found to increase wrist extension and grip strength in the affected arm of the patients with epicondylitis and pain decrease with armband use was not found to be statistically significant [86].

### 10. Surgical procedure

Less than 10% of patients will fail to improve with conservative therapy and thus require surgical intervention [53]. Although reported success rates, using numerous techniques, are very high most are from cases studies where no sham procedure was done for comparison. Nevertheless, for the few patients resistant to conservative therapy, surgery is an option. Indication for surgery include failure of prolonged conservative therapy (more than 6 to 12 months), evidence of extrarticular calcification, and clinical areas of multiple areas of tendonitis (mesenchymal syndrome). After surgery patients can usually expect to regain normal arm function within less than 2 months and to resume racquet sports within 3 to 6 months [18].

#### 10.1. Lengthening the ECRB tendon

Several operations to relieve the symptoms of tennis elbow have been described. Garden catalogued “excision of the tender area, ablation of the common extensor origin [27,78], Hohmann’s operation releasing the extensor aponeurosis from the lateral epicondyle. Bosworth’s resection of the orbicular ligament and Kaplan’s denervation of the radio humeral joint” [8].

Surgical intervention at the elbow is never to be taken lightly. According Garden et al. [26] suggested that the action of the ECRB should be interrupted by a Z-lengthening of its tendon at the wrist. Under local anaesthesia, a short incision on the dorso-lateral aspects of the forearm proximal to the part where the thumb extensors cross the radius obliquely exposes the ECRB tendon. A Z-shaped tenotomy lengthens the tendon, and a catgut suture hold the ends divided together [26].

Spencer and Herndon described a simple fasciotomy of the extensor origin as a surgical approach for lateral epicondylitis [72]. They reported excellent or good result in 96% of the 23 patients studied. A long term follow up study was published on this technique by Posch et al., who reported “excellent” or “good” in 31 of 35 patients. The author recommended the simple fasciotomy because of its simplicity, minimal complications, and general rapid recovery of 3–4 weeks [60].

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