OPEN ACCESS

ORIGINAL ARTICLE

American football and other sports injuries may cause migraine/persistent pain decades later and can be treated successfully with electrical twitch-obtaining intramuscular stimulation (ETOIMS)

J Chu,[1] S McNally,[2] F Bruyninckx,[3] D Neuhauser[4]

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bmjinnov-2016-000151).

[1]Department of Physical Medicine and Rehabilitation, Perelman School of Medicine, University of Pennsylvania, Ardmore, Pennsylvania, USA
[2]Manchester United, Manchester, UK
[3]Leuven University Hospitals, Leuven, Belgium
[4]Department of Epidemiology and Biostatistics, School of Medicine, Case Western Reserve University, Cleveland, Ohio, USA

Correspondence to
Dr J Chu, Department of Physical Medicine and Rehabilitation, Perelman School of Medicine, University of Pennsylvania, Ardmore, PA 19003-2321, USA; jchu@etoims.com

Received 8 August 2016
Revised 10 December 2016
Accepted 7 March 2017
Published Online First 24 March 2017

To cite: Chu J, McNally S, Bruyninckx F, *et al*. *BMJ Innov* 2017;**3**:104–114.

ABSTRACT

Introduction Autonomous twitch elicitation at myofascial trigger points from spondylotic radiculopathies-induced denervation supersensitivity can provide favourable pain relief using electrical twitch-obtaining intramuscular stimulation (ETOIMS).

Aim To provide objective evidence that ETOIMS is safe and efficacious in migraine and persistent pain management due to decades-old injuries to head and spine from paediatric American football.

Methods and materials An 83-year-old mildly hypertensive patient with 25-year history of refractory migraine and persistent pain self-selected to regularly receive fee-for-service ETOIMS 2/week over 20 months. He had 180 sessions of ETOIMS. Pain levels, blood pressure (BP) and heart rate/pulse were recorded before and immediately after each treatment alongside highest level of clinically elicitable twitch forces/session, session duration and intervals between treatments. Twitch force grades recorded were from 1 to 5, grade 5 twitch force being strongest.

Results Initially, there was hypersensitivity to electrical stimulation with low stimulus parameters (500 μs pulse-width, 30 mA stimulus intensity, frequency 1.3 Hz). This resolved with gradual stimulus increments as tolerated during successive treatments. By treatment 27, autonomous twitches were noted. Spearman's correlation coefficients showed that pain levels are negatively related to twitch force, number of treatments, treatment session duration and directly related to BP and heart rate/pulse. Treatment numbers and session durations directly influence twitch force. At end of study, headaches and quality of life improved, hypertension resolved and antihypertensive medication had been discontinued.

Conclusions Using statistical process control methodology in an individual patient, we showed long-term safety and effectiveness of ETOIMS in simultaneous diagnosis, treatment, prognosis and prevention of migraine and persistent pain in real time obviating necessity for randomised controlled studies.

INTRODUCTION

A recent publication[1] contains a 2015 conclusion statement regarding American football from American Academy of Paediatrics that allows children to decide if risks 'are outweighed by the recreational benefits associated with proper tackling'. In contrast, the 2015 policy of US Soccer Federation prohibits ≤10-year-old players from heading the ball and limits the number of headers for 11–13-year-old athletes to avoid short-term and long-term consequences of concussions. Blunt trauma is a risk factor for future development of multiple-level spondylotic radiculopathies-induced denervation supersensitivity refractory to standard treatments that can be safely and efficaciously managed long term with electrical twitch-obtaining intramuscular stimulation (ETOIMS).[2]

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

AIM

To provide objective evidence that ETOIMS can safely and efficaciously diagnose, treat, prevent and provide prognosis simultaneously in real time in management of migraine and persistent pain due to unrecognised decades-old injuries to head and spine from paediatric American football.

PATIENT HISTORY

An 83-year-old man, renowned draftsman-artist had episodic headaches at age 20 that became persistent at age ~57. Headache description included 'tight head band' beginning from left posterior head and upper neck to forehead, above eyebrows and behind eyes. Visual aura, hearing difficulties, dizziness and disorientation occurred 1–2 times per month. He pursued multiple consultations and treatments from headache specialists. Among the oral medications he received were the following: a tricyclic antidepressant, calcium channel blocker, antiepileptic, β-blocker, antihistamine, anticholinergic, NSAIDs and short-acting and long-acting opioids. In addition, he received topical medications including local anaesthetics and a high-potency opioid patch. These medications did not ameliorate his symptoms. Similarly ineffective were injections into the neck and suboccipital muscles and occipital nerve, cervical epidural injections and spinal nerve blocks, occipital nerve injections, acupuncture and massage. Medical history included mild hypertension, exercise-induced asthma, gastro-oesophageal reflux disease (GERD) with Barrett's oesophagus and stiff-man syndrome diagnosis verified with 50 times higher autoantibodies against glutamic acid decarboxylase.[3] Surgical history involved L5–S1 laminoforaminotomy for lumbar spinal stenosis, left total knee replacement and repair of left biceps and right triceps muscle ruptures. His medications on presentation included tramadol, an antihypertensive and a steroid inhaler for asthma. Verbal pain score was 7/10. He decided to receive twice weekly fee-for-service ETOIMS sessions.

Social and family history: He was born into mining regions of Western Pennsylvania impoverished by the Great Depression. Between ages 8 and 13, he routinely played American football when protective gear/helmets were unaffordable. He played daily during summers of early 1940s with nine other children and had frequent head/body collisions and falls. He had limited range of joint motion and shortened muscles which made him clumsy. He fell often since he was unable to balance well and unable to use his limbs and spine protectively to buffer the impact of falls. His teammate, his 84-year-old elder brother, also has persistent low back pain (LBP) not relieved with spine surgery and knee replacement surgeries. Mother had migraine.

Medical tests: Figures 1–3 show cervical, lumbosacral and brain magnetic resonance scans.

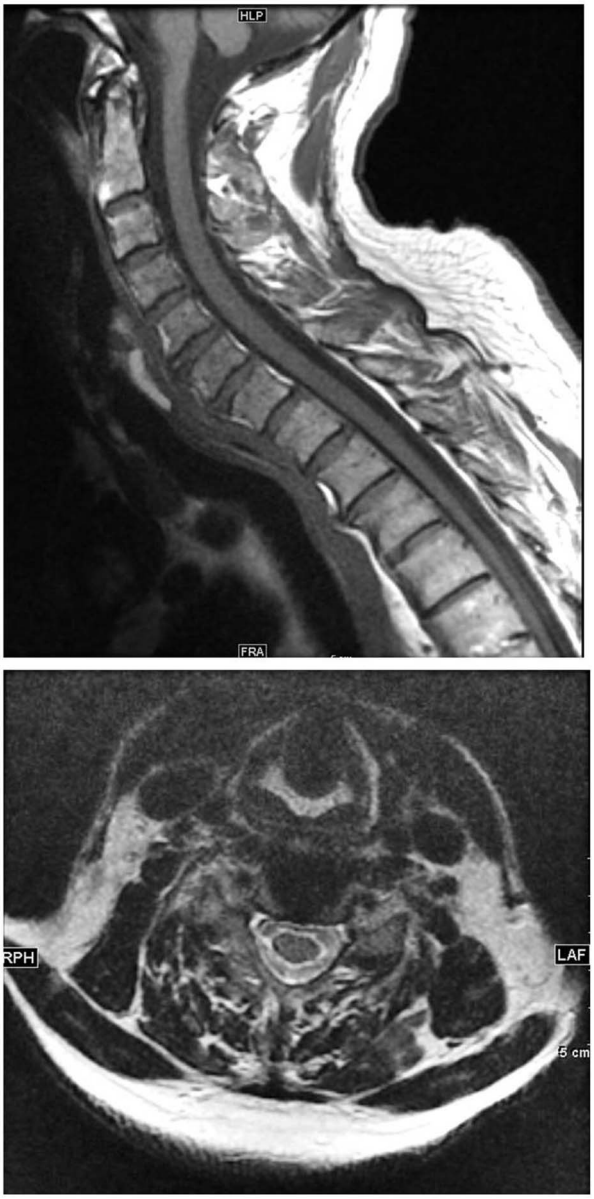

Figure 1 Sagittal MRI scan of the neck (28 April 2014): mild grade 1 anterolisthesis of C5–C6 and C6–C7, multilevel disk space mild desiccation. Axial view: No cervical spinal compression. Also facet joints arthropathy and C5–C6 mild right foraminal stenosis.

Physical examinations: There were hypertonic, taut muscles with significant limited range of motion of all joints (figures 4 and 5). Numbness noted along lateral left leg and foot. Strength 4/5. All reflexes were sluggish and ankle reflexes absent. No upper motor neuron signs. No psychiatric disorders or significant cognitive/memory/concentration deficits on testing with Mini Mental Examination Test.

MATERIALS AND METHODS

Using an automated sphygmomanometer, patient regularly self-measured and recorded the average of three sitting blood pressure (BP) and heart rate/pulse

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

Figure 2 Sagittal MRI scan of the lumbosacral spine (01 April 2014): spinal stenosis with marked narrowing of the central canal at L4–L5 and mild-to-moderate foraminal narrowing at L4–L5 and L5–S1.

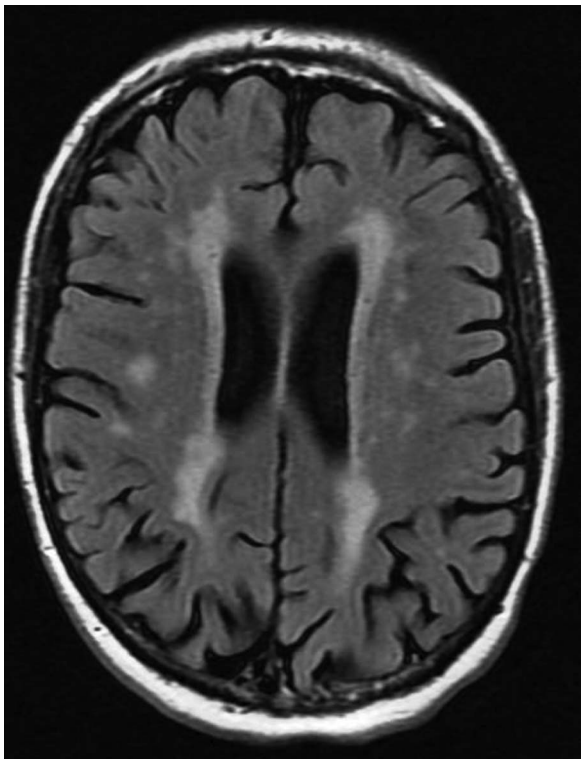

Figure 3 Brain MRI (8 February 12): probable microvascular ischemic changes in cerebral white matter.

before and immediately post-ETOIMS. The corresponding author applied ETOIMS with constant-current stimulator and unique bipolar probe using water-wetted pad electrodes separated by 15 cm, treating bilateral spinal and large muscles of C2–S1 myotomes.

Initially, there was hypersensitivity to ETOIMS with low stimulus parameters (500 μs pulse-width, 30 mA stimulus intensity, frequency 1.3 Hz). This resolved with gradual stimulus increments as tolerated during successive treatments. By treatment number 27, when he was able to tolerate 80 mA stimulus intensity applied at 2–3 Hz, autonomous twitches were noted. Denervation supersensitivity manifested as twitching in remote sites on stimulating a totally unrelated body area, for example, autonomous twitches in the lower limbs on ETOIMS in contralateral upper limb/neck muscles or simultaneous twitching of both lower limbs (see online video supplements 1 and 2). Twitch forces were weaker on symptomatic left side. During the 20-month analysis period (28 October 2014 to 15 July 2016), he underwent 180 ETOIMS sessions (60 min of professional ETOIMS immediately after 90 min of self-applied ETOIMS 500 ms pulse-width, 40 mA stimulus intensity, frequency 2 Hz as a warm-up). Recorded were pain levels, BP, heart rate/pulse before and immediately after each treatment, highest level of elicitable twitch forces/session, session duration and treatment intervals.

ETOIMS treatment goal is to elicit autonomous twitches accompanied by simultaneous twitches in multiple remote areas. Twitch force is graded from 1 to 5, grade 5 twitch force being strongest. Recorded/session was highest grade twitch force in any muscle.

UNDESIRABLE SIDE EFFECTS

Hypertonic muscles are recognised when twitch force is weak and myofascial trigger points (MTrPs) difficult to find. Thus, when performing repeated stimulation of available MTrPs, the probe needs to be lifted after every 2–4 twitches to prevent direct muscle stimulation by the other electrode which is not over an MTrP. This prevents treatment and post-treatment pain.

CONTRAINDICATIONS

Open wounds/tumours, infections, systemic diseases, angina, seizure disorders, pacemakers, implanted neurostimulators, bleeding disorders, profound psychiatric disorders, skin scarring, morbid obesity, autoimmune diseases, central pain, sympathetically maintained pain, multiple failed spinal surgeries, narcotics and pregnancy.

RESULTS AND ANALYSIS

Maximum twitch force elicited was grade 4. Pain level improved to 3/10. Tight band feeling around head

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

Figure 4 The left profile images showed tight and taut trapezius and sternocleidomastoid muscles with head forward position on 28 October 2014, with improvement on 2 May 2015 and 14 January 2016 especially left sternocleidomastoid muscle than trapezius. Left knee flexion contracture improved by 10° on last two images. Patient was able to stand more erect.

disappeared with headache restricted to posterior head. Aura frequency improved to one episode per 4 months.

Medical improvements

Hypertension was resolved and he was able to discontinue antihypertensives. Our experience showed pain reduction with ETOIMS to be associated with reduction of blood pressure and heart rate/pulse.[2] He did not require high-potency narcotics and was helped with gabapentin 600 mg two times a day. He can ambulate 400 m, drive 60 min, attend church/theatre/social events. Prior to ETOIMS, he was primarily house-confined and bedbound frequently every week.

Statistics

SPSS V.12 software package was used for analysis. Spearman's correlation coefficients showed pain levels negatively correlated to twitch force, number of treatments, treatment session duration and directly related to BP and heart rate/pulse shown in tables 1 and 2.

DISCUSSION

We illustrate delayed neuromusculoskeletal consequences of exposure to paediatric American football during the immediate post-Great Depression era. Children played without head/body protective gear, adult supervision, proper tackling instructions or formal game knowledge since home television was

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

Figure 5 Significant limitation of bilateral shoulder range of motion especially on the left with more forward flexion of neck to assist left shoulder flexion. Patient leaned more to the left to perform symptomatic left shoulder internal rotation with shoulder extension, and definite spasm and swelling of left > right thoracic paraspinal muscles noted indicating their recruitment to assist shoulder extension due to left latissimus dorsi weakness. Left triceps was also recruited.

unavailable. Wearing helmets became mandatory for college and high school American football players only in 1978 and 1980, respectively, to protect against concussion/mild traumatic brain injury (MTBI). Helmets protect forces to the head from the periphery and crown, but MTBI occurs due to translational acceleration/deceleration forces resulting from impacts on facemask or side, or fall striking helmet back. The average MTBI peak force on head is 4.4±1.2 kN. The acceleration tolerance for 15 ms head impact is

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

Table 1 Descriptive statistics of different measured parameters

Pain level mean±SD (range)	Tx no. (#) mean±SD (range)	TWF (#) mean±SD (range)	Tx time (min) mean±SD (range)	Tx intv (days) mean±SD (range)	SBP mm Hg mean±SD (range)	DBP mm Hg mean±SD (range)	PP mm Hg mean±SD (range)	Pulse (#/s) mean±SD (range)
4.1±0.8 (2.9–7)	91±52 (1–180)	3.5±1 (1–4.5)	130±30 (60–165)	3.6±1.7 (1–17)	123±6 (108–152)	59±3.5 (51–71)	65±5 (53–84)	66±4 (53–79)

DBP, diastolic blood pressure; intv, interval; no., number; PP, pulse pressure; SBP, systolic blood pressure; TWF, twitch force; Tx, treatment.

42–80 g.[4 5] Human tolerance is lower with repeated MTBI and those with previous MTBI need helmets with the greatest protection.[6]

MTBI affects memory and orientation with or without loss of consciousness (LOC)[7] causing significant morbidity and mortality worldwide with ~54–60 million injuries/year. Mild head injury accounts for ≥80% of MTBIs. The relative causes of head trauma in USA include motor vehicle accidents (MVA), 45%; falls, 30%; occupational accidents, 10%; recreational accidents, 10% and assaults, 5%.[8 9] Approximately 50% of patients with MTBI are between ages 15 and 34 with male to female ratio of 2:1. Of people who have MTBI ~20–40% do not seek treatment.[10]

MTBI symptoms include awareness or consciousness alteration, feeling dazed, stunned, woozy, foggy or amnesic. Occasional LOC/seizures, persistent headaches, vertigo, imbalance, syncope/near-syncope, cognitive/memory disturbances, hearing loss/tinnitus, blurred vision/diplopia, visual loss, personality changes, lethargy, fatigue and inability to perform activities of daily living (ADL).[11] MTBI involved 2.74 symptoms/injury. Our patient never experienced such symptoms but with reasonable medical certainty he received subconcussive or even concussive forces to his skull and spine from frequent multiple daily falls and physical collisions associated with American football which was the only contact sport that he played that had the most impactful potential to injure different parts of his entire spine and head repetitively. He was susceptible to unprotected falls from poor balance due to stiff-man syndrome. As a child he did not complain of pain since during the Great Depression era, children and adults were more stoic and understood that complaints seldom helped.

Over time these risk factors predisposed him to develop significant degenerative changes in his entire spine with diffuse spondylotic radiculopathies. When exposed to weightlifting 50 kg for 30 years, work, ageing and ADL, the denervation-related muscle shortening contributes to the refractoriness of adult migraine when it manifested from genetic causes (maternal). This case underscores the role of ETOIMS in the proper diagnosis and management of coexistent persistent pain from diffuse spondylotic radiculopathies and denervation supersensivity that aggravates migraine. Both diseases needed to be treated together and not in isolation to improve the migraine. The accompanying online supplemental document entitled Denervation Supersensivity explained this topic more in detail in a clinical context. Our patient has no clinical evidence of cervical myelopathy nor do other patients who were able to elicit autonomous twitches when treated with ETOIMS therapy where autonomous twitch elicitation especially in multiple remote areas is the goal for optimal pain relief results.

Sports-related MTBI is a significant public health problem in USA. The Centers for Disease Control and

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

Table 2 Spearman correlations between pain level to treatment number, treatment time and treatment interval, blood pressure and pulse rate

	Tx no. (#) (r) p Value	TWF (#) (r) p Value	Tx time (min) (r) p Value	Tx intv (days) (r) p Value	SBP mm Hg (r) p Value	DBP mm Hg (r) p Value	PP mm Hg (r) p Value	Pulse (#/s) (r) p Value
Pain level	**(−0.366) 0.000**	**(−0.373) 0.000**	**−0.230 0.002**	0.086 0.252	**0.205 0.006**	0.119 0.111	**0.202 0.006**	**0.185 0.013**
Tx no.		**0.593 0.000**	**0.864 0.000**	0.044 0.559	**(−0.277) 0.000**	−0.066 0.377	**(−0.285) 0.000**	(−0.084) 0.263
Tx time		**0.595 0.000**		0.095 0.206	**(−0.237) 0.001**	−0.045 0.548	**(−0.265) 0.000**	−0.038 0.614
Tx intv		0.017 0.820			0.102 0.173	−0.015 0.844	**0.161 0.032**	0.085 0.259

Significant results (p<0.05) are bolded. Pain levels are negatively related to twitch force, number of treatments, duration of the treatment session, and directly related to blood pressures and pulse rate with no correlation to treatment interval.
Numbers of treatments and duration of treatment sessions are negatively correlated to systolic blood pressure and pulse pressure and directly related to twitch force.
DBP, diastolic blood pressure; intv, interval; no., number; PP, pulse pressure; SBP, systolic blood pressure; TWF, twitch force; Tx, treatment.

Prevention estimates that 1.6–3.8 million MTBI occur in sports and recreational activities annually. There are >800 000 outpatient visits and 1.2 million emergency department visits for MTBI. The annual incidence of MTBI is as high as 600/100 000 in USA including unreported cases.[12]

In a study of 5–23-year-old American football players, the major source of MTBI were football practices. Among all age groups, falls are the leading cause of MTBI (35.2%) with 50.2% in children ≤14 years, compared with 60.7% among adults aged ≥65 years.[13] Headache predicts abnormal computerised tomography results. Among paediatric patients with MTBI, 56% clinically improved and were discharged the following day.[14]

Even at the level of the American National Football League (NFL) players, only 9.3% of the NFL players experienced LOC as a result of severe head impacts. Headaches were observed in 55% of NFL players who suffered MTBI.[14] The average impact speed for MTBI was 9.3±1.9 m/s.[5] No MTBIs occurred in striking players since the striking player uses his whole body in the impact causing a rapid change in head velocity of the struck player from the striker's transferred momentum. If the striker has his head down, he increases his applied mass by 67% as a result of coupling his torso into the collision against the struck player's head.[15] The peak head acceleration for players with MTBI averaged 98±28 g over 15 ms whereas that for uninjured struck players was significantly lower at 60±24 g. A head velocity change of 7.2 m/s and an impact 90 g (70–75 g with padded impacts) delineates whether MTBI occurs or not.[6 16]

The critical reason for sustaining MTBI when exposed to similar impact speeds and accelerations is presence of neck stiffness and neck weakness making females and children vulnerable. Increasing neck muscle strength to resist head rotation and lateral bending might help lower abrupt changes in head velocity.[6] Medical clearance allowed 56.5% of NFL players with MTBI to play on postinjury day 1 with 97.1% returning to play by day 9.[17]

MVA is more injurious than sports-related MTBI. Head impact durations with interior structures are <6 ms but last >40 ms when the head impacts into airbag with seat belt restraints.[17] Our patient was never involved in MVA as a cause for migraine or persistent pain.

In American football and European (EU) football (soccer) MTBI impacts are predominantly from the striker's helmet/head/arm against the struck player's side/temporal area of helmet/head. In hockey, MTBI likely occurs from contact with another body part/object rather than another helmet/head. As many as 22% of soccer injuries are MTBIs. Half of MTBI in soccer were related to attempting to head the soccer ball.[18] Relationships between number of headers sustained in a single season and degree of cognitive impairment have been demonstrated. MTBI was a risk factor for sustaining subsequent injury within the following year.[19] Soccer athletes with multiple MTBI took longer to return to play with each subsequent MTBI and may suffer cumulative neuropsychologic impairment.[20] Reducing athlete–athlete contact across all phases of play may be more effective in preventing MTBI and other injuries than banning heading from youth soccer.[21] However, MTBI can result in recurring migraine attacks with/without aura and can be triggered by any sport and has been documented in young men who play soccer with attacks triggered only by impact.[22]

Headaches are a global public health problem often caused by trauma and present in 30–90% of patients after MTBI.[11] Several types of headache can be present simultaneously. Our patient has trauma-related cervicogenic headache arising from the cervical spine elements and MTrPs in cervical myotomes, usually with neck pain. Although our patient does not have neck pain, his migraine starts as a tight band that arises from left side of back of head and upper neck

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

to the forehead as is common in cervicogenic headaches.[11] Migrainous features such as nausea, vomiting and photophobia/phonophobia can occur. He does not have occipital neuralgia and has had occipital nerve injections which had no effect on the headaches

Tension-type headache (TTH) is unilateral/bilateral headache, exacerbated by neck muscles palpation and head movement.[11] It is significantly associated with neck or back injury at age <13 years.[23] Our patient also has TTH elements. He does not fit in the *cluster headache (CH)* profile where attacks are accompanied by eye redness, excessive tearing, nasal congestion, facial sweating and agitation. Patients with CH incur more frequent MTBI during their lifetimes when compared with migraine controls and the general population.[24]

Migraine can increase in frequency or occur acutely or chronically after MTBI. The attack has prodrome, aura and headache. All phases are not experienced by all patients. The migraine headache lasts 4–72 hours and has ≥2 of these characteristics: unilateral, pulsating, moderate/severe intensity, aggravation by ADL, nausea and or sensitivity to light/sound. Migraine is diagnosed if a person has ≥5 attacks fulfilling these criteria. Persistence is established when attacks last ≥8 days with ≥15 headache days/month, for ≥3 months.[25]

Chronic traumatic encephalopathy (CTE) is a progressive neurodegenerative syndrome of mood disorders, behavioural and cognitive impairment, with or without sensorimotor impairment. Following documented episodes or cessation of repetitive MTBI, there may be a latent period of days to even 40 years before symptoms begin. Prevalence rates of CTE in cohorts exposed to MTBI ranges from 3% to 80% across age groups.[26] Brain autopsy in CTE shows microscopic evidence of primary tauopathy over amyloidopathy and proteinopathy. Special positron emission tomography in retired American football players showed brainstem white matter tracts with early axonal damage and cumulative axonal injuries along cortical, subcortical and limbic circuitries supporting mood, emotions and behaviour.[27]

Boxers may present with dysarthria, cerebellar, extrapyramidal, pyramidal dysfunctions and cognitive–behavioural impairments. Routine histology shows distinct septum pellucidum abnormalities, substantia nigra depigmentation with neuronal loss, cerebellar scarring, and numerous neurofibrillary tangles with a sparsity of amyloid plaques.[28] Our patient does not have any clinical nor brain MRI evidence of intracranial pathology or CTE.

Head trauma from sports such as boxing, wrestling, American football, soccer and hockey can cause CTE much earlier than neurodegenerative diseases of elderly.[29] [30] An observational follow-up study 50 years after high school graduation showed high school boys who played American football compared with those who did not play had no increased risk of later developing dementia, Parkinson's disease or amyotrophic lateral sclerosis.[31] This study, however, did not investigate delayed outcomes that include headaches or persistent pain.

Neuromusculoskeletal pain conditions

Persistent pain patients have symptoms of MTBI at a rate similar to a comparison group of patients after head injury.[32] The prevalence of neck pain in migraineurs is 9.6% and disability is determined by migraine frequency. Radiographic evidence of retrospondylosis and osteochondrosis at multiple spinal levels is noted especially at C5–C6>C4–C5>C6–C7>C3–C4 in 100% of patients.[33]

MTrPs in neck muscles are prevalent and such patients have hypomobility in upper cervical facet joints.[34] Migraine can begin or markedly exacerbate after onset of LBP. Our patient has migraine exacerbation when triggered by LBP and left leg pain. Job absenteeism is particularly high when both neurological disorders are present.[35]

The patient and his teammate brother needed low back surgeries and knee replacements as adults from cumulative trauma initiated by risk factors of paediatric American football injuries. The knee joint is in the centre of the lower limb kinetic chain and is implicated in every aspect of locomotion even standing still.[36] Owing to myofascial connections any pathology that disturbs low back, groins, hips and abdominal musculature can increase risk of injury to knees, shoulders and upper extremities as exemplified in our patient with hypertonic muscles (figures 4 and 5).

MRI obtained within 24–48 hours after EU football injury demonstrated that 70% of injuries were without signs of muscle fibre tear yet causes >50% of absence of players in the clubs.[37] These categories of fatigue-induced muscle disorder, delayed onset muscle soreness, spine-related and muscle-related neuromuscular disorders are important for sports medicine specialists since treatment pathways are different.[37]

Lower incidence of injuries from prevention programmes strongly correlates with team success in terms of team ranking position, more games won, more goals scored, greater goal difference and total points.[38] Injury risks may have been reduced for Australian rules football players who received 'motor control intervention' involving active contraction of spinal and deep abdominal muscles.[39] Prompt rehabilitation interventions after games/training should benefit athletes, especially those who received blunt trauma to head and spine.

Radiological and imaging studies cannot identify motor endplates zones (MTrPs) dysfunction. Electromyography and nerve conduction studies, although useful for diagnosis and prognosis of demyelination/conduction block, axonal degeneration/denervation and neuromuscular transmission problems, are

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

not applicable for detecting denervation supersensitivity. ETOIMS, however, has capacity to provide instantaneous diagnosis, treatment, prognosis and preventive feedback in real time as frequently as needed over the persistent pain patient's lifetime.

Muscle cramps: Repetitive-lumbar-injury is common in individuals engaged in long-term performance of repetitive occupational/sports activities involving the spine. Prolonged cyclic loading induces imperceptible spinal creep, reduces muscular activity/stability and triggers muscle spasms.

Dysfunctional end plates exhibiting increased acetylcholine release may be the starting point for abnormal regional contractions as the neuromuscular junction is the site most susceptible to acute ischaemia, essential for formation of MTrPs.[40 41]

Cramps have a peripheral origin in distal intramuscular branches of nerves. Passive muscle stretching that lengthens cramped muscle can sharply interrupt cramps.[42] ETOIMS to acutely cramped muscle effectively stretches and lengthens shortened muscle fibres at cramped areas through active twitch contractions and immediate twitch relaxation in responsive MTrPs.

ETOIMS therapy has helped elite EU footballers as an adjunctive 'muscle motor function restoration' tool alongside active, targeted individual muscle exercise that stimulates MTrPs in trunk, spine and limb muscles. Immediate acute and follow-up ETOIMS to those with neuromuscular disorders or frequent cramps can prevent prolonged rehabilitation, loss of valuable downtime and disabilities. Premature return to full activity due to an underestimated injury can thus be avoided.

We studied our case with statistical process control (SPC). Studying a case in detail sequentially over time can produce statistical results superior to that of a randomised control trial since SPC has greater statistical power to exclude chance as an explanation.[43]

When migraine or persistent pain does not respond to treatments, risk factors that include acute, episodic, repetitive and cumulative head and spine blunt trauma history must be obtained. Pain/discomfort of spondylotic radiculopathies triggered by denervation supersensitivity needs ETOIMS treatments that include axial and large proximal muscles of upper and lower limbs even for regional pain syndromes such as headache.

Clinical presence of hypertonic, shortened muscles and joint contractures (as in this patient) prevents optimal electrical penetration to deeper MTrPs and prognosis for achieving more substantial or longer duration pain relief is guarded. Keeping a regular schedule of ETOIMS treatments can improve prognosis in such patients and is necessary to prevent pain escalation via pre-emptive treatments.

Considering that our patient self-paid to receive ETOIMS treatments at US$200/session, twice per week over 20 months, it was cost-effective to this patient with high investment returns since he could not tolerate medications due to GERD. Various treatments he received gave many side effects and were neither effective nor safe for him. He had migraine and persistent pain relief with definitive improvement in quality of life with ETOIMS. No amount of money could compensate for days lived with disability of severe headaches that confined him. He succinctly states, "I have tried everything over the course of 25 years, so I am willing to pay any price to get rid of the migraine and pay for it by myself because it affects everything I do" (see also online supplemental document entitled Patient's Perception of His Pain and Suffering).

The cost-effectiveness of ETOIMS makes it appropriate for use even in resource-poor countries as first line treatment for patients with neuromusculoskeletal pain/discomfort.[2] Fee for service needs to be adjusted according to the patient's affordability in different parts of the world. Most insurances will reimburse for the treatment as neuromuscular re-education physical therapy, payable on time spent treating the patient. ETOIMS is a unique and highly valuable clinical tool that can objectively quantify presence of such pain. It has capacity to provide simultaneous real time diagnosis, treatment, prognosis and prevention of migraine and persistent pain.

Twitter Follow Jennifer Chu @stopmusclepain

Contributors JC was responsible for planning, conducting, and reporting of the work described in the submitted article. For the sports section and input/feedback for grammar and syntax: SM, Head of Football Medicine & Science, Manchester United, Manchester, UK, email: steve.mcnally@manutd.co.uk. For the neurophysiology section input/feedback: FB, Clinical Professor, Department of Physical Medicine and Rehabilitation, Director, Clinical Electromyography Laboratory, University Hospitals Leuven, Herestraat 49, B—3000 Leuven, Belgium, email: frans.bruyninckx@uzleuven.be. For the statistics section input/feedback: DN, The Charles Elton Blanchard Emeritus Professor of Health Management and Emeritus Professor, Epidemiology and Biostatistics, Department of Epidemiology and Biostatistics, School of Medicine, Case Western Reserve University, Ohio, USA.

Competing interests JC is the sole inventor of ETOIMS and holds patents for the bipolar probe and electrodes. She is Emeritus Associate Professor, Physical Medicine and Rehabilitation, Perelman School of Medicine, University of Pennsylvania, USA, email: jchu@etoims.com.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Our data sharing is available. We have not mentioned this following manuscript for this submission but the effects of ETOIMS on ability to lower blood pressure and heart rate/pulse has been submitted for publication to BMJ Innovations (2016; JC, FB, DN). The blood pressure and heart rate changes as components of complex regional pain syndrome are improved with electrical twitch-obtaining intramuscular stimulation (ETOIMS) as pain treatment modality. Data are available to BMJ Innovations.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

REFERENCES

1 Bachynski KE. Tolerable risks? Physicians and youth tackle football. *N Engl J Med* 2016;374:405–7.
2 Chu J, Bruyninckx F, Neuhauser DV. Persistent refractory myofascial pain and denervation supersensitivity as global public health disease. *BMJ Case Reports* 2016;
3 Meincka HM, Fabera L, Morgenthalerb N. Antibodies against glutamic acid decarboxylase: prevalence in neurological diseases. *J Neurol Neurosurg Psychiatry* 2001;71:100–3.
4 Cassidy JD, Carroll LJ, Peloso PM, *et al*. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med* 2004;43:28–60.
5 Pellman EJ, Powell JW, Viano DC, *et al*. Concussion in professional football: epidemiological features of game injuries and review of the literature—part 3. *Neurosurgery* 2004;54:81–96.
6 Pellman EJ, Viano DC. Concussion in professional football: summary of the research conducted by the National Football League's Committee on Mild Traumatic Brain Injury. *Neurosurg Focus* 2006;21:E12.
7 Giza CC, Kutcher JS, Ashwal S, *et al*. Summary of evidence-based guideline update: evaluation and management of concussion in sports: report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology* 2013;80:2250–7.
8 Jennett B, Frankowski RF. The epidemiology of head injury. In: Brinkman R, ed. *Handbook of clinical neurology*. vol. 13. New York: Elsevier, 1990:1–16.
9 Thurman DJ, Alverson C, Dunn KA, *et al*. Traumatic brain injury in the United States: a public health perspective. *J Head Trauma Rehabil* 1999;14:602–15.
10 Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil* 2006;21:375–8.
11 Evans RW. Posttraumatic headaches in civilians, soldiers, and athletes. *Neurol Clin* 2014;32:283–303.
12 Mannix R, O'Brien MJ, Meehan WP III. The epidemiology of outpatient visits for minor head injury: 2005 to 2009. *Neurosurgery* 2013;73:129–34.
13 Faul M, Xu L, Wald M, *et al*. *Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths 2002–2006*. US Department of Health and Human Services Centers for Disease Control and Prevention, 2010. http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf
14 Bramley H, Mcfarland C, Lewis MM, *et al*. Short-term outcomes of sport—and recreation-related concussion in patients admitted to a pediatric trauma service. *Clin Pediatr* 2014;53:784–90.
15 Viano DC, Pellman EJ. Concussion in professional football: biomechanics of the striking player part 8. *Neurosurgery* 2005;56:266–80.
16 Pellman EJ, Viano DC, Tucker AM, *et al*. Concussion in professional football: reconstruction of game impacts and injuries. *Neurosurgery* 2003;53:799–812.
17 Pellman EJ, Viano DC, Tucker AM, *et al*. Concussion in professional football: location and direction of helmet impact -part 2. *Neurosurgery* 2003;53:1328–41.
18 Delaney JS, Al-Kashmiri A, Correa JA. Mechanisms of injury for concussions in university football, ice hockey, and soccer. *Clin J Sport Med* 2014;24:233–7.
19 Nordstrom A, Nordstrom P, Ekstrand J. Sports-related concussion increases the risk of subsequent injury by about 50% in elite male football players. *Br J Sports Med* 2014;48:1447–50.
20 Levy ML, Kasasbeh AS, Baird LC, *et al*. Concussions in soccer: a current understanding. *World Neurosurg* 2012;78:535–44.
21 Comstock RD; Currie DW; Pierpoint LA, *et al*. An evidence-based discussion of heading the ball and concussions in high school soccer. *JAMA Pediatr* 2015;169:830–7.
22 Matthews WB. Footballer's migraine. *BMJ* 1972;2:326–7.
23 Waldie KE, Poulton R. Physical and psychological correlates of primary headache in young adulthood: a 26 year longitudinal study. *J Neurol Neurosurg Psychiatry* 2002;72:86–92.
24 Lambru G, Matharu M. Traumatic head injury in cluster headache: cause or effect? *Curr Pain Headache Rep* 2012;16:162–9.
25 Tajti J, Pardutz A, Vamos E, *et al*. Migraine is a neuronal disease. *J Neural Transm (Vienna)* 2011;118:511–24.
26 Omalu B. Chronic traumatic encephalopathy. *Prog Neurol Surg* 2014;28:38–49.
27 Barrio JR, Small GW, Wong KP, *et al*. In vivo characterization of chronic traumatic encephalopathy using [F-18]FDDNP PET brain imaging. *Proc Natl Acad Sci U S A* 2015;112: E2039–47.
28 Lampert PW, Hardman JM. Morphological changes in brains of boxers. *JAMA* 1984;251:2676–9.
29 Gavett BE, Stern RA, McKee AC. Chronic traumatic encephalopathy: a potential late effect of sport-related concussive and subconcussive head trauma. *Clin Sports Med* 2011;30:179–88.
30 McKee AC, Cantu RC, Nowinski CJ, *et al*. Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. *J Neuropathol Exp Neurol* 2009;68:709–35.
31 Savica R, Parisi JE, Wold LE, *et al*. High school football and risk of neurodegeneration: a community-based study. *Mayo Clin Proc* 2012;87:335–40.
32 Smith-Seemiller L, Fow NR, Kant R, *et al*. Presence of post-concussion syndrome symptoms in patients with chronic pain vs mild traumatic brain injury. *Brain Inj* 2003;17:199–206.
33 Jansen J, Vadokas V, Vogelsang JP. Cervical peridural anaesthesia: an essential aid for the indication of surgical treatment of cervicogenic headache triggered by degenerative diseases of the cervical spine. *Funct Neurol* 1998;13:79–81.
34 Yoon MS, Manack A, Schramm S. Persistent migraine and persistent tension-type headache are associated with concomitant low back pain: results of the German Headache Consortium study. *Pain* 2013;154:484–92.
35 Dartigues JF, Michel P, Lindoulsi A, *et al*. Comparative view of the socioeconomic impact of migraine versus low back pain. *Cephalalgia* 1998;18(Suppl 21):26–9.
36 McNally S. Soft tissue injuries at the knee. In: Hutson M, Ward A, eds. *Musculoskeletal medicine*. Oxford: Oxford University Press, 2015:436. Chapter 38.
37 Mueller-Wohlfahrt HW, Haensel L, Mithoefer K, *et al*. Terminology and classification of muscle injuries in sport: the Munich consensus statement. *Br J Sports Med* 2013;47:342–50.

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.

38 Eirale C, Tol JL, Farooq A, *et al*. Low injury rate strongly correlates with team success in Qatari professional football. *Br J Sports Med* 2013;47:807–8.
39 Hides JA, Stanton WR. Can motor control training lower the risk of injury for professional football players? *Med Sci Sports Exerc* 2014;46:762–8.
40 Hatzipantelis KP, Natsis K, Albani M. Effect of acute limb ischaemia on neuromuscular function in rats. *Eur J Surg* 2001;167:831.
41 Mense S, Simons DG, Hoheisel U, *et al*. Lesions of rat skeletal muscle after local block of acetylcholinesterase and neuromuscular stimulation. *J Appl Physiol* 2003;94:2494–501.
42 Bertolasi L, De Grandis D, Bngiovanni LG, *et al*. The influence of muscular lengthening on cramps. *Ann Neurol* 1993;33:176–80.
43 Diaz M, Neuhauser D. Pasteur and parachutes: when statistical process control is better than a randomized controlled trial. *Qual Saf Health Care* 2005;14:140–3.

BMJ Innov: first published as 10.1136/bmjinnov-2016-000151 on 24 March 2017. Downloaded from http://innovations.bmj.com/ on April 17, 2024 by guest. Protected by copyright.