Clinical characteristics of the cervical spine in patients with persistent post-concussion symptoms: a retrospective analysis

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ABSTRACT

Background

Concussion is typically defined as a mild brain injury, and yet the brain is unlikely to be the only source of persistent post-concussion symptoms. Concurrent injury to the cervical spine in particular is acknowledged as a potential source of common persistent symptoms such as headache, dizziness and neck pain.

Objectives

To describe the cervical spine findings in a series of patients with persistent post-concussion symptoms, and describe the clinical characteristics of a cervicogenic component when it is present.

Design

Retrospective chart review of a consecutive series of patients with concussion referred to a physiotherapist for cervical spine assessment.

Method

Patient charts for all patients over a calendar year referred by a concussion service provider to a physiotherapist for cervical spine assessment were de-identified and transferred to the research team. Clinical data were independently extracted by two research assistants and analysed using descriptive statistics.

Results/findings

Data were analysed from 46 patient charts. Those with a cervicogenic component (n=32) were distinguished from those without a cervicogenic component (n=14) by physical examination findings, particularly pain on manual segmental examination. Physiotherapy treatment of the cervicogenic component (n=21) achieved improvements in function (mean increase of 3.8 in the patient-specific functional scale), and pain (mean decrease of 4.6 in the numeric pain-rating scale).

Conclusions

The clinical characteristics described in this study give preliminary support to the idea that the cervical spine may contribute to persistent post-concussion symptoms, and highlight the value of physiotherapy assessment and treatment of the cervical spine following a concussive injury.

Key words: brain concussion; neck; cervicogenic; physiotherapy

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INTRODUCTION

Concussion (also known as mild traumatic brain injury) is a common and significant health issue that can result in persistent symptoms. While definitions of 'persistent' symptoms vary, one commonly accepted definition is symptoms lasting beyond 10 days (McCrory et al., 2013). The after-effects of concussion are increasingly being recognised, with recent research showing nearly half (47.9%) of patients report significant persistent symptoms at one year post-injury (Theadom et al., 2016). Common symptoms are headache, dizziness, fatigue and a range of cognitive deficits. Why symptoms persist for so many people is unclear, with a wide range of factors potentially responsible. Many authors suggest that the brain is unlikely to be the only source of ongoing symptoms, and other contributing sources such as the cervical spine are likely (Leddy et al., 2016, Leddy et al., 2012, Leslie and Craton, 2013, Makdissi et al., 2013, Marshall et al., 2015, Schneider et al., 2014, Treleaven et al., 1994). Consistent with this view, Ellis et al. (2015) propose classifying concussion into physiological (brain-related), vestibulo-ocular and cervicogenic 'post-concussion disorders'. The authors suggest this classification would facilitate multi-disciplinary interventions addressing the sources of symptoms, and potentially improve outcomes.

The cervical spine is a well-established source of headaches (Bogduk, 2001, Jull et al., 2007, Sjaastad et al., 1998) and dizziness (Kristjansson and Treleaven, 2009, Malmstrom et al., 2007, Treleaven, 2011, Treleaven et al., 2003); symptoms that overlap with those experienced following concussion (Junn et al., 2015). Furthermore, common causes of concussion such as falls, transport accidents and sporting accidents are certainly capable of causing cervical spine injury (Leslie and Craton, 2013, Marshall et al., 2015). This is well illustrated by studies highlighting areas of overlap between the fields of whiplash and concussion (Alexander, 2003, Elkin et al., 2016, Hynes and Dickey, 2006).

Identifying the source(s) of persistent symptoms is important because the management of cervical spine related symptoms differs considerably from that of brain injury. The cornerstone of concussion management is physical and cognitive rest, followed by graded exertion (McCrory et al., 2013). In contrast, for cervicogenic pain, headaches and dizziness physiotherapy treatment has been shown to be effective, particularly manual therapy (Jull et al., 2002, Reid et al., 2015). The challenge lies in differentiating symptoms due to brain injury from those with cervicogenic or vestibulo-ocular causes. Leddy et al. (2015) found that reported symptoms, in particular cognitive symptoms, did not

differentiate brain-related from cervical or vestibular causes. As a result, the authors advocate for physical examination of the cervical spine to help identify cervicogenic contributors. Understanding the nature of cervical spine involvement in post-concussion symptoms may provide valuable insight that would guide management.

Original research investigating the role of the cervical spine in people with persistent post-concussion symptoms is currently limited. It is generally accepted that persistent post-concussion symptoms are not specific to brain injury, and other symptom sources should be considered (McCrory et al., 2013). The cervical spine is proposed to play an important role in persistent symptoms (Ellis et al., 2015, Leslie and Craton, 2013, Marshall et al., 2015), but this idea is largely untested. Patients with sport-related concussion have been shown to benefit from combined cervical spine and vestibular rehabilitation (Schneider et al., 2014). This clearly indicates a role for physiotherapy, but does not distinguish between the effects of cervical spine and vestibular rehabilitation or report the cervical spine findings in detail. A case-control study examined the cervical spine musculoskeletal dysfunction in 12 patients with chronic (>6 months) post-concussional headache who presented to a hospital neurosurgical department (Treleaven et al., 1994). Manual segmental examination of the cervical spine most clearly distinguished patients with chronic post-concussional headache from controls, indicating that physical examination of the cervical spine may be important following a concussion. These findings may be important, but it is not clear if these findings relate more broadly to patients with post-concussion symptoms, including those presenting to less specialised services. As a preliminary step to explore the role of the cervical spine the purpose of this study is to describe the clinical cervical spine findings in a cohort of patients with persistent post-concussion symptoms, following those referred to an experienced physiotherapist for cervical spine assessment in a private practice setting. Particular attention is given to the physical examination findings and treatment outcomes for those considered to have a cervicogenic component to their symptoms.

METHODS

A retrospective chart review of a consecutive series of patients with persistent post-concussion symptoms was performed. Ethical approval was granted by the university human ethics committee (H16/032). The study protocol was developed in line with recommendations for retrospective chart reviews by Vassar and Holzmann (2013).

Participants and setting

All patients referred from 1st April 2015 to 31st March 2016 to a single experienced physiotherapist (XX) in a private practice setting were considered for inclusion in the study. The study physiotherapist (XX) has worked clinically for 28 years, has a Masters degree in the field of orthopaedic manual therapy, and specific experience in assessing and treating patients post-concussion.

Patients were eligible if they were referred from a specialised and multidisciplinary concussion service, and seen by the study physiotherapist (XX) at least once for the purpose of cervical spine assessment. Patients referred from this concussion service have a medical diagnosis of concussion, require care beyond what is generally available at a general practice clinic, and typically have symptoms lasting >10 days. Note that not all patients in this service are referred for cervical spine assessment, the decision to refer is based on an initial interview and triage by the multidisciplinary team. The study physiotherapist (XX) performed a detailed cervical spine assessment and used a clinical reasoning process to categorise patients as with or without a cervicogenic component. This was reflected in the documented analysis and plan. Patients categorized as cervicogenic were recommended a course of physiotherapy treatment, typically including manual therapy. When this was undertaken by the study physiotherapist, the treatment notes were reviewed for this report.

Data extraction

The electronic charts for every eligible patient provided the data for the study (stored in Gensolve Practice Manager 5.3.0.124). These were de-identified and transferred to the research team. Two research assistants reviewed the patient charts and independently extracted the data variables of interest (Vassar and Holzmann, 2013). Both received training in how to navigate and understand the clinical notes, used an extraction manual outlining how each variable was to be recorded, and input data into a standardised excel spreadsheet. The assistants were blind to the main study purpose. A pilot test was conducted using the data extraction form with four patient charts (selected from outside the year of interest), to refine and standardize the process. Both assistants completed a full data extraction of all eligible patient charts. Following a week stand-down period, each assistant re-

extracted the data from five randomly selected patient charts to allow testing for intra-rater reliability. Inter-rater and intra-rater reliability were calculated using Cohen's kappa in SPSS version 24.

The data were categorized based on set criteria. Variables of interest that had >20% missing data were excluded from the analysis (e.g. headache frequency). In line with this, if a variable was not reported then this was treated as missing data, and could potentially result in exclusion of the variable. Ethnicity data were based on standard census categories. Injury cause categories were based on ICD-10 external cause classification as described by previous work (Feigin et al., 2013). Symptoms were categorised based on the history, symptoms/complaints and main problems recorded. Physical examination and treatment data were categorised as described in Table 1. Selected data were able to be transferred directly to the research team, including: work status (accessed directly from the concussion service provider); patient specific functional scale (PSFS), numeric pain rating scale (NPRS), and the outcome of assessment (accessed directly from the electronic note system). The PSFS and NPRS outcomes are standard routinely collected outcome measures in this clinic, and are presented in accordance with previous research (Nicholas et al., 2012). This includes reporting changes in actual score, percentage change, and percentage achieving full resolution. The percentage change was calculated by dividing the actual change in score by the available possible change. As the researchers describe, "… a patient moving from a 2 to an 8 in PSFS score would have a 75% resolution (a change of 6 out of a possible 8), whereas a patient moving from a 6 to an 8 in PSFS score would show a 50% resolution (a change of 2 out of a possible 4)" (pg. 149, Nicholas et al., 2012). The mean number of sessions was calculated for cervical spine sessions only (excluding treatment sessions for co-morbidities).

Table 1. Methods for categorising physical examination and treatment data

Characteristic	Categories	Notes
Neck AROM	Full range (no restriction), end-range restriction (end-range restriction only), mild restriction (at least one movement limited to 75% of normal), moderate restriction (at least one movement limited to 50% of normal), and severe restriction (at least one movement limited to 25% of normal). Movement restriction was documented as due to pain or stiffness.	Extracted from a diagram of movement
Neck pain during AROM	Yes / No	Based on any note of pain on AROM movement diagram (as opposed to stiffness)
Segmental findings of pain	Yes / No	Any findings of pain in the cervical and thoracic spine were considered a 'segmental finding of pain'
Segmental level(s) affected	Upper cervical (occiput-C3), lower cervical (C4-C7), thoracic (T1-12), or mixed (a combination of findings in any two categories).	
Segmental sidedness	Unilateral, bilateral	Segmental findings were considered bilateral if affecting both sides of the spine, or documented as central pain.
Tenderness on palpation	Head, neck, thoracic (including the shoulder), and general (affecting more than one region).	
Outcome of assessment	'Received further treatment', 'referred on', 'did not return', or 'no further treatment required'	Patients 'referred on' for cervical spine treatment typically lived out of town, or had an existing preferred provider.
Type of treatment	Manual therapy, acupuncture, stability exercises, or a combination of these.	Based on information from the pilot. Note patients also routinely received education, case management and advice, but for research purposes data extraction was limited to physical treatment.

AROM = Active range of movement

RESULTS

The clinic identified 46 patients who met the inclusion criteria (Figure 1). The inter-rater and intra-rater reliability using Cohen's Kappa are reported in Table 2. According to Landis and Koch (1977) overall this represents a substantial level of inter-rater agreement (0.61 – 0.80), and almost perfect intra-rater agreement (0.81 – 1.00).

The demographic and subjective data from all 46 patients is summarised in Table 3. Following the initial assessment 32 were considered to have a cervicogenic component to their symptoms, while 14 were referred back to the concussion service provider and did not receive further physiotherapy cervical spine treatment. The clinical characteristics of both groups are presented in Table 4. Of the 32 with a cervicogenic component to their symptoms; eight were referred on to other providers for cervical spine treatment, two were considered not to require treatment, and one did not return. The 21 remaining patients had subsequent cervical spine treatment from the study physiotherapist (XX). The treatment and outcomes for these patients are presented in Table 5. Note that a positive outcome is represented by an increase in PSFS score, but a decrease in NPRS score.

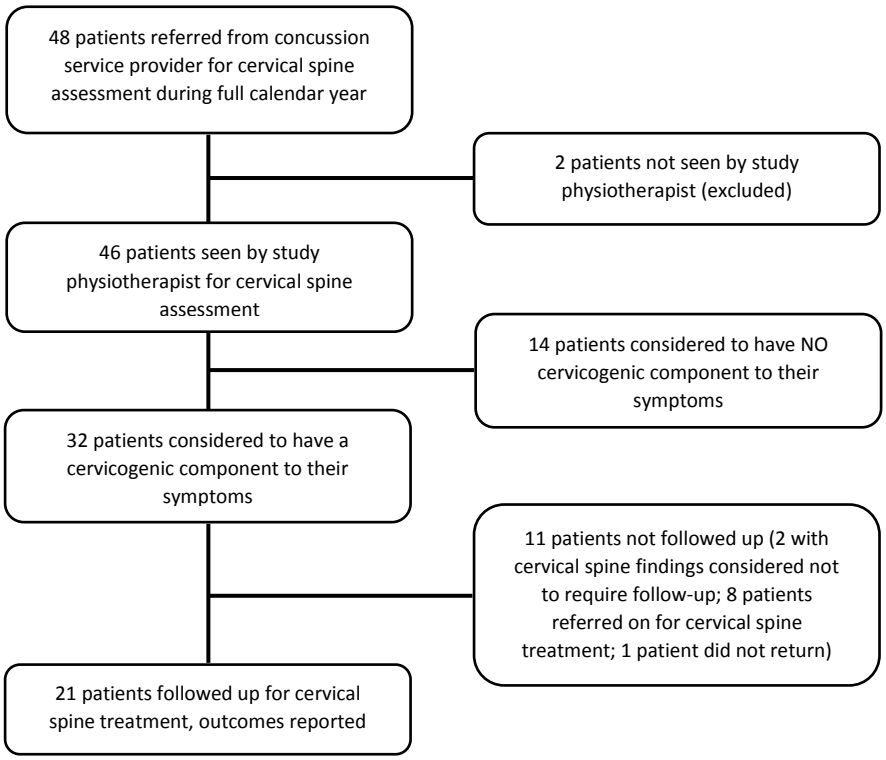

Figure 1. Flowchart of patient numbers from selection for chart review to exit

Table 2. Reliability of data extraction

Inter-rater reliability	**Average Cohen's Kappa (range)**
Demographic	0.99 (0.98 – 1.00)
Subjective data	0.70 (0.39 – 1.00)
Physical examination data	0.79 (0.67 – 0.93)
Treatment/outcome data	0.75 (0.37 – 0.97)
Overall average	*0.79*
Intra-rater reliability	**Cohen's Kappa**
Data extractor A	0.94
Data extractor B	0.88

Note that Kappa values were not calculated for fields where the data was not extracted from the clinical notes, but rather sent directly to the research team. These fields were: Work status (accessed directly from the concussion service provider); Patient specific functional scale, numeric pain rating scale, and outcome of assessment (accessed directly from the electronic note system).

Table 3. Demographic and subjective data

Characteristics	**n=46**
Mean age (Range, SD)	26.5 (Range 12-62, Standard deviation 12.0)
Male gender	21 (46%)
Ethnicity	NZ European 39 (85%) Other European 4 (9%) Maori 1 (2%) Asian 2 (4%)
Work status	Full time work 12 (26%) Part time work 4 (9%) Student 26 (57%) *(Polytech 1 (2%), School 9 (20%), University 16 (35%))* Retired 1 (2%) Unemployed 3 (7%)
Time since injury	Less than one month 7 (15%) 1-3 months 29 (63%) 4-6 months 3 (7%) More than six months 4 (9%) Unclear 3 (7%)
Cause of injury	Transport accident 8 (17%) Fall 11 (24%) Mechanical force 16 (35%) *(Sport related 13 (28%), Non sport related 3 (7%))* Assault 11 (24%)
Headache symptoms	Yes 45 (98%)
Dizziness symptoms	Yes 23 (50%)
Subjective neck pain	Yes 21 (46%)
Subjective neck stiffness	Yes 12 (26%)

Data are n (%) unless otherwise specified.
Data in italics give a further breakdown of a category.

Table 4. Clinical characteristics of patients with and without a cervicogenic component*

Characteristics	Cervicogenic component (n=32)	No cervicogenic component (n=14)
Mean age (Range, SD)	26.9 (Range 12-62, Standard deviation 11.9)	25.8 (Range 16-59, Standard deviation 12.7)
Male gender	15 (47%)	6 (43%)
Ethnicity	NZ European 29 (91%) Other European 3 (9%) Maori 0 Asian 0	NZ European 10 (71%) Other European 1 (7%) Maori 1 (7%) Asian 2 (14%)
Work status	Full time work 10 (31%) Part time work 2 (6%) Student 17 (53%) *(Polytech 1 (3%), School 7 (22%), University 9 (28%))* Retired 1 (3%) Unemployed 2 (6%)	Full time work 2 (14%) Part time work 2 (14%) Student 9 (64%) *(Polytech 0, School 2 (14%), University 7 (50%))* Retired 0 Unemployed 1 (7%)
Time since injury	Less than one month 5 (16%) 1-3 months 19 (59%) 4-6 months 2 (6%) More than six months 3 (9%) Unclear 3 (9%)	Less than one month 2 (14%) 1-3 months 10 (71%) 4-6 months 1 (7%) More than six months 1 (7%) Unclear 0
Cause of injury	Transport accident 5 (16%) Fall 9 (28%) Mechanical force 13 (41%) *(Sport related 10 (31%), Non sport related 3 (9%))* Assault 5 (16%)	Transport accident 3 (21%) Fall 2 (14%) Mechanical force 3 (21%) *(Sport related 3 (21%), Non sport related 0)* Assault 6 (43%)
Headache symptoms	Yes 31 (97%)	Yes 14 (100%)
Dizziness symptoms	Yes 17 (53%)	Yes 6 (43%)
Subjective neck pain	Yes 18 (56%)	Yes 3 (21%)
Subjective neck stiffness	Yes 12 (38%)	Yes 14 (100%)
Neck AROM	Full range 6 (19%) End of range restriction 8 (25%) Mild restriction 14 (44%) Moderate restriction 4 (13%) Severe restriction 0	Full range 14 (100%)
Neck pain during AROM	Yes 21 (66%) No 11 (34%)	Yes 0 No 14 (100%)
Segmental findings of pain	Yes 32 (100%) No 0	Yes 1 (7%) No 13 (93%)
Segmental level(s) affected	Upper cervical 24 (75%) Lower cervical 1 (3%) Mixed 7 (22%)	Thoracic 1
Segmental sidedness	Bilateral 18 (56%) Unilateral 14 (44%)	Bilateral 1
Tenderness on palpation	Neck 26 (81%) General 6 (19%)	Head 1 (7%) Thoracic 1 (7%) Nil 12 (86%)
Outcome of assessment	Received further treatment 21 (66%) Referred on for neck treatment 8 (25%) No further contact 1 (3%) No treatment required 2 (6%)	 No treatment required 14

Data are n (%) unless otherwise specified
** Patients were categorised as having a cervicogenic component to their symptoms or not based on the assessing Physiotherapist's documented analysis*

Table 5. Clinical treatment and outcomes for patients followed up by the study physiotherapist

Treatment and outcomes	Received further treatment (n=21)
Type of treatment	Manual only 5 (24%) Acupuncture only 2 (10%) Manual/Acupuncture 10 (48%) Manual/Acupuncture/Stability 3 (14%) Manual/Stability 1 (5%)
Mean patient specific functional scale increase (absolute) *	3.8 (Range 1-7.3, Standard deviation 1.9)
Mean patient specific functional scale increase (%) *	93.5 (Range 55-100, Standard deviation 15.1)
Patient specific functional scale achieved full function *	15 (71%)
Numeric pain rating scale decrease (absolute) ^	4.6 (Range 2-7, Standard deviation 1.8)
Numeric pain rating scale decrease (%) ^	96.6 (Range 60-100, Standard deviation 10.5)
Numeric pain rating scale % achieved full resolution ^	17 (81%)
Mean number of sessions	5.2 (Range 2-12, Standard Deviation 2.5) Note all patients (n=46): 2.9 (Range 1-12, Standard deviation 2.7)

Data are n (%) unless otherwise specified
** Note PSFS data was complete for n=18 (three missing).*
^ Note NPRS data was complete for n=19 (two missing).
Minimally clinical important differences reported for the patient specific functional scale and numeric pain rating scale (in cervical radiculopathy and mechanical neck pain) are: PSFS 2.2; NPRS 2.2 (Cleland et al., 2008, Young et al., 2010).

DISCUSSION

The study findings support the premise that some patients with persistent post-concussion symptoms have clinical characteristics consistent with a cervicogenic component. In addition to the expected complaints of neck pain, headache and dizziness, patients considered to have a cervicogenic component showed notable findings of upper cervical pain on manual segmental examination (75%) and tenderness on palpation (81%). Furthermore, the reported physiotherapy outcomes suggest that selected patients benefit from specific treatment of the cervical spine.

These findings are consistent with previous research. It is well accepted that the cervical spine is capable of producing symptoms including headache (Bogduk and Govind, 2009) and dizziness (Kristjansson and Treleaven, 2009, Treleaven et al., 2003). How this might relate to persistent post-concussion symptoms has received less attention, but has been addressed by several studies. Symptomatic upper cervical joints on manual segmental examination has previously been identified as distinguishing patients with chronic post-concussional headache from a control group (Treleaven et al., 1994). This study echoes these findings in patients with concussion referred by a concussion service provider for neck assessment in a private practice setting. Together, these findings highlight the potential importance of manual segmental examination in the physical examination. In contrast, subjective symptoms of headache, dizziness, neck pain and stiffness were relatively even distributed between cervicogenic and non-cervicogenic groups. Again, this is consistent with previous research indicating that the nature of post-concussion symptoms does not distinguish brain-related concussion from cervical or vestibular injury (Leddy et al., 2015). In particular, the authors show that cognitive symptoms are not specific to brain-related injury, and also advocate for a detailed physical examination of the cervical spine to identify non-brain sources of symptoms. From another perspective, current research in post-concussion syndrome has failed to characterise a physiological change in the brain responsible for persistent symptoms, and which could potentially be explained by cervical spine dysfunction (Marshall et al., 2015). The consensus in the field of sport-related concussion is that symptoms persisting beyond 10 days are not specific to concussion, and other potential contributors should be explored by a multidisciplinary team (Makdissi et al., 2013, McCrory et al., 2013). While not the only potential source of post-concussion symptoms, research shows indications of converging support for a cervicogenic component, and highlights the importance of a cervical spine physical examination including manual segmental examination.

The pattern of cervical musculoskeletal impairment in patients considered to have a cervicogenic component bears close comparison to published research, particularly relating to cervicogenic headache. In this study the sample had a particularly high prevalence of headache (98%). This is not

unexpected given that headache is very common post-concussion symptom (Lucas et al., 2014), but is higher than reported in general concussion populations. As a result, the study findings are particularly relevant to patients with headache post-concussion. Patients with a cervicogenic component had a restriction in range of motion in 81% of cases (most often end-range or mild restriction), and all patients had neck pain on manual segmental examination – mostly affecting upper cervical joints. These findings align with previous research indicating that manual segmental examination discriminates those with cervicogenic from non-cervicogenic headache (Jull et al., 2007, Rubio-Ochoa et al., 2016, Zito et al., 2006). Furthermore, the segmental examination predominantly implicated upper cervical levels (occiput-C3), which are capable of referring pain to the head (Bogduk, 2001). It is worth noting that in previous research a restriction in range of motion, while clearly relevant, less clearly discriminates cervicogenic from non-cervicogenic sources of symptoms (Hall and Robinson, 2004, Rubio-Ochoa et al., 2016, Zito et al., 2006). As a result it is significant that this study found impairments both in range of motion and segmental examination. A further point is that only 56% of those considered to have a cervicogenic component complained of neck pain. This highlights that by itself subjective neck pain does not characterise a cervicogenic component, and a physical examination may still be important even in those without neck pain. What is interesting about this research is that all patients had a primary concussion diagnosis. This implies that the well-established role of physiotherapy (particularly manual therapy) in the management of cervicogenic headache may apply to people with persistent post-concussion symptoms. Given that physiotherapy research in cervicogenic headache is well advanced, potential links between this field and persistent post-concussion symptoms would be a valuable area for future prospective study.

It is worth acknowledging that all patients in this study were referred to physiotherapy for cervical spine assessment. As a result patients do not represent a general post-concussion population, but rather a selection considered likely to benefit from cervical spine assessment. In this context a high proportion of cervical spine findings could be expected. This bias will affect the proportion of patients identified as having a cervicogenic component, but is unlikely to affect the descriptive aspects of this study. As shown in Table 6, the demographic and injury cause characteristics were generally comparable with a comprehensive New Zealand population-based study of traumatic brain injury (TBI) incidence (Feigin et al., 2013). While there are some technical differences in definition, for the purposes of comparison we are treating a medical diagnosis of concussion (in this study) as equivalent to the category of ‘mild traumatic brain injury’ described by Feigin et al. One difference is the current study did have a comparatively low proportion of Maori. This is worth noting, as Maori are disproportionately affected by concussion (Feigin et al., 2013), and may have higher costs per claim (King et al., 2014). While low numbers of Maori may to some extent represent regional

differences, these data suggest that it may be worth exploring if there are barriers to Maori accessing concussion health services. This study also had comparatively less patients who had sustained a fall, and more patients who had sustained a mechanical force (Table 6). This may be due to less very young (<15 years) and elderly (>65 years) patients included in the current study sample, both of whom are more likely to sustain injuries due to a fall (Feigin et al., 2013). More broadly, these data reiterate that while sport-related concussion is the topic of much research and interest, other causes of concussion are significant.

Table 6. Demographic and cause of injury comparison with Feigin et al. (2013)

	Current study	**Feigin et al. (2013)***
Mean age in years (SD)	26.5 (12)	27.5 (21.3)
Male	46%	62%
Ethnicity		
European	93%	61%
Maori	2%	31%
Pasifika	Nil	4%
Asian	4%	3%
Other	Nil	1%
Cause of injury		
Transport accident	17%	19%
Fall	24%	38%
Mechanical force	35%	22%
(Sport related)	*(28%)*	-
(Non-sport related)	*(7%)*	-
Assault	24%	17%
Other/unknown	Nil	4%

Data are % unless otherwise specified.
Data in italics give a further breakdown of a category.
** Note Feigin et al. data shown is for people categorised as sustaining a 'mild traumatic brain injury'.*

For patients identified as having a cervicogenic component to their symptoms, this study showed benefits from treatment by a physiotherapist with expertise in orthopaedic manual therapy (Table 5). A key point is that a referral for physiotherapy cervical spine assessment led to selected patients receiving specific treatment for the cervicogenic component of their problem, which differs from standard concussion management involving physical and cognitive rest. This approach is consistent with research indicating that cervical and vestibular physiotherapy decreases the time to medical clearance for return to sport following a sport-related concussion (Schneider et al., 2014). The reported PSFS and NPRS outcomes exceed the minimal clinically important differences (PSFS 2.2,

NPRS 2.2) reported for cervical radiculopathy and mechanical neck pain (Cleland et al., 2008, Young et al., 2010), giving confidence that neck treatment is valuable. The positive effects of treatment may be in part attributable to careful patient selection, as patients were screened for indications of cervical spine involvement both at referral and prior to physiotherapy treatment commencing. Furthermore, these outcomes were achieved in a mean of five sessions. This is comparable to sessions reported for manual therapy interventions in cervicogenic headaches and dizziness (Jull et al., 2002, Reid et al., 2008). While an uncontrolled study, these data indicate physiotherapy treatment may have a valuable role in the management of persistent post-concussion symptoms, and warrants closer examination. Even if these outcomes prove modest in the wider context of concussion, physiotherapy treatment may well prove beneficial and cost-effective for patients.

This study has limitations in relation to the retrospective design, but provides encouraging results that support further prospective study of a cervicogenic contribution to persistent post-concussion symptoms. The number and detail of the variables were limited by the available data, which were collected for clinical purposes. While it is tempting to further examine the relationships between different variables, the retrospective design and small number of charts reviewed would undermine the credibility of such an analysis. To reflect this, the results and discussion have been limited to descriptive statistics. Although encouragingly positive, treatment outcome data should be viewed conservatively, as patients were potentially accessing other healthcare services concurrently (e.g. medical treatment, vestibular rehabilitation) that would have influenced outcomes. While the PSFS scale typically addresses goals particular to physiotherapy, the outcomes may overestimate the individual effects of cervical spine treatment. Further, this study does not confirm a causative relationship between post-concussion symptoms and signs of a cervicogenic component, but rather reflects the clinical judgement and management of the main study physiotherapist and surrounding clinical team. Along with existing literature this study gives limited support for the premise that the cervical spine may contribute to persistent post-concussion symptoms, and indicates that this is worthy of future prospective and controlled study.

CONCLUSIONS

This study describes the cervical spine clinical characteristics in a series of patients diagnosed with concussion, and reporting persistent post-concussion symptoms. The findings give preliminary support to the idea that the cervical spine may contribute to persistent post-concussion symptoms, and highlight the value of physiotherapy assessment and treatment of the cervical spine following a concussive injury. Subjective symptoms alone are insufficient to identify a cervicogenic component to symptoms, while painful upper cervical joints on manual segmental examination appear to be a key feature. As upper cervical joint dysfunction is a feature of treatable cervicogenic symptoms including headache and dizziness, these findings are encouraging. While this research is preliminary and has limitations the results have interesting clinical implications as they identify a potential target for treatment, and are sufficient to justify future prospective study exploring the role of the cervical spine in post-concussion symptoms.

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Conflict of interest

The authors declare that they have no conflict of interest.

> Note that Mr Dusty Quinn was the study physiotherapist, which could be viewed as a potential conflict of interest. To minimise this the data extraction was performed by two independent assistants, the data was collated by the lead author (EK) and Mr Quinn's role as the study physiotherapist is clearly stated in the manuscript.

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