Return to Meaningful Activities After a Multi-Modal Rehabilitation Programme among Individuals Who Experience Persistent Dizziness and Debility Longer Than 9 Months after Sustaining a Concussion: A Case Series

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ABSTRACT

Purpose: The authors explored changes in outcome measures and return to meaningful life activities in six individuals who participated in a home-based multi-modal rehabilitation programme to address persistent dizziness and debility that had continued for more than 9 months since a documented concussion. **Methods:** In a case series using a repeated-measures design, changes from pre- to post-treatment assessments were assessed after a 6-month intervention. The outcome measures used were the Rivermead Post-Concussion Symptoms Questionnaire's subsidiary scales (RPQ-3, RPQ-13), Dizziness Handicap Inventory (DHI), Activities-specific Balance Confidence Scale, Functional Gait Assessment, return to work or study, and return to activity. **Results:** Six months after the multi-modal rehabilitation programme, statistically significant differences were found on the RPQ-3 ($p = 0.026$), RPQ-13 ($p = 0.037$), and DHI ($p = 0.033$). In addition, four participants had returned to their previous work, and all six participants had been able to return to physical activity. **Conclusion:** A supervised home programme, provided in the context of a multi-modal rehabilitation programme, has the potential to improve outcomes even when rehabilitative services are delayed and persistent concussion-related symptoms continue for a significant amount of time after the onset of a concussion.

Key Words: aerobic exercise, brain concussion, post-concussion syndrome, traumatic brain injury, vestibular rehabilitation

RÉSUMÉ

Objectif: analyser l'évolution et le retour aux activités quotidiennes chez six personnes ayant participé à un programme de réadaptation multimodal à domicile pour traiter les faiblesses et les étourdissements persistants plus de neuf mois après une commotion cérébrale démontrée. **Méthodologie :** les chercheurs ont évalué les changements aux évaluations avant et après le traitement de six mois d'une série de cas à l'aide d'un modèle de mesures répétées. Pour mesurer les résultats, ils ont utilisé les échelles secondaires du *Rivermead Post-Concussion Symptoms Questionnaire* [questionnaire sur les symptômes post-commotion cérébrale] (RPQ-3, RPQ-13), le *Dizziness Handicap Inventory* [questionnaire sur les incapacités liées aux étourdissements] (DHI), l'*Activities-specific Balance Confidence Scale* [échelle de confiance en l'équilibre associé à la réalisation de tâches de la vie quotidienne], le *Functional Gait Assessment* [évaluation de la démarche fonctionnelle], le retour au travail ou à l'école et le retour à l'activité. **Résultats :** six mois après le début du programme de réadaptation multimodal, les chercheurs ont observé des différences statistiquement significatives au RPQ-3 ($p = 0,026$), au RPQ-13 ($p = 0,037$) et au DHI ($p = 0,033$). De plus, quatre participants étaient retournés au travail et les six participants étaient en mesure de reprendre l'activité physique. **Conclusion :** un programme à domicile supervisé, proposé dans le contexte d'un programme de réadaptation multimodal, pourrait améliorer les résultats même lorsque les services de réadaptation sont retardés et que les symptômes persistants liés à la commotion perdurent pendant une longue période après la commotion.

The Centers for Disease Control and Prevention has estimated that 1.7 million people in the United States sustain a traumatic brain injury (TBI) every year,¹ and approximately 75% of those injuries involve concussion or some other form of brain injury that would be designated as mild.² However, injuries that seem mild initially can occasionally cause severe complications, including headache, dizziness, irritability, anxiety, blurred vision, in-

omnia, easy fatigability, and concentration and memory difficulties.³ The majority of individuals will have a complete functional recovery and return to their life activities without the burden of these sequelae, but a "miserable minority"^{4(p.551)} will experience an incomplete recovery, and their symptoms often persist for months or even years after their initial injury.^{2,3,5}

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Between 15% and 20% of individuals who experience a concussion have been reported to have persistent symptoms 1 year after the initial injury.^{5,6} Using these estimations, and taking into consideration the percentage of individuals with persistent symptoms after mild TBI (mTBI) published by Azulay and colleagues,² nearly 200,000 individuals in the United States are likely to experience persistent symptoms after a head injury every year.

Although controversy continues as to the organic nature of these persistent complaints and why certain individuals may be prone to higher rates of prolonged impairment and disability, studies have suggested that active rehabilitation programmes can be effective treatments for affected individuals.^{7–14} Research has shown that some active therapies provided in isolation, such as vestibular physical therapy, aerobic training, or vision therapy, can lead to improvements in concussion-related symptoms, walking and balance performance,^{7–11} and speed and comfort of reading,¹⁵ or they can influence the timing of return to recreational activities.¹⁴ However, more recent literature has suggested that a combination of these active rehabilitation interventions, presented in a multi-modal rehabilitation program, may be the most comprehensive approach to addressing persistent symptoms of debility after a concussion.^{7,12,13,16,17} These reports, collectively, show promise for addressing concussion-related symptoms and functional limitations with an active multi-modal rehabilitation programme for children and adolescents who report persistent symptoms lasting, on average, less than 3 months after a sports-related concussion.

Research has paid comparatively less attention to the efficacy of a multi-modal rehabilitation programme for adults who experience persistent symptoms longer than 3 months after sustaining a concussion.¹⁸ Some may question whether meaningful changes can be made in an individual's life when seemingly little to no spontaneous recovery has occurred after a prolonged period. Therefore, the primary aim of this report is to explore changes in outcome measures and return to meaningful life activities (return to work or study and return to recreational activities) in six individuals who participated in a multi-modal rehabilitation programme to address persistent dizziness and debility that had continued for at least 9 months since a documented concussion. On the basis of our experience in the clinic, we hypothesized that changes would be seen across self-report measures in all six participants but that those individuals who had delayed rehabilitation the longest from the time of injury would likely not experience a return to meaningful activities.

METHODS

Electronic records were reviewed for individuals who presented to a physician in the Concussion Center at New York University (NYU) Langone Medical Center, met the World Health Organization¹⁹ criteria for post-

concussion syndrome, reported persistent dizziness, and were treated in the Rusk Vestibular Rehabilitation Clinic between September 2013 and November 2014. The Concussion Center at NYU Langone Medical Center uses a multidisciplinary approach to treating individuals with persistent symptoms and debility after concussion. Patients presenting with symptoms in addition to dizziness were given secondary services, as recommended by Ellis and colleagues,¹⁶ who have advocated categorizing patients after a concussion into specific neurological subsystems on the basis of the salient features of a patient's history, physical examination, and exertion on aerobic testing.

Thus, if a patient initially presented with cervical pain, stiffness, and decreased cervical spine range of motion, he or she was referred to orthopaedic physical therapy for the cervical spine in addition to vestibular rehabilitation. If a patient presented with exercise intolerance, such as symptom exacerbation by exertion, he or she was tested and treated with a sub-symptom-level aerobic exercise programme in addition to vestibular rehabilitation. If a patient presented with difficulty with static gaze stability, such as convergence insufficiency or description of diplopia, "shadowing" of an image, reports of eye strain, or fatigue with reading,²⁰ he or she was referred to vision therapy in addition to vestibular rehabilitation. The ability to distinguish among these neurological subsystems allows the center to provide more tailored interventions.

The authors were interested in changes that occurred in individuals participating in a multi-modal rehabilitation programme during the chronic stage of recovery after sustaining a documented concussion. Although there is no consensus on a cutoff time for a chronic injury after a concussion, the time period has been documented to be longer than 3 months from the onset of the concussion.¹⁴ To ensure that individuals met the criteria by a conservative margin, and to decrease the likelihood of spontaneous recovery contributing to changes in the outcomes measured, individuals who began the rehabilitation programme no earlier than 9 months after the onset of a documented concussion were included in the analysis.

Benign paroxysmal positional vertigo (BPPV) occurs after a head injury in 5%–28% of cases.^{21,22} Although concussion-related symptoms and BPPV can have the same mechanism of injury, the resultant pathophysiology, treatment, and prognosis are markedly different. BPPV is a mechanical derangement of displaced otoconia from the utricle to one of the semicircular canals. It requires repositioning manoeuvres and often has a rapid recovery with the correct treatment;²³ persistent symptoms after a concussion can last for months to years and are the focus of this study. Patients were screened for BPPV using the Dix-Hallpike and supine roll tests with infrared video lenses and, if they evidenced BPPV, they were excluded from the study.

Table 1 Participant Characteristics and Outcome Measure Values at Pre-Test Assessment

Variable	Participant					
	S1	S2	S3	S4	S5	S6
Age	37	18	27	55	44	55
Gender	M	M	F	F	F	F
Mechanism of injury	Fall	MVA	Sport	Fall	MVA	Fall
Time from concussion (days)	423	974	306	992	660	266
Medications	Trazodone, carvedilol	Minocycline, methylphenidate, acetaminophen	Amphetamine and dextroamphetamine	Ibuprofen, rosuvastatin calcium	Amantadine, lorazepam, amphetamine and dextroamphetamine	Clonazepam, tamoxifen, diltiazem
Co-morbidities	Anxiety, headaches, neck pain	Headaches, neck pain, depression	Attention-deficit disorder, headaches	Anxiety, headaches	Anxiety, headaches	Anxiety, headaches, hypertension
Concussion history	0	1	3	0	0	0
Multidisciplinary care	Vest + aerobic, vision therapy, neuropsychology	Vest + aerobic, vision therapy, neuropsychology	Vest + aerobic, vision therapy, orthopaedic PT	Vest + aerobic, vision therapy, orthopaedic PT	Vest + aerobic, vision therapy, psychotherapy	Vest + aerobic, vision therapy
No. of clinic treatment sessions						
Vest + aerobic	27	17	21	18	14	15
Vision therapy	13	15	3	0	13	6
Orthopaedic PT	0	0	14	10	0	0
Psychology/neuropsychology	2	1	0	0	22	0
Pre-treatment values						
RPQ-3 (/12)	11	8	3	11	8	10
RPQ-13 (/54)	45	40	13	45	53	32
DHI (/100)	96	60	30	61	64	74
ABC (/100)	70	92	93	77	68	61
FGA (/30)	18	26	29	19	24	20

Note: Values for outcome measures (RPQ-3, RPQ-13, DHI, ABC, FGA) represent scores at the initial evaluation.

M = male; F = female; MVA = motor vehicle accident; Vest = vestibular physical therapy; PT = physical therapy; RPQ-3 = Rivermead Post Concussion Questionnaire symptoms; RPQ-13 = Rivermead Postconcussion Questionnaire psychosocial impact; DHI = Dizziness Handicap Inventory; ABC = Activities-specific Balance Confidence Scale; FGA = Functional Gait Assessment.

Six participants were included in the study; their characteristics are shown in Table 1. The median age was 41 years (range 18–55), and four of the six participants were female. The median time since onset of injury was 542 days (range 266–992). Three participants' concussion was due to a fall; two, due to injury from a motor vehicle accident; and one, sports related. Two physical therapists, board certified in neurological physical therapy and with 3–5 years of experience in treating individuals with vestibular impairments, used a repeated-measures design to assess individuals before treatment (pre-treatment) and 6 months after they began a multi-modal rehabilitation programme (post-treatment). Participants were examined by the same therapist at pre- and post-treatment. This study was approved by the institutional review board of the NYU Langone Medical Center.

Objective measures

We used self-report measures, observational balance and walking assessment, and return to meaningful life activities to measure changes between pre- and post-treatment assessments.

Self-report measures

The Rivermead Post Concussion Symptoms Questionnaire (RPCQ) is a 16-item self-report checklist on which patients rate cognitive, somatic, and emotional symptoms according to their severity in comparison with how they were functioning before their injury.²⁴ The 16 RPCQ items can be divided into two subcategories: the RPQ-3 and the RPQ-13. The RPQ-3 is associated with early symptom clusters of post-concussive symptoms (scored 0–12; the higher the score, the earlier re-assessment and closer monitoring are recommended), and the RPQ-13 is associated with having a greater impact on participation, psychosocial functioning, and lifestyle in individuals (scored 0–52; the higher the score, the greater the impact).²⁵ The RPQ-3 has moderate test–retest reliability ($r = 0.72$), and the RPQ-13 has good test–retest reliability ($r = 0.89$).²⁵ The RPCQ is a valid measure of outcome, particularly after mild to moderate head injury.²⁶

The Dizziness Handicap Inventory (DHI) is a 25-item self-assessment inventory designed to evaluate the self-perceived handicapping effects imposed by dizziness.²⁷

Answers are graded 0 (*no*), 2 (*sometimes*), or 4 (*yes*), for a maximum score of 100; the higher the score, the greater the perceived handicap because of dizziness. The DHI has good internal consistency for the total score ($\alpha = 0.89$) and high test-retest reliability ($r = 0.97$).²⁸ The minimal detectable change (MDC) has been calculated as 17 points, and a clinically meaningful change between pre-treatment and post-treatment scores has been established as 18 points.²⁷

The Activities-specific Balance Confidence (ABC) Scale is a 16-item self-report measure on which patients rate their balance confidence in performing various ambulatory activities without falling or experiencing a sense of unsteadiness.²⁹ Items are rated on a scale ranging from 0 to 100, on which a score of 0 represents no confidence and a score of 100 represents complete confidence. A significant change in the ABC score is either a return to a score of at least 80% or a change of more than 10%.^{30–32}

Observational balance and walking assessment

The Functional Gait Assessment (FGA) assesses postural stability during various walking tasks. It is a 10-item test (with a maximum score of 30) that includes 7 of the 8 items from the Dynamic Gait Index, the original walking and balance measure.³³ Each item is scored on an ordinal scale ranging from 0 to 3; higher scores indicate better performance. The FGA demonstrates concurrent validity with other outcome measures used in vestibular rehabilitation ($r_s = 0.64–0.80$).³⁴ It has excellent interrater reliability (intra-class correlation coefficient [ICC] = 0.84) and excellent intrarater reliability (ICC = 0.83).³⁴ The FGA has excellent test-retest reliability in evaluating individuals with Parkinson's disease³⁵ and stroke,³⁶ although it has not been established for individuals with TBI. A score of less than 22 provides an optimum validity for classifying fall risk in older adults at risk for falling and for predicting unexplained falls in community-dwelling older adults.³⁷ For individuals with a vestibular disorder, the minimal clinically important difference (MCID) has been determined as 8 points, and the MDC is 6 points.³⁸

Return to meaningful life activities

Return to work or study (RTW) was evaluated using a method adopted from van der Naalt and colleagues.³⁹ Scoring consists of four categories: 0 = previous work or study resumed; 1 = previous work or study resumed, but with lower demands or part time; 2 = previous work or study not resumed or different work or study taken up on a significantly lower level; and 3 = not working or studying.³⁹ Return to activity (RTA) was measured using a method adopted from a previous study investigating RTW.³⁹ Scoring consists of four categories: 0 = participation in previous physical or recreational activities resumed; 1 = previous physical or recreational activities resumed, but with lower demands; 2 = previous physical or recreational activities not resumed, different activities taken

up on a significantly lower level; 3 = no participation in physical or recreational activities. An individual is assumed to participate in a different activity or in different work because it is less intense than a partial return to the previous work or activity.

Intervention

The multi-modal rehabilitation programme was provided to each participant through a supervised home programme that consisted of vestibular rehabilitation combined with any of the following therapies: aerobic training programme, vision therapy, orthopaedic physical therapy, neuropsychology, and psychotherapy. The goal of the supervised sessions in the clinic was to review, modify, and update a participant's home programme. The frequency of these sessions and the prescription activities for the home programme were not standardized; rather, they were based on a clinician's experience and a participant's ability to visit the clinic. A therapist assessed a participant's adherence to the home programme by asking questions during each supervised session in the clinic. Examples of tasks, frequency, and duration of the home programmes are provided in Table 2 as a comprehensive list, not as a standardized protocol.

Vestibular rehabilitation

Vestibular rehabilitation consisted of three categories of exercise: gaze stabilization (dynamic and static), gait, and sensory organization and balance.⁹ Dynamic gaze stabilization included dynamic exercises aimed to promote adaptation of the gain in the vestibulo-ocular reflex by presenting a foveal stimulus while the head was rotated. This is termed X1 and X2 viewing.⁴⁰ Gait exercises included ambulation with head motion in all planes and on varying surfaces and bases of support and using varying complexity of static and dynamic visual input while ambulating. Sensory organization exercises included postural control challenges with similar varying surfaces and bases of support and using varying complexity of visual input.

Vestibular exercises began in simple situations such as an empty, quiet, dimly lit room and were progressed to involve complex sensory environments such as a busy gym or city street. Vestibular exercises started with straight plane motions (yaw, pitch, roll) and progressed to simulating functional activities in combination motions. These techniques and methods are described in detail by Gurley and colleagues.²⁰

Aerobic exercise training

Individuals were given an aerobic exercise training programme to supplement the traditional vestibular physical therapy programme. A sub-maximal symptom threshold test, adapted from the Balke protocol,^{14,41} was completed using a stationary bike rather than a treadmill because of head excursion while walking or running³⁴ and to minimize conflicting sensory stimulation.⁴⁰ Individuals who were able to complete the sub-maximal symptom threshold test, as described by Leddy and colleagues,^{14,41}

Table 2 Interventions as Part of the Multimodal Rehabilitation Program

Training category	Examples of tasks	Training frequency
Vestibular rehabilitation	<i>Dynamic gaze stabilization exercises</i> X1 viewing, X2 viewing seated or standing <i>Gait training</i> Ambulation with head turns (vertical, horizontal, and diagonal planes) Ambulation with head turns plus visual fixation Ambulation on compliant surface with and without visual occlusion Ambulation while changing direction with and without head turns Tandem walking with and without head turns <i>Sensory organization</i> Standing balance on compliant surface with and without head turns Standing balance with varying base of support with visual field distortion	20–30 min daily
Aerobic exercise training	Aerobic training program performed on stationary bicycle Intensity was determined on the basis of submaximal symptom test performed in clinic	30 min 3–5 times/wk
Vision therapy	Static gaze stabilization convergence training (brock string exercise) Near/far accommodation Eye movements Visual motor tracking Saccades Simulated reading	10 min daily
Orthopaedic therapy	Stretching Levator scapulae and upper trapezius Cervical rotation Cervical sidebending Resistance exercise and range of motion Scapular retraction Cervical rotation Cervical sidebending Manual therapy Soft tissue mobilization Suboccipital release	Stretches to be held for 30 s each for 5 sets Resistive exercises Performed 3 sets for 10 repetitions

were instructed to train on a stationary bicycle as part of their home exercises for 30 minutes, 3–5 times per week, with a prescribed heart rate interval of 60%–80% of the maximal heart rate reached during the testing protocol. Aerobic training was progressed by repeating the submaximal symptom threshold test every 2–3 weeks to establish a new heart rate training intensity.

Vision therapy

Individuals who presented with static gaze stability difficulty, such as convergence insufficiency or description of diplopia, “shadowing” of an image, or reports of eye strain or fatigue with reading,²⁰ were instructed to perform tasks involving vergence, fixation, saccade, and pursuit eye movement training. This eventually progressed to simulated reading, as described by Kapoor and colleagues.^{42,43}

Orthopaedic physical therapy

The accepted standard of care in circumstances in which a patient presents with cervical dysfunction and dizziness is to use techniques for rehabilitation of both the cervical spine and an impaired vestibular system.⁴⁴ Cervical treatment targeted the underlying cervical dysfunction. Therapeutic exercises for cervical range of

motion and strengthening of the cervical spinal muscles as well as manual therapy for segmental hypomobility were also used. Stretching and manual and self-cervical traction were used to improve range of motion and alleviate symptoms of pain and stiffness. Deep cervical flexor isometric stabilization exercises were also included; these exercises have been outlined in previous studies.^{17,20,44,45}

Neuropsychology and psychotherapy

High levels of emotional and cognitive exertion frequently accompany persons experiencing persistent symptoms after a concussion. Increased stimulation can be the result of cognitive-behavioural issues, including task perseveration, disinhibition, and an increased degree of neural recruitment for even simple cognitive and physical tasks.^{46–48} In addition, psychological distress is frequently present in individuals experiencing dizziness, both with and without head injury; prevalence ranges from 40% to 64%.^{49–51} Anxiety has been associated with a prolonged recovery in persons with head injury and vestibular disorders.⁵²

Patients presenting with anxiety or cognitive deficits were given a neuropsychology examination. Those determined to have primarily anxiety that contributed to their

Table 3 Differences between Pre- and Post-Test Outcomes (n = 6)

Outcome measure	Pre-test, mean (SD)	Post-test, mean (SD)	<i>p</i> -value
RPQ-3 (/12)	8.5 (3.0)	5.0 (2.6)	0.026*
RPQ-13 (/52)	38.0 (14.1)	19.5 (10.3)	0.037*
DHI (/100)	64.1 (21.5)	39.2 (15.0)	0.033*
ABC (/100)	76.8 (13.2)	82.5 (8.3)	0.276
FGA (/30)	22.7 (4.4)	25.0 (1.8)	0.122

Note: Post-assessment test was completed an average 174.7 (SD 9.1) days after the pre-test. Student's *t*-test completed to determine difference between means.

**p* < 0.05

RPQ-3 = Rivermead Post Concussion Questionnaire symptoms;

RPQ-13 = Rivermead Post Concussion Questionnaire psychosocial impact;

DHI = Dizziness Handicap Inventory; ABC = Activities-specific Balance

Confidence Scale; FGA = Functional Gait Assessment.

activity limitations were given psycho-education on the mechanism of stress response, symptom trigger identification, mindfulness training, and cognitive-behavioural therapy. Those determined to have primarily cognitive deficits that contributed to their activity limitations were given exercises to restore cognitive functions such as attention, organization, memory, reasoning, and problem solving. Also, compensatory strategies were given to augment restorative interventions.

Data analysis

The Shapiro-Wilk test was used to test for normality of data. Comparisons of variables at two different times (pre- and post-treatment) were performed using Student's *t*-tests for paired observations, for which *p*-values are reported (*p* < 0.05). Statistical analysis was performed using IBM SPSS for Windows, version 22.0 (IBM Corp., Armonk, NY).

RESULTS

Group differences between pre- and post-treatment periods are shown in Table 3. At 6 months after the multi-

Table 4 Number of Participants with Scores Meeting MCID or MDC (n = 6)

Outcome measure	MCID (no., %)	MDC (no., %)
DHI	3 (50)	3 (50)
FGA	0 (0)	0 (0)
ABC	3 (50)	

MCID = minimal clinically important difference; MDC = minimal detectable change; DHI = Dizziness Handicap Inventory; ABC = Activities-specific Balance Confidence Scale; FGA = Functional Gait Assessment.

modal programme, statistically significant differences were found on the RPQ-3 (*p* = 0.026), RPQ-13 (*p* = 0.037), and DHI (*p* = 0.033). No statistically significant improvement was found on the ABC Scale or FGA; however, four of the six participants showed improvements on the ABC Scale and FGA from pre- to post-treatment. Table 4 shows the number of participants whose scores at post-treatment assessment reflected a change large enough to achieve an MCID or MDC for the DHI, ABC Scale, and FGA. No participants made a change large enough to reflect an MCID on the FGA.

At pre-test assessment, four of the six participants were not working. By post-treatment assessment, four participants had returned to their previous work part time or with lower demands (see Figure 1a). One participant's level of work (S3) had not changed after participating in the multi-modal rehabilitation programme because she had already returned to work at her prior capacity before beginning the programme. One participant's level of work (S2) changed from not working at all to working, but in a different field and at a significantly lower level.

At pre-test assessment, no participant had returned to his or her previous physical activity or activities, and five of the six participants were inactive, meaning that they were not performing any activities at all (see Figure 1b). By post-treatment assessment, all six participants were physically active in some capacity, and two participants

Figure 1 Pre- and post-treatment outcomes for each participant (S1–S6) for return to work or study (A) and return to physical activity (B).

Note: Return to meaningful life activities was measured using a method adopted from van der Naalt and colleagues.³⁹ Scoring consisted of four categories: 0 = previous work or study resumed; 1 = previous work or study resumed, but with lower demands or part time; 2 = previous work or study not resumed or different work or study taken up on a significantly lower level; and 3 = not working or studying.

had returned to their previous physical activity or activities, either without restrictions or at a lower level of physical demand (Figure 1b). One participant's level of physical activity (S3) had not changed after participating in the multi-modal rehabilitation programme.

DISCUSSION

A key finding of this study is the potential for using a supervised, home-based intervention in the context of a multi-modal rehabilitation programme to improve the outcomes of adults with persistent symptoms of dizziness and debility, even after significant amounts of time have passed since the onset of a concussion. Although this study is not the first to use a multi-modal approach, it is the first to describe changes in participation in meaningful activities of adults with persistent dizziness and debility who began a multi-modal rehabilitation programme in the chronic stage of recovery after sustaining a documented concussion.

Three previous reports^{12,13,17} have described a multi-disciplinary programme similar to that presented in the current report to investigate return to physical activity; however, there are three important differences to consider when comparing those reports with the current study:

1. The age of the participants: All three reports included only adolescents in their samples.
2. The time since injury: Participants reported persistent symptoms lasting no more than 3 months, on average, before beginning the rehabilitation programme.
3. The cause of injury: All causes of injury were sport-related concussions.

The current report is novel in that we report the degree to which adults who had persistent symptoms lasting longer than 9 months after sustaining a concussion that was not necessarily the result of a sport-related injury returned to work or study and to previous physical activity or activities.

In addition to finding improvement in return to meaningful activities, statistically significant improvements in concussion-related symptoms and dizziness, as measured by clinical outcome measures, were found at 6 months after participation in the rehabilitation programme. The majority of participants also showed improvements in balance confidence and balance performance at 6 months. These findings are in agreement with those of Alsalaheen and colleagues,²¹ who documented improvement in standardized symptom report and balance measures in individuals with symptoms of dizziness and imbalance post-concussion after they had participated in a vestibular physical therapy programme. It is interesting that Alsalaheen and colleagues reported that the average magnitude of change across all participants in their study met the MCID for dizziness, as measured by the

DHI; balance performance, as measured by the FGA; and balance confidence, as measured by the ABC Scale.

We did not find similar magnitudes of change in these clinical measures across the six participants included in this analysis. However, the larger sample size, the younger age of the sample, and the acuity of the injuries investigated by Alsalaheen and colleagues²¹ could explain these differences; data from 41 children were grouped with those from 23 adults, and the median time from injury to evaluation in their study was 3 months post-concussion. Our analysis included six individuals, none of whom were children; this could affect the degree of recovery because whether recovery from injury is similar between children and adults is unknown, and the median time from injury in our sample was considerably longer at 18 months.

We had hypothesized that each individual would report an improvement on self-report measures. However, all outcome measures for participant S3 unexpectedly remained unchanged 6 months after the rehabilitation programme began. It is impossible to determine why this participant did not benefit from the rehabilitation programme, but several factors distinguish her from the other participants that could account for the lack of improvement. S3 was the only participant who was working full time without limitation at her previous type of work at the pre-test assessment (score of 0 on the RTW scale). This could suggest that she was not so affected by her symptoms that she could not carry a full-time workload. Conversely, all of the other participants had either stopped working altogether or were working only part time at the pre-test assessment.

In addition, when compared with the other participants, S3 started with the best scores on every outcome measure, including the lowest score on the RPCQ, lowest score on the DHI, highest score on the ABC Scale, highest score on the FGA, and highest participation level on the RTW and RTA measures. These findings may suggest that RTW and RTA may not have as much to do with the time between onset of an injury and the time an individual begins a rehabilitation programme as we had hypothesized; instead, these measures could be influenced more by a person's level of debility and inactivity.

We had also hypothesized that those individuals who had delayed rehabilitation the longest from the time of injury would likely not experience a return to meaningful activities. As previously mentioned, improvement in meaningful activities was found regardless of how much time had elapsed since the initial injury. For example, participants S2 and S4, having waited 974 and 992 days, respectively, made gains in concussion-related symptom complaints while concurrently increasing their level of participation in work-related and recreational activities. These findings point to the potential for change to occur after participation in a multi-modal rehabilita-

tion programme despite the seemingly dismal likelihood of returning to meaningful work and recreational activities for individuals with persistent symptoms and debility after a concussion.⁵³

Although it is uncommon for prolonged symptoms to continue beyond 3 months after a person sustains a concussion, this report is not the first to identify a group of individuals with persistent symptoms and debility longer than 9 months after the injury. King and Kirwilliam,⁵³ for example, reported high levels of concussion-related symptoms and high post-injury unemployment rates in 24 participants, with a mean time of 6.9 years post-injury, and Kleffelaar and colleagues⁵⁴ documented 11 participants with symptoms of dizziness and imbalance that persisted up to 4 years after mTBI. These reports highlight the importance of the current analysis because it points to a rehabilitative approach that has the potential to change the outcome for individuals who may be disengaged from life activities as a result of concussion-related symptoms.

The mechanism by which each of these interventions may affect recovery after a concussion is not clear, and any attempt to discuss the mechanisms by which the combination of interventions in a multi-modal rehabilitation programme would affect recovery would be speculative. Still, we can propose one mechanism if one considers the advances in neuro-rehabilitation research of the past two decades. These advances have identified mechanisms for motor learning and adaptive neuroplastic change that accompany active rehabilitation programmes that are salient and task specific and that provide repetition over a sufficient period to allow an individual to acquire the skill required by specific activities.⁵⁵

It is possible that the components of each of the home-based programmes contribute to an experience-dependent change in the sensory and motor systems targeted by each intervention that may model the demand required of the system in the individual's work and recreational activities. As the adaptive change in each system begins to match the demand placed on the system by individual tasks performed in the workplace or during physical activity, the less likely it is that an error will be detected and the less likely it is that an individual will experience symptoms. At this point, the individual will be able to engage, remain engaged, and continue to participate in meaningful activities.

However, it is equally as possible that beginning an active rehabilitation programme that is progressive may do nothing more but counter the deleterious effects of prolonged rest, which may contribute to physical deconditioning¹⁶ and the further impairment of integration in the sensorimotor systems⁵⁶ that is often observed in this population. In this last example, it is likely that tolerance to increasingly complicated environments will lead to habituation of the sensory and motor systems, which will allow an individual to return to previous work-related and recreational activities. At this time, there is

little evidence available in the literature to definitively describe the mechanism by which these interventions could contribute to change; however, this article and others like it may drive future studies to investigate physiological mechanisms that influence recovery in this patient population.

It is worth taking time to highlight the responsiveness of the clinical outcome measures used in this study. Participants S2 and S3, for instance, improved at the symptom level but did not show improvements in balance self-efficacy or observational gait analysis. It is important to note that both of these participants received near the highest scores possible on the ABC Scale and FGA (ABC Scale, 92% and 93%, respectively; FGA, 26/30 and 29/30, respectively), representing a possible ceiling effect of the outcome measures in this specific population. In a previous study, 50% of a testing sample was found to have a perfect score on the FGA, indicating that the measure likely has a ceiling effect.²⁹ This could explain why no individual in our study made the 6- or 8-point improvement necessary to indicate a meaningful change on the measure (MCID) in this population. In fact, because of the relatively high scores obtained at pre-test, only three participants had the opportunity to make such a change by post-test on the FGA.

Several limitations of this study must be considered. Because it used a pre-experimental design, the authors are unable to draw conclusions about the effectiveness of the intervention. Therefore, it is impossible to draw a causal relationship between the intervention provided and the changes observed in the outcome measures. Furthermore, this was a sample of convenience, with substantial variability in the period since injury for the participants, the age of the participants, and the degree of change in the outcome measures over time. As a case series, the aim of this report is to present the changes that occurred at 6 months in six individuals with persistent symptoms lasting longer than 9 months, not to draw causal relationships between the intervention and the changes observed. Although there is evidence to support the validity and reliability of most of the outcome measures used in this study for other diagnoses, the full psychometric analysis of these measures, with the exception of the RPCQ,^{15,16} is not available for patients with persistent symptoms after head injury. The possible ceiling effect found for the FGA seems to highlight this issue.

Another limitation of this study is that the assessors were not blinded to the participants' intervention. There is potential for an unblinded rater to bias data and, in turn, to influence the conclusions drawn from the results of the study. In addition, using adherence to the home exercise programme as a self-report measure made it impossible to accurately monitor how much the participants actually performed their exercise prescription.

However, the study has several strengths. The programme was set up to allow patients to visit the clinic for each service at variable frequencies to reduce the

burden of travel and encourage independence with the home programme. Therapy was administered using a home exercise-based model, which allowed the participants to receive multiple therapy services and gave them time to focus on RTW and RTA. In addition, the programme was administered in a clinical setting with patients performing exercises at home, which provides compelling evidence that a similar multi-modal rehabilitation programme could be replicated and implemented by clinicians.

CONCLUSION

The present findings suggest that a supervised home programme, provided in the context of a multi-modal rehabilitation programme, has the potential to improve outcomes even when rehabilitative services are delayed and persistent concussion-related symptoms continue for a significant amount of time after the onset of a concussion. It should be emphasized, however, that no individuals were found to respond with meaningful improvement over the time period. Therefore, this case series points to the need for future controlled studies with larger sample sizes to assess the efficacy of the described intervention in persons with persistent symptoms after sustaining a concussion. These areas of investigation are essential so that clinicians are able to provide interventions that can be most beneficial in leading to meaningful recovery for individuals with persistent symptoms and debility after a concussion.

KEY MESSAGES

What is already known on this topic

The majority of individuals will have a complete functional recovery from concussion and return to their life activities without the burden of these sequelae, but a “miserable minority” experience an incomplete recovery, and their symptoms often persist for months or even years after their initial injury. High levels of concussion-related symptoms and high post-injury unemployment rates have been reported in individuals with persistent symptoms.

What this study adds

The present findings suggest that a supervised home programme, provided in the context of a multi-modal rehabilitation programme, has the potential to improve outcomes even when rehabilitative services are delayed and persistent concussion-related symptoms continue for a significant amount of time after the onset of a concussion.

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