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Multi-modal management of sport and non-sport related concussion by chiropractic sports specialists: a case series

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This case series describes the multi-modal treatment plans delivered by two chiropractic sports specialists for the management of post-concussive symptoms (PCS). Three concussion cases are presented each with different mechanisms of injury (two sport-related and one non-sport-related) and each within a different stage of recovery (acute, sub-acute, and chronic). Treatment plans included patient education, sub-symptom threshold exercise, soft-tissue therapy, spinal manipulation, and cervical spine as well as visual/vestibular rehabilitation exercises. This series highlights three important observations: (1) the efficacy of individualized, multi-modal treatment plans based on suggested clinical profiles for patients with PCS of

Cette série de cas sert à présenter les plans multimodaux utilisés par deux spécialistes de la chiropratique sportive pour traiter des symptômes postcommotionnels (SPC). Trois cas de commotion cérébrale pour chaque type de mécanisme de lésion (deux cas de blessure liée au sport et un cas de blessure non liée au sport), chacun avec un stade différent (aigu, subaigu et chronique). Les plans de traitement englobaient l'information au patient, la réduction du seuil nociceptif par des exercices, le traitement des tissus mous, des manipulations vertébrales, des manipulations cervicales et des exercices de rééducation visuelle et/ou vestibulaire. Cette série de cas met en relief trois importantes observations, à savoir : 1)l'efficacité des plans multimodaux personnalisés élaborés selon les profils cliniques suggérés de patients présentant des SPC de divers stades sont efficaces; 2) la segmentation de la littérature sur la commotion cérébrale selon le

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various stages; (2) that the delineation of concussion literature based on mechanism of injury (i.e. sport- vs. non-sport-related) may be unnecessary; and (3) these cases provide encouraging evidence to support the inclusion of manual therapists with advanced knowledge of concussion treatment, such as chiropractors, as part of the interdisciplinary healthcare team when managing patients with PCS.

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KEY WORDS: concussion, concussion treatment, mild traumatic brain injury, multi-modal care, post-concussion syndrome, sport-related concussion, chiropractic

mécanisme de la blessure (commotion liée au sport et commotion non liée au sport) pourrait s'avérer superflue; et 3) ces cas fournissent des preuves encourageantes qu'il est pertinent d'inclure un thérapeute manuel possédant des connaissances poussées en matière de traitement des commotions cérébrales, comme le chiropraticien, à l'équipe interdisciplinaire de soins de santé prenant soin du patient ayant des SPC.

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MOTS CLÉS : commotion cérébrale, traitement de la commotion cérébrale, lésion cérébrale traumatique bénigne, traitement multimodal, syndrome postcommotionnel, commotion cérébrale liée au sport, chiropratique

Introduction

Concussion is a form of mild traumatic brain injury (mTBI) which can occur as a result of a motor vehicle accident, workplace related injury, a fall, or through participation in both contact and non-contact sport.[1,2] The Canadian Institute for Health Information (CIHI) reported that over a one-year period (2016-2017) non-sport related concussion (non-SRC) accounted for the majority (74%) of all brain injuries presenting to emergency departments in Ontario and Alberta, with sport-related concussions (SRCs) therefore only being responsible for the remaining 26%.[2] With that in mind, the CIHI also reported that the number of emergency department visits for SRC has increased by almost 28% over the last five years.[2]

Although the current trend in concussion literature is to separate SRC and non-SRC as individual entities, the only real distinction between the two conditions is the context in which the concussion is acquired. Given this seemingly arbitrary division between SRC and non-SRC, this paper will use the terminology 'concussion / mTBI' to refer to both SRC and non-SRC.

Numerous definitions of concussion / mTBI have been proposed, which remains a significant limitation in the existing literature. However, according to the most recent Consensus Statement on Concussion in Sport, concussion is defined as the onset of short-lived impairments of neurological function following a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.[3] The associated non-specific symptoms of both SRC and non-SRC may be of cognitive, visual, vestibular, physiological, or cervical spine origin.[4-7] The typical recovery time for adults is within 10 to 14 days, and up to four weeks in adolescents.[3] Unfortunately, a significant number of patients (23-47%) [8-10] will experience symptoms persisting longer than this time frame, and are subsequently diagnosed with persistent post-concussion symptoms (PPCS). The definition of PPCS is also inconsistent, but according to the most recent position statement released by the American Medical Society for Sports Medicine, it refers to the persistence of symptoms beyond the expected recovery time frame (greater than two weeks in adults, and four weeks in children) and does not necessarily represent ongoing concussive injury to the brain.[11] Other organizations, like the Ontario Neurotrauma Foundation (ONF), define PPCS as those still experiencing symptoms for greater than three months.[1]

There are a number of possible causes for post-concussion symptoms. There is evidence supporting theories such as brain blood flow abnormalities, metabolic/inflammatory contributors, visual and vestibular disorders, cervical spine dysfunctions, and even psychological causes.[1,3,7,11,12]

Despite this uncertainty, there is a consistent recommendation that individuals with PCS resulting from both SRC and non-SRC be managed by an interdisciplinary healthcare team with advanced concussion training through an impairment-based, multi-modal plan of management.[1,3,11] The purpose of this case series is to describe the efficacy of individualized multi-modal treatment plans delivered by chiropractic sport specialists for the management of acute, sub-acute, and chronic post-concussion symptoms originating from both sport and non-sport-related mechanisms of injury.

Case study 1

A 15-year-old elite female taekwondo athlete presented to the sports chiropractor with complaints of headache, dizziness, and neck pain of two days in duration. Symptoms began after she lost balance during an attacking kick and fell on her right shoulder while striking her head on the ground. The patient reported hearing a loud 'crack' sound in her neck at the moment of head impact and proceeded to lose consciousness for several seconds. She was immediately assessed by a certified emergency first responder for the taekwondo event who, at the time, reported her Glasgow Coma Scale as being 15/15. The sideline assessment also revealed cervical spine tenderness and the patient reported bilateral upper limb paresthesias with some objectively noted weakness in her fingers and toes. The emergency first responder proceeded to immobilize the athlete's cervical spine and contacted Emergency Medical Services. After being transported to the hospital by ambulance, cervical spine radiographs were taken and ultimately read as unremarkable. The attending emergency medical doctor diagnosed the athlete with a concussion and discharged the patient that evening.

At the two-day follow-up, further questioning by the chiropractor revealed that the patient was still experiencing a constant throbbing sensation in her head with occipital headaches rated 7-8/10 in intensity. These occipital headaches were aggravated primarily by noise and were not associated with any photophobia or aura. The patient was, however, reporting continued neck pain, nausea, and dizziness upon waking in the mornings. Her neck pain was located along the lower midline of her cervical spine, was rated at an intensity of 7/10, and was aggravated with cervical ranges of motion in all directions but particularly in right cervical rotation. The athlete was not reporting any referred pain into the upper extremities but was experiencing intermittent tingling in her fingers and toes bilaterally which occasionally lasted up to five-minutes before slowly resolving. A Neck Disability Index (NDI) was administered and was scored as 21/45 which is considered to be the upper limit of the 'moderate disability' category (five points excluded from the total because the patient did not drive). Additionally, the patient completed a Post-Concussion-Symptom Scale (PCSS) as part of the Sport Concussion Assessment Tool 3rd Edition (SCAT3) assessment which was scored as 125/132 (higher score equates to greater reported symptom severity). The SCAT5 was not yet released at the time of the patient presentation in this case. However, minimal changes were made to the symptom scale portion of the SCAT between the third and fifth editions.

Physical examination did not reveal any evidence of bruising, swelling, or deformities in the patient's upper body or head. Her active and passive cervical ranges of motion were restricted by 50% in all directions eliciting lower cervical spine pain in all directions, but most significantly with right cervical rotation. Resisted cervical spine ranges of motion caused right-sided cervical spine pain during right rotation, right lateral flexion, and extension. A cranial nerve exam (I-XII) along with a neurological assessment of the upper and lower limb deep tendon reflexes (C5-7, L4-S1) and motor and sensory systems (C5-T1, L2-S1) were within normal limits. Assessment of cerebellar function consisting of the Romberg test, rapid alternating movements, graphesthesia, and point-to-point tests were also performed and were within normal limits. Upper and lower nerve tension tests were negative. Orthopedic tests such as Jackson's, Spurling's, Kernig's, and the Slump test were unremarkable. Hypertonicity and tenderness were noted in the right upper trapezius, suboccipital muscles, levator scapulae, and rhomboid with her headache symptoms being reproduced during palpation of the right upper trapezius, suboccipital muscles, and challenging the right C1-2 facet joint. Further joint restrictions were found from C5-7 on the right, C2-3 on the left, along with T3-5 and the third and fourth costotransverse joints bilaterally.

The patient was diagnosed with: (1) a SRC; (2) grade-II Whiplash Associated Disorder (WAD II) with associated cervical and upper thoracic / costotransverse joint dysfunctions; and (3) cervicogenic headaches. The inter-

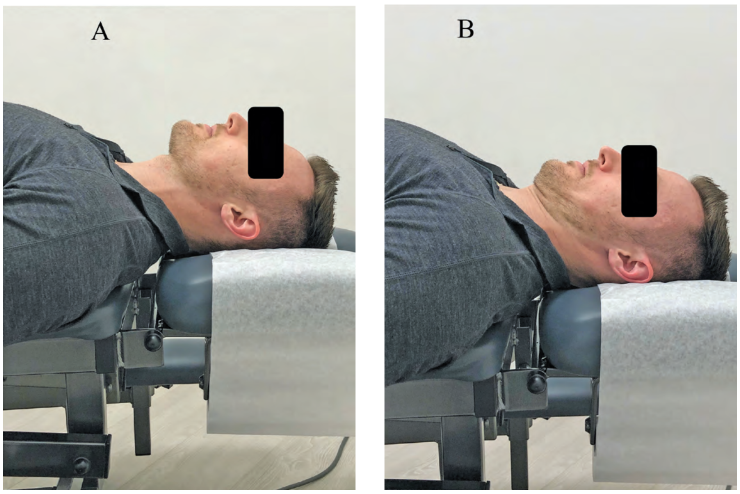

Figure 1.
Deep neck flexor strengthening exercises.
(A) Patient lies supine in a relaxed position.
(B) Patient performs a chin-tuck through active cervical retraction.

Figure 2.
(A) Single leg & (B) tandem stance exercises.
The patient performs three sets of 20 second holds beginning with their eyes open and progressing to eyes closed.

mittent tingling reported in the upper and lower limbs was suspected to be a result of possible transient spinal shock (cervical cord neuropraxia), given that the patient's symptoms had been progressively resolving during the 48-hour period following her injury. Differential diagnoses included a central cervical disc herniation, or a bilateral brachial plexus injury (i.e. 'burner/stinger'). She was treated for a total of 16 sessions over eight-weeks (three sessions per week for four-weeks, then one session per week for four-weeks). Over the course of her care, her treatment included a combination of spinal manipulation, Vibromax Therapeutics Soft Tissue Therapy® (VMTX), interferential current therapy (IFC), heat, and needle acupuncture (Du-20, LI-4). A graded return-to-play (RTP) protocol as described in the 5^{th} Consensus Statement on Concussion in Sport [3], along with home-based neck stretches and cervico-vestibular rehabilitation exercises such as single leg and tandem stance were prescribed.

The patient was initially advised to undergo a period of relative rest at home for one-week where she was allowed to engage in activities that did not aggravate her symptoms. The numbness / tingling in her fingers and toes completely resolved within the following 24 hours, and she reported that the concomitant chiropractic treatments were decreasing the intensity of her headache and neck pain. Following this one-week period the patient returned to school but was unable to tolerate the noise of the classroom environment, and had difficulty working on her computer for greater than one-hour without aggravation of her headaches. The patient was advised to continue to participate in school-related activities only within symptom tolerance and to perform short, daily walking sessions. At this point in time she was able to walk for 20-minutes before experiencing headaches.

10-days post-injury, the patient was prescribed a deep neck flexor exercise and single / tandem stance balancing exercises (three sets held for 20-seconds each) (Figures 1 and 2 respectively). At two-weeks post-injury, the patient was attending school full-time and was able to walk for 30-minutes without aggravating her headache symptoms. She reported one incident of noise-related headache exacerbation after watching a training session at her taekwondo school, but then did not experience any headache symptoms for a 48-hour period while still adhering to her exercise program. At this point in time, the chiropractor recommended that the patient begin jogging 10 minutes per day in conjunction with her current exercise program. Within a short time, the patient was able to spectate during a full day of competition and jog for 20 consecutive minutes without eliciting a headache, at which point non-contact taekwondo kicking drills were recommended.

At the six-week mark the patient reported 80% improvement in her symptoms and a repeat NDI was scored as 7/50. Cervical spine ranges of motion were now full but mildly painful at all end ranges and palpation of her right suboccipital muscles and C1-2 joint challenging still slightly reproduced her headaches. As a result, the patient was treated with continued spinal manipulation and VMTX therapy once per week for an additional two-weeks after which these symptoms resolved. The patient was subsequently cleared to go back to full activity and was advised to return to the clinic if her headache or dizziness symptoms returned. A final follow-up appointment was performed three-months post-injury where the patient reported she had successfully returned to normal daily activities but was no longer competing in taekwondo due to unrelated personal reasons. Unfortunately, no final SCAT3 was performed at this time.

Case study 2

A 14-year-old elite female taekwondo athlete presented to a sports chiropractor with complaints of headaches, neck pain, and feelings of disorientation and dizziness after receiving a kick to the left jaw during her training nine-days earlier. She denied any loss of consciousness and did not report any nausea or vomiting at the time of the injury or in the following days. She did not seek out treatment initially, but rather managed her symptoms by resting at home for two days. The patient returned to school two days after the injury and reported aggravation of her headache and neck pain symptoms, with further aggravation of these symptoms following a light taekwondo training session (non-contact) now eight days after the injury.

Her neck pain was located in the sub-occipital region and was rated at 7/10 in intensity and characterised as 'stiff and tight'. The patient denied any radicular or referred symptoms into the upper limbs but noted that her neck pain was aggravated with both left and right cervical rotation. The chiropractor administered an NDI which was graded as 20/45 indicating a 'moderate' level of impairment due to her neck pain (five points excluded from the total because the patient did not drive). The patient indicated that her headaches were located in the temporal and frontal regions of her head, and that she experienced sharper headaches rated at 7-8/10 in intensity intermittently throughout the day. These periods of sharper headaches were accompanied by instances of photophobia, but she denied any nausea, vomiting, or presence of an aura in the hours preceding the sharp pains. The patient also reported bouts of dizziness when transitioning from a seated to standing position. A SCAT3 was also administered during the initial assessment with the patient recording 22/132 on the PCSS component of the test battery (Table 1). A baseline SCAT3 had been completed three-months prior to the injury where the patient recorded a PCSS score of 1/132. Similar to Case 1, the SCAT5 was not yet released at the time of the patient presentation in this case. However, minimal changes were made to the symptom scale portion of the SCAT between the third and fifth editions.

Table 1.
Summary of SCAT3 scoring for case study 2.
Max – Maximum; Sec – Seconds;
M-BESS – Modified Balance Error Scoring System

Test Domain	Score		
	3-months pre-injury (baseline)	**9-days post-injury**	**1-month post-injury**
Number of symptoms (max: 22)	1	7	7
Symptom severity score (max: 132)	1	22	13
Orientation (max: 5)	5	5	5
Immediate memory (max: 15)	15	14	15
Concentration (out of 5)	2	3	2
Delayed recall (out of 5)	4	5	5
M-BESS (total errors)	0	3	1
Tandem Gait (sec)	0	16	14
Coordination (max: 1)	1	1	1

On the physical examination the patient's blood pressure was measured as 106 / 72 with a heart rate of 60 beats per minute. Her active and passive cervical ranges of motion were limited by 25% in bilateral lateral flexion and extension which reproduced her suboccipital neck pain. Her temporal and frontal headaches were recreated during palpation of her suboccipital musculature, right C0-1 and left C1-2 vertebral segments. Further hypertonicity and tenderness were noted in the upper trapezius, levator scapulae, rhomboid, and thoracic longissimus muscles bilaterally. An assessment of the temporomandibular joint was unremarkable and did not reveal any dental injuries, nor did it recreate the patient's headache symptoms. A cranial nerve exam (I-XII), and a neurological assessment of the upper limb deep tendon reflexes (C_{5-7}) and motor and sensory systems (C_5-T_1) were within normal limits.

The patient was diagnosed with: (1) a SRC; and a (2) grade-II Whiplash Associated Disorder (WAD II) with associated cervicogenic headaches. She was treated by the chiropractor eight-times over five-weeks (three sessions per week for one-week, then two sessions per week for one-week, followed by one session per week for three-weeks). Over the course of her care, the multimodal plan of management included spinal manipulation, VMTX soft-tissue therapy, IFC, heat, needle acupuncture (Du-20, LI-4), a graded RTP protocol, and a home-based cervico-vestibular rehabilitation program similar to that described in Case Study 1 (Figures 1 and 2). Additionally, because the athlete's mother reported that the athlete had been craving more 'sweets' since the time of her concussion, a 'brain recovery diet' high in unrefined carbohydrates (i.e. real fruit juices, brown rice, pasta) was encouraged to try and counteract the possible blood-brain-barrier dysfunction and reduced intra-cerebral glucose levels that have been associated with concussion.[13]

After the first two treatments the patient reported improvements in the intensity and frequency of her headaches, however certain daily activities such as reading and climbing stairs continued to be mildly aggravating for her. After the third visit, the patient's headaches were no longer occurring daily and only lasting one-to-five minutes despite being back in school. The chiropractor then proceeded to prescribe deep neck flexor strengthening exercises (Figure 1) along with daily walking to symptom tolerance. The patient was re-assessed after three-weeks of treatment (one-month post-injury). She no longer reported having headaches, and that reading and climbing stairs, amongst other daily activities, no longer aggravated her symptoms. A repeat NDI revealed a reduced score of 4/45 ('no impairment'), and a reduced PCSS of 13/132 (Table 1). All cervical ranges of motion were now full and pain free and palpation of cervical and upper thoracic musculature no longer recreated her headache symptoms. The patient was then cleared to return to full activity / training with the exception of full contact taekwondo sparring. Following an additional two treatment sessions over a two-week period, the athlete reported 11 consecutive days without reoccurrence of her headache symptoms. At this point the athlete was cleared for full RTP and was discharged with the recommendation to follow-up for re-assessment should her symptoms return. At the time of her last follow-up (now six-weeks post-injury), the athlete was symptom-free and had successfully returned to full-contact taekwondo. No additional outcome measures were completed at the six-week mark.[11]

Case study 3

A 27-year-old female presented to the sports chiropractor with a six-year history of PPCS. Her symptoms initially began six years ago after she fell and subsequently struck the left parietal and temporal region of her head on a step. The patient reported experiencing an immediate headache, nausea, balance issues with blurred vision, along with mental confusion and feeling like she was 'in a fog'. She did not report the occurrence of any red flags such as evidence of cranial fracture, progressively worsening headache, deteriorating mental state, or progressive neurological symptoms such as motor or sensory deficits. The patient also did not report any antero-or-retrograde amnesia.

After seeking immediate care for the initial injury at a local hospital and having all diagnostic imaging studies (computed tomography and magnetic resonance imaging) return negative results for cranial fracture or moderate-to-severe traumatic brain injury, the attending physician placed her on prescribed bed rest for a period of approximately four-weeks. With little improvement in her symptoms over this rest period, she sought further care from a sports medicine physician. Once again, she was placed on bed rest, advised to withdraw from school activities, and instructed to spend time in a dark room to prevent further exacerbation of her symptoms.

Table 2.
Initial Post-Concussion Symptom Scale (PCSS) scores for case study 3.

Symptom	Score	Symptom	Score
Headache	3/6	Pressure in Head	3/6
Neck Pain	0/6	Nausea or Vomiting	2/6
Dizziness	3/6	Blurred Vision	6/6
Balance Problems	2/6	Sensitivity to Light	2/6
Sensitivity to Noise	5/6	Feeling Slowed Down	4/6
Fogginess	5/6	Don't Feel Right	5/6
Difficulty Concentrating	3/6	Difficulty Remembering	1/6
Fatigue or Low Energy	4/6	Confusion	3/6
Drowsiness	0/6	Trouble Falling Asleep	2/6
More Emotional	4/6	Irritability	4/6
Sadness	4/6	Nervous or Anxious	3/6
Totally Symptom Severity		68/132	
Total Symptoms		20/22	

She remained on bed rest for a period of eight-months. Gradually her symptoms improved enough to resume her schooling, however she never achieved complete recovery. The patient experienced several additional minor head impacts which repeatedly exacerbated her symptoms over the following six years. With each exacerbation of her symptoms, the patient was prescribed further bed rest by her medical doctor. Upon presenting to the chiropractor, the patient had been prescribed a cumulative total of 11-months bed rest since the initial injury.

During the initial assessment with the chiropractor, the patient reported ongoing headaches primarily in the left temporal/parietal region, along with intermittent frontal headaches felt bilaterally. These headaches were accompanied by dizziness and blurred vision. She experienced continued phonophobia, difficulty concentrating, fatigue and low energy, along with irritability and sadness. A complete copy of her PCSS can be seen in Table 2. The patient ultimately scored 68/132 on the PCSS, experiencing a total of 20 out of the 22 symptoms assessed. The patient denied ever being diagnosed with any behavioural disorders or learning disabilities, and has no previous history of headaches, anxiety, depression or sleep disorders – conditions commonly thought to increase the likelihood of developing PPCS [3,11].

A neurological exam consisting of a cranial nerve (I-XII) screen, pronator drift and cerebellar testing, upper limb deep tendon reflexes (C5-C7), dermatomal sensory testing (C5-T1), and motor function (C5-T1) were all within normal limits. Upon conclusion of this initial assessment, the patient was diagnosed with PPCS of unknown origin. The patient was provided with the diagnosis, educated on the plan of management and expected clinical course of PPCS, cleared for full days of work/school with modifications, and was restricted from exercise until a graded exercise tolerance test could be performed. Similar to Case Study 2, this patient was also provided with a 'brain recovery diet' consisting of three balanced meals. More specifically, the patient was encouraged to avoid refined sugars/carbohydrates (i.e. white bread or pasta) and select natural sources of carbohydrate instead, to select quality sources of protein (i.e. lean cuts of grass fed, free-range meats), to include quality fats (i.e. products high in omega-3 fatty acids), and select foods rich with natural antioxidants. Contrary to Case Study 2, this diet was designed to temporarily reduce the patient's caloric intake – a concept which will be further examined in the Discussion section of this paper.

The patient returned one-week later to conduct a Buffalo Concussion Treadmill Test (BCTT). The BCTT protocol was completed as originally described by Leddy *et al*. (2013).[14] The patient's BCTT results are shown in Table 3. The patient was able to complete the entire test, which was stopped at the 14-minute mark due to the patient reaching her age-predicted maximum heart rate of 193 bpm. After passing her graded exercise testing, the patient was then encouraged to participate in light aerobic sub-symptom threshold exercise where there was no or little risk of head contact (i.e. treadmill walking or stationary biking).

Two days after the graded exercise testing, the patient returned to the chiropractor reporting that she completed a 20 to 25 minute walk the previous day, and that the intensity of her headache was reduced. The total symptom severity score on the PCSS dropped 55 points to 13/132, and the total number of symptoms dropped by 11 points to 9/22. The chiropractor then performed a Vestibular / Ocular Motor Screening (VOMS) test as well as a cervical spine examination consisting of cervical spine ranges of motion, joint motion palpation, and an assessment of the cervical spine soft tissues. The complete VOMS testing protocol along with a discussion of its' internal consistency and validity is described by Mucha *et al*. (2014).[15]

The patient reported symptom provocation of ≥ 2 points (a positive result) during both the horizontal and vertical vestibulo-ocular reflex (VOR) components of the

Table 3.
Buffalo Concussion Treadmill Test (BCTT) results with recorded walking time (minutes), treadmill incline (%), heart rate (bpm), any reported change in symptoms, and rational for terminating the test.

Time (minutes)	Treadmill Incline (%)	Heart Rate (bpm)	Reported Change in Symptoms
0:00	0	90	—
1:00	1	106	—
2:00	2	106	—
3:00	3	115	—
4:00	4	125	—
5:00	5	133	—
6:00	6	139	—
7:00	7	149	—
8:00	8	158	—
9:00	9	168	—
10:00	10	174	—
11:00	11	177	—
12:00	12	185	—
13:00	13	188	—
14:00	14	192	Test stopped due to patient reaching max heart rate
15:00	Cool Down		
16:00	Test Complete		

VOMS test (Table 4). During the VOR procedure, the patient fixates on a central point while moving his/her head in repetitive left and right rotation and then flexion and extension.[15] This procedure tests the function of the VOR and one's ability to stabilize his or her gaze during dynamic head movements.[15] The horizontal and vertical VOR movements were then prescribed as gaze-stability exercises to be performed daily to symptom tolerance (Figure 3). Although accommodation and convergence scores were also flagged during the VOMS test, this was thought to be caused by previously existing circumstances as the patient was wearing prescription glasses for these deficits. The cervical spine examination revealed tenderness upon palpation of primarily the left deep neck flexor muscle group, along with the left sternocleidomastoid (SCM) and suboccipital muscles – both of which referred pain to the left frontal region of the patient's forehead. Motion palpation revealed joint restriction at the C0-C1 and C2-C4 levels, with manual provocation of the C2-C3 levels recreating the patient's bi-temporal and frontal headaches. Joint restrictions were also found in the mid-thoracic (T3-T5) region and the associated costotransverse joints.

The chiropractor treated the above clinical findings at a frequency of one session per week over four-weeks with an average of five days between visits. A combination of myofascial release therapy and acupuncture was used to

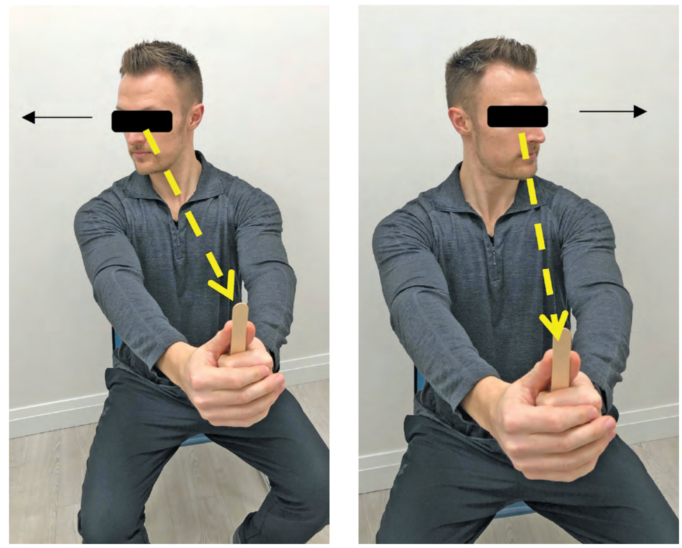

Figure 3.
Gaze stability exercises. The patient is asked to rotate his/her head horizontally while keeping the eyes focused (yellow arrow) on the target held roughly three feet in front of him/her. The head is rotated 20 degrees to each side and a metronome is used to ensure the speed of rotation is maintained at 180 beats/minute (one beat in each direction). The same procedure is used during the vertical gaze stability exercise, except the patient flexes and extends their head 20 degrees in each direction.

Table 4.
Vestibular / Ocular Motor Screening (VOMS) test results for case study 3.

Test Component	Headache (0-10)	Dizziness (0-10)	Nausea (0-10)	Fogginess (0-10)	Distance (cm)	Detected Abnormality?
Baseline Symptoms	**3**	**0**	**1**	**1**	**—**	**—**
Smooth Pursuits	2	0	1	1	—	No
Saccades -Horizontal	2	0	1	1	—	No
Saccades -Vertical	2	1	1	1	—	No
VOR – Horizontal	3	2	0	2	—	Yes
VOR – Vertical	4	3	1	2	—	Yes
Visual Motion Sensitivity Test	2	2	1	1	—	No
Accommodation – Left	2	1	1	1	13	Yes
Accommodation – Right	2	1	1	1	11	Yes
Convergence	2	2	1	2	8	Yes

treat the affected soft tissues, and spinal manipulation for the restricted joint segments. The patient reported immediate improvements in her symptoms following the first treatment. At the time of the patient's final visit, her symptom severity score had reduced to 4/132, and total symptom number to only 3/22. The three remaining symptoms of neck pain, pressure in the head, and blurred vision were only scored between one-and-two on a scale of six (most severe). Over the following two-weeks, the patient described that the frequency and intensity of her headaches and blurry vision had reduced significantly, going some days with no symptoms at all. To date, the patient remains in contact with the treating chiropractor receiving care for unrelated complaints and continues to report complete resolution of her concussion symptoms.

Discussion

The featured cases describe the experiences of three young females who suffered a concussion / mTBI each with a different mechanism of injury (SRC vs. non-SRC) and each with a different duration of symptoms (acute, sub-acute, and chronic). All three patients were eventually managed by chiropractic sports specialists using an individualized, multi-modal therapy program that included manual therapy, sub-symptom-threshold aerobic exercise, cervical and visual/vestibular rehabilitation, and dietary modifications (Cases 2 and 3).

One important comparison to make among the featured cases is the approach to prescribed rest by the various clinicians involved. The patient in Case Study 3, the only one to develop persistent and chronic symptoms, was primarily managed via prescribed rest by the first three healthcare practitioners she accessed. Prescribed rest until the point of symptom resolution is one of the most commonly used treatments in concussed patients.[11,16,17] However, the recommendation for physical and cognitive rest following a concussion is based mainly on dated expert opinion / consensus.[3,16] A recent systematic review found that the "best available evidence from clinical studies does not support the efficacy of prescribing complete rest for more than a few days" [16], and the most recent position statement by the American Medical Society for Sports Medicine seconds this argument.[11] As a result, the scientific community has begun to more thoroughly investigate the impact of individualized multi-modal treatments both acutely following a concussion, and in situations of PPCS.[6,7,12,18-21]

The concept of 'clinical profiles' or 'domains' of concussion presentation has become a more popular approach when designing multi-modal treatment plans.[11] Encouraging the discussion of these profiles was one of the main purposes of this case series. The proposed sub-types are based on the underlying deficits thought to be responsible for the patient's post-concussion symptoms, and may be: (1) physiologic, (2) vestibular/oculomotor, (3) cervicogenic, or (4) biopsychosocial in nature.[7,11] Additionally, it has been suggested that patients with PCS likely fall into multiple domains, and as such, should undergo a thorough evaluation for each profile before their treatment is decided.[7,11] This describes the treatment approach that was used by the chiropractic sports specialists in each of the three cases in this series.

The physiologic clinical domain primarily refers to those whose symptoms are exacerbated by aerobic exercise. It has been reported that some concussed individuals experience autonomic dysfunction following injury, leading to significant alterations in cerebral blood flow (CBF) and cardiac rhythm.[7,11,12] One study noted that in female athletes with persistent symptoms similar to those experienced by the patient in Case 3, "CBF increased out of proportion to exercise intensity when compared with non-concussed athletes exercising at the same intensities".[12] Further, it was found that this increased CBF was associated with the development of headaches and dizziness in those patients.[12] The BCTT is said to be one of the most well studied graded exercise tests that can be used to establish sub-symptom exercise thresholds, and is ideal for use in patients with PCS.[11] Additionally, sub-symptom aerobic exercise based on the results of the BCTT has been found to be safe and improve symptom resolution particularly in those patients with PPCS.[11,12] Hence, the BCTT was used to try and identify exercise thresholds in the PPCS case described above (Case Study 3). In this particular instance, the BCTT did not reveal any signs of persistent physiologic exercise intolerance, as the patient was able to reach her age-predicted maximum heart rate (193 bpm) without symptom exacerbation (Table 4). This is not uncommon, since it is thought that approximately two-thirds of concussed patients do not fall into the physiologic clinical profile.[12]

On the other hand, many PCS symptoms are more commonly thought to be a result of some combination of the visual, vestibular, or cervicogenic domains.[12] The aforementioned domains can be clinically assessed in a number of ways. The three cases discussed in this series included a combination of cranial nerve testing, the balance component of the SCAT3 evaluation (a test that is unchanged in the updated SCAT5 version), a cervical spine assessment, and the VOMS test to assess for the contributions of the visual and vestibular systems toward the patients' symptoms. The VOMS test has demonstrated good sensitivity for identifying patients with concussive symptoms originating from visual or vestibular impairments.[11,15] Additionally, targeted vestibular rehabilitation therapy based on the significant findings from the VOMS test have been shown to improve symptom resolution in individuals with complaints of unbalance or dizziness, and may be more beneficial than continued physical and cognitive rest in this patient population.[4,22] The patient in Case Study 3 demonstrated positive test results during both the horizontal and vertical VOR components of the VOMS test. She was given gaze-stability exercises where the patient is required to fix her eyes on stable target while moving her head in repetitive horizontal and then vertical motions (Figure 3).[5] Gaze-stability training is prescribed based on an 'expose-recover' model where patients perform the given exercises to the point of symptom provocation, then rest, and repeat the exercise again.[5] Patients then progressively increase the volume of training as their capacity to do so improves.[5] The vestibulo-ocular systems in the patients from Case Studies 1 and 2 were trained via more traditional balance exercises, single leg and tandem stance, and were guided through a series of progressions to further challenge their balance and spatial awareness (i.e. eyes open / closed, stable/unstable surface, and accessory movements of the upper limbs).

The remaining clinical profile relevant to all three cases was the involvement of the patients' cervical spine. Each of the patients in Cases 1 through 3 presented with numerous cervical joint restrictions and hypertonic muscles, some of which recreated their chief complaints when provoked. The American Medical Society for Sports Medicine concluded that there is preliminary evidence that addressing cervical spine dysfunctions through targeted physical therapy programs can lead to improved outcomes in patients with PCS.[11] The effectiveness of spinal manipulation for post-concussion headaches specifically is limited, however cervical manipulation has proven to be beneficial in the management of common headache disorders including migraines and cervicogenic headaches.[23] Given the clinical findings in all three cases, spinal manipulation was deemed appropriate and appeared to provide benefit to the patient as part of a multi-modal treatment plan. Further research investigating the efficacy of spinal manipulation specifically for the management of neck pain and headaches in PCS patients is warranted.

One final component to the management of Case Studies 2 and 3 was the inclusion of a 'brain recovery diet'. There is a paucity of literature on specific nutritional / dietary interventions for the prevention and treatment of mTBI in humans, with the majority of research focusing on the role of nutrition in cognitive function of elderly and for the management of moderate to severe TBI. It is understood that following a concussion / mTBI there is a cascade of immunological, excitotoxic, and neuroinflammatory events leading to oxidative stress and cell death.[13,24] This on-going neuroinflammatory and excitotoxic state has been suggested as a possible contributor to the continuing symptoms in those who develop PPCS.[24] Recent evidence suggests that natural anti-inflammatory agents such as omega-3 essential fatty acids, vitamin D_3, and curcumin may offer benefit in immunoexcitotoxicity-associated neurodegenerative disorders by suppressing microglial activation and the ensuing excitotoxic / inflammatory cascade that follows.[24-26] Diets high in refined sugars and processed meats are thought to be pro-inflammatory.[27] Therefore, both of the brain recovery diets provided to the patients in Cases 2 and 3 encouraged the selection of unrefined carbohydrates and non-processed meats. Lastly, the patient in Case Study 3 was encouraged to only consume three balanced meals per day, as there is preliminary data from both animal and human models (primarily the elderly) to suggest that short-term caloric restriction (30-40% reduction) may exert neuroprotective effects following concussion / mTBI.[28,29,30] Another key feature of the neurometabolic cascade discussed above is the 'energy crisis' created within the brain due to the uncoupling of CBF and glucose metabolism early on following injury. This uncoupling describes a state of reduced CBF (and therefore the delivery of glucose/ energy) combined with the temporary state of hyperglycolysis within the brain, which creates a mismatch in the supply and demand for glucose.[31] It was thought that the cravings for glucose / 'sweets' reported by the patient in Case Study 2 during the first few days post-injury could be related to such an 'energy crisis'. Thus, the athlete was encouraged to increase her intake of unrefined carbohydrate to try and mediate this energy mismatch and facilitate normal cerebral functioning acutely post-injury. The dietary modifications implemented in Cases 2 and 3 provide potentially promising but preliminary evidence of beneficial effects in patients with concussion / mTBI. However, further research on the efficacy of dietary interventions for concussion / mTBI and PPCS in young athletic populations is warranted. More specifically, it would be prudent to determine whether or not different nutritional recommendations should be made depending on the patient's age or phase of recovery (i.e. acute, sub-acute, or chronic), and whether or not pre-injury dietary habits may play a role in concussion recovery.

Limitations

This case series has a number of limitations. First, is the absence of original diagnostic imaging and laboratory reports for Case 3. During this time the patient relocated and changed family physicians and was not able to obtain copies of these investigations. These diagnostic reports would aid in describing the breadth of evaluations the patient in Case 3 had undergone and would emphasize the difficulty experienced in previous attempts at managing this case. Second, results from a baseline PCSS score in Cases 1 and 3, and a final follow-up PCSS score in Case 2 would provide reference upon which one could better judge the extent of the patients' recovery. Although the patient in Case 3 reported the continuation of three low-level symptoms at the point of discharge, it has been noted that both healthy controls and those with other co-morbidities report the presence of various non-specific symptoms that are also commonly experienced by those with PCS.[32] Therefore, one is unable to determine whether or not the patient would have reported these symptoms on a baseline PCSS even before her injury. Such a situation is well demonstrated by the baseline PCSS results of the patient in Case 2. Third, the use of a multi-modal treatment plan creates a challenge when trying to determine which intervention is providing therapeutic benefit to the patient. Fourth, although the recovery outcomes were positive in each of the three cases in this series, it should be noted that there are inherent limitations in the generalizability of case series results to other concussed patients. Fifth, the concept of 'clinical profiles / domains' is still an emerging theory, and it is uncertain at what time during recovery these clinical profiles become important with respect to treatment outcomes.[11] Additional research on the use of impairment-based, multi-modal treatment plans, along with the timing for which such a plan should be implemented is needed.

Summary

Concussion / mTBI can occur as a result of motor vehicle accidents, slip-and-falls, and through participation in professional or recreational sport. Emerging research suggests that patients diagnosed with PCS, regardless of the mechanism of injury, can be characterized by one or more clinical profiles based on their clinical assessment. These clinical profiles can then guide the development of individualized, multi-modal treatment plans that can significantly improve patients' symptoms. There is limited evidence describing the role that chiropractic sport specialists may play in the interdisciplinary management of concussion outside of sport. This case series describes three individualized multi-modal treatment plans delivered by sports chiropractors that included sub-symptomatic threshold exercise, vestibulo-ocular rehabilitation, spinal manipulation, soft-tissue therapy, and dietary modification during the management of both sport and non-sport related concussion. The positive results from this case series further contribute to the evolving literature supporting the role of chiropractors in the primary management of concussive symptoms of various origin and duration.

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