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Abstract

Purpose: To describe physical examination (PE) findings of individuals with protracted concussion recovery and evaluate an integrated primitive reflex (PR) disinhibition, vision, and vestibular rehabilitation intervention. **Method:** Retrospective study of 82 patients with protracted concussion (60.98% female) who received ≥ 2 phases of treatment. Following a baseline PE, patients completed the Post-Concussion Symptom Survey (PCSS), Activities-Based Balance Confidence Questionnaire (ABC), Dizziness Handicap Index (DHI), and Acquired Traumatic Brain Injury (aTBI) Vision Questionnaire. A subset of patients (Group 1), completed a final PE and second questionnaire administration. Descriptive statistics characterized the sample. T-tests and Wilcoxon rank sum tests compared characteristics of Group 1 vs Group 2. Wilcoxon sign rank tests assessed changes in patient-reported outcomes. **Results:** Patients in Groups 1 (median age=23.5) and 2 (median age=17.5) were similar regarding demographic and PE findings. Statistically and clinically significant improvements were seen for Group 1: PCSS (-21 points, MCID 6.8), DHI (-27 points, MDC 17.8, MCID 19), ABC (+ 8.5 points, MDC 9)and aTBI Vision Questionnaire (-16.5 points). **Conclusion:** Patients with protracted concussion recovery can benefit from a multitude of interventions ranging from orthopedic to vision and vestibular interventions in order to address objective deficits and subjective complaints such as headache, dizziness, or blurry vision following a concussion. Patients who completed the full intervention demonstrated clinically significant improvements in function, including return to school/work and recreational activities. These data suggest there is a potential positive benefit to a structured, integrative concussion rehabilitation approach for individuals with protracted concussion recovery.

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Physical Examination Findings in Patients with Protracted Concussion and the Impact of an Integrative Concussion Rehabilitation Protocol

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ABSTRACT

Purpose: To describe physical examination (PE) findings of individuals with protracted concussion recovery and evaluate an integrated primitive reflex (PR) disinhibition, vision, and vestibular rehabilitation intervention. **Method:** Retrospective study of 82 patients with protracted concussion (60.98% female) who received ≥ 2 phases of treatment. Following a baseline PE, patients completed the Post-Concussion Symptom Survey (PCSS), Activities-Based Balance Confidence Questionnaire (ABC), Dizziness Handicap Index (DHI), and Acquired Traumatic Brain Injury (aTBI) Vision Questionnaire. A subset of patients (Group 1), completed a final PE and second questionnaire administration. Descriptive statistics characterized the sample. T-tests and Wilcoxon rank sum tests compared characteristics of Group 1 vs Group 2. Wilcoxon sign rank tests assessed changes in patient-reported outcomes. **Results:** Patients in Groups 1 (median age=23.5) and 2 (median age=17.5) were similar regarding demographic and PE findings. Statistically and clinically significant improvements were seen for Group 1: PCSS (-21 points, MCID 6.8), DHI (-27 points, MDC 17.8, MCID 19), ABC (+ 8.5 points, MDC 9) and aTBI Vision Questionnaire (-16.5 points). **Conclusion:** Patients with protracted concussion recovery can benefit from a multitude of interventions ranging from orthopedic to vision and vestibular interventions in order to address objective deficits and subjective complaints such as headache, dizziness, or blurry vision following a concussion. Patients who completed the full intervention demonstrated clinically significant improvements in function, including return to school/work and recreational activities. These data suggest there is a potential positive benefit to a structured, integrative concussion rehabilitation approach for individuals with protracted concussion recovery.

KEYWORDS: brain concussion; reflex; vertigo; dizziness.

INTRODUCTION

A 30-day window of spontaneous recovery following a sports-related concussion is widely accepted in concussion literature. Although clear guidelines have been validated for the Return to Learn and Return to Sport processes, there are no established guidelines regarding return to daily activities for the 10-20% of patients with protracted recovery.[1]

Visual abnormalities immediately following concussion are found in 90% of individuals, with upwards of 50% of all patients demonstrating prolonged visual deficits.[2,3] The benefits of vision therapy to address common oculomotor dysfunction and binocular vision disorders (convergence insufficiency and accommodative insufficiency) post-concussion have been extensively documented.[4-9] Current research provides clear clinical guidelines in the treatment of benign paroxysmal positional vertigo (BPPV) post head trauma and demonstrates traumatic BPPV responds similarly to idiopathic BPPV with canalith repositioning treatment.[2,6,10] Loss in the vestibulo-ocular reflex (VOR) gain results in complaints of oscillopsia, dizziness, and spatial disorientation.[7,11,12] While research is expanding, there continues to be a knowledge gap of how best to implement these therapies in the safest and most efficient and effective manner.

Primitive reflexes (PRs), mediated by the brainstem, are responsible for complex movement patterns critical for survival in the first year of life.[8,13] Retention of PRs in individuals can contribute to difficulty with visual tracking, balance, motion intolerance, concentration, and coordination. PR therapy effectiveness has been demonstrated and is used in early intervention for children with cerebral palsy, behavior disorders, or reading difficulties.[14,15] PR re-emergence has been identified in pyramidal tract disorders such as Parkinson's and Alzheimer's due to cortical damage of white matter in the frontal lobe causing disturbances to the inhibitory tracts from the prefrontal cortex, specifically the orbitofrontal cortex and dorsolateral prefrontal cortex.[16,17]

Research in early intervention suggests retention of moro reflex, symmetrical tonic neck reflex (STNR), asymmetrical tonic neck reflex (ATNR), tonic labyrinthine reflex (TLR), and spinal galant reflex contributes to difficulties with coordination, balance, concentration, visual tracking, reading, and writing (Table 1).[15,18] The clinical presentation overlay between individuals with concussions and children with PR retention due to developmental delay, prompted these authors to use PR integration therapy in individuals with concussive disorders.

Table 1: Common primitive reflexes associated with brain injuries and visual deficits.[15,18]

Reflex	Purpose	Appearance	Occurrence	Integration	Signs of Retention/Disinhibition
Moro	Flight or fight response, startle reflex	Automatic reaction to a sudden change in sensory stimulation	Birth	2-4 months	Sensory sensitivities/overload, hyper-activity/poor impulse control, mood regulation, difficulty sleeping, poor balance and coordination, difficulty with vision, reading or writing, easily fatigued
STNR*	Preparation for crawling	While on stomach: head is flexed towards chest - arms bend and legs extend; head is extended - arms straighten and legs bend	6-9 months	9-11 months	Slumped sitting, poor muscle tone, "W" sitting, poor hand eye coordination, inability to sit still and concentrate
ATNR#	Assist through birth canal and develop of cross pattern movements	Rotating the head to one side – ipsilateral arm and leg will extend while contralateral limbs flex	Birth	6 months	Difficulty with hand eye coordination, handwriting, crossing vertical midline, visual tracking
Spinal Galant	Assist with birth process, crawling and creeping	Hip rotation with back is touched on either side of the spine	Birth	3-9 months	Postural deficits, fidgeting, bedwetting, clothing sensitivities, poor concentration, poor short term memory, fatigue
TLR+	Head management, rolling over, crawling, creeping,	In supine: head is flexed - arms and legs are flexed into "fetal position."	Birth	3-5 years	Difficulty with balance, eye tracking, convergence, poor sequencing and sense of time, decreased muscle tone, toe walking, motion sickness, visual perceptual difficulty

	standing and walking	Prone: head is extended and arms and legs extend into "superman position."			

*STNR, symmetrical tonic neck reflex; #ATNR, asymmetrical tonic neck reflex; +TNR, tonic labyrinthine reflex.

The purpose of this retrospective study is to 1) describe physical examination (PE) findings of patients with protracted concussion recovery, 2) determine whether a protocol integrating primitive reflexes was tolerated by patients, defined as no reporting of adverse events and completion of the protocol, and 3) explore the impact of the structured, phased primitive reflex integration therapy protocol for the treatment of concussions with protracted recovery on patient-reported outcomes (PROs). We hypothesized that incorporating primitive reflex integration therapy in post-concussion recovery would have a positive effect on patient outcomes, improving their return to school, work, and recreational activities.

METHODS

Study Design, Ethics, and Participants

This retrospective study included all patients treated in a private outpatient physical therapy clinic specializing in concussion management between March 1, 2017 and December 31, 2017. Study procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation, and IRB approval was granted by the institution. IRB approval did not require written informed consent as the study was classified as a quality assurance study. Patients were included if they were referred to physical therapy with a primary diagnosis of concussion; had protracted recovery defined as recovery requiring longer than 3 weeks; were screened for primitive reflex disinhibition; and were between the ages 6-80 years.[1] Patients were excluded if their compliance to PT was <75% of scheduled appointments, treatment was initiated outside targeted date range, they had an orthopedic injury limiting their ability to complete the treatment protocol, had negative findings on the PR screen, or if they did not complete both phases of the primitive reflex integration portion of the protocol

The medical records of 205 patients referred to physical therapy for concussion were screened for eligibility by two physical therapists (PTs) using a standardized medical record form developed by the research team. Of these patients, 82 met the inclusion criteria. These individuals were divided into 2 groups. Group 1 (n=34) received a final physical examination, completed the follow up questionnaires, and were formally discharged. Patients in Group 2 (n=48) completed the Primitive Reflex portion of the protocol but self-discharged prior to re-evaluation and completion of questionnaires. The reasons for discontinuation of treatment included: perceived physical improvement with no need for further treatment (n=13), discharged with final HEP without a re-evaluation (n=4), distance from the clinic/difficulties with travel (n=3), not "buying into" treatment (n=1), treatment non-compliance (n=2), no follow-up after being cleared by referring physician for return to sport (n=3), anxiety or other serious mental health complications leading to early discharge (n=2), finished vision therapy with neuro-optometrist (n =1), cost (n=1), and no reason provided (n=18) **(**Figure 1**).**

Assessment

All patients received a PE by a licensed physical therapist employed by the clinic. Patients were also given new patient intake packets that included medical history forms, consent for treatment, and self-reported outcome measures. Initial intake forms included the Post Concussion Symptom Scale (PCSS) to assess concussion symptoms including physical, cognitive, and emotional aspects; the Activities-Based Balance Confidence Questionnaire (ABC) to assess patient's self-confidence in completing a task based on impairment; the Dizziness Handicap Index (DHI) to assess the impact of dizziness on physical and emotional aspects of one's quality of life; and the Acquired Traumatic Brain Injury (aTBI) Vision Questionnaire to assess vision and vestibular impact on reading and functional tasks. Patients in Group 1 who completed the protocol, received the same self-reported outcome measures at the discharge evaluation for pre/post intervention comparison.

The Post Concussion Symptom Scale (PCSS) is a valid and reliable scale which includes 22 self-reported concussion symptoms rated on a 0 (none) to 6 (severe) point Likert scale, yielding a maximum score of 132. The PCSS has an established minimal clinically important difference (MCID) of 6.8 points.[19] The Dizziness Handicap Inventory (DHI) has 25 items which assess perceived dizziness with activities of daily living and is scored on a scale of 0-100. Scores are classified as follows: 16-34 points indicates a mild handicap, 36-52 as moderate, and 54+ as a severe handicap. The DHI is a valid and reliable scale with both an established minimal detectable change (MDC) of 17.8 points and MCID of 19 points.[20] The Activities-Specific Balance Confidence Scale (ABC) is a 16-item survey measuring patients' confidence in their ability to complete tasks such as walking on icy/slippery sidewalks, walking in crowded places, or walking up or down stairs. ABC scores range from 0-100% with higher scores indicative of greater confidence in function. The ABC is a valid and reliable measure with an established MDC of 9 points.[21]

The aTBI Vision Questionnaire, which has since been adapted to the Brain Injury Vision Symptom Survey (BIVSS), includes the Convergence Insufficiency Symptom Survey (CISS) as the first 15 questions. The questionnaire is scored on a 0-92 point scale with a greater score indicative of greater dysfunction. The CISS has been validated for identifying binocular vision disorders (>21 points positive for convergence insufficiency) in concussion however, minimal clinical important change scores have not yet been established.[22,23]

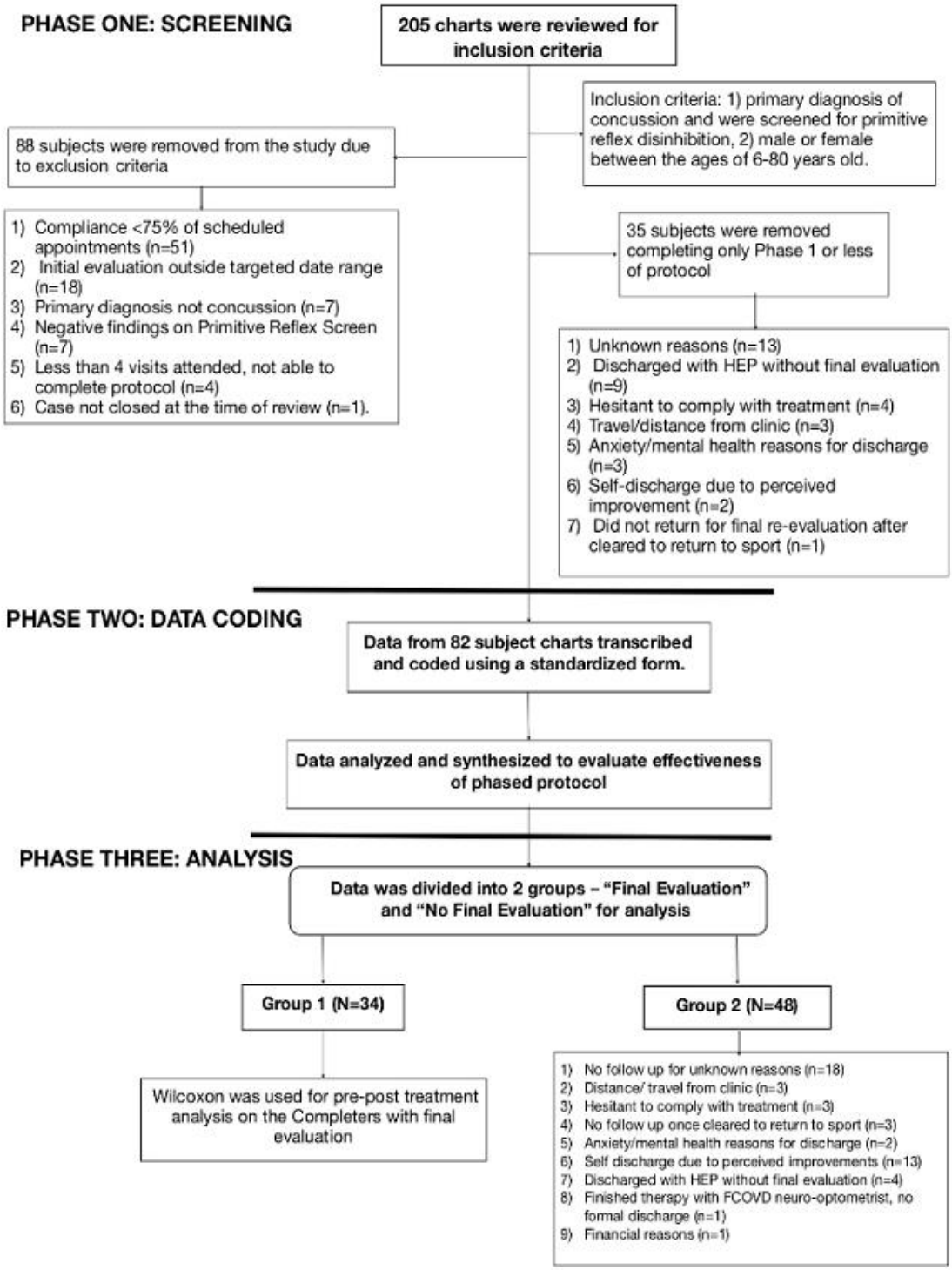

Figure 1. Screening Protocol (Study design with inclusion and exclusion criteria.)

Treatment Protocol

Patients were screened by two licensed PTs with 1-5 years of experience in the field, who specialize in treating individuals with protracted concussion recovery. The therapists developed a screen to implement in their practice using tests adapted from existing screens for ATNR, STNR, and Galant reflex retention.[18,24] Suggested testing procedures exist for the Moro and TLR reflexes however, they were not selected for this specialized population due to: excessive stimulation, balance challenges, or required excess cervical range of motion. Existing low-level exercises were adapted into screening tests for ease of implementation and to decrease confounding variables secondary to co-morbid concussion deficits. To improve consistency in scoring among both therapists, explicit criteria were provided for a positive test results. The screen for each reflex can be found in Figure 2.

Reflex	Procedure
Moro	Hooklying position with feet together and hands in the "prayer position" palms together at midline. Instruct to maintain inward pressure at the palms and lift the hips off the floor to create a straight line from the knees through the hips to the shoulders. Repeat 3 times. ***Compare to same movement with arms crossed over the chest*** Ask the patient (pt) about a difference in effort between positions.
TLR*	Prone with arms by sides, palms facing the ceiling. Instruct the pt to lift arms and legs off the table. Then instruct to repeat while keeping the head on the table. *Ask the pt about difference in difficulty.*
STNR+	Quadruped position: therapist passively flexes the pt's neck and holds for 5 seconds before extending the neck in a comfortable range and holds for 5 seconds. Repeat 3x.
STNR-2	To confirm in mild cases: Quadruped position. Pt will actively extend opposite arm and leg then return to starting position and repeat on opposite side. Repeat 3x.
ATNR#	Quadruped position: therapist to passively rotate the pt's head to the side hold for 5 seconds before rotating to the opposite sides. Repeat 3x.
ATNR-2	To confirm in mild cases: complete in standing, arms flexed to 90 degrees, fingers pointed to the floor. With the pt's eyes closed, passively rotate the head to each side, hold for 5 seconds.
Spinal Galant	Quadruped position: therapist strokes the skin on the pt's back lateral to the spinous process from lower thoracic region to lumbar region 3x. Repeat on the opposite side of the spine.

Score Sheet

Reflex	Level 1 Presentations	Level 2 Presentations
Moro	☐ Inability to maintain inward pressure ☐ Inability to keep pelvis level ☐ Dorsiflexion of the ankles ☐ Abduction of the hips	☐ Increased symptoms ☐ Increased difficulty c hands in prayer vs crossed over shoulders
TLR	☐ Difficulty eliminating cervical extension ☐ Difficulty lifting either arms or legs ☐ Knee flexion	☐ Complaint of significant difficulty completing exercise ☐ Difficulty with motor planning
STNR	☐ Flexing of the elbows/weight shift posterior ☐ Arching the back ☐ Plantarflexion of the ankles	☐ Lateral weight shifting/postural sway
STNR-2		☐ Significant pelvic tilt ☐ Significant balance deficits ☐ Discrimination of quality of posterior sling
ATNR	☐ Flexion of the contralateral elbow to head rotation ☐ Weight shifting backward or lateral	
ATNR-2		☐ Drop of the arms below 90 degrees ☐ Rotation of the arms
Spinal Galant	☐ Arching of the back ☐ Weight shift away from the ipsilateral side.	☐ Subjective complaints of increased fidgeting behaviors or clothing sensitivities.

Therapist Initials: _____ Date: _____

Results: _____

_____

Figure 2. Primitive Reflex Screening Tool (Screening tool with test position descriptions and grading system for the presence of the five primitive reflexes.)
Abbreviations: *Tonic Labyrinthine Reflex; +Symmetrical Tonic Neck Reflex; #Asymmetrical Tonic Neck Reflex

The PT incorporated the treatment protocol in each patient's plan of care according to his or her deficits and trajectory through rehabilitation. A staged exercise program was used based on protocols for PR retention. The Level 1 exercise program includes the Moro bridge, bird dog, marching zombie, superman, swimmer, and snow angel **(Figure 3)**. Patients were instructed to complete all exercises in a slow and purposeful manner with focus on detailed movement patterns to assist with fatiguing the reflex. Patients were also asked to complete each exercise in 2 sets of 10, except for zombie, which was to be completed once on each side for 60 seconds.

Reflex	Exercise	Key Points	Reference Image
Moro	Moro Bridge	• Maintain inward pressure at the hands, keeping knees together, lift hips off the table • Focus on maintain inward pressure and level pelvis	A
STNR*	Bird Dog	• Lift opposite arm and leg • Focus on maintain level pelvis, fingers together and balance	B
ANTR#	Marching Zombie	• Keep arms flexed to 90 degrees, fingers pointed to the floor, head rotated to the side, march in place • Focus on keeping arms straight and at 90 degrees, maintain position- avoiding moving forward or to the side	C
TLR^	Superman	• Keeping head on the floor, lift arms and legs at the same time • Focus on keeping the head down, extremities straight and prevent arching back	D
	Swimmer	• Keeping head on the floor, lift opposite arm and leg at the same time • Focus on keeping the head down, extremities straight and limit weight shift at the pelvis.	E
Spinal Galant	Snow Angel	• Abduct arms and legs to reach apex at the same time while in the supine position • Focus on keeping arms and legs level, reaching apex at the same time	F, G

Figure 3. Example Home Exercise Program – Level 1 [(A)Moro Bridge (B) Bird Dog (C) Marching Zombie (D) Superman (E) Swimmer (F) Snow Angel start position (G) Snow Angel final position]
Abbreviations: *Symmetrical Tonic Neck Reflex; #Asymmetrical Tonic Neck Reflex; ^Tonic Labyrinthine Reflex
Note: See Reference Images in Appendix

It should be noted that emotional symptoms are often provoked in these patients when completing PR therapy. This emotional overflow is theorized to be due to the activation of the orbitofrontal cortex, which assists with the regulation of mood and emotion.[17] Behaviors observed included anger, frustration, irritability, or emotional changes such as crying. The protocol was adapted to educate patients regarding the risk for these behaviors and appropriate modifications as needed prior to initiating the home program.

Clear progression criteria for each reflex were established: correct form, ability to tolerate 20 repetitions, and an absence of symptom provocation. As the patient demonstrated integration of Level 1 exercises, Level 2 exercises were added to the plan of care. While some of the Level 2 exercises are specific to certain PR, others targeted multiple reflexes while also addressing postural and righting reflexes.[25] Patients were prescribed a daily home exercise program including low-level integration exercises that can typically be targeted towards a specific reflex.[25] The home program included 6-8 exercises (20 minutes per day) each week. As Level 1 exercises were discontinued Level 2 exercises were typically added in the following progression: Moro: duck on a bike and pigeon carrying a pizza; STNR deadbug; Complex Motor: slap tap and starfish; with the robot and archer for ATNR last. During this phase of PR therapy, the same principles apply, quality repetitions are most important for full integration.

On the 2nd visit, patients underwent a comprehensive vision and vestibular examination with referral to the supervising neuro-optometrist, as necessary. Office visits 2-4 were typically completed at a frequency of once per week with a subjective review, comprehensive vision and vestibular evaluation, repeat treatment of BPPV as required, and review and progression of PR exercises. The remaining 20-30 minutes of the 60-minute sessions were used to progress complex motor exercises to address: dual tasks, cognitive load, laterality, and balance and coordination deficits associated with concussion. Examples of these exercises included: balance on compliant surfaces while performing dual tasks such as a cognitive load; dual task visual charts (bpqd and 1234); and ball toss exercises for hand-eye coordination. Patients also completed low-level oculomotor exercises such as: monocular/binocular figure ground and visual discrimination, peripheral awareness activities, introductory anti-suppression exercises, and exercises targeting saccadic and smooth pursuit eye movements

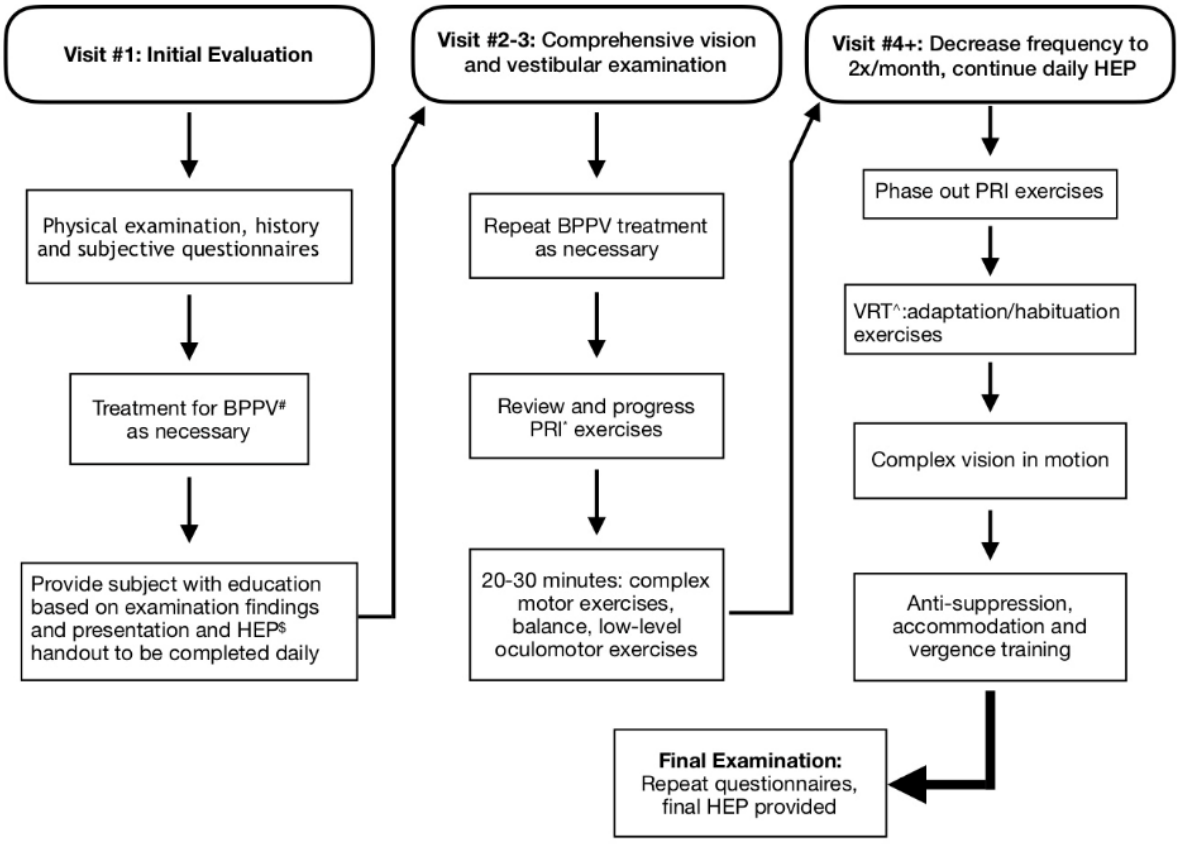

Figure 4. Treatment Progression Protocol (Figure shows protocol followed by therapists each visit for treatment progression with PR therapy.)
Abbreviations: #Benign paroxysmal positional vertigo; $Home exercise program; *Primitive reflex integration; ^Vestibular rehabilitation therapy

Office visits 5 and onwards were typically conducted at a frequency of twice per month, and the therapist introduced vestibular rehabilitation exercises for adaptation, complex vision in motion exercises, progressive anti-suppression exercises, accommodation, and vergence training. The vision and vestibular therapy portions of this protocol followed the authors previously published visuo-vestibular therapy integration guidelines.[26] The home exercise program was limited to 6-8 exercises or 20 minutes per day, progressing to include vision and vestibular exercises as the PRs integrated. Those who completed the program received a final PE, completed a second round of the questionnaires, and were discharged with a final home program to address the remaining deficits found on a final examination. It is unknown how long patients in Group 1 and Group 2 continued their home programs independently.

Patients who met the inclusion criteria but required orthopedic interventions for whiplash associated disorders, lumbar spine injuries, and extremity injuries also received treatments by orthopedic PTs who did not specialize in concussion (23.9%). Patients treated in this clinic attended a median of 0 (IQR 25-75% = 0-2) for Group 1 and a median of 0 (IQR 25-75% = 0-1) for Group 2. Some patients received additional treatments by a massage therapist, chiropractor, or physical therapist of their choice; it is unknown how many additional treatments they received for confounding orthopedic injuries.

Analysis

Descriptive statistics including mean and standard deviations (SD), medians and interquartile ranges (IQR), and frequencies (%) were used to characterize the sample. T-tests, Chi square tests, and Wilcoxon rank sum tests were used, based on data distribution and measurement level, to determine whether there were any differences in patient attributes between Group 1 vs Group 2. As patients with Group 1 completed the second questionnaire administration, we used Wilcoxon signed rank tests to assess changes in patient-reported outcomes. A posthoc power calculation was conducted for the change in PCSS as the main outcome. Using a difference of -21 points and a SD of 17.9, to achieve 80% power we needed 9 patients. In this study, 33 patients completed the full protocol, and completed the second PCSS.

RESULTS

Demographics and Baseline Medical History

There were 82 patients included in the study. Among the patients in Group 1, there were 22 females (64.7%) with a median age of 23.5 years (IQR 25-75% = 14-41). In Group 2, there were 28 females (58.3%) with a median age of 17.5 years (IQR 25-75% = 13-40). Forty patients in the cohort (48.8%) had a prior history of concussive injuries; 60.6% of patients in Group 1 had a positive concussive history (Table 2).

TABLE 2: Comparison of Baseline Physical Examination Findings Between Those Who Completed the Integrated Concussion Protocol and Those Who Did Not Complete the Protocol (n=82)

Variable	Completers n=34	Non-Completers n=48		Statistic p-value
Age (years)	23.50 (IQR 25-75% = 14-41)	17.50 (IQR 25-75% = 13-40)		Z = 0.74 p = 0.46
Female	22 (64.71%)	28 (58.33%)		X_1^2 = 0.15 p =0.65
+ Concussion History	20 (60.61%)#	20 (42.55%)^		X_1^2 = 0.02 p =0.09
Date of Injury to Initial Evaluation	21.50 (IQR 25-75% =13-48)	24.50 (IQR 25-75% =13-56)*		Z = 0.02 p = 0.98
Date of Injury to Primitive Reflex Screen	26.50 (IQR 25-75% =14-84)	31 (IQR 25-75% =16-67)*		Z = -0.02 p = 0.98
<20 days from Initial Evaluation to Primitive Reflex Screen	41	10		Z = 0.43 p = 0.66
Days for Integration	23 (IQR 25-75% =15-35)#	28 (IQR 25-75% =15-39.5)		Z = -0.68 p = 0.49
Moro Reflex Present	30 (88.2%)	39 (82.3%)		X_1^2 = 0.72 p = 0.39
Asymmetrical Tonic Neck Reflex Present	31 (91.2%)	47 (97.9%)		X_1^2= 0.16 p = 0.3
Symmetrical Tonic Neck Reflex Present	32 (94.1%)	46 (95.8%)		X_1^2= 0.36 p = 1.0

Tonic Labyrinthine Reflex Present	32 (94%)	42 (87.5%)		X_1^2= 0.19 p = 0.46
Galant Reflex Present	12 (35.3%)	22 (48.3%)		X_1^2= 0.91 p = 0.34
3 or more reflexes present	32 (94.1%)	45 (93.7%)		X_1^2= 0.35 p = 1.0
Subjective report of significant change	23 (79.3%)+	37 (82.2%)**		X_1^2= 0.09 p = 0.75

#n=33, ^n=47, *n=46, +n=29, **n=45

There was no statistically significant difference in days from initial injury to initial physical therapy evaluation between the two groups (Group 1 = median of 21.5 days (IQR 25-75% = 13-48). The majority of patients completed their Primitive Reflex Screen on the initial evaluation, but due to medical complexities, a percentage of patients completed the screen on their second visit, however, this difference was not statistically significant (median $_{Group\ 1}$ = 26.5 days (IQR 25-75% = 14-84). There were no statistically significant differences in demographics (e.g. age, gender, history of concussion) or for subjective questionnaire data between those who completed the full protocol including final PE and questionnaires, and those who did not return for the final evaluation. Data from the PROs suggest significant impairments in all domains across both groups (Table 3).

TABLE 3: Concussion Protocol and Those Who Did Not Complete the Protocol (n=82)

Variable	Completers n=34	Non-Completers n=48	Statistic p-value
Post Concussion Symptom Survey Score	34 (IQR 25-75% = 14-59)	32.5 (IQR 25-75% =16-54)^	Z = 0.00 p = 1.0
Activities-Based Balance Confidence Score	88.13 (IQR 25-75% =73.75-95.60)	88.13 (IQR 25-75% =63.75-96.25)^	Z = 0.14 p = 0.89
Dizziness Handicap Index Score	40 (IQR 25-75% =22-54)	31 (IQR 25-75% =20-60)^	Z = 0.02 p = 0.98
Acquired Traumatic Brain Injury Vision Questionnaire	30.5 (IQR 25-75% =16-53)	35 (IQR 25-75% = 27-50)*	Z = -0.59 p = 0.56

^n=46, *n=47

Physical Examination Findings

All patients included in the study had at least one positive finding on the primitive reflex screen, with 93.1% having three or more primitive reflexes present. The most common reflexes present were ANTR and STNR (95.1%), followed by TLR (90.2%) and Moro disinhibition (84.1%). Spinal Galant reflex had the least common prevalence with 41.2% of patients demonstrating a positive screen. There were no statistically significant differences in occurrence rates of primitive reflexes between Group 1 and Group 2 (Table 2).

Patients in Group 1 required a median of 23 days (IQR 25-75% = 15-35) to fully re-integrate the disinhibited primitive reflexes using the 2-phased protocol, while patients in Group 2 required 28 days (IQR 25-75% = 15-39.5) to reintegrate (z = -0.68, p=0.5). Group 1 attended a median of 7 visits (IQR 25-75% = 4-15) with 3 visits (IQR 25-75% = 1-5) attended following PR integration, whereas Group 2 attended a total of 6.5 (IQR 25-75% = 4-12) during their episodes of care with 1.5 visits (IQR 25-75% = 0-3.5) following PR integration (z = 0.75, p=0.46).

Patient-reported Outcomes Among those Completing the Final Evaluation

Among the 34 patients in Group 1 who received a final PE and completed the patient reported outcomes, we found clinically meaningful and statistically significant improvements from baseline to discharge evaluation in all patient reported outcome measures (p = <0.0001). The greatest improvement was found in the Post Concussion Symptom Survey scores (n = 33) with a decrease of a median of 21 points (IQR 25-75% = -42 to -8; S = -260; MCID 6.8 points). Changes among the other measures were as follows: the Dizziness Handicap Inventory decreased a median of 27 points (IQR 25-75% = -10 to -36; S = -259; MDC =17.8 points, MCID =19); and Activities-Specific Balance Confidence Scale improved a median of 8.5 (IQR 25-75% =1.8-22.5; S = 242; MDC=9).[19-21] The aTBI Vision Questionnaire decreased a median of 16.5 (IQR 25-75% = -32 – -12; S = -272.5) points. The aTBI has since been adapted to the Brain Injury Vision Symptom Survey (BIVSS), includes the Convergence Insufficiency Symptom Survey (CISS) as the first 15 questions. The CISS has been validated for identifying binocular vision disorders in concussion however, minimal clinical important change scores have not yet been established.[22,23]

DISCUSSION

The first aim of this study was to provide a comprehensive clinical picture of patients with protracted concussion recovery. Patients presented with complaints of headaches, dizziness, difficulty concentrating, diminished memory, problems with close work and reading tasks, marked by significant scores on subjective questionnaires for post-concussive injuries. Previous literature demonstrates similar symptom presentation in individuals with protracted concussion recovery where individuals benefited from physical therapy interventions including cervical and vestibulo-ocular interventions.[27]

The second aim was to determine whether patients tolerated the protocol integrating primitive reflexes. According to the 2004 CONSORT reporting of harm in clinical studies statement, it is important both to report adverse events and to record reasons for study withdrawal as both may indicate whether patients tolerate a given treatment.[28] Among the patients in Group 1, all of whom completed the treatment protocol, there were no adverse events reported. Of the 48 patients who did not return for the final evaluation, 20 felt they were improved and that the final PE was not warranted or they were cleared by their physician for return to sport and one completed final treatment with FCOVD neuro-optometrist. Four patients discontinued for reasons not related to the treatment (cost and distance), 2 had serious mental health issues, 3 were hesitant to comply with treatment plan and for the remaining 18 patients, patients did not provide a reason. Thus, more than half of these patients discontinued based on perceived improvement or for issues not related to the intervention. As there were no statistically significant differences in demographics or medical history at baseline, it is possible but unlikely that patients withdrew due to poor tolerance of the protocol.

Finally, we aimed to determine the effectiveness of this integrative protocol demonstrating the potential benefit of a structured, stepwise protocol with an emphasis on what the authors believe to be Primitive Reflex Integration therapy. Literature has primarily focused on identifying vision and vestibular deficits post-concussion and emphasized the importance of a comprehensive evaluation.[29] Research has demonstrated a multimodal approach including physical therapy for cervical, vestibular, and ocular interventions is effective for post-concussion syndrome but there is a gap in clinical knowledge for established step-wise protocols.[29] Our protocol demonstrated clinically and meaningfully significant change scores for all patient reported outcome measures among those in Group 1 indicating improvement in concussion related symptoms after 7 visits (IQR 25-75% = 4-15). Additionally, at the outset of therapy, most patients had severe symptoms, and by the end of the protocol, the majority of patients had mild to moderate symptoms. While protracted concussion recovery timelines varied, individuals who completed the protocol tolerated and progressed with advanced vision and vestibular interventions faster than traditionally seen in this clinic prior to the implementation of the primitive reflex protocol.

Integrative protocols to manage protracted concussion show promising results. In a study by P. Grabowski, et al (2017) a multi-modal impairment-based approach (mean treatment time 84 days; mean treatments 4) for post-concussion syndrome was effective in improving symptoms as demonstrated by an average improvement of 9 points on PCSS scores.[10] This study incorporated cardiovascular and vestibular/oculomotor exercises, cervicothoracic manual therapy and exercises, and sport-specific training based on the PT evaluation and individual impairments.[10] Whereas, our protocol demonstrated a 21 point improvement in PCSS scores over a median of 7 visits (IQR 25-75% = 4-15 visits) and a median of 23 days for integration. In a study by Alsalaheen et al that assessed the effectiveness of vestibular therapy following a concussive injury, improvements in DHI and ABC scores were found over a median of 4 PT visits (+/- 2-13 visits) over a median of 33 days (rand, 7-181 days).[11] This study showed DHI improved by 19 points and ABC scores improved by 20 points.[11] Our step-wise protocol demonstrated a 27-point improvement in DHI and an 8.5-point improvement in ABC scores. While these studies all show improvements in symptom scores and function. previous research does not include a stepwise protocol to replicate interventions amongst the post-concussive patient population.

This retrospective study is the first to acknowledge a potential link between PR and concussion. Current literature supports the use of primitive reflexes in TBI for bedside assessments to predict severity of subacute cognitive and functional impairments.[30] The research used to establish this protocol had been demonstrated for PR retention in early intervention, visual deficits, and learning differences.[13-15,25] PR therapy exercises have predominantly been used upon recommendations from the neuro-optometrist.

Whether the treatments are truly addressing primitive reflexes or the changes observed are due to other root causes, this study demonstrates the effectiveness of this phased protocol with significant ($p = <0.0001$) change scores on pre and post-test subjective questionnaires. It should be noted that form matters when completing these exercises, as small changes such as the head down position in superman and swimmer is integral to the patient's success. It is plausible that these complex motor patterns with attention to postural control may be contributing to significant changes in concussion outcomes for other reasons than PR therapy including habituation, cerebellar recruitment, building patient confidence in movement, a mind-body integrative approach, and a variety of other causes.

Limitations of this retrospective study include low retention rate and lack of formal discharge re-assessments for those who completed the protocol. The authors attribute the low retention rate primarily to patients' self-discharge secondary to improved symptoms, tolerance to daily activities and returned to a "normal lifestyle," financial barriers, or distance from clinic. Due to the nature of the study, it is unknown how many patients received chiropractic, massage, or other treatments while completing the protocol which could have also contributed to their improvements in function and subjective reports.

Strengths of this retrospective study include accessibility of treatment due to time required for practitioners to learn this new skill set; the variety of providers who could complete training and implement the treatment protocol; minimal risk of harm in comparison to more advanced therapies such as vision and vestibular therapy; and a power of 80% to detect change on the PCSS.

SUMMARY

The significant change scores observed in this study are the initial steps to demonstrate a positive effect in concussion rehabilitation with a structured, step-wise progression targeting complex movements, cross-body integration as a precursor to vision and vestibular therapy. Despite the encouraging outcomes in this study, it is too early to know exactly why these outcomes are being observed, and further research could be done with a focus on validating the treatment protocol or screening tool, identifying the etiology of what the authors believe to be disinhibition of primitive reflexes, and controlled trials to compare with alternative treatment strategies.

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Appendix: Reference Images

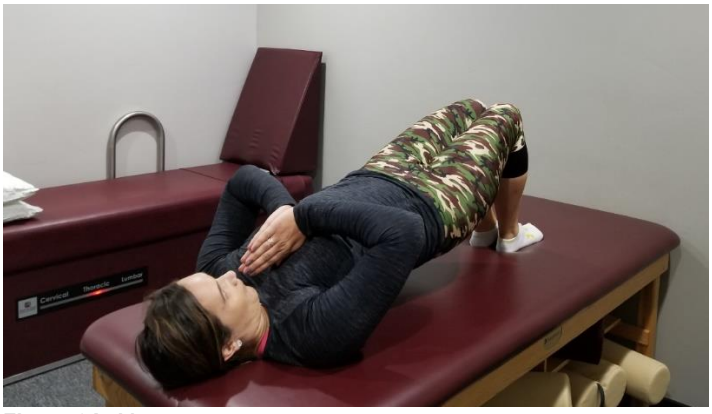

Figure 3A: Moro

Figure 3B: Bird Dog

Figure 3C: Zombie

Figure 3D: Superman

Figure 3E: Swimmer

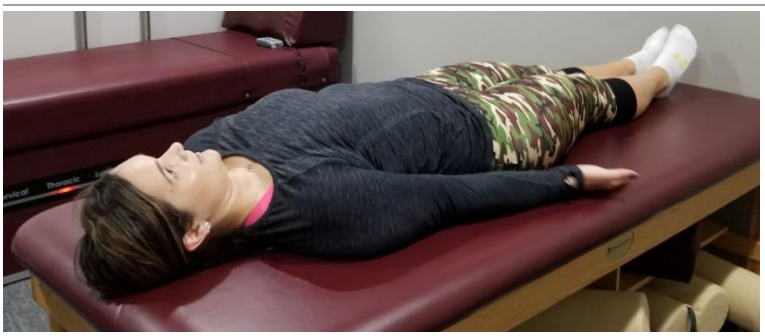

Figure 3F: Snow Angel (start)

Figure 3G: Snow Angel (end)