ORIGINAL RESEARCH

Effect of Chiropractic Intervention on Oculomotor and Attentional Visual Outcomes in Young Adults With Long-Term Mild Traumatic Brain Injury: A Randomized Controlled Trial

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ABSTRACT

Objective: This study aimed to establish if chiropractic care can improve oculomotor and cognitive symptoms in individuals with persistent postconcussion syndrome (PPCS).
Methods: A single-blind, randomized controlled intervention study recorded baseline computerized eye-tracker assessment (CEA) outcomes in 40 young adults with PPCS following mild traumatic brain injury. Participants were randomly allocated to either a chiropractic or age-matched active control intervention, and the change in CEA outcomes following intervention was compared between the chiropractic and control groups. A battery of CEAs including egocentric localization, fixation stability, pursuit, saccades, Stroop, and the vestibulo-ocular reflex, were used to assess oculomotor function, visual attention/processing, and selective attention.
Results: Relative to the control group, participants receiving the chiropractic intervention scored better in the Stroop test ($P < .001$), had improved gaze stability during both vestibulo-ocular reflex ($P < .001$) and fixation stability ($P = .009$), and a lower vertical error in egocentric localization ($P < .001$). However, performance was poorer in pursuits, where they had an increased tracking error ($P < .001$).
Conclusion: Chiropractic care in participants with PPCS significantly improved static and dynamic gaze stability, and performance in the Stroop test, compared with a control intervention. These results suggest that chiropractic care can offer a novel avenue for alleviating certain visual and cognitive symptoms in patients with PPCS. It also adds to the growing evidence that suggests that some longstanding PPCS visual symptoms may have a spinal or proprioceptive basis. (J Manipulative Physiol Ther 2024;47;1-11)
Key Indexing Terms: *Postconcussion Syndrome; Chiropractic; Brain Concussion; Eye-Tracking Technology; Proprioception*

INTRODUCTION

Traumatic brain injury (TBI) is a change in typical brain function that affects neurologic function after an external force to the head.[1,2] Diagnosis and categorization of TBI severity is currently subjective, open to bias, and predicting an individual's outcome after injury is challenging.[3,4] Although symptoms can vary depending on the neurologic area of injury, visual symptoms are common following even mild TBI (mTBI) owing to the many areas of the brain involved in processing vision[5] and controlling the eyes. Visual symptoms can include oculomotor dysfunction including disorders of convergence and accommodation, poorer fixation, slower or less accurate saccades, poorer pursuit movements, and modification of the vestibulo-ocular reflex (VOR).[6] Other common symptoms are less specific, but impact tasks that tax attentional, inhibitive, or

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visuospatial processing.[7,8] To gain accurate and objective measures of eye gaze behaviors, computerized eye-tracker assessments (CEAs) have become increasingly common.[6] Previous work using CEAs has suggested that changes in vision after mTBI may be, in addition to the primary neurologic insult, due to proprioceptive changes from cervical spine dysfunction or damage.[9,10] This is supported by other research that shows altering proprioceptive drive with vibration changes CEA outcomes in those with mTBI.[11] Further augmenting this dual site of injury concept is those with mTBI have a higher incidence of neck pain[12,13] and significantly worse objective measures of cervical spine function.[11]

Altering proprioceptive drive to the brain with either whole body or localized cervical spine vibration[11] has been shown to improve CEA performance in mTBI, and cognitive performance in a range of other conditions, including Alzheimer's disease,[14] Parkinson's disease,[15] and stroke,[16] and improves performance on the Stroop test in young adults.[17] Although the exact process remains unclear, enhancing proprioceptive input to the brain is believed to aid in the integration of vestibular and sensorimotor functions, as well as improve cognitive performance.[14,18] A drawback of vibration therapies is the transitory nature, so another proprioceptive based intervention—chiropractic care—was investigated as a potential pathway to manage visual deficits post mTBI. Chiropractic is a type of manual therapy whose aim is to manage spinal articular dysfunction and the altered neurologic component associated with it.[19] Spinal joint dysfunction can result in altered afferent input to the central nervous system, which modifies the way it processes and integrates sensory and proprioceptive input.[20,21] Once spinal dysfunction is corrected, the sensorimotor integration and cognitive function can improve.[22-24] Theoretically, if participants with mTBI have symptoms (as assessed by CEAs) that were caused or worsened by a related spinal injury, then managing the spinal dysfunction could, in turn, improve CEA outcomes and potentially their symptomology.

As an initial step in investigating this therapeutic intervention, this study aimed to investigate whether a chiropractic intervention intended at reducing spinal proprioceptive dysregulation can alter some of the commonly reported defects in eye-tracking function and spatial awareness that occur following mTBI.

Methods

Trial Design and Participants

This single-blinded, randomized controlled, single intervention study compared preintervention and postintervention measures from 6 CEAs between 2 age-matched groups with self-reported long-term mTBI symptoms for more than 3 months (persistent postconcussion symptoms, postconcussion syndrome [PPCS])—1 group receiving a chiropractic intervention and the other as a control group. Following measurements of baseline CEA outcomes, participants then completed the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) to further assess and quantify the severity of their symptomatology.[25] They then had either a chiropractic or active control intervention (detailed below), before repeating postintervention CEAs, Figure 1. Participants were randomized into an intervention group (chiropractic or control), balanced for age and gender, using a computer-generated block randomization sequence using a free, online program (QMinim[26]). The researcher that performed the randomization was the only person who knew which intervention participants were allocated to. Once randomization was completed the chiropractor was informed, outside the presence of the participant, which group the participant was assigned to, to maintain single blinding. Once allocated to either the chiropractic or control intervention participants underwent their appropriate intervention with the chiropractor.

To avoid the influence of presbyopia on the near computer task, all participants were between 18 and 35 years old, and had no known oculomotor deficits prior to their mTBI, and self-reported normal or corrected to normal vision. Persistent postconcussion symptoms were defined as symptoms of mTBI that persisted past the typical 3-month healing time.[27]

Participants were recruited by word of mouth from the New Zealand Chiropractic College using a snowball sampling method.[29] The study took place at the Centre for Chiropractic Research at the New Zealand Chiropractic College between July 2021 to April 2022 and was managed around COVID-19 related lockdowns in compliance with the government and university restrictions as required.

Sample size calculations were performed using the R software[30] package pwr.[31] Sample size calculations were based on a previous study assessing chiropractic intervention on eye tracking, where a mean improvement of 1.73 was found in the number of trials performed correctly.[32] To detect a true difference in the experimental and control means, it was calculated that 30 participants were needed to be able to reject the null hypothesis that the population means of the intervention and control groups were equal with probability (power) 0.8 and an alpha of 0.05. Bujang[33] recommends adding another 20% to 25% to participant numbers from power calculations to offset potential dropouts, population differences, or unforeseen circumstances (such as COVID-19 related challenges); therefore, a minimum of 40 participants was the recruitment aim.

Ethics

The experimental protocol and procedure were approved by the New Zealand Health and Disability Ethics

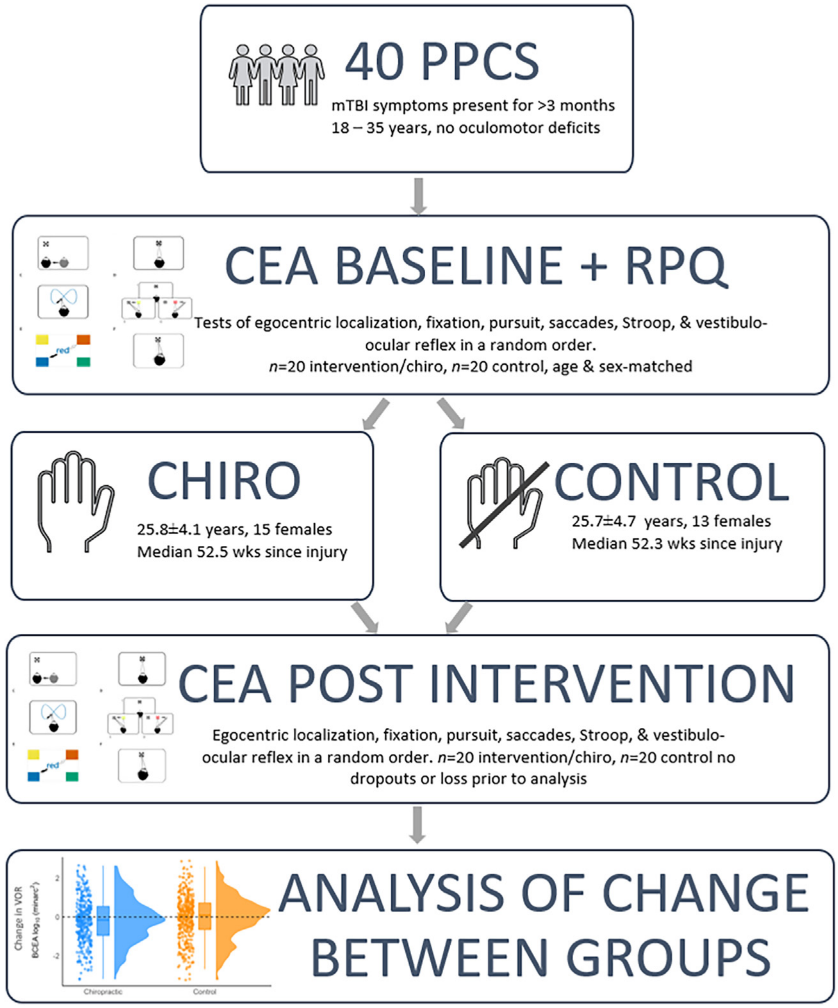

Fig 1. *Progression of study flow from enrolment of 40 participants with persistent postconcussion syndrome (PPCS) to data analysis of the change in computerized eye-tracking assessment (CEA) outcomes between groups post intervention. Chiro, chiropractic; mTBI, mild traumatic brain injury; RPQ, Rivermead Post-Concussion Symptoms Questionnaire.*

Committee (HDEC 19/CEN/130, Australian New Zealand Clinical Trials Registry: ACTRN12620000407897) on August 21, 2019, and complied with the Declaration of Helsinki.[28]

Materials/Computer Setup

A laptop mounted eye tracker (Tobii 5, Tobii Group) was used to record binocular gaze (133 Hz) and head position data (33 Hz) during completion of the CEAs. Visual stimuli were presented on a laptop computer (Surface Book 2, Microsoft), and the eye tracker was calibrated using the Tobii calibration software for each participant. During testing, the participant sat approximately 70 cm from the screen, and the target stimuli consisted of a black cross-shaped target presented on a white background.[34]

Computerized Eye-Tracking Assessments

Six tests with previously established diagnostic value in differentiating mTBI,[6,11] were used in this study.

Egocentric Localization. Participants were asked to move to align the center of their head with the target 10 times. The main outcomes were mean offset error and the mean trial completion time.

Fixation Stability. Participants maintained fixation on the target for 3 trials of 10s each. The main outcomes were the bivariate contour ellipse area (log10 minarc^2), and mean gaze error.

Smooth Pursuit. Participants gaze followed a moving target as it traversed the screen in a Lissajous pattern for 4 trials of 30s. The outcomes measures were mean offset error, total gain, and the number of catch-up saccades.

Saccade Test. Saccade test was performed with 14 pro-saccade and 14 antisaccade tasks interleaved and assessed simultaneously. Main outcomes were saccade latency and the number of correctly performed trials.

The Stroop Test. The Stroop test was performed following a protocol adapted from the Stroop Color-Word test.[35] Part 1 involved reading the word for 15 trials, and then part 2 required participants to match the font color for another 15 trials. Stroop outcomes included mean saccade decision-making latency, total trial time, and proportion of correct trials.

The VOR Test. Participants' gaze was fixed on the target while they actively rotated their head left or right for 10 trials in each direction (20 trials in total). The main outcomes were fixation stability (bivariate contour ellipse area), head to eye velocity gain, and the number saccades in each trial. Eye gaze data was captured throughout the trials and analyzed after all participants had completed the study.

Intervention Procedures

Chiropractic intervention was provided by 4 different chiropractors who were asked to examine and treat each participant using best practice guidelines and the scope of chiropractic practice specified by the New Zealand Chiropractic Board.[36,37] Each chiropractor saw between 1 and 14 participants each.

A patient history was taken from both the intervention and control groups to control for potential placebo effects from practitioner attention and time.[38,39] Chiropractic was provided with the intention of correcting spinal dysfunction anywhere in the spine, also known as vertebral subluxations[23] using high velocity low amplitude (HVLA) adjustive thrusts to correct spinal dysfunction found. Clinical indicators were palpable restricted intersegmental range of motion, asymmetric intervertebral muscle tension, abnormal joint-play, and tenderness to palpation of the joint.[22,40] Control participants underwent a series of passive and active movements of the head, spine, and body. These movements were intended to act as a physiological control for possible afferent changes that may have occurred due to cutaneous, muscular, or vestibular from the passive and active movements used in preparing for spinal manipulation.[32,41] This involved the participants being moved into spinal manipulation setup positions but without delivering actual chiropractic intervention or loading tension into any spinal joints.[42] No spinal manipulation was performed during any control session.

Statistical Analyses

Statistical analysis was performed using R software (version 4.0.3, https://www.r-project.org/) in RStudio (version 1.3.1093, Posit, PBC, https://posit.co/). A 1-way analysis of covariance to determine if there was a difference in variable change between groups (chiropractic or control) controlling for preintervention variable scores.[43] Count data used a binomial mixed effects regression model,[44] or a 0-inflated Poisson model if more than half the values were 0.[45] Statistical significance was defined as $P < .05$. Estimated marginal means of each group pre and post intervention were calculated using the emmeans package.[46] Pairwise differences with adjusted P values between pre and post for each group were also calculated the emmeans package.

Results

Twenty intervention (aged 25.8 ± 4.1 years; 15 females; median weeks since injury, 52.5) and 20 controls (aged 25.7 ± 4.7 years; 13 females; median weeks since injury, 52.3) with PPCS were recruited and completed the whole experiment, with no participants withdrawing from the trial, and no harms of any kind reported. The mean RPQ score for all participants was 30.2 ± 11.9. There were no significant differences between proportions for the 3 RPQ domains (somatic, 16.2 ± 6.6; emotional, 7.1 ± 4.4; and cognitive, 6.9 ± 2.7; $\chi^2(2, N = 3) = 0.632$; $P = .729$) for all participants, nor between the control or chiropractic groups ($P > .999$). The RPQ mean total score (30.2 ± 11.93) fell between previously recorded PPCS mean scores,[47,48] revealing this study's participants reported themselves similarly affected, symptomatically, to the average person with PPCS from mTBI. For comparison, RPQ scores when administered to healthy people have a mean of ~3.5.[49]

The type of chiropractic care was HVLA spinal adjustments; table assisted chiropractic adjustments, and instrument assisted adjustments. Table 1 summarizes the type of chiropractic care that was provided to participants and the vertebral segments adjusted. Instrument and HVLA adjustments were each provided to 5 participants, instrument

Table 1. *Types of Chiropractic Care Provided to Study Participants and Vertebral Segments Adjusted*

Type of care	Frequency	Which Chiropractor Provided Care
High velocity, low amplitude only	14	1, 2, 3, 4
Instrument assisted only	1	1
High velocity, low amplitude, and instrument assisted	5	1, 2
Segments adjusted		
Cervical (C0, 1, 2, 4, 5, and 7)	28	1, 2, 3, 4
Thoracic (T1 rib and T2-8)	28	1, 2, 3, 4
Lumbar (L2 and 5)	5	1, 2, 3
Pelvis (sacrum and ilia)	20	1, 2, 3, 4

only was used with 1 participant, and HVLA only approaches were used exclusively with 14 participants. There were 81 separate vertebral segments adjusted over all the participants with each participant having a mean of 4.1 ± 1.1 segments adjusted.

Most participants, 45%, sustained their mTBI from a sporting injury (χ^2[5, N = 40] = 34.29; $P < .001$) and mechanism of injury (assault, domestic violence, falls, motor vehicle accidents, and other) were balanced between groups ($P > .050$).

CEA Measures

For ease of interpretation of the large number of CEA outcomes, a summary of significant differences between the chiropractic and control groups following intervention, alongside estimated marginals means, are provided in Table 2. For transparency, all CEA test (significant and nonsignificant) results are provided in a Supplementary Material table (Results for all variables).

The change in gaze stability was different between groups (F[1, 1] = 8.17; $P = .005$), improving after chiropractic intervention (pre, 3.26; post, 3.16 $\log_{10}$ minarc^2) but worsening in the control group (pre, 2.94; post, 3.12 $\log_{10}$ minarc^2). Horizontal gaze error showed a similar change (F[1, 1] = 9.35; $P = .003$), reducing after chiropractic (pre, 0.35; post, 0.21 degrees) but worsening after control intervention (pre, 0.20; post, 0.22 deg). There was no impact of chiropractic on the vertical gaze error (F[1, 1] = 0.19; $P = .659$). During the VOR test, gaze stability improved for the chiropractic group (pre, 4.00; post, 3.86 $\log_{10}$ minarc^2; F[1, 1] = 41.41; $P < .001$) compared with the control group (pre, 3.94; post, 3.90 $\log_{10}$ minarc^2). Vertical gaze error during VOR improved in both groups, but more so in the chiropractic group (pre, −0.46; post, −0.39 deg, F[1, 1] = 28.68; $P < .001$) compared with the control group (pre, −0.14; post, −0.34 deg). Similarly, the time taken to reach maximum gain was much poorer in the control (pre: 83.3, post: 116.6 ms) compared with the chiropractic group (pre, 83.4; post, 83.3 ms, F[1, 1] = 57.43; $P < .001$). There was no difference in the change in horizontal gaze error between groups during VOR (F[1, 1] = 2.00; $P = .157$).

For the Stroop test of selective attention, the chiropractic group showed significant improvements in the number of correct trials for part 1 (chiro pre, 14; IQR, 2; minimum, 6; post, 14; IQR, 2; minimum, 11; control pre, 15; IQR, 1; minimum, 11; post, 14; IQR, 2; minimum, 11; χ^2[1, N = 40] =3508.64; $P < .001$), but not part 2 (χ^2[1, N = 40] = 0.17; $P = .678$), whereas there was no difference in performance in the control group (part 1: χ^2[1, N = 40] = 0.10; $P = .758$; part 2: χ^2[1, N = 40] = 2.92; $P = .087$). Decision-making saccade latency for part 1 of the Stroop test increased in both groups, but slightly more in the control (pre, 733.5; post, 842.1 ms; F[1, 1] = 60.99; $P < .001$) than the chiropractic (pre, 716.9; post, 783.5 ms). This led to longer trial times following interventions in both groups, but more so in the control group (chiro pre, 900.0; post, 1000.0 ms; vs control pre, 917.0; post, 1067.0 ms; F[1, 1] = 68.00; $P < .001$). Part 2 showed no differences between groups for saccade latency (F[1, 1] = 2.48; $P = .114$) or total test time (F[1, 1] = 0.13; $P = .721$).

During saccade testing, the change in saccade latency was different between groups for both prosaccade (F[1, 1] = 14.94; $P < .001$) and antisaccade tests: F[1, 1] = 36.13; $P < .001$), improving for both groups, but more so for the chiropractic group (pro pre, 366.9; post, 317.0 ms; anti pre, 350.3; post, 317.0 ms) compared with the control group (pro pre, 366.9; post, 350.3 ms; anti pre, 367.0; post, 341.9 ms). There was no difference in the number of tests performed correctly for either group or type of saccade ($P > .05$). In pursuit testing, the total gaze error worsened after chiropractic intervention (F[1, 1] = 43.14; $P < .001$; pre, 0.20; post, 0.24 deg) compared with the slight improvement seen in the control group (pre, 0.11; post, 0.09 deg). Total gain worsened in the chiropractic group (pre, 1.02; post, 1.03; F[1, 1] = 54.97; $P < .001$) while staying the same for the control group (pre, 1.01; post, 1.01).

For egocentric localization, there was a difference in the vertical alignment error between groups (F[1, 1] = 52.30; $P < .001$), with a small improvement in the chiropractic group (pre, −37.69; post, −36.42 mm), but a much greater improvement for the control group (pre, 13.55; post, −0.37 mm). There were no changes to horizontal error after intervention (F[1, 1] = 0.72; $P = .395$).

Discussion

Key Findings

The results of this study show that for those with PPCS, chiropractic intervention improved gaze stability, both with a stable head (fixation) and during dynamic head movement (VOR). Chiropractic also reduced saccade latency, and improved performance in the Stroop test, but increased total gaze error during pursuits compared with the age-matched controls. These findings support the idea that vision-based mTBI symptoms involve some abnormal spinal or proprioceptive input, and that interventions aimed at reducing spinal dysfunction may potentially have some benefit in the management of mTBI.

Chiropractic Improved Gaze Stability

The chiropractic group showed improvement in gaze stability during both the fixation test and during VOR testing. Previous research has shown brain-injured people have poorer fixation than healthy controls,[50] suggesting that chronic injury may negatively affect gaze stability. Additional research also suggests that those with mTBI have

Table 2. *Results for Computerized Eye-tracking Assessment Outcomes with Significant Effects*

Outcome	*F* (df), *P* Value	Estimated Marginal Means: Change Score (CI)		Difference Between Groups *P* Value
		Chiro	Control	
Egocentric localization				
Vertical error (mm)	52.30 (1, 1), <.001	−8.61 (−11.351 to −5.86)	6.00 (3.255 to 8.746)	<.001
Fixation stability				
BCEA ($\log_{10}$ minarc^2)	8.17 (1, 1), .005	−0.14 (−0.228 to −0.062)	0.03 (−0.056 to 0.111)	.005
Horizontal error (deg)	9.35 (1, 1), .003	−0.14 (−0.218 to −0.056)	0.04 (−0.039 to 0.129)	.003
Pursuit				
Total error (deg)	43.14 (1, 1), <.001	0.11 (0.087 to 0.136)	−0.01 (−0.03 to 0.019)	<.001
Total gain	54.97 (1, 1), <.001	0.01 (0.011 to 0.016)	−0.0008 (−0.003 to 0.002)	<.001
Horizontal gain	21.02 (1, 1), <.001	−0.004 (−0.016 to 0.008)	−0.04 (−0.055 to −0.031)	<.001
Vertical gain	27.91 (1, 1), <.001	0.01 (−0.0003 to 0.018)	−0.03 (−0.036 to −0.017)	<.001
Prosaccade				
Latency (ms)	14.94 (1, 1), <.001	−75.4 (−86.6 to −64.2)	−44.2 (−55.4 to −33.1)	<.001
Antisaccade				
Latency (ms)	36.13 (1, 1), <.001	−74.3 (−86.1 to −62.5)	−22.6 (−34.7 to −10.6)	<.001
Stroop part 1				
Decision-making latency (ms)	60.99 (1, 1), <.001	0.1 (0.1 to 0.1)	0.1 (0.1 to 0.1)	<.001
Test time (s)	68.00 (1, 1), <.001	0.04 (0.032 to 0.041)	0.06 (0.06 to 0.07)	<.001
Vestibulo-ocular reflex				
BCEA ($\log_{10}$ minarc^2)	41.41 (1, 1), <.001	−0.10 (−0.12 to −0.084)	−0.02 (−0.036 to −0.001)	<.001
Vertical error (deg)	28.68 (1, 1), <.001	−0.15 (−0.185 to −0.123)	−0.05 (−0.072 to −0.03)	<.001
Time to max gain (ms)	57.43 (1, 1), <.001	−25.1 (−26.7 to −23.4)	−16.2 (−17.8 to −14.7)	<.001
Number of saccades	42.92 (1, 1), <.001	0.06 (0.044 to 0.073)	−0.01 (−0.022 to 0.006)	<.001
	Binomial mixed effects regression model for the number of correctly performed trials (of 15 trials)			
	Time/Trial Number Interaction (χ^2[degrees of freedom, N], *P* Value)	Number of Correct Trials: Chiro		Number of Correct Trials: Control
P1 Stroop chiro	**χ^2(1, N = 40) = 3508.64, <.001**	Pre, 14; IQR, 2; min, 6; post, 14; IQR, 2; min, 11		Pre, 15; IQR, 1; min, 11; post, 14; IQR, 2; min, 11

Results for all outcomes are available in the Supplementary Material.
BCEA, bivariate contour ellipse area; *chiro*, chiropractic.

concomitant neck dysfunction[13] and sensory abnormalities.[51,52] The brain can down-weight abnormal cervical afferent information when it conflicts with vestibular and visual inputs,[53,54] leading to less reliable input to gaze stability. Chiropractic intervention, by modifying the proprioceptive input from more functional spinal joints, could help restore this input to the brain's multisensory processing, leading to an improved internal representation of the body's spatial orientation, helping to improve fixation.

This improvement in fixation was also seen during the dynamic head movement as part of VOR testing, where additional cerebellar-vestibular pathways are involved.[55] Altered proprioception from the cervical spine, after chiropractic, may have bolstered brainstem activation or vestibulo-cerebellar components of the VOR pathway augmenting its function.[56-58] Chiropractic intervention may have also improved gaze stability via decreasing disordered proprioceptive drive from the neck and allowing the cervico-ocular reflex to function more effectively. The cervico-ocular reflex helps to steady gaze in the presence of neck movement and enhancing VOR function and further stabilizing gaze.[59]

Chiropractic Improved Attentional Reading Tasks

During the Stroop test, our PPCS participants had higher error rates[60,61] and the time to complete a trial was much longer than that of previously found normative data.[60] This suggests that inhibitory control is affected in PPCS, perhaps more so in part 1 than part 2 of Stroop.[62] Part 1 of the Stroop test, where the required response is indicated by the color denoted by the word requires additional language processing across a wider range of neurologic areas, compared with part 2, which only requires identification of the word color before generating a response.[62]

Looking at the overall picture of Stroop results, it seems that although either intervention increased trial time or decision-making latency, only the intervention aimed at improving proprioceptive drive—chiropractic—resulted in fewer errors. There is sparse previous data for chiropractic in relation to the Stroop test, but research on a choice-reaction time test—somewhat analogous to the Stroop test—found whole body vibration used to stimulate proprioceptors reduced P300 brain wave latency.[63] The P300 wave latency is lengthened in brain injury, and a longer latency indicates slower cognition.[64] Early research supports the P300 wave having a somatosensory component but how, exactly, somatosensory stimulation affects the P300 is yet unknown.[65] Chiropractic intervention has been shown to improve proprioceptive drive, so it is possible that chiropractic care can shorten P300 wave latency by way of altering proprioceptive drive,[20,21] and improve the ability to respond to a choice-reaction test such as the Stroop test.

Other Findings

The chiropractic intervention group showed impairments in several measures of gaze accuracy during pursuit testing. This may be because the chiropractic intervention was aimed at reducing proprioceptive, rather than vestibular dysfunction. Brainstem eye-head neurons, which help control and coordinate eye and head movements for gaze stability, are affected by vestibular inputs but not cervical proprioceptors.[66] Therefore, an intervention aimed at improving disordered proprioception, such as chiropractic, may not be expected to improve errors during pursuit. Lastly, our study suggests that chronic injury may result in an increased number of catch-up saccades during pursuits.[67] Predictive gaze movements in pursuits stem from anticipating target movement and learning target patterns, which originate from the middle temporal area and medial superior temporal area and receive inputs from the frontal eye fields in the prefrontal cortex.[68] These are areas that can be hypo-perfused and exhibit reduced glucose metabolism after mTBI,[69] which could lead to difficulty integrating sensorimotor information. Disordered sensorimotor integration and dysfunctional cortical gaze movement areas may have led to less accurate or slower anticipatory eye movements,[70,71] and more catch-up saccades.

Saccade latencies were both longer and showed minimal differences between prosaccade and antisaccade, compared with previous research.[72] This could be attributed to the interleaving of prosaccade and antisaccade trials, requiring participants to simultaneously consider the steps involved in both tasks. Additionally, imagining a prosaccade or antisaccade task activates the supplementary eye fields, which may inhibit frontal eye field drive.[73] Although both groups demonstrated a postintervention reduction in saccade latency, this was more pronounced in the chiropractic group. Previous research shows that chiropractic intervention can change prefrontal cortex[74] function, especially the N30 sensory evoked potential peak, which is implicated in sensorimotor processing and learning new motor skills.[75] Therefore, any improved proprioceptive drive post chiropractic intervention may have affected sensorimotor processing and assisted in learning how to perform the saccade test, resulting in a reduced decision-making latency.

Chiropractic and Its Potential Influence

How we view and interpret our visual environment is dependent on where our brains believe us to be in space.[76] The spine provides the largest amount of proprioceptive information to the brain,[77] so it follows that if the injury also causes spinal dysfunction, it could alter how we interpret visual information.[78] Chiropractic intervention is thought to activate musculature and spindles that surround spinal joints, firing 1A afferents to the brain, which are processed in the motor and prefrontal cortices.[19,79] These inputs help to build the brain's internal map of where the joints and body is in space.[80] Additionally, chiropractic changes motor evoked potentials,[79] and their generation time,[81] suggesting chiropractic adjustments not only affect sensory drive to the brain, but also motor outputs.[82] Although research into how chiropractic affects the brain is in its infancy, studies show that chiropractic adjustments can lead to changes in multimodal sensory integration involving visual and auditory inputs[21,83] and motor and motor-learning outputs.[84-88] Our study results indicate that chiropractic can impact sensorimotor function and influence a range of CEA outcomes, so could be considered in those suffering from PPCS.

Strengths and Limitations

A strength of this study was the use of many different CEA-based outcome measures including attentional and inhibitive process testing, rather than focusing on just 1 aspect, such as oculomotor function, or even a single eye tracking–based test.[89] A factor which was both a strength and limitation was allowing chiropractors flexibility to make their own clinical decisions when deciding on the intervention for participants. Although the lack of intervention standardization—chiropractors were allowed to adjust where they saw fit for each participant—may have reduced internal validity, it also increased its external validity with results more likely to be consistent with what could be expected in clinical practice.

The heterogeneity of the study population, and lack of specific inclusion criteria (such as location or cause of mTBI) was also a limitation of this study. Participants varied widely in their mechanism of injury, time since injury, symptomatology, and spinal findings. These observations highlight a known issue in mTBI research—population heterogeneity and the difficulties surrounding mTBI identification, diagnosis, treatment, and chronification of the disorder.[2] The wide range of causative injuries, differing previous treatment, time since injury, and comorbid issues could have confounded or influenced the results of this study, although the randomization of groups and use of age-matched controls would have helped mitigate these factors.

Conclusion

This study found that chiropractic care can improve some aspects of visual function, particularly gaze stability, when compared with an age-matched control group. This reinforces the idea that some of the ongoing visual symptoms in PPCS may be due to abnormalities in the cervical spine. The study also demonstrated that a simple CEA battery can be successfully used in a clinical interventional trial in a diverse PPCS population to help provide objective markers for diagnosis and tracking the effectiveness of interventions over time.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jmpt.2024.08.003.

Funding Sources and Conflicts of Interest

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Contributorship Information

Concept development (provided idea for the research): A.E.C., P.K.R.T.
Design (planned the methods to generate the results): A.E.C., P.K.R.T.
Supervision (oversight, organization and implementation): P.K.R.T.
Data collection/processing (experiments, organization, or reporting data): A.E.C.
Analysis/interpretation (analysis, evaluation, presentation of results): A.E.C., P.K.R.T.
Literature search (performed the literature search): A.E.C.
Writing (responsible for writing a substantive part of the manuscript): A.E.C.
Critical review (revised manuscript for intellectual content): A.E.C., P.K.R.T.

Practical Applications

- This single-blinded randomized controlled study used a chiropractic intervention to assess the difference in eye-tracking outcomes for an intervention (chiropractic) and control group.
- Chiropractic care resulted in significant differences between the chiropractic and control groups for many eye-tracking outcomes, indicating that improving spinal dysfunction aids in recovery—from visual symptoms—after mTBI.

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