ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2018/98–104/$2.00/©JCCA 2018

Tendon neuroplastic training for lateral elbow tendinopathy: 2 case reports

Patrick Welsh, BSc, DC, FRCCSS(C)[1]

Objective: *To report 2 cases of lateral elbow tendinopathy treated with a novel adaptation of tendon neuroplastic training (TNT).*

Clinical features:

Patient 1: A 61-year-old male machine operator presented with one year of bilateral lateral elbow pain related to his occupation of using torque wrenches.

Patient 2: A 37-year-old male electrician presented with two months of recurrent left lateral elbow pain related to repetitive motions of gripping and pulling at work.

Intervention and outcome: *Both patients underwent 8 weeks of a novel rehabilitation program, including TNT, which involved pacing their resistance exercises to a metronome. Both patients experienced clinically meaningful improvements in pain and functional outcome scores that were sustained at the 3-month follow-up.*

Summary: *Recent evidence suggests that the*

Objectif : *Présenter 2 cas de tendinopathie latérale du coude traitée par un nouveau type d'entraînement neuroplastique tendineux (ENT).*

Caractéristiques cliniques :

Patient 1 : Un opérateur de machines de 61 ans se plaignait d'une douleur latérale aux deux coudes, apparue il y a un an, et qui était liée à l'utilisation de clés dynamométriques sur les lieux de travail.

Patient 2 : Un électricien de 37 ans se plaignait d'une douleur latérale récurrente au coude gauche, qui était apparue il y a deux mois et qui était reliée à des mouvements répétitifs de serrage et de traction effectués au travail.

Intervention et résultat : *Les deux patients ont suivi un nouveau type de programme de rééducation, d'une durée de 8 semaines, y compris un ENT, qui consistait à exécuter des exercices de résistance avec un métronome. Les deux patients ont éprouvé un soulagement cliniquement significatif de la douleur et les scores obtenus sur l'échelle d'évaluation des capacités fonctionnelles se sont maintenus durant le suivi de 3 mois.*

Résumé : *Des preuves récentes semblent indiquer*

[1] Department of Graduate Studies, Canadian Memorial Chiropractic College

Corresponding author:
Patrick Welsh
High Point Wellness Centre, 5110 Creekbank Road,Mississauga, Ontario, L4W 0A1
E-mail: drpatrickwelsh@gmail.com
Tel: 905-624-0233

The authors has no disclaimers, competing interests, or sources of support or funding to report in the preparation of this manuscript.
The involved patients provided consent for case publication.

central nervous system may play a role in chronic tendinopathies. It is possible that TNT may address the central nervous system component of chronic/recurrent tendinopathy that is not addressed by traditional passive therapies. However, further research is needed.

que le système nerveux central pourrait jouer un rôle dans les tendinopathies chroniques. L'ENT pourrait permettre d'intervenir sur la composante neurologique des tendinopathies chroniques ou récurrentes associée au système nerveux central, alors que les traitements passifs classiques ne le permettent pas. Mais d'autres travaux de recherche pourraient s'avérer nécessaires.

(JCCA. 2018;62(2):98-104)

KEY WORDS: chiropractic, elbow, tendinopathy, tendon neuroplastic training, tennis elbow

(JCCA. 2018;62(2):98-104)

MOTS CLÉS : chiropratique, coude, tendinopathie, entraînement neuroplastique tendineux, épicondylite

Introduction

Lateral elbow tendinopathy, often referred to as "tennis elbow", is a common condition in athletes and the general population.[1,2] Risk factors for this condition include repetitive and forceful movements, smoking, and obesity.[2] Many conservative treatment options are available including rest, bracing, cryotherapy, manual therapy, instrument-assisted soft-tissue mobilization, eccentric exercise, acupuncture, and extracorporeal shockwave therapy as well as injection of various agents.[3–10] Despite the multitude of treatment options available, up to 10% of cases continue to experience long-term pain and disability[11], with 89% of patients taking up to one year to recover[3].

Anatomically, pathologic tendons experience an increase in tenocyte cell size and number, disorganization of collagen, increased proteoglycan and water content, and neovascularization.[12] In addition to structural, functional, and biochemical changes seen in tendinopathy[13,14], recent evidence has also demonstrated alterations to the motor cortex in patients with this condition[15–17]. This includes measureable changes in corticospinal excitability and short-interval cortical inhibition.[18,19] Traditional passive treatments may not address these motor control issues and therefore might lead to less than desirable outcomes or chronicity of symptoms. In 2015, Rio *et al*.[20] introduced a tendon rehabilitation protocol aimed at addressing these motor control deficits seen in patients with tendinopathy. Tendon neuroplastic training (TNT) combines isometric or isotonic strength training with an externally-paced audio or visual cue. Patients perform a strength training task that loads the affected tendon, such as a single leg squat to load the patellar tendon. Rather than a self-paced eccentric-concentric maneuver, the patient matches the speed of the exercise to the audio and/or visual cue provided by a metronome. This type of externally-paced exercise has been shown to improve motor control in an acute strength training session[19] as well as in patients with patellar tendinopathy[20]. To our knowledge, TNT has not been applied for upper extremity tendinopathies.

The purpose of this manuscript is to describe the rehabilitation of two cases with a clinical diagnosis of lateral elbow tendinopathy using a novel TNT protocol.

Case Presentations

Two patients were seen in a private multi-disciplinary clinic for lateral elbow pain, and both provided written, informed consent to publish their data.

Patient 1 was a 61-year-old machine operator with a one year duration of bilateral elbow pain caused by repetitive torque wrench use. The pain was worse in his left elbow at the time of examination. He described the pain as achy, sharp when aggravated, and reported relief with rest. Previous treatment included ultrasound, laser, and a cortisone injection six months prior with only temporary relief. He also used an elbow brace, which provided some mild relief. The patient reported the pain as 7/10 on the visual analog scale (VAS) when aggravated. Plain radiographs were unremarkable for pathology. The patient's medical history included essential tremor (i.e. a nerve disorder causing uncontrollable shaking), lumbar discectomy, and high cholesterol. The patient took medications including a statin, beta-blocker, and low dose aspirin

Table 1.
Patient examination findings.

	Patient 1	**Patient 2**
Inspection: Elbow, Forearm, Wrist regions	Unremarkable	Unremarkable
Cervical Spine Screen: ROM testing	Full and pain-free	Full and pain-free
Upper Extremity Neurological Screen: Reflex, Motor, Sensory testing	DTRs 1+ Bilateral C5-7 Motor 5/5 Bilateral C5-T1 Sensory Bilaterally intact C5-T1	DTRs 1+ Bilateral C5-7 Motor 5/5 Bilateral C5-T1 Sensory Bilaterally intact C5-T1
Elbow ROM: Active and Passive	Full and pain-free	Full and pain-free
Location of Symptoms	Bilateral common extensor tendon	Left common extensor tendon
Strength	Wrist extension: 5/5 with pain	Wrist extension: 5/5 with pain
Orthopedic Tests	+ Cozen's + Maudsley's + Mill's	+ Cozen's + Mill's
Palpatory Findings	Recreate chief complaint with palpation of common extensor tendon	Recreate chief complaint with palpation of common extensor tendon
QuickDASH Disability/Symptom Score	45.5	36.4

DASH = Disabilities of the Arm, Shoulder and Hand; DTR = deep tendon reflex; ROM = range of motion

daily. He did not report experiencing any other tendon pain.

Patient 2 was a 37-year-old electrician with a two month duration of left elbow pain, which was re-exacerbated following an original onset one year prior. At present the pain was aggravated with performing his daily duties as an electrician, such as pulling electrical cord and using hand tools. He rated the pain 6/10 on the VAS and reported rest as the only relieving factor. For this current episode, the pain was not improving and was affecting his ability to perform his job. His medical history was unremarkable.

A thorough global and regional examination including observation, range-of-motion (ROM), neurological, and orthopedic testing (Cozen's, Mill's, Maudsley's)[21,22] was performed on each patient by the same chiropractor, with notable findings presented in Table 1. Based on history and physical examination findings, both patients fit the typical diagnostic criteria for tendinopathy including pain on palpation, pain with tendon loading, and the reduction of pain during activity, also known as the "warm-up phenomenon."[14] As such, both patients were diagnosed with lateral elbow tendinopathy.

Self-reported outcome measures included the QuickDASH disability/symptom score and numeric pain-rating scale (NPRS). The QuickDASH disability/symptom score is a valid and reliable instrument used to measure disability and symptomatology in patients with shoulder, arm, and hand pain.[23] The minimal clinically important difference has been reported to be 19 points with minimal detectable change being 11 points.[24]

Intervention and Outcomes

Both patients performed a novel, eight week TNT protocol (Table 2) for the elbow without modifying any of their ongoing self-care strategies (i.e. bracing, rest), and

Table 2.
8-week tendon neuroplastic training protocol for lateral elbow tendinopathy.

WEEK	SETS	REPS	TEMPO	WEIGHT (LBS)
1	4	8	3sec up - 3sec down*	3
2	4	8	3sec up - 3sec down*	3
3	4	8	3sec up - 3sec down*	3
4	4	8	3sec up - 3sec down*	3
5	4	8	3sec up - 3sec down*	5
6	4	8	3sec up - 3sec down*	5
7	4	8	3sec up - 3sec down*	5
8	4	8	3sec up - 3sec down*	5

sec = seconds
*Externally-paced with an audio/visual metronome (ProMetronome; http://eumlab.com/pro-metronome/). 2-minute rest between sets

they continued to perform their regular duties at work. In addition to the TNT protocol, Patient 1 received low-frequency electro-acupuncture in the elbow (LI10-11, supinator; 8 minutes; 2.5Hz) each week to help reduce his pain so that he could perform his rehabilitation protocol. He chose to have the left side treated only, as it was more symptomatic, and to use the right side as a control. Due to scheduling issues, Patient 2 performed the TNT protocol in isolation, only on the symptomatic side.

The TNT protocol was to be performed on three non-consecutive days per week for eight consecutive weeks. The exercise involved isolated wrist extension and flexion with a dumbbell (Figure 1 & Supplementary Video online), paced to an external audio/visual cue on the patients' smartphone (ProMetronome; http://eumlab.com/pro-metronome/). The patients were to listen to the sound and track the movement of the metronome with their eyes, as pacing to these types of external cues has been shown to modulate corticospinal excitability.[18,19,25] The pace of the metronome was set to 20 beats per minute such that each beat was three seconds apart. This allowed a three second concentric and three second eccentric phase. Four sets of eight repetitions were to be completed with a two minute rest in between each set. These parameters were adapted from previous supplementary data by Rio *et al*.[20] The patients were instructed to begin with a three to five pound weight and to ensure that this did not cause pain to exceed a severity of 5/10 during exercise. Gradual progression of weights was attempted at four week intervals, within tolerance.

Outcomes for each patient can be seen in Table 3. The same chiropractor who performed the initial evaluations also oversaw each treatment session and performed

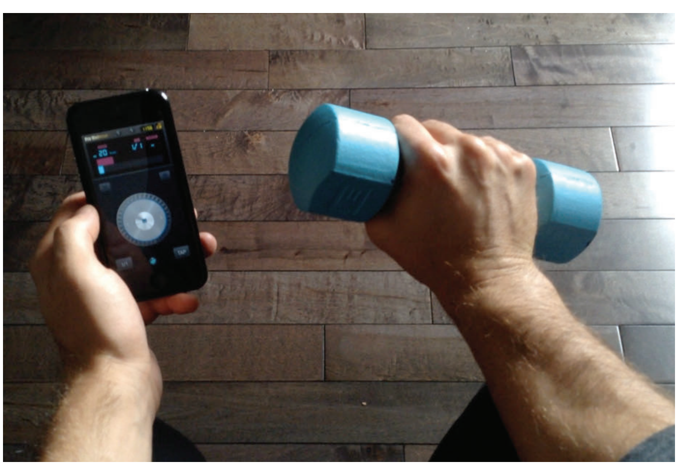

Figure 1.
Wrist extension exercise paced to an audiovisual metronome (see supplementary video).
(ProMetronome; http://eumlab.com/pro-metronome/)

Table 3.
Outcome measures at pre- and post-intervention.

	Patient 1	Patient 2
PRE NPRS score	7	6
POST NPRS score	3	1
NPRS change	4	5
PRE QuickDASH Disability/Symptom score	45.5	36.4
POST QuickDASH Disability/Symptom score	25.0	11.4
QuickDASH Disability/Symptom change	20.5	25.0

DASH = Disabilities of the Arm, Shoulder and Hand;
NPRS = Numeric Pain Rating Scale

final evaluations and discharge. Following the novel TNT protocol, both patients had clinically meaningful improvements in pain and function. Both patients self-reported higher than 90% compliance with the TNT protocol.

Patient 1 received eight electro-acupuncture treatments once per week over eight weeks. At the end of the trial of care, he reported significant reduction in the frequency and intensity of pain, with the occasional flare up if he had performed more strenuous activities at work. He also noted some improvement in the right elbow symptoms, which had not undergone treatment or rehabilitation. At three month follow-up, the patient's symptoms had remained stable and he had begun performing the TNT protocol on the opposite arm.

Patient 2 did not receive any passive treatment and only performed the TNT protocol. At eight weeks the patient reported significant improvements in his ability to work with reduced pain and with increased strength. He continued the TNT protocol for an additional four weeks. At three month follow-up, he had ceased the rehabilitation protocol because he was able to perform all of his duties at work pain-free and no longer experienced any symptoms.

Both patients were able to perform the protocol and achieve significant recovery without reducing the frequency or intensity of their work duties.

Discussion

Tendinopathies are common in the general and athletic populations and many conservative treatments fail to resolve these injuries.[1,26–29] These cases were the first to describe a novel rehabilitation protocol for lateral elbow tendinopathy using TNT. Many structural and biomechanical pain generators have been identified for tendinopathy[13,14], however recent evidence also suggests that the central nervous system may play a role[30]. This can be measured using transcranial magnetic stimulation (TMS), an electromagnetic method used to stimulate small regions of the cerebral cortex. Corticospinal excitability and short interval cortical inhibition, both quantitative measures of motor control, have been shown to be altered in tendinopathy.[16,20] A study by Heales *et al*.[15] also found bilateral sensory and motor deficits on the unaffected side of patients with unilaterally identified tendinopathies in both the lower and upper extremity. In our two cases, these sensorimotor deficits may have contributed to their condition, however this type of quantitative measurement is not common in clinical practice and was not available.

Several methods have been proposed to address these deficits in motor control. It has been demonstrated that corticospinal excitability can be increased when skill training is externally-paced using a metronome.[31] Furthermore, Leung *et al*.[19] found that metronome-paced strength training can reduce short interval cortical inhibition and increase corticospinal excitability compared to self-paced training in healthy individuals. In our two cases, addressing these deficits through metronome-based training may have contributed to the successful outcome, as traditional self-paced strength training does not alter motor control.[19] As TNT is proposed to address the central nervous system component of tendinopathy, it is plausible to also consider that our first case saw improvement in the untreated arm due to the crossover phenomenon.[32] Due to several neuroanatomical connections between the left and right brain, it has been observed that strength training of one limb can lead to strength gains of the opposite limb.[32] This may provide the opportunity for a clinician to recommend rehabilitation of the contralateral limb in a painful tendinopathy, when the condition is too painful to begin training on the affected side.

Our protocol was adapted from Rio *et al*.[20] and involves using an audiovisual metronome to pace the exercise. A weighted wrist extension was chosen to target the extensor carpi radialis brevis, as this accounts for 90% of lateral elbow tendinopathies.[3] Compared to other conservative therapies, TNT addresses the motor control deficits present in tendinopathy. The mainstay of tendon rehabilitation is eccentric training, and there is more recent evidence to support the efficacy of heavy slow resistance training.[33] These training modalities address the tensile strength deficits present in tendinopathy through progressive loading, but fail to adequately address the deficits in the central nervous system. TNT is a combination of resistance exercise and metronome-based training; therefore, this technique may adequately address both the deficits in tendon strength and motor control seen in tendinopathy. However, further research in needed to validate this claim.

Limitations of these case reports are inherent in their study design. Due to the lack of a control group, we cannot rule out the possibility that the patients' improvement was due to the treatment provided, the multimodal treatment (in the case of Patient 1), or some other unidentified confounding factor. Owing to the chronic/recurrent nature of the condition, it seems unlikely that natural history led to the resolution of the patients' symptoms. Additional research is needed to demonstrate improvement in motor control in patients with tendinopathy, as current evidence has not studied these techniques in this population. Furthermore, randomized controlled trials are needed to determine the efficacy of TNT compared to other conventional treatment methods for tendinopathy.

Summary

Tendon neuroplastic training is a novel technique that aims to address the central nervous system involvement of tendinopathies. Combining resistance exercise with metronome-based training can potentially improve the tensile capacity of the tendon and reduce motor control deficits. This two-patient case series presents a new intervention for lateral elbow tendinopathy using TNT concepts. Both patients achieved clinically meaningful changes in the Quick Dash and the NPRS, without time lost from work, after performing the eight week rehabilitation program.

References

1. Wilson JJ, Best TM. Common overuse tendon problems: a review and recommendations for treatment. Am Fam Physician. 2005;72(5):811-818.
2. Shiri R, Viikari-Juntura E, Varonen H, Heliövaara M, Heliovaara M. Prevalence and determinants of lateral and medial epicondylitis: a population study. Am J Epidemiol. 2006;164(11):1065-1074. doi:10.1093/aje/kwj325.
3. Bhabra G, Wang A, Ebert JR, Edwards P, Zheng M, Zheng MH. Lateral elbow tendinopathy: development of a pathophysiology-based treatment algorithm. Orthop J Sport Med. 2016;4(11):1-10. doi:10.1177/2325967116670635.
4. Howitt SD. Lateral epicondylosis: a case study of conservative care utilizing ART and rehabilitation. J Can Chiropr Assoc. 2006;50(3):182-189.
5. Miners AL, Bougie TL. Chronic Achilles tendinopathy: a case study of treatment incorporating active and passive tissue warm-up, Graston Technique, ART, eccentric exercise, and cryotherapy. J Can Chiropr Assoc. 2011;55(4):269-279.
6. Jarosz BS. Chiropractic treatment of chronic patellar tendinopathy in a professional basketball player: a case report. Chiropr J Aust. 2010;40(1):3-8.
7. White KE. High hamstring tendinopathy in 3 female long distance runners. J Chiropr Med. 2011;10(2):93-99. doi:10.1016/j.jcm.2010.10.005.
8. Yuill EA, Macintyre IG. Posterior tibialis tendonopathy in an adolescent soccer player: a case report. J Can Chiropr Assoc. 2010;54(4):293-300. doi:10.1177/036354658301100110.
9. Molsberger A, Hille E. The analgesic effect of acupuncture in chronic tennis elbow pain. Rheumatology.1994;33(12):1162-1165.
10. Papa JA. Two cases of work-related lateral epicondylopathy treated with Graston Technique® and conservative rehabilitation. J Can Chiropr Assoc. 2012;56(3):192-200.
11. Coombes BK, Bisset L, Vicenzino B. A new integrative model of lateral epicondylalgia. Br J Sports Med. 2009;43(4):252-258. doi:10.1136/bjsm.2008.052738.
12. Cook JL, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. Br J Sports Med. 2009;43(6):409-416. doi:10.1136/bjsm.2008.051193.
13. Rees JD, Stride M, Scott A. Tendons - time to revisit inflammation. Br J Sports Med. March 2013:1-7. doi:10.1136/bjsports-2012-091957.
14. Rio E, Moseley L, Purdam C, et al. The pain of tendinopathy: physiological or pathophysiological? Sport Med. 2014;44(1):9-23. doi:10.1007/s40279-013-0096-z.
15. Heales LJ, Lim ECW, Hodges PW, Vicenzino B. Sensory and motor deficits exist on the non-injured side of patients with unilateral tendon pain and disability--implications for central nervous system involvement: a systematic review with meta-analysis. Br J Sports Med. 2013;48(19):1400-1406. doi:10.1136/bjsports-2013-092535.
16. Ngomo S, Mercier C, Bouyer LJ, Savoie A, Roy JS. Alterations in central motor representation increase over time in individuals with rotator cuff tendinopathy. Clin Neurophysiol. 2015;126(2):365-371. doi:10.1016/j.clinph.2014.05.035.
17. Rio E, Kidgell D, Moseley GL, Cook J. Elevated corticospinal excitability in patellar tendinopathy compared with other anterior knee pain or no pain. Scand J Med Sci Sports. 2015:n/a-n/a. doi:10.1111/sms.12538.
18. Gerloff C, Richard J, Hadley J, Schulman AE, Honda M, Hallett M. Functional coupling and regional activation of human cortical motor areas during simple, internally paced and externally paced finger movements. Brain. 1998;121(8):1513-1531. doi:10.1093/brain/121.8.1513.
19. Leung M, Rantalainen T, Teo WP, Kidgell D. Motor cortex excitability is not differentially modulated following skill and strength training. Neuroscience. 2015;305:99-108. doi:10.1016/j.neuroscience.2015.08.007.
20. Rio E, Kidgell D, Moseley GL, et al. Tendon neuroplastic training: changing the way we think about tendon rehabilitation: a narrative review. Br J Sports Med. 2015;50:209-215. doi:10.1136/bjsports-2015-095215.
21. Magee DJ. Orthopedic Physical Assessment. 4th ed. Philadelphia: Saunders; 2006.

22. Saroja G, Aseer P, Venkata Sai P. Diagnostic Accuracy of Provocative Tests in Lateral Epicondylitis. Int J Physiother Res. 2014;2(6):815-823. doi:10.16965/ijpr.2014.699.
23. Beaton DE, Wright JG, Katz JN. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Jt Surg. 2005;87(5):1038-1046. doi:10.2106/JBJS.D.02060.
24. Polson K, Reid D, McNair PJ, Larmer P. Responsiveness, minimal importance difference and minimal detectable change scores of the shortened disability arm shoulder hand (QuickDASH) questionnaire. Man Ther. 2010;15(4):404-407. doi:10.1016/j.math.2010.03.008.
25. Rio E, Kidgell D, Purdam C, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. Br J Sports Med. 2015;49:1277-1283. doi:10.1136/bjsports-2014-094386.
26. Cook JL, Khan KM, Harcourt PR, Grant M, Young DA, Bonar SF. A cross sectional study of 100 athletes with jumper's knee managed conservatively and surgically. The Victorian Institute of Sport Tendon Study Group. Br J Sports Med. 1997;31(4):332-336. doi:10.1136/bjsm.31.4.332.
27. Kettunen JA, Kvist M, Alanen E, Kujala UM. Long-term prognosis for jumper's knee in male athletes. Am J Sports Med. 2002;30(5):689-692. doi:10.1177/03635465020300051001.
28. Sayana MK, Maffulli N. Eccentric calf muscle training in non-athletic patients with Achilles tendinopathy. J Sci Med Sport. 2007;10(1):52-58. doi:10.1016/j.jsams.2006.05.008.
29. Malliaras P, Barton CJ, Reeves ND, Langberg H. Achilles and patellar tendinopathy loading programmes: a systematic review comparing clinical outcomes and identifying potential mechanisms for effectiveness. Sport Med. 2013;43(4):267-286. doi:10.1007/s40279-013-0019-z.
30. Plinsinga ML, Brink MS, Vicenzino B, van Wilgen P. Evidence of nervous system sensitization in commonly presenting and persistent painful tendinopathies: a systematic review. J Orthop Sport Phys Ther. 2015;45(11):864-876. doi:10.2519/jospt.2015.5895.
31. Ackerley SJ, Stinear CM, Byblow WD. Promoting use-dependent plasticity with externally-paced training. Clin Neurophysiol. 2017;122(12):2462-2468. doi:10.1016/j.clinph.2011.05.011.
32. Carroll TJ, Herbert RD, Munn J, Lee M, Gandevia SC, Timothy J. Contralateral effects of unilateral strength training: evidence and possible mechanisms. J Appl Physiol. 2006;101(5):1514-1522. doi:10.1152/japplphysiol.00531.2006.
33. Beyer R, Kongsgaard M, Hougs Kjær B, Øhlenschlæger T, Kjær M, Magnusson SP. Heavy slow resistance versus eccentric training as treatment for Achilles tendinopathy: a randomized controlled trial. Am J Sports Med. 2015;43(7):1704-1711. doi:10.1177/0363546515584760.