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Case Report Open Access

Aggressive Rehabilitation Pathway Targeting Concussion Symptoms: Illustration with a Case Study

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Abstract

We present an aggressive rehabilitation program that addresses specific post-concussion symptoms for patients with a mild traumatic brain injury (mTBI). Our pathway is illustrated by our report of a 38-year-old female who was injured during a wind storm as a result of a direct blow to the left temporal area. In the fourth month following her injury, she was diagnosed with a right-sided central and peripheral vestibular neuropathy. She had cognitive difficulties and consistently poor multitasking abilities. After five months of brain rest and incomplete resolution of symptoms, she was referred to our program. A comprehensive rehabilitative program, including patient specific goals, was initiated to address the multiple deficiencies and symptoms to improve her quality of life (QOL). The program utilized a multidisciplinary team approach including instructing the patient on “feel better” and “get better” strategies. The patient’s progress and symptoms were continuously monitored, addressed, and targeted. Progression of activity was based upon achievement of multiple symptom-regulated goals. The program also included training cognitive function under physical stresses to return her to her pre-injury high-level of function and activity. Approximately 11 months following the concussive event she was discharged and placed on a long term maintenance program, as her QOL was essentially normal. As is typical with mTBIs, the recovery in this case was not linear and rehabilitation often evoked symptoms, but the concussion management team closely managed and addressed the symptoms. One particular intervention, the adjustment of visual acuity to 20/30 instead of 20/15, was particularly effective in reducing symptoms triggered by vision corrections. A focused, personalized rehabilitation program that targets the symptoms of a concussion helps identify and resolve concussion symptoms. This philosophy is based on traditional sports medical rehabilitation methods that first assess an injury and then work to strengthen weaknesses.

Keywords: Neuroscience; Vision training; Cognition; Quality of life; Outcomes

Introduction

In the neuroscience community, as well as the global community, mild traumatic brain injury (mTBI) or concussion is experiencing a rapid growth in awareness. Youth sports organizations are highly concerned with the risk of mTBI and its long term effects on the brains of young athletes. Concussion is somewhat an anathema because of a lack of understanding of the pathogenesis involved post concussive event as well as a frequent lack of imaging or pathological evidence for it [1]. This relative lack of understanding of concussion, concussion diagnosis, concussion management and evidence based medicine concerning rehabilitation post mTBI has led to confusion regarding the types of treatment needed in these patients [2]. It is generally recommended that a subject rest until symptoms resolve [3-6]. The presence of frontal lobe damage and the dysfunctions that accompany it can impact a rehabilitation program [7]. There is emerging evidence suggesting that exploiting the residual function in deficient systems is beneficial as well [8].

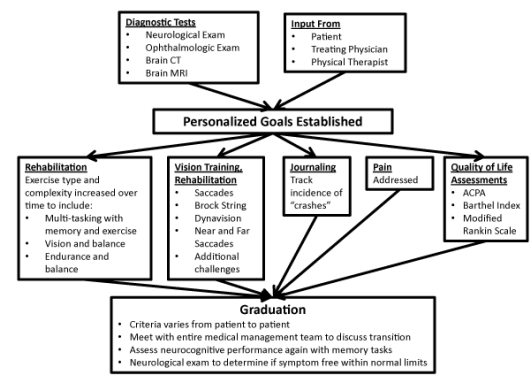

Figure 1: This flow diagram outlines the strategy for managing a concussion patient. Rehabilitation of central and somatic symptoms are addressed and individualized strategies. This strategy is concordant with our goal to help a patient feel better and eventually get better with rehabilitation.

Our concussion management program operates with the philosophy of getting the concussion patient back to normal utilizing a multidisciplinary team approach (Figure 1). We continuously assess the patients' progress and symptoms during rehabilitation, which is specifically designed to address, and attack, symptoms with the goal of getting better. It is well established that neurocognitive, vestibular and multisystem dysfunction post mTBI can cause or contribute to decreased quality of life (QOL). In the current paper we report a female subject who began a rehabilitation protocol while still symptomatic five months post-concussion with an America Chronic Pain Association (ACPA) QOL Score of 4/10 [9]. This program involved the implementation of an aggressive rehabilitation program with progression of activity based upon achievement of multiple symptom-regulated goals.

Case Report

Our patient, a 38-year-old female, was struck in the head by flying debris during a windstorm. The incident, witnessed by her husband, caused a direct blow to the left temporal area and had sufficient force to cause her to be propelled, approximately 1.5 meters, and land on her right side. At the time of this injury she was recovering from foot surgery that had taken place three weeks prior. She sought medical attention the same day, of the head injury, in a local emergency room where she reported retrograde amnesia without loss of consciousness and was discharged with the diagnosis of facial contusion. This diagnosis was confirmed by an otolaryngologist approximately three days following the event, which saw no skeletal damage and diagnosed concussion with an initial recommendation of brain rest.

Approximately one month following the head injury, she reported continued concussion symptoms to her orthopedic surgeon during a routine six-week post-operative follow-up from her foot surgery. She was reassured initially, but when symptoms continued for an additional one month her orthopedic surgeon referred her to our concussion management team. We initially saw her approximately five months post-injury and she reported continued headaches, neck pain, abnormally poor sleep quality, easy fatigability, short-term memory deficiencies and poor multi-tasking ability. She was observed to have short-term left-sided jaw tenderness, right sided posterior occipital neck pain, positional vertigo and orthostatic hypotension, short term memory issues, and abnormal peripheral vision, especially in the right lower visual field. Because of these multiple, significant post-concussion symptoms (Table 1), her initial management plan was to continue brain rest as much as possible. She was also started on Gabapentin to help improve vertigo and sleeplessness symptoms.

In the third and fourth months of her recovery period, she continued to report difficulties with multitasking, word finding, and considerable worsening of all symptoms when trying to resume exercise at a heart rate (HR) above 120 beats per minute (bpm). She continued to have increased transient bouts of extreme fatigue, most likely a result of attempting to get back to normal activities of daily living. With no significant improvement in her post-concussive symptoms, she was again referred to our multi-specialty concussion program for further evaluation and management.

Post-Concussive Symptoms	Our Case Subjects Symptoms	Pediatrics 2014 [24]	J Arch Clin Neuropsychol 2002 [25]
Physical symptoms			
Blurry vision		6	
Dizziness		14.2	59
Double vision		1.8	
Fatigue	Easy fatigability	21.6	91
Headache	Headache	24.8	78
Light sensitivity		13.8	44
Nausea		8.7	
Noise sensitivity		12.4	46
Sleep disturbance	Abnormally poor sleep quality	10.1	70
Cognitive symptoms			
Forgetfulness	Short term memory deficiencies	14	73
Poor concentration	Poor multi-tasking ability	17	
Taking longer to think		18.3	69
Emotional symptoms			
Depression		8.3	
Frustration		14.7	

Irritability		14.2	62
Restlessness		10.6	59
Other			
	Neck pain		
	Positional vertigo and orthostatic hypotension		
	Abnormal peripheral vision		
	Vision induced fatigue and headache		

Table 1: Post-concussive symptoms

After more than four months of brain rest, the patient appeared to have reached a functional plateau. A functional plateau, as well as resolution of symptoms, at any given stage in rehabilitation is a trigger to promote a patient to the next stage of rehabilitation. The functional plateau is a plateau, real or perceived, in the progress made during the rehabilitation program for the mTBI patient and should not hinder a successful escalation through rehabilitation. We try to avoid having a patient remain on brain rest for too long as it entrenches the person to a sedate and often unfulfilling lifestyle. It was initially clear that prior to injury this patient was highly functional and wanted to regain the cognitive and executive functions needed for day to day life. Therefore, the aggressive rehabilitation program was initiated in the fifth month after her injury.

Aggressive Rehabilitation Program

The aggressive, progressive rehabilitation program started (at 10 weeks for this patient) with multiple diagnostic tests. A neurological exam consisting of several components, including a cranial nerve examination, balance assessment, examination of vestibular function, memory tasks (Dynavision number recall, 5 word recall with interrupted memory), measurement of executive function, and answering questions concerning symptoms and QOL was performed. A Computed Tomography (CT) scan and a Magnetic Resonance Image (MRI) of the brain were also obtained.

An ophthalmologic exam was done that included an assessment of basic visual acuities for near and far as well as monocular and binocular vision. Near point of convergence was noted in inches. An internal examination with particular emphasis on the optic nerve, color, margins and cup to disc ratio was performed. Retinoscopy results, monocular refraction, and binocular distance vision and close visual acuity were noted. Acuities with correction were noted [10]. Stereopsis and intra ocular pressures were determined. Her neurological exam found a cranial nerve 6 palsy (incomplete tracking of the left eye lateral left resulting in blurred vision); misses with hand-eye coordination, mainly within the left hemi-visual field; and an abnormal Romberg, along with several errors during single leg and tandem stance balance testing. An important portion of the neurological exam included the D2™ (Dynavision International, West Chester, Ohio), an FDA-cleared visuomotor and cognitive assessment/training system. The D2™ evaluation utilizes two proprietary programs as well as three additional diagnostic programs which determine crude and peripheral vision, reaction time, short-term memory and hand-eye problem solving abilities. Her D2™ exam included completion of five exams including the A* training session, the reaction test and 3 concussion specific exams [11]. Her "outer" ring score was substantially slower than the rest of the test, suggesting diminished peripheral vision [12]. Her absolute score on the memory test was within normal limits but she had multiple addition errors when multitasking. Thus, her D2™ exam did demonstrate deficiencies. Her brain CT scan was found to be within normal limits and her brain MRI was normal with no lesions or structural findings.

Once all of the initial diagnostic tests were completed, personalized goals were established, which included input from the patient, treating physician and physical therapist. The neuroscientist/neuro rehabilitation specialist began to see her weekly and then eventually bi-weekly and counsel her on her rehabilitation pathway [13]. The rehabilitation program began with exercises that included basic stretching, walking with a target HR of 104 ± 10 bpm, seated eye movements with and without a target, balance exercises and three basic re-habituation exercises (Table 2). Table 2 outlines a typical set of tasks for a rehab session for the patient. These tasks and accomplishments help the patient feel better as progress is being made. As the patient progressed the type and complexity of exercises were increased to include multi-tasking with memory and exercise, vision and balance, and endurance and balance. MR Cube (Monitored Rehab Systems BV, Netherlands) was a part of the physical and mental re-training and was done at least once a week [14].

The vision training component of the rehabilitation program occurred weekly. It started with saccades with turns to the right and the left while on a trampoline for one minute and escalated from 40 to 180° separation. This was followed by one minute of the Brock string procedure where the patient called the colored beads into focus while being monitored for convergence [15] followed by Dynavision. Near far or saccades were also used for warm up exercises [16].

These activities strengthen the muscles of accommodation (focus), and convergence. The speed at which these mechanisms work is increased through the faster neuroprocessing in the brain [10,17]. As the patient progressed, additional challenges, like using a trampoline or balance board, were added, taking the therapy to a higher level.

Program Components	Description
Cardiovascular	Cardiovascular activity was an integral component due to its established metrics for improvement and changes the metabolism in the body. This exercise component is progressed based on the patient's response to activity and the targeted heart rate based on the current stage in the progressive rehab protocol. Equipment used in this case study: a treadmill, upper body ergometer, recumbent bike, and, later on in the rehab program, a Stairmaster and level surface track.
Vestibular	Positional tolerance was a major component for the rehabilitation program. Habituation exercises targeting symptom provoking movements and spatial awareness exercises such as lateral cup stepping (without visual aide) and single leg balance were prescribed. Progression of the program involved more dynamic exercise that incorporated multiple vestibular and cognitive systems.
Neurocognitive	In this case study, we started with targeting specific systems and, throughout the program, progressed to multiple systems being challenged in a multitude of ways. We utilized, Dynavision, the MR CUBE system, number grid hopping exercise that challenges balance and neurocognitive skills simultaneously, and problem solving while balancing on an unstable surface.
Musculoskeletal	Evaluation results will drive this component. Due to the sedentary nature post-concussion, addressing areas of weakness are important for proper progression of the rehabilitation program. As a general recommendation with concussion patients, it is always good to establish a warm-up consisting of stretching exercises designed to relax and also prevent tightness.
Modalities	Modalities use will aid in quicker recovery between sessions and lessen the post-session symptoms. In this case study, we utilized electrical stimulation, cryotherapy and various thermal modalities.

Table 2: Program components

The patient maintained a journal to track the incidence of "crashes". Crashes were defined as temporary escalation of symptoms which were limited to that day, and/or symptoms both during and after the sessions.

During the general care and management of the patient, pain at the left temporomandibular (TMJ) joint was identified through subjective complaints during a particular treatment session and discovered to be a result of the initial impact to the head [18]. The physical therapist administered conventional electrical stimulation treatment techniques aimed at improving mandibular opening and decreasing pain. This treatment used an intermittent current on a 10 second on then 10 second off duty cycle, and applied over the masseter muscles. We continued to utilize the treatment for the remainder of the rehabilitation process.

The patient participated in the rehabilitation both in the busy rehabilitation clinic and at home. During these months, she was able to progress parts of her rehabilitation through all stages. She reported a significant improvement in her cognitive symptoms and was able to resume most of her pre mTBI cognitive activities. Her vision issues remained both at rest and worsened with a submaximal heart rate above 160 bpm. She also still reported experiencing "crashes" in multiple environments following multi-tasking. Our protocol of mini re-evaluations isolated several of the symptom triggers and we began to address them independently.

The subject frequently had to miss sessions because of symptoms in the initial few months of rehabilitation (Figure 2). Inversely, missed sessions due to extracurricular activities such as family commitments, were few initially as she had apparently disengaged from many social activities. These started to increase in Months 9 and 10 post injury while symptom misses were decreasing.

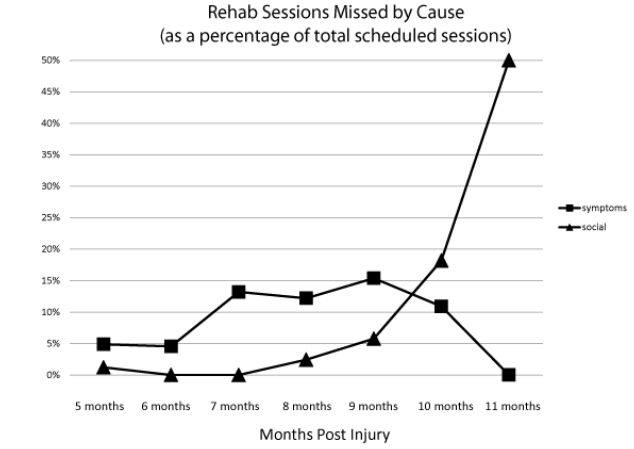

Figure 2: The percentage of total scheduled rehabilitation sessions missed due to symptoms (n) versus social engagements (s) are graphed above. The incidence of missed sessions during the initial stages of progressive rehabilitation are due to symptoms preventing participating in rehabilitation whereas in the late stages of rehabilitation missed sessions due to symptoms decreases and is dominated by participating in social engagements. The increased social engagements are likely a reflection of improved quality of life.

Her cognitive responses from MR Cube exercises initially increased dramatically (Figure 3). When fit to a third degree polynomial there was a plateau and fall in seven months post injury with an increase in performance the next month. The slight fall may be related to the increased intensity of the sessions, causing a slight fall in performance which she quickly regained. Once the plateau was reached in Month 9, the subject's rehabilitation with MR Cube was modified.

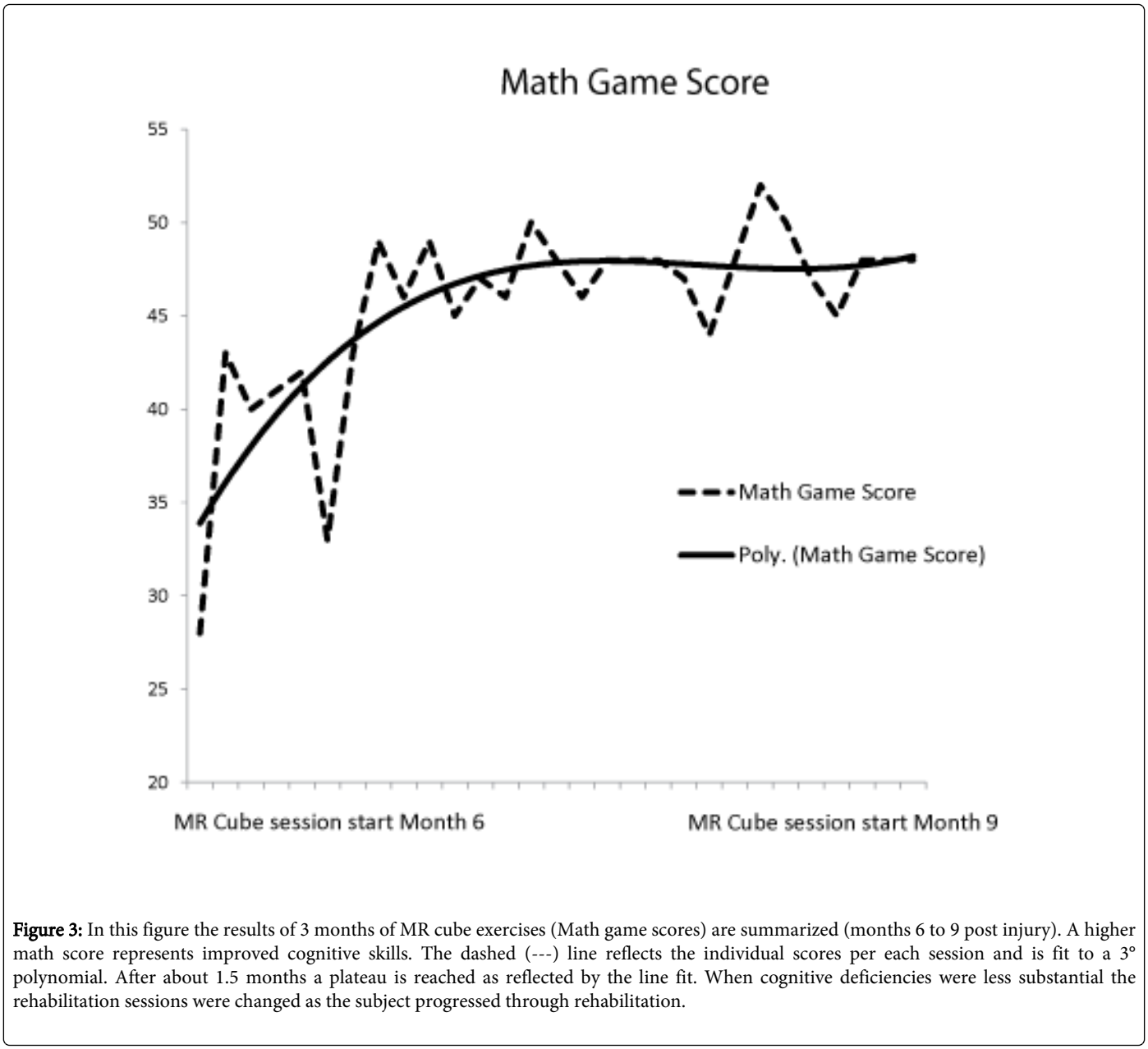

Figure 3: In this figure the results of 3 months of MR cube exercises (Math game scores) are summarized (months 6 to 9 post injury). A higher math score represents improved cognitive skills. The dashed (---) line reflects the individual scores per each session and is fit to a 3° polynomial. After about 1.5 months a plateau is reached as reflected by the line fit. When cognitive deficiencies were less substantial the rehabilitation sessions were changed as the subject progressed through rehabilitation.

The patient completed the multi-specialty comprehensive rehabilitation program in five months, approximately 10 months post-injury. There was a significant improvement in the D2™ scores. Pre Month 10 the D2™ average was 77.6 ± 9.2 hpm; Post Month 10 it was 85.2 ± 3.9 hpm, which was statistically significant ($p<0.05$).

During the program validated QOL scales (ACPA, Barthel Index, and Modified Rankin Scale (mRS)) [9,19,20], were used. All three were completed by the subject and her husband. Initial assessments taken before rehabilitation had good concordance between the two sets of scores with ACPA of 4, mRS of 3 and Barthel of 93 and 95 respectively. It is important to remember that this was five months post a concussive event and prior to our rehabilitation program. After the program ACPA improved to 9, mRS improved to 1 and 2 respectively and Barthel was normal at 100. These results suggest a substantial improvement in the subject's and her husband's perceived QOL of life. The completion of the concussion rehabilitation protocol is called "graduation" and the criteria vary from patient to patient. After our patient progressed through the program, a meeting with the entire medical management team occurred to discuss her transition out of the rehabilitation program and return to an acceptable QOL. At the end of the rehabilitation program, her neurocognitive performance was again assessed with memory tasks [21].

At 11 months following the concussive injury, the patient was referred to our specialist optometrist. At this time her only symptoms were transient episodes of extreme fatigue early in the day ("crashes early") and headaches - perhaps due to delayed visual accommodation. Her acuities were corrected: 20/15 OU, and uncorrected 20/80 OU. The optometrist determined that correction to 20/30 acuity (adequate for driving) [22], significantly diminished the patient's symptoms and finalized her vision prescription to -1.50 SPH.

By the rehabilitation's conclusion, the patient was put on a long term maintenance program. Upon graduation, the patient had not achieved full recovery in all areas, but the patient reported her QOL had returned to an acceptable level. A neurological exam, similar to the one completed at the beginning, determined the patient to be symptom free within normal limits. The patient in this case study was asked to give her personal opinion on her overall recovery status at the time this paper was written, 13 months post-concussive event.

Discussion

At 11 months post injury the training room rehabilitation program was considered to be at or near its conclusion because the patient could complete a full rehabilitation protocol without evoking symptoms or crashing after the session or upon returning home. The modalities engaged during rehabilitation are the same modalities used for sports medicine and neuropsyche rehabilitation sessions. The reduction in symptoms resulted in a decrease in the duration of the rehabilitation sessions with nearly a 50% decrease in session time. The reduction occurred from less rehabilitation stoppages.

It remains to be determined if the left TMJ pain contributed to symptoms and its resolution helped resolve concussion symptoms or if the therapy somehow mitigated symptoms. It highlights the need for a whole body approach of central and somatic symptom management when treating concussion patients. More work on the mechanism for treating somatic pain in conjunction with concussion recovery is warranted.

It is often recommended to wait for resolution of symptoms before initiating a structured rehabilitation program [3,4,23], but based on our patient's circumstances the symptoms needed to be addressed more directly [24]. Our program regularly engages symptoms in rehabilitation designed to work around and address them so improvement can be achieved. Assessments are made to identify symptom evoking exercises and those are added to the protocol, but generally late in a rehabilitation session with close monitoring. The philosophy for this patient's treatment has been utilized by our concussion management team, and followed by the physical therapists employed on the campus.

We initiated a symptom challenge to assess and elicit symptoms to help guide further rehabilitation escalation with the patient. While this does elicit some symptoms it also encourages the patient by demonstrating progress with more tasks and gives a perception of improvement. During each progression phase care is given to avoid overtaxing the cognitive systems while conditioning them to improve. We have found that this gentle, but guided, escalation of rehabilitation stages can help improve refractory symptoms as other brain systems are sharpened; the one that is lagging is facilitated by the training of the other systems. It is important for the clinician to monitor the quality of each exercise specifically to ensure the patient is breathing properly and to ensure safety isn't compromised and additional head injuries are avoided.

Advancement in the rehabilitation process is based on patient response and symptom management. The protocol followed is a guide to make each treatment session dynamic in nature. Reviewing the patient's journal and specific subjective intake is crucial prior to starting each session. Information gathered from patient responses throughout each session allow the physical therapist to make decisions on how and when to advance within each stage of the protocol. Escalating the patient to another stage of the protocol, including higher target heart rate, is made in conjunction with the concussion management team.

The repeating of evaluations has multiple beneficial effects during rehabilitation. As many of the methods are quantitative (Dynavision D2; saccades, Brock string and near far) the subject can be encouraged by demonstrable improvement as discussed regarding the functional plateau. As tasks become easier, other tasks can be added to ensure that the multiple brain systems involved in tasks or dysfunctional post injury can be assessed and rehabbed. For example, the subject appeared to plateau with normal saccades, so to engage balance and vestibular systems she did saccades on a balance board or trampoline. The results from these assessments were also used to modify and manage the rehabilitation program.

Her long-term prognosis is very good. At one year, she is relatively symptom-free, has good QOL indicators and has taken on a new career interest including volunteering to help other patients with similar injuries. We would not expect her to have any long-term QOL insufficiencies. She has adapted well in terms of her vestibular ocular system.

Personal statement on recovery process from the patient

"The last year has been the most challenging year of my life. For the first five months after my injury, I feared I would never again return to my old self. Prior to my injury I was active at church, part-time political consultant and most importantly a wife and homeschooling mother. I don't think I ever sat down as I loved to be with and around people. After my injury, I was instructed the same as most people post-concussion, to rest (also known as brain rest) until my symptoms were gone. After 5 months it was evident that brain rest was not working. Once I found my current doctor, my world quickly began to change. He ordered tests that documented my physical issues from the concussion. At this time, my headaches were so bad I was hardly able to leave the house for any reason. I even forgot I had to use potholders to get stuff out of the oven. I could no longer empty the dishwasher and talk at the same time. I simply was not able to complete that level of multitasking. I have a finance background and I was unable to balance our checkbook in less than three days, when it would normally take an hour, and made mistakes each time.

I created a journal to write down my progress, initially just to help me remember the exercises! This alone was a humbling process because prior to the accident, I was blessed with a great memory and never wrote down anything. Determined to regain my previous level of functioning, I followed the entire rehabilitation program exactly as it was given to me. With the help of family and friends, I dedicated myself to recovering. Creating the journal in Microsoft excel was a basic example of my diminished function. This basic 4 column table took me 6 hours to 'author'. In contrast, when I was only 24 years old, I created such high-level excel workbooks, that my employer, a publically traded company, used them for SEC reported data. This injury was a nice slice of humble pie plus I had lost sources of income. I will never again take for granted any of my gifts!

I started my official rehabilitation five long months after my accident. I immediately began to notice major improvements. My head no longer felt like it was going to explode, I was less forgetful and I started to multi-task basic simple things like talking on the phone while getting the mail. My progress during these initial months was very motivating. Each day was a challenge, but my physical therapist worked with me closely and we reviewed my journal each clinic session. The journey was not without setbacks, but I felt like my life

now looked like a well-performing stock graph and that alone was comforting."

Conclusion

In this case study, showcasing our aggressive concussion rehabilitation strategy, we show that a focused, personalized rehabilitation program that targets the central and somatic symptoms elicited from a concussion helps identify and resolve symptoms. Symptoms are addressed acutely to help the patient feel better and others are addressed with chronic rehabilitation strategies to help the patient get better. This philosophy is based on traditional sports medical rehabilitation methods that assess an injury and work to strengthen weaknesses. Patient weaknesses are assessed via regular evaluations designed to evoke symptoms and then exercises are used to strengthen the abilities. Regular communication between the rehabilitation specialists, the patient and the managing physician allows for monitoring progress and personalized medicine to optimize the rehabilitation at all stages of recovery.

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The patient presented in this study gave consent for her records to be used for publication her support of this report is acknowledged. This report has been reviewed by the University of Cincinnati Institutional Review Board and is compliant with IRB practices.

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