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Rehabilitation and Physical Therapy for Persistent Mild TBI: Insights from Case Studies

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ABSTRACT:

BACKGROUND AND PURPOSE:

Although most patients recover from a mild traumatic brain injury (mTBI) within 7-14 days, 10-30% of people will experience prolonged mTBI symptoms. Currently, there are no standardized treatment protocols to guide physical therapy interventions for this population. The purpose of this case series was to describe the unique, multimodal evaluation and treatment approaches for each of the patients with post-concussion syndrome (PCS).

CASE DESCRIPTION:

Six pediatric athletes with PCS who had participated in physical therapy and fit the inclusion criteria for review were retrospectively chosen for analysis. Patients received a cervical evaluation, an aerobic activity assessment, an oculomotor screen, and postural control assessment. Each patient participated in an individualized physical therapy treatment plan-of-care based on their presentation during the evaluation.

OUTCOMES:

Patients were treated for a mean of 6.8 treatment sessions over 9.8 weeks. Four of six patients returned to their pre-injury level of activity while two returned to modified activity upon completion of physical therapy. Improvements were observed in symptom scores, gaze stability, balance and postural control measures, and patient self-management of symptoms. All patients demonstrated adequate self management of symptoms upon discharge from physical therapy.

DISCUSSION/CONCLUSIONS:

Physical therapy interventions for pediatric athletes with PCS may facilitate recovery and improve function. Further research is needed to validate effective tools for assessment of patients who experience prolonged concussion symptoms as well as to establish support for specific post-mTBI physical therapy interventions.

KEYWORDS: Concussion, post-concussion syndrome, physical therapy

I. BACKGROUND

An estimated 1.6 to 3.8 million sports-related mild traumatic brain injuries (mTBI), also commonly referred to as concussions, occur each year in India.1 Heightened media attention, increased awareness about complications, and widespread enactment of legislation has stimulated a large increase in the number of patients and families seeking care for these injuries.2 Concussion was once considered to be a relatively benign injury that resolved within 7-10 days, however now studies are showing that 10-30% of individuals that sustain mild head injuries may go on to experience symptoms and impairments for months to-years.3,4 Physical therapists possess the tools necessary to treat many of these underlying impairments, and the role of the physical therapist is evolving into a key part of the health care team responsible for the management of patients struggling to recover from mTBIs.5,6

Appropriate interventions are derived from focused assessment strategies in physical therapy. Assessment and management of patients following mTBI can be challenging due to the elusive and unique presentation of symptoms associated with the diagnosis and a lack of standardized tools to assess impairments.7 Common examples of clinical post-mTBI assessment tools include symptom scales (e.g., Post-Concussion Symptom Scale; PCSS), neuropsychological tools (e.g., Immediate Post Concussion Assessment Tool; ImPACT), oculomotor function screens (e.g., gaze stability testing) and balance assessments (e.g., Balance Error Scoring System).5,8,9 A number of other types of assessments have also been suggested for evaluation of patients with mTBIs including: headache assessments,5,10,11 cervical strength and motion assessments,5,7 vestibular assessments,5,12,13 and cardiovascular and respiratory assessments.4,5,14-17

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Typical treatment for a patient with acute mTBI is complete physical and cognitive rest until a full resolution of symptoms.8 Intense exercise too soon after concussion may increase the risk for cerebral hemorrhage by increasing intracranial pressure18 and further exacerbate the metabolic brain energy gap.15, 19, 20 This concept of complete physical rest is being challenged in the population with prolonged symptoms. With symptomatic time frames extending into months, active rehabilitation protocols with a sub symptom or low-level symptoms range are becoming increasingly recognized as a potential way to facilitate recovery in this population.4,5,15,21,22 Active rehabilitation is believed to promote the neuroplasticity in the brain that contributes to symptom resolution and can benefit the overall well-being of the patient.21 Gradual, sub-symptom exercise training can be beneficial in allowing the brain to adapt to the increased physiologic demands of activity over time and allow the athletes to begin regaining their physical fitness.4 Multidisciplinary care, including physical therapy, is widely recognized as a key element for success with patients struggling to recover from mTBIs.8 Although numerous consensus statements exist from a variety of medical domains,9 there are few studies regarding rehabilitative strategies, and specifically physical therapy interventions, for patients struggling to recover from mTBIs.4 Therefore, an evidence-based physical therapy protocol is not currently available for patients suffering from prolonged concussion effects. However, given the high incidence of headache,10,23 dizziness,12,13 balance deficits,24 and aerobic intolerance15 in these patients, physical therapists have a wide repertoire of potential intervention strategies that could help facilitate recovery in these patients. The purpose of this case series is to describe the multimodal interventions used to treat six separate pediatric patients with prolonged post mTBI symptoms to provide physical therapists with insight into treating this challenging population.

II. CASE DECRIPTION

Patient data were extracted from 18 months of electronic medical records for patients referred to physical therapy for protracted recovery from mTBI. The International Statistical Classification of Diseases, 10th Revision (ICD-10), defines cases at 1-month duration with persistent symptoms as protracted, whereas other entities may define protracted as three months or more of persistent symptoms. For the purposes of this case series, protracted recovery was determined by the referring physician's personal designation of the subject. A recent systematic review highlighted the difficulty with this diagnosis due to a lack of consensus on how PCS is defined.25 A patient's record was eligible for inclusion if they: 1) consented to have their medical record data used for research purposes and signed a Health Insurance Portability and Accountability Act (HIPPA) waiver, 2) completed a physical therapy evaluation and at least three subsequent physical therapy treatment sessions, 3) had pre-treatment and post-treatment assessments for multiple tests and measures related to symptoms, postural control and activity tolerance. Patients' records were excluded if they: 1) did not have plans to return to high level athletic activity, 2) were not compliant with the physical therapy plan of care, or 3) had any concomitant diagnoses that could significantly complicate concussion recovery (e.g., positive findings on imaging, previous history of cardiovascular or neurological conditions). Access to the database from which the records were pulled was approved by the Institutional Review Board and participants' rights and privacy were protected throughout the entire process. Six patients (4 males, 2 females; age range 15-19 years) met the inclusion and exclusion criteria. Days since injury ranged from 19 to 192 (mean=81.7, SD=60.8) at the time of evaluation. All patients were evaluated by one of two licensed physical therapists, who are Doctors of Physical Therapy and board certified Sports Clinical Specialists with significant experience in treating children and adolescents experiencing protracted recovery from concussion. The average number of treatment sessions was 6.8 over an average of 8.9 weeks.

III. EXAMINATION

History Subjective history, as reported by the patient and confirmed by parent or guardian when present, included: mechanism of injury, initial symptoms at the time of the injury, current symptoms, days of school missed, current activity levels and sports participation, activity intolerance, current medications, other treatments being pursued, goals, and diagnostic testing. Imaging tests performed for all patients were unremarkable and none reported a loss of consciousness at the time of injury. Patient and family goals for physical therapy included returning to their prior level of everyday activity (ADLs, levels of fitness) and return to sports and recreational activities.

Systems Review

A systems review was conducted for all body systems with vigilance to any red flags indicating systemic disease.26 Findings were negative for all basic cardiovascular, pulmonary, integumentary, neuromuscular and cognitive screens.

Clinical Impression

The vast symptomatology associated with mTBI makes screening for contributing co-morbidities and/or ruling out other diagnoses or medication side effects difficult.27 Benign paroxysmal positional vertigo (BPPV) is one example

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co-morbidity that may be present after mTBI.12 To rule this potential diagnosis out, a Dix Hallpike maneuver was performed when indicated. Pre-injury of migraine headaches or other chronic headache conditions, anxiety, depression, and attention-deficit hyperactivity disorder were also strongly considered as potential factors contributing to the unresolved symptom reports that included symptoms associated with these diagnoses.28 In addition, patients who experience a prolonged recovery may experience feelings of isolation and withdrawal from physical and social activity which could in-turn contribute to secondary manifestation of psychosocial characteristics that may not be related to the initial injury.21,28 Therefore, these factors were also considered as potential contributors to patients' symptom reports.

Cervical Evaluation

Due to the whiplash-like mechanism that often occurs with head injuries, patients with mTBI may be susceptible to cervicogenic headaches. To evaluate if patient's post-mTBI headache symptoms had the potential to be cervicogenic in origin, then measures of strength, range of motion, tenderness to palpation and posture were assessed for the shoulder, periscapular, and cervical regions for all participants. More specifically, patients were assessed for a unilateral headache with pain that was aggravated by neck movements and a tenderness with palpation of sub occipital muscles and/or the upper three cervical joints.11 Any increase or decrease in symptom exacerbation while performing the cervical exam was interpreted as a potential indication to incorporate cervical spine manual therapy and/ or therapeutic interventions specifically targeting the cervical spine and periscapular regions. Tests for cervical instability, nerve root impingement, vertebral artery syndrome and thoracic outlet syndrome were also performed as necessary when indicated by a patient's history and/or findings during the cervical screen. Four of six patients demonstrated deficits indicative of potential cervicogenic headache contributory factors. No patients demonstrated any red flag signs for cervical instability, vertebral artery syndrome or thoracic outlet syndrome that would preclude their participation in manual therapy techniques.

Activity Tolerance Assessment

Following mTBI, patients can demonstrate increased heart rate and uncommon variation in systolic blood pressure during exercise which can lead to symptom exacerbation.14, 16, 17 Moreover, exercise tolerance can be affected due to exaggerated sympathetic response, an impaired cerebral auto-regulation of cerebral blood flow.4, 15 This could be a primary effect of the mTBI associated with autonomic dysfunction,4, 15 a secondary effect from decreasing typical activity levels during the acute recovery stages,15, 21 or a combination of both. Research suggests that a modification in mTBI symptoms as a result of physical activity lends to a physiological basis of prolonged concussion symptoms that can theoretically be treated by a graded, sub-symptom exercise program.15 Therefore, an activity tolerance assessment was performed to screen for potential cardiovascular dysfunction or symptom exacerbation with exercise. Prior to engaging in the activity tolerance assessment, patients completed the Post-Concussion Symptom Scale (PCSS) checklist.29 The PCSS asks patients to rate their symptoms such as "headache" or "dizziness" on a Likert scale of 0 to 6, with 0 meaning "none" and 6 meaning "severe." Resting heart rate and blood pressure were also assessed using an automatic wrist blood pressure monitor (Omron Healthcare Inc, Bannockburn, IL) prior to beginning the activity assessment. These results are reported in Table 2. Patients were then instructed to ride a bicycle ergometer for 10 minutes at a Rating of Perceived Exertion determined by the physical therapist ranging between 11 and 13 on the Borg Scale.30 A "13" on the Borg Scale corresponds to "somewhat hard." The Borg scale has been validated as a reliable patient reported measure of perceived exertion in children performing cycle ergometry.31 In the event the patient reported an immediate increase in symptoms, the activity was stopped, and the amount of time and Borg Scale level were documented for the patient. Post-exercise, patients' symptoms, blood pressure, and heart rate were re-assessed. Once safe physiologic parameters for heart rate and blood pressure were established, sub-symptom exercise could be performed below these levels to allow the patient with a protracted recovery to participate in active rehabilitation.14 Patients 3 and 6 demonstrated a large reduction in symptoms scores after riding the bicycle ergometer, while the other patients' symptoms scores remained the same or slightly increased. Improvements in symptom report after exercise are not uncommon in this population as exercise has been shown to improve blood flow to the brain and may simply improve mood levels.18 No abnormal responses in heart rate and blood pressure responses to the exercise were observed for any of the subjects

Oculomotor Screen

Oculomotor and visual impairments (e.g., difficulty with horizontal and vertical tracking for such tasks as reading or navigating busy environments) are also common with mTBI.32-34 To rule out the need for specific vestibular and visual specialist interventions, patients underwent a basic oculomotor screen. This screen included a test of gaze stability to assess function of their vestibulo-ocular reflex (VOR).24 For this assessment, patients' were positioned three feet away from an "X" on the wall. While keeping their eyes focused on the "X," patients turned their heads repeatedly approximately 45 degrees to each side. Patients were instructed to attempt to complete up to 30 repetitions

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(one full cycle from right to left and back was recorded as one repetition). If symptoms were exacerbated by the activity, the patient was instructed to stop and the number of repetitions was noted. Although none of the patients demonstrated clear signs of a vestibular complication or visual impairment that warranted further evaluation by a vestibular or visual specialist, four of six demonstrated some general, diminished tolerance to this oculomotor challenge.

Balance and Postural Control Assessments

Balance deficits and postural control dysfunction are also common after concussion24 and have been shown to persist in children for 12 weeks or more.21, 35 Balance and postural control testing for these patients included the Balance Error Scoring System (BESS)10,36,37 and a force plate assessment of postural sway.8,35 The BESS is a commonly utilized observer-rated measure that consists of three stances performed on two different surfaces for 20 seconds each with the subject's eyes closed. The observer counts the total number of errors that occur during each trial.38 Olson39 reports normative values for the BESS for healthy children ages 11-18 as 12.94±4.5. BESS scores for the initial evaluation relative to this normative mean score. Clinical force plate assessments of postural control dynamics (patterns within a person's sway over time) are still evolving40-42 and have recently emerged as a potential way to evaluate postural control deficits in youth following mTBI.43,44 However, several studies indicate that postural sway dynamics may be altered following mTBI, and these alterations may persist even when other measures of postural sway and balance have resolved.35,40 Patients stood without shoes on an AMTI force plate sampled at 100 Hz with their arms hanging naturally at their sides and eyes focused on a target approximately three feet in front of them.A two-minute protocol was selected based on the recommendations of Gao et al.45 and the eyes open condition was selected as it tends to yield more reliable postural dynamics results.43 Although a number of studies pertaining to postural sway dynamics and mTBI have utilized Approximate Entropy as the primary form of analysis of the dynamics,35,41 Sample Entropy (SampEn) was chosen for this case study based on more recent recommendations.46,47 SampEn quantifies the repeatability of sub-sets of data strings within a time series. A high degree of repeatability (lower SampEn) is indicative of a time series that is more regular and predictable, while a low degree of repeatability (higher SampEn) indicates that the time series is less structured and more random. Custom MATLAB code was utilized to identify optimal template sizes (m; m= 2) and a matching threshold value (r; r = .2) and compute SampEn for the medial-lateral direction for each patient. In addition, a mean SampEn score of .1483 with a standard deviation of .05 was created a sample of 135 healthy adolescents ages 8-21 years. Patients' initial SampEn scores relative to this mean score for healthy normals are presented.

Interventions All patients received a combination of in-clinic sessions consisting of cardiovascular, musculoskeletal, postural control and vestibular/oculomotor interventions based upon their personal needs identified during the examination .Re-introduction of low-level physical activity after long periods of deconditioning in the athlete has been shown to help restore physiological homeostasis in the brain and reduce symptom exacerbation.15 All in-clinic treatment sessions began with up to 10 minutes on the bicycle ergometer at an RPE determined by the patient's response to their initial examination. A PCSS checklist and vital assessments were performed before and immediately following the aerobic activity. As appropriate, patients were progressed through longer duration, higher intensity, and multimodal aerobic and anaerobic activity that included light jogging, run/jog intervals, intervals on the bike, upper body ergometer, and elliptical. Progression to interval and sport-specific exercise was incorporated as the patient demonstrated increased tolerance to physical activity by stable or reduced symptom scores with long-duration aerobic activity. Interval training utilizing variable work and rest ratios was implemented to challenge the patient's tolerance to high intensity activity. Modes included stationary bicycling, upper body ergometer cycle, walking/jogging, and the elliptical. Sport specific skills included the agility ladder, mountain climbers, box jumps, tuck jumps, single and double leg line jumps, and incorporation of sporting balls into activities such as kicking a soccer ball into net. Vitals and symptoms were monitored periodically throughout the session at the therapist's discretion; most commonly with the introduction of a new or particularly strenuous exercise or with a patient report of symptom exacerbation. As children and adolescents tend to have less well developed neck and shoulder musculature in general, which may increase their risk for initial and recurrent mTBIs,7 all patients also received exercises that specifically targeted neck strength. Patients whose cervical examination demonstrated a possible cervicogenic origin of headache pain also received manual therapy interventions such as soft tissue mobilization, suboccipital release, and manual stretches for the upper trapezius and levator scapulae muscles.5,11 Several authors have demonstrated that even once postural stability has appeared to stabilize following mTBI, patients may continue to have impairments in their postural control and motor control abilities.35,48,49 Therefore, general postural control, balance and motor control exercises were incorporated for all patients, regardless of their performance on the postural control tests during the initial examination. These exercises targeted balance, proprioception, and general lower extremity neuromuscular control such as balancing with ball tossing, walking lunges, multi-directional step-ups with emphasis on trunk control and many others. Vestibular

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rehabilitation in children, including gaze stability exercises, has been shown to significantly reduce dizziness resulting from mTBI.12 Since all patients demonstrated at least a mild intolerance during gaze stability screen, gaze stability exercises were incorporated into the patients' treatments until they were able to perform at least 30 repetitions of horizontal head turns. These exercises began in sitting with a slower speed and then were progressed to standing, faster speeds, and greater repetitions. Due to the cognitive sequelae that accompany a concussion injury, dual tasking can be a useful and functional way to progress exercises.50 In addition athletic performance often requires the simultaneous performance of cognitive and motor tasks. As such, tasks in the clinic were combined to challenge the patient's multi-tasking ability and to stress their cognitive processes. For example, a balance exercise such as single leg balance on a firm surface was progressed to an unstable surface, to an unstable surface with a ball toss, to an unstable surface with a ball toss while reciting the alphabet backwards. Dual tasking has been shown to improve performance during balance activities in healthy subjects versus individual balance tasks performed alone.50 Dual-tasking intervention methods were also factored in with regard to the clinic environment and the scheduling of treatment sessions. Patients who were very sensitive to external stimuli were scheduled during quiet, morning appointments early in their treatment sessions rather than in the busy after school environment. Once the therapist felt it was appropriate to progressively expose the patient to increased external stimuli, these patients were scheduled at busier times in the clinic, which was viewed as a progression of treatment. In addition to the in-clinic interventions, each patient was also given a progressive home exercise program (HEP) with recommendations to complete three to five days per week. HEPs for all patients included at least 10 minutes of an aerobic modality (e.g., stationary bike or walking) as well as vestibular/oculomotor exercises, postural exercises and stretching of the neck musculature. The HEP was progressed and sport-specific exercises were added in on a case-by-case basis relative to the patient's progress and goals. All patients were encouraged to monitor their response while performing their HEPs and to make modifications as necessary to avoid excessive symptom exacerbation.

IV. OUTCOMES

It is important to note that post-exercise assessments were actually performed at a higher intensity at the final session relative to their initial assessment as it was based on each participant's post-intervention RPE levels. All six patients reported lower resting symptom severities at their final session compared to their initial sessions. Four out of the six patients made fewer errors on the BESS test during their post-intervention assessment compared to their pre-intervention assessment, while two patients made the same number of errors in both assessments. Four out of the six patients had SampEn scores that were closer to the mean score for the healthy cohort of subjects compared to their initial scores. All six patients reported lower symptom severity in their resting PCSS assessments at their final evaluations. In spite of these improvements, only one of the six patients had returned to full pre-injury activity levels at the time of their final physical therapy assessments. However, a follow-up chart review indicated that four of six patients were back to pre-injury levels and types of activity within 3-6 months after discharge from physical therapy. Of the remaining two patients, one decided to pursue only recreational activities and the other chose a sport with less risk of contact injury.

V. DISCUSSION

The purpose of this case series was to provide a framework of evaluation and subsequent treatment techniques for the assessment and management of patients with prolonged recovery from mTBI. Most studies currently focus on psychotherapeutic and pharmaceutical management of prolonged mTBI symptoms.51-53 These forms of treatment do not directly target the physical impairments present in this population. Prior literature has also shown a multi-modal approach to treatment in adolescents to be safe and effective at symptom reduction, however without great detail about how their evaluations shaped their individualized treatment approaches.54 The outcomes of the patients from this case series suggest that a physical therapy program incorporating a multi-modal approach may help facilitate symptom reduction, improve self-management abilities, and safely enhance function in this patient population. The use of symptom scores is a widely accepted and useful tool used for acute and prolonged-concussion management.53, 55 However, Iverson et al56 recorded a score of at least five on the PCSS scale for healthy, non-concussed, young adult subjects. A review of consensus statements9 highlight the goal of being asymptomatic prior to return to play, however it is recognized that the final determination is a medical decision based on clinical judgment.8 Therefore, the presence of symptoms in patients following an mTBI may not necessarily be an indication of stunted recovery but rather typical symptoms present in a healthy population. A modification in sports participation is sometimes necessary to avoid excessive symptom exacerbation in patients or to minimize risk for future complications such as a subsequent head injury. Two of the six patients did not return to their previous sports due to personal choice to minimize risk for future injury. For these reasons, a return to full participation in pre-injury activities with no reported symptoms at the time of

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discharge from physical therapy may be an unrealistic expectation for this patient population. A patient-reported ability to function at near baseline capacity, perform ADL's, and participate in chosen activities may be a more appropriate gauge of success. Assessment and intervention tools are rapidly evolving for post-mTBI assessments with children and adolescents. For future clinical integration, the oculomotor screen used in this study could be improved by coordinating head turns with a metronome set at 120 to 140 beats per minute which would more closely mimic the movement velocity required for activities of daily living and standardize the measure across patients. The addition of a Brock string assessment and exercise33 protocol could also be a good improvement for oculomotor screening and intervention for this population. Similarly, there are still a variety of studies that need to be performed to improve the clinical utility and integration of the balance and postural control measures used in this case series. Nearly all of the patients in this study had initial BESS scores that would have been considered within or better than the range of scores expected for healthy adolescents. The BESS is also known to be associated with learning effects with serial administrations.57 Consequently, it is difficult to determine the clinical meaningfulness of the patients' changes in BESS performance. Likewise, SampEn measures are still relatively novel and complicated from a clinical implementation standpoint. They require expensive equipment and expertise to be able to implement. In addition, it is theorized that there may be an optimal range of healthy dynamics, and impairments may be observed as either higher or lower than this "healthy range." There are currently no studies that provide evidence about what the healthy range for SampEn might be for children and adolescents. With regard to the patient scores in this study, scores were observed both above and below an unpublished mean score for a cohort of healthy individuals. However, the healthy cohort consisted of a wide range of ages, and a relatively small sample for making a good population estimate. Future studies with large sample sizes that account for potential age-related confounders should be performed to improve the utility of this assessment method.

VI. CONCLUSIONS

Over the past few years the healthcare system has seen a rise in the number of patients requiring treatment for mTBIs. Patients experiencing prolonged symptoms are often a challenge to treat and benefit from comprehensive care from a multidisciplinary healthcare team. Many of the deficits experienced by patients with protracted recovery can be treated within the physical therapist's scope of practice. Although a number of consensus statements and commentaries regarding the assessment and management of mTBIs in the acute phase of injury recovery are currently available, guidelines and studies related to management of patients with prolonged symptoms following mTBIs are sparse.7, 8 This case series describes a set of multimodal physical therapy interventions and subsequent outcomes for six separate pediatric patients with prolonged post mTBI symptoms to provide physical therapists with insight into treating this challenging population.

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