Outcomes Following a Vestibular Rehabilitation and Aerobic Training Program to Address Persistent Post-Concussion Symptoms

An Exploratory Study

Brian M. Moore, PT, DPT[1,2]
Joseph T. Adams, PT, DPT[2]
Edward Barakatt, PT, PhD[1]

PURPOSE: To describe changes in adults with persistent symptoms and disability following a concussion after completing a supervised home exercise vestibular rehabilitation (VR) program combined with aerobic training. **METHOD**: Participants included 14 consecutive individuals referred for VR within the context of a comprehensive concussion center. Outcome measures were administered at initial evaluation, 3 mos, and 6 mos. Outcome measures included: Rivermead Post-Concussion Questionnaire symptom (RPQ-3) and function (RPQ-13) subcategories, Dizziness Handicap Inventory (DHI), Activities-specific Balance Confidence Scale (ABC), functional gait assessment (FGA), return to work/study (RTW), and return to activity (RTA). **RESULTS**: At 6 months, all clinical outcome measures were found to be statistically significant or approaching statistical significance: RPQ-3 ($p<0.001$), RPQ-13 ($p<0.004$), DHI ($p<0.001$), ABC ($p<0.007$), FGA ($p<0.001$). For return to meaningful activity, associations between time of measure and both RTW ($p<0.019$) and RTA ($p<0.001$) were found to be statistically significant or approach statistical significance. **CONCLUSION**: Following 6 months of participation in a supervised home exercise VR program with aerobic training, significant improvements were observed in participants' report of concussion-related symptoms, function, and return to meaningful activities. *J Allied Health* 2016; 45(4):e59–e68.

AN ESTIMATED 1.7 million people sustain a traumatic brain injury (TBI) annually,[1] and approximately 75% of those injuries are mild traumatic brain injury (mTBI) or concussion.[2] Although the majority of individuals will recover from a concussion without disability, the duration that symptoms persist following a concussion for individuals varies from minutes to months to years.[3,4] Persistent dizziness and imbalance are common complaints following a head injury.[4–6] These symptoms may impact an individual's ability to return to meaningful work or leisure activities. Rees and Bellon[7] reported that 75% of individuals with persistent symptoms following a head injury did not return to their previous work status for two to five years following the injury.

Specialized rehabilitation clinics use modality-specific training, such as vestibular physical therapy, to address persistent symptoms of dizziness and imbalance following a head injury.[4,8–10] Military-based research has described the natural history of impaired vestibular system recovery following mTBI,[11] and has provided predictors of return to work parameters in samples of active duty service members.[12] In an investigation of acute trends in vestibular dysfunction of military personnel following a head injury, Gottshall et al.[11] reported that performance on the dynamic visual acuity test for the mTBI group was significantly worse at baseline compared to healthy controls, but the visual acuity test was no longer statistically different between these groups 4 weeks following the injury. In a second report, Gottshall et al.[12] reported that 68% of military personnel who have experienced acute vestibular impairment following a head injury return to active duty within 1 year. However, it is not appropriate to generalize the findings from this military-based research to the general population because the sample is likely not representative of the civilian population, and the cause of head injury in the military population may be different from that of the civilian population. Further, participants in these studies were not reported to have persistent symptoms following a concussion as is described by the World Health Organization (WHO) guidelines of post-concussion syndrome.[13]

Others have investigated the affect of activity-based rehabilitation programs on outcomes in children and adults in the civilian population who have experienced a concussion.[4,14] In a retrospective review of 114

[1] California State University, Sacramento, CA; [2] Rusk Institute for Rehabilitation Medicine, NYU Langone Medical Center, New York, NY.

The authors report no funding or conflicts of interest related to this study.

PP1738—Received Jul 29, 2016; accepted Nov 21, 2016.

Address correspondence to: Dr. Brian M. Moore, Physical Therapy Department, Sacramento State University, Sacramento, CA 95819, USA. Tel 916-278-5056, fax 916-278-6842. brian.moore@csus.edu.

TABLE 1. Baseline Characteristics (n=14)

	Mean (Range)		
	Young Adults (n=8)	Older Adults (n=6)	p-Value*†
Age	31 (18-44)	59 (55-72)	
% Male	50%	33%	
Mechanism of injury			
MVA	3 (37.5%)	0 (0%)	
Sport	3 (37.5%)	0 (0%)	
Fall	2 (25%)	6 (100%)	
Prior medical history			
Previous concussion	4 (50%)	1 (16.6%)	
Anxiety	2 (25%)	1 (16.6%)	
Depression	1 (12.5%)	2 (33.3%)	
Migraine	1 (12.5%)	2 (33.3%)	
Asthma	1 (12.5%)	0 (0%)	
Days from injury to evaluation	325 (23–974)	248 (14–992)	0.698
No. of sessions at 3 mos	12 (7–20)	11 (8–14)	0.569
No. of sessions at 6 mos	19 (12–27)	19 (15–27)	0.976
Days at follow-up 3 mos	91 (80–116)	95 (87–100)	0.425
Days at follow-up 6 mos	173 (160–183)	183 (173–193)	0.049

* Statistical significance set at $p<0.002$.
† Independent t-test was used for comparisons between continuous variables.

participants with complaints of persistent symptoms following a concussion, Alsalaheen et al.[4] found a significant treatment effect for all dizziness and function self-reported measures, and for walking and balance performance measures following vestibular rehabilitation. In addition, Leddy et al.[14] has reported preliminary results that aerobic training may improve the autoregulation of cerebral blood flow and significantly reduce the report of persistent symptoms of young adults following concussion. The samples used in these studies are more representative of the age and mechanism of injury that would be referred to a vestibular rehabilitation clinic in the civilian population. However, no studies were found to investigate the outcomes of an intervention that combines vestibular physical therapy with an aerobic training program to address persistent symptoms and debility following a concussion.

The aim of this study is to describe changes in adults with persistent symptoms and disability following a concussion after completing a supervised home exercise vestibular rehabilitation program combined with aerobic training with respect to their perception of concussion related symptoms, function, and return to meaningful activities. The authors hypothesized that it would take greater than 3 months following the initiation of a vestibular rehabilitation program combined with aerobic training for the majority of younger participants to return to meaningful activities, and that the majority of the older adults would not return to meaningful activities within 6 months of beginning the program.

Methods

Participants

Participants were included in the study based on meeting the WHO's criteria for post-concussional syndrome, which includes the presence of three or more of the following eight symptoms: 1) headache, 2) dizziness, 3) fatigue, 4) irritability, 5) insomnia, 6) impaired concentration or 7) memory difficulty, and 8) intolerance of stress, emotion, or alcohol with or without loss of consciousness following head trauma.[13] Individuals were excluded if they were found to have benign paroxysmal positional vertigo (BPPV) or ongoing litigation.

Sixteen consecutive participants who presented to a physician within the New York University Langone Medical Center Concussion Program were referred to and treated in the Vestibular Rehabilitation Clinic between September 2013 and November 2014. Fourteen participants were included in this study. Demographic information is presented in Table 1. Forty-three percent of the participants were male (n=6). The median age was 43 yrs (range 18–72), and median time between injury and initial evaluation was 107 days (range 14–992). Eight individuals experienced a concussion related to a fall (58%), 3 individuals had a concussion due to a motor vehicle accident (21%), and 3 experienced a sports-related concussion (21%). To determine if there were differences in recovery post-concussion based on age, participants were stratified by age into two groups. Eight participants between the ages of 18 and 44 years comprised the young adults group, and 6 participants aged 55 and older made up the older adults group. Similar age stratification has been used previously for individuals following a brain injury.[15,16] Two individuals were excluded from the sample: 1 individual was found to have BPPV and another was excluded due to ongoing litigation.

Two physical therapists, both of whom were board certified by the American Physical Therapy Association in neurologic physical therapy and had 3–5 years of experience in treating vestibular impairments, assessed participants at the initial evaluation, at 3 months post-evaluation, and at 6 months post-evaluation. Each physical therapist assessed the same participants at each assessment period.

This study was approved by the Institutional Review Board of the New York University Langone Medical Center.

Objective Measures

***Rivermead Post Concussion Questionnaire* (RPCQ):** The RPCQ is a 16-item self-report questionnaire in which patients rate the severity of cognitive, somatic, and emotional symptoms in comparison with how the patient felt they were functioning prior to their injury.[17] The 16 items of the RPCQ can be divided into two sub-

categories: the RPQ-3 and the RPQ-13. The RPQ-3 is associated with common sequela of post-concussive symptoms (eg, headaches, dizziness, nausea and/or vomiting) that often occur early following the injury (score range 0–12). The RPQ-13 is associated with having a greater impact on individuals' participation, psychosocial functioning, and lifestyle (score range 0-52).[18] For both subcategories, a higher score indicates a more impaired condition. The RPQ-3 has moderate test-retest reliability (r=0.72) and the RPQ-13 has good test-retest reliability (r=0.89).[18] The RPCQ has been shown to be a valid measure of outcome, particularly after a mild to moderate head injury.[19]

***Dizziness Handicap Inventory* (DHI):** The DHI is a 25-item self-assessment inventory designed to quantify the self-perceived handicapping effects on daily life imposed by dizziness.[20] The higher the score, the greater the perceived handicap (score range 0–100). The DHI has good internal consistency (α=0.89) and has high test-retest reliability (r=0.97).[21]

***Activities-Specific Balance Confidence Scale* (ABC):** The ABC is a 16-item self-report measure that patients complete to rate their balance confidence while performing various household or community level activities. Levels of confidence are rated concerning the ability to perform these activities without a loss of balance or experiencing a sense of unsteadiness.[22] Items are rated on a scale that ranges from 0 to 100, where a score of 0 represents no confidence and 100 represents complete confidence. Excellent test-retest reliability of the ABC scale has been established for individuals with stroke (ICC=0.85; 95% CI),[23] however, this metric has not been established for individuals with persistent symptoms and debility following a concussion.

***Functional Gait Assessment* (FGA)**: The FGA assesses postural stability during various walking tasks. It is a 10-item test that is scored on a 4-level ordinal scale (0–3). Aggregate scores range from 0 to 30, with lower scores indicating greater impairment.[24] The FGA has moderate correlation to the ABC Scale (r=0.64), the DHI (r=–0.64), the Perception of Dizziness Symptoms Scale (r=–0.70), and the Dynamic Gait Index (r=0.80), indicating concurrent validity with other balance related measures used in vestibular rehabilitation.[25] It has excellent interrater reliability (ICC=0.84) and excellent intrarater reliability (ICC=0.83) for individuals with vestibular disorders.[26] Test-retest reliability has not been established for individuals with TBI, however, the measure has been found to have excellent test-retest reliability in the evaluation of individuals with Parkinson's disease[27] and stroke.[28]

Return to Work/Study: The outcome of return to work/study was measured by a method previously described by van der Naalt et al.[29] Participants were asked to report their work-related activities. Scoring comprised 4 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 on a significantly lower level; 3=unemployed/not studying.[29]

Return to Activity: Return to physical activity was measured by a method adapted from the method described previously by van der Naalt et al.[29] Participants were asked to report the level of intensity of activities and the activities they were currently participating in compared to the activity(s) and the level of intensity they performed those activities prior to the injury. Scoring comprised 4 categories: 0=participation in previous physical/recreational activities resumed; 1=previous physical/recreational activities resumed, but with lower demands; 2=previous physical/recreational activities not resumed, or participation in different activities on a significantly lower level; 3=inactive/no participation in physical/recreational activities.

Intervention

Participants completed a supervised home exercise program consisting of vestibular rehabilitation combined with aerobic training. In the clinic, sessions lasted 40–45 minutes with the goal of reviewing, modifying, and updating the participant's home exercise program. The frequency of the supervised sessions was not standardized and was based on both the clinician's experience and the participant's ability to get to the clinic.

Vestibular rehabilitation consisted of 3 categories of exercises: gaze stabilization (dynamic and static), sensory organization, and gait.[4]

- Dynamic gaze stabilization included dynamic exercises aimed to promote adaptation of the gain of the vestibulo-ocular reflex (VOR) through presenting a stationary target to fixate while the head is rotated (X1 viewing) or a moving visual target while the head is rotated (X2 viewing).[30]
- Static gaze stabilization exercises targeting the visual and oculomotor pathways may have been included in the intervention for ocular stability such as vergence training if indicated.[31]
- Sensory organization exercises included postural control challenges such as standing on varying surfaces, bases of support of varying width and varying complexity of static and dynamic visual input.
- Gait exercises included ambulation with head motion in all planes and varying complexity of static and dynamic visual input while ambulating. These techniques and methods are described in detail by Gurley et al.[5]

Aerobic Exercise Training. Individuals were provided an aerobic exercise program in conjunction with vestibular physical therapy. A submaximal symptom threshold test, adapted from the Balke protocol,[14,32] was completed using a stationary bike rather than a treadmill due to the performance of head excursion while walking or running on a treadmill,[33] and to minimize conflicting sensory stimulation.[34] Vital signs including blood pressure, heart rate, and oxygen saturation were monitored while indi-

TABLE 2. Baseline Scores (n=14)

	Mean (Range)		
	Young Adults (n=8)	Older Adults (n=6)	p-Value*†
RPQ-3	8 (3–11)	8 (2–11)	0.662
RPQ-13	31 (13–53)	31 (17–45)	0.900
DHI	53 (30–96)	65 (51–78)	0.252
ABC	72 (19–94)	57 (44–77)	0.248
FGA	24 (18–29)	18 (9–24)	0.035

All variables measured at initial evaluation.
* Statistical significance set at p<0.002.
† Independent t-test was used for comparisons between continuous variables.

viduals pedaled against resistance. Resistance was increased by a factor of two units every 2 minutes. Provocation of symptoms was measured using a FACES pain chart and the participants' perception of the intensity of the exercise was measured using the Rate of Perceived Exertion (RPE). Each measure was monitored every minute. If participants experienced an exacerbation of baseline symptoms or onset of additional concussive symptoms, as is described by Leddy et al.,[32] the heart rate achieved just prior to the point of exacerbation was documented. Participants who did not experience an exacerbation of symptoms were encouraged to continue until they reached 60–80% of their maximal heart rate, or they reported a 17 on the RPE scale indicating the perception of "very hard" exertion.[35] Participants were instructed to train on a stationary bicycle as part of their home exercises for 20–30 minutes duration 3–5 times per week with a prescribed heart rate of 60–80% of the maximal heart rate achieved during the test.

The Concussion Center at New York University Langone Medical Center provides a multi-disciplinary approach for treatment of individuals with persistent symptoms and debility following concussion. Participants were referred by physicians to multiple disciplines in the rehabilitation center. If the clinician and the physician determined it was medically appropriate for the participant to receive rehabilitation services, the participant completed sessions in one of the following disciplines in combination with the vestibular rehabilitation and aerobic training program: cognitive behavioral therapy, psychology, occupational therapy, and/or orthopedic physical therapy.

Nine of the 14 participants received therapy services from only one other discipline. Seven of these 9 individuals received vision therapy from an occupational therapist, 1 received orthopedic physical therapy for the cervical spine, and 1 individual received cognitive-behavioral therapy from a neuropsychologist. The other 5 of the 14 participants received two types of rehabilitative therapies in addition to the vestibular rehabilitation and aerobic training program. Of these 5 participants, all 5 individuals received vision therapy from an occupational therapist, 3 individuals received psychology services, 1 received orthopedic physical therapy for the cervical spine, and 1 individual received cognitive-behavioral therapy from a neuropsychologist. Four of the 5 participants receiving two additional types of therapies were in the young adult cohort.

Data Analysis

The following statistical tests were used to assess the participant outcomes to identify change over time, considering age. The distribution for each continuous measure was evaluated for normalcy by assessing kurtosis and skewness. For each of the measures found to have a normal distribution, a two-way analysis of variance (ANOVA) mixed design was used to evaluate differences in outcome over time considering age. Bonferonni adjusted t-tests were used as follow-up tests. A Fischer's exact test was used to assess associations between categorical variables. Participants with missing values for a particular outcome variable were excluded from the analysis of that outcome variable. Considering 20 inference tests were performed on this sample (ANOVA's, t-tests, and Fischer's exact tests), the level of statistical significance was conservatively set at α=0.002.[36] Statistical analysis was performed using SPSS for Windows, 22.0.

Results

Two participants had missing values; one subject did not have any ABC outcome measures, and another subject did not have 3-month follow-up measures for the ABC or FGA outcomes. Baseline scores for outcome measures assessed are provided in Table 2. Participant outcomes for young and older adults at initial evaluation, 3 months, and 6 months following participation in the rehabilitation program are presented in Tables 3a and 3b, respectively.

The distributions of all the continuous outcome variables were found to be normally distributed. When each of the outcome variables were assessed using a two-way ANOVA mixed design for the independent variables time-of-measure and age group, no significant interactions were found between the independent variables. No association was found between age group and return to work, or age group and return to meaningful activities at any time period (p>0.05 for all associations). Due to the lack of significant interactions considering age group, results of the analyses are reported for all 14 participants across age groups.

Changes in Participants' Perception of Concussion-Related Symptoms and Function

Statistically significant differences or differences approaching statistical significance between initial outcome measures and those recorded at 3 months were found for the outcome measures RPQ-13 (p<0.002), DHI

TABLE 3A. Participant Outcomes for Younger Adults at Initial Evaluation, 3 Months, and 6 Months (n=8)

Variable	Participant							
	S1	S2	S3	S4	S5	S6	S7	S8
Age (yrs)	41	22	37	18	27	33	27	44
Gender	F	F	M	M	F	M	M	F
Days from injury to evaluation	39	23	423	974	306	61	112	660
Mechanism of injury	MVA	Sport	Fall	MVA	Sport	Fall	Sport	MVA
No. of sessions								
3 mos	18	12	20	11	14	9	7	7
6 mos	26	21	27	17	21	12	16	14
RPQ-3								
IE	8	8	11	8	3	6	8	8
3 mos	9	4	9	6	6	3	4	10
6 mos	6	4	8	7	3	3	1	2
RPQ-13								
IE	35	21	45	40	13	15	29	53
3 mos	24	13	33	37	18	11	22	45
6 mos	17	19	15	25	15	7	14	10
DHI								
IE	58	36	96	60	30	41	41	64
3 mos	46	20	68	50	26	31	40	53
6 mos	22	18	54	44	34	6	12	12
ABC scale								
IE	71	19	70	92	93	94	66	68
3 mos	—	81	67	96	92	96	89	66
6 mos	96	80	71	84	92	95	90	91
FGA								
IE	26	20	18	26	29	25	20	24
3 mos	—	25	20	23	27	28	26	26
6 mos	27	25	23	25	27	28	27	27
RTW								
IE	3	0	3	3	0	2	2	3
3 mos	1	0	3	3	0	3	0	2
6 mos	0	0	1	2	0	0	0	1
RTA								
IE	3	3	3	3	2	3	3	3
3 mos	2	2	2	2	2	2	2	2
6 mos	2	1	2	2	2	0	0	0

IE, initial evaluation. Boxes marked with a dash (–) indicate score was unable to be obtained for the FGA (participant S1) and for the ABC scale as more than one question was left blank on the questionnaire (participant S1).

(p<0.001), and FGA (p<0.01). Statistically significant differences or differences approaching statistical significance between initial outcome measures and those recorded at 6 months were found for the outcome measures RPQ-3 (p<0.001), RPQ-13 (p<0.004), DHI (p<0.001), ABC (p<0.007), FGA (p<0.001). For the time period between the 3-month follow-up and 6-month follow-up, differences in outcome measure scores were either statistically significant or approached significance for RPQ-3 (p<0.001), RPQ-13 (p<0.04), DHI (p<0.003), FGA (p<0.007). Changes in clinical outcome measures over time are presented in Table 4, and depicted in Figure 1.

Assessing the Occurrence of Return to Work/Meaningful Activities in Adults

Associations that were statistically significant or approached statistical significance were found between the time of measure and both RTW (p<0.03) and RTA (p<0.001). For both associations, visual observation of the distributions revealed a pattern of what one would expect for recovery over time as there is an overrepresentation of individuals who were inactive prior to initiating the rehabilitation program and an underrepresentation of individuals who were inactive 3 months and 6 months following the initiation of the rehabilitation program. There was also an overrepresentation of individuals who had returned to previous activity or previous activity with lower demand at the end of the 6-month program compared to the initial evaluation. Participant changes for return to meaningful activities for all 14 participants are depicted in Figure 2.

Discussion

This article is the first that the authors are aware of to investigate the change over time of adults in the civilian population with persistent symptoms following a con-

TABLE 3B. Participant Outcomes for Older Adults at Initial Evaluation, 3 Months, and 6 Months (n=6)

Variable	Participant					
	S9	S10	S11	S12	S13	S14
Age (yrs)	72	55	60	57	55	62
Gender	F	F	M	F	F	M
Days from injury to evaluation	14	992	96	18	266	102
Mechanism of Injury	Fall	Fall	Fall	Fall	Fall	Fall
No. of sessions at:						
3 mos	14	12	8	12	9	11
6 mos	27	18	17	19	15	20
RPQ-3						
IE	10	11	7	9	10	2
3 mos	5	11	4	11	11	2
6 mos	7	7	0	5	3	2
RPQ-13						
IE	28	45	35	26	32	17
3 mos	16	40	22	22	29	19
6 mos	34	38	4	20	14	12
DHI						
IE	78	61	56	68	74	51
3 mos	70	55	41	58	70	47
6 mos	78	50	6	41	41	30
ABC scale						
IE	—	77	48	55	61	44
3 mos	—	76	77	67	63	53
6 mos	—	81	96	88	76	58
FGA						
IE	9	19	24	20	20	15
3 mos	16	21	26	26	22	16
6 mos	16	23	29	30	25	24
RTW						
IE	3	2	3	1	3	2
3 mos	3	2	2	0	2	2
6 mos	3	1	1	0	1	0
RTA						
IE	3	3	3	3	3	3
3 mos	2	2	2	1	1	1
6 mos	2	2	1	1	1	0

IE, initial evaluation. Boxes marked with a dash (–) indicate score was unable to be obtained for the ABC scale as more than one question was left blank on the questionnaire (participant S9).

cussion after participating in a vestibular rehabilitation program with aerobic training. Following 6 months of participation in a supervised home exercise vestibular rehabilitation program with aerobic training, significant improvements were observed in participants' report of concussion related symptoms, function, and return to meaningful activities. The aim of the study was to investigate changes over time in adults that had experienced a concussion. Age was considered as a covariate to assess if outcomes varied by age. We found that improvements in concussion related symptoms, function, and return to meaningful activities were made independent of the age of the participant.

Changes in Participants' Perception of Concussion-Related Symptoms and Function

There was a meaningful improvement found across all clinical outcome measures from the initial evaluation to the 6-month assessment. This may not be surprising as the 6-month program is a longer course than is typical in providing rehabilitation services to individuals in the community. What may be more useful to a clinician is to provide insight into the timing of recovery. With many conditions, healthcare providers struggle to provide answers that pertain to when improvements may be expected to occur. Due to the design of this study, the authors were able to establish a pattern for the timing and magnitude of change a clinician can expect to observe with respect to a client's symptom complaint, perception of disability, and function. The RPQ-3 (which measures self-reported post-concussion sequela) and the FGA (performance-based balance measure) were not found to be significantly different from baseline levels until the 6-month assessment. This suggests that patients may experience a slower recovery rate of concussion-related symptoms and functional balance ability following a concussion.

TABLE 4. Mean ± SD of Outcome Measures at Initial Evaluation, 3-Month, and 6-Month Follow-up (n=14)

	IE	3 Mos	6 Mos
RPQ-3‡*	7.7 ± 2.6	6.7 ± 3.2	4.1 ± 2.5
RPQ-13†	31 ± 12.1	25 ± 10.3	17.4 ± 9.5
DHI †*	58.1 ± 17.8	48.2 ± 15.7	32 ± 20.9
ABC	61.2 ± 27.1	76.9 ± 14.1	78.4 ± 25
FGA*	21 ± 5.1	23.2 ± 4	25.4 ± 3.4

Significant difference for outcome measure was found between: † initial evaluation and 3-month follow-up; ‡ 3-month and 6-month follow-up; and * initial evaluation and 6-month follow-up. IE, initial evaluation.
[§]Independent t-test was used for comparisons between continuous variables, $\alpha = 0.002$.

The findings from the FGA are interesting when compared to the results of a participant's confidence in their balance at 6 months as measured by the ABC scale. The ABC scale was not found to be significant at the 3 month or 6 month assessments. This highlights that individuals' perception of their balance does not necessarily match their actual physical balance performance as individuals' confidence in their balance ability lagged behind the improvement that was found in the performance-based balance measure. This finding is not in agreement with Legters et al.[37] who reported a moderate correlation (r=0.58; p<0.001) between the ABC scale and the Dynamic Gait Index (a performance-based balance measure that shares 7 items with the FGA) for individuals with peripheral vestibular disorders. However, the relationship was not consistent across all conditions of peripheral vestibular dysfunction, as the correlation between decreased balance confidence and gait dysfunction was not strong (r=0.49; p<0.005) in individuals with BPPV. It is worth noting that individuals with persistent symptoms following a concussion is not consistent with a peripheral vestibular disorder, and the balance performance measure used by Legters et al.[37] can be viewed, clinically, as a less rigorous balance performance measure. Therefore, the finding of the current report showing conflicting trends between the ABC scale and the FGA in individuals following a concussion cannot be dismissed.

Finally, results suggest that patients may experience improvement in participation level measures early and steadily in the rehabilitation process. Significant improvements in the RPQ-13 and DHI scores were found within the first 3 months of the rehabilitation program, and continued to improve from the 3-month follow-up through the 6-month follow-up.

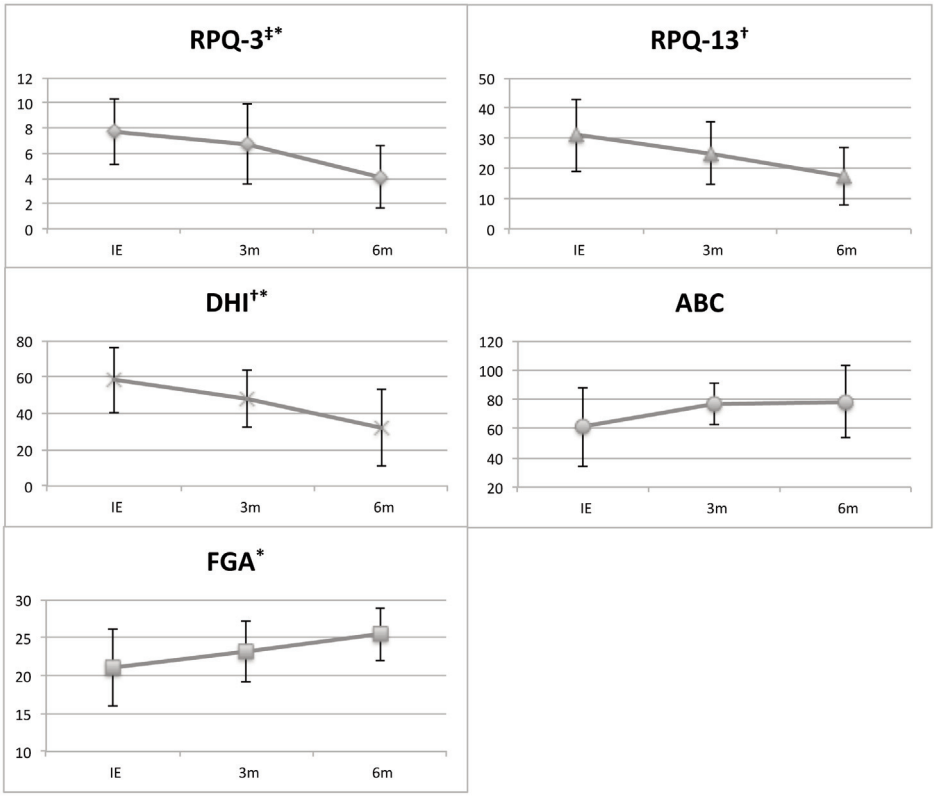

FIGURE 1. Mean ± SD of outcome measures at initial evaluation, 3-month, and 6-month assessment (n=14). A significant difference for outcome measure was found between: † initial evaluation and 3-month follow-up; ‡ 3-month and 6-month follow-up; and * initial evaluation and 6-month follow-up.

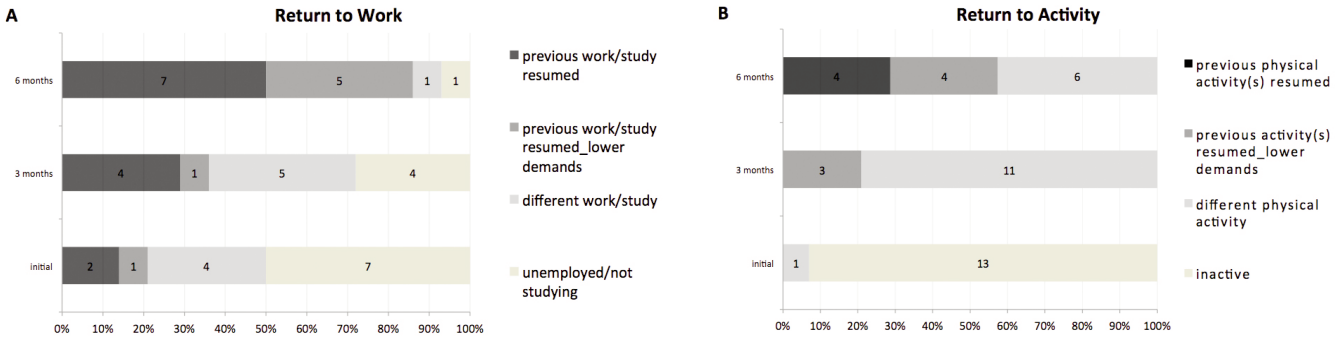

FIGURE 2. Participant changes for return to meaningful activities of the 14 participants at initial evaluation, at 3 months, and 6 months after beginning the vestibular rehabilitation with aerobic training program.

Return to Work/Meaningful Activities in Adults

The patterns of association for RTW and RTA are consistent with what one would expect to observe with improvement over time. There was a definite shift in the positive direction for both RTW and RTA, although there was a much stronger relationship between RTA and time of measurement. The strong association found between the time of measurement and return to physical activities is a critical finding of this study. Following treatment, a significantly greater number of individuals were able to participate in their premorbid activities when compared to the initial assessment. This finding was true for all individuals, independent of age. Although the study design constrains our ability to attribute cause to this finding, it seems as though this may be related to the addition of the aerobic training regimen to the vestibular rehabilitation program. We argue here, that these findings seem to provide further support for the growing literature[6,14,38] advocating for healthcare providers to screen and monitor physical activity in order to keep individuals engaged in recreational and social physical activity(s) following head injury.

As the authors had hypothesized, it took greater than 3 months for the majority of participants to return to meaningful activities. When considering a participant's return-to-work status, only 5 of the 14 (35%) participants had returned to their previous position of employment (with or without work modifications) by 3 months. It was not until the 6-month assessment that the majority of participants, 12 of 14 (85%), had returned to their prior level of work. These findings conflict with the return to work results published by Rees and Bellon[7] who reported that only 25% of individuals with persistent symptoms following a mTBI returned to their prior level of work 2 to 5 years following a head injury (30% returned to different work and 45% of the patient population remained unemployed). However, one must consider the individuals followed by Rees and Bellon[7] were not receiving rehabilitation services at the time of follow-up, and the participants likely had more severe TBIs as each individual was assigned a Glasgow Coma Scale score of 13-15 at the time of injury. Both of these factors distinguish the current sample population from that studied by Rees and Bellon,[7] and likely accounts for the discrepancy in RTW status.

A similar trend was found considering participants' return to physical activities. Only 21% of the participants were able to return to their premorbid physical activities (with or without restrictions) by 3 months. But, by the 6-month assessment, the majority of participants, 8 of the 14 (57%), were able to return to their previous activity(s). The authors also hypothesized that the majority of older adults would not return to meaningful activities within 6 months. However, results suggested this was not the case as 5 of 6 individuals returned to their previous position of employment by 6 months, and 4 of the 6 older adults had returned to their previous physical activities by the 6-month follow-up.

One aspect of this study to consider is the disparity observed in the cause of injury between young and older adults, as all individuals over the age of 55 had a fall that resulted in a hit to the head, while only two participants (25%) in the younger group had a fall-related injury. This finding is reflective of the cause of injury associated with age in TBI reported in the literature.[39] However, it is worth noting that the sample of individuals in this study contained a higher percentage of older adults than what is reported in the literature for rehabilitation following concussion. To date, most studies evaluating treatments for individuals with persistent symptoms following concussion have been directed almost exclusively toward recovery after sports-related concussion and those experienced by military personnel.[8–12,14] The current investigation could point to a growing need to direct attention toward recovery in non-sports/non-military-related concussions. Individuals in the civilian population have a great degree of debility following injury as well (lost income due to absence from work, psychological stress relational/family-stress with spouse/children, contri-

bution to secondary medical conditions from inactivity due to rest prescribed by medical professionals). The debility experienced by the civilian, nonathletic population justifies further investigation of intervention effectiveness by the rehabilitation for these individuals.

The design of this study limits the conclusions that may be drawn. A quasi-experimental investigation cannot determine what may have accounted for the changes observed over time, just report on the changes that were found. The lack of a control group constrains the ability to assess a treatment effect from the rehabilitation program. The small sample size utilized in this study always is of concern when generalizing to a larger population. Finally, the means by which this data was analyzed to report statistical significance may be overly conservative. Bonferroni adjustments were made to determine the level of significance used for this study based on the assumption that the outcome variables utilized in the study were independent from each other. As the consistency in findings suggest, a number of outcome measures were correlated with each other. While the conservative level of significance used biases our findings toward the null hypotheses, the findings suggest improvements in outcome variables across time were strong enough to overcome the conservative bias.

In this study, participants' adherence to home-based exercises were not monitored. This information could have been utilized to determine if the amount of time individuals actively engaged in the prescribed physical therapy intervention was related to their outcomes. The number of supervised, structured sessions of the vestibular rehabilitation program was reported, but were not controlled. It is possible, therefore, that the number of sessions could have influenced outcomes. A sub-analysis was completed to determine the relationship between the number of sessions and the outcome achieved at the 3-month and 6-month assessments. It was found that there was no correlation between time of measurement and the number of sessions completed for any individual, independent of age.

The multidisciplinary nature of the delivery of the program could be seen as contributing to the improvements experienced by the participants, especially since nearly all participants received vision therapy in conjunction with the vestibular rehabilitation and aerobic training program. The degree to which each of these therapies contributed to participants' improvement is difficult to determine. Oculomotor rehabilitation has been found to significantly improve reading rate and be associated with improved subjectively-based visual comfort and visual attention during reading in individuals who experienced a mTBI.[40] Further, when ocolomotor training was performed in conjunction with multiple therapies (vestibular, cognitive-behavioral therapy, speech therapy, and/or psychotherapy), Ciuffreda et al.[41] reported marked improvement in individual's attentional state while reading under simple and complex environmental conditions for those with mTBI. It is not hard to imagine that improvements in the ability to read could influence an individual's perception of their concussion-related symptoms, balance performance, and return to function.

A more sophisticated study design with a larger sample size is required to determine if specific components of a comprehensive post-concussive rehabilitation program is necessary and sufficient for successful outcomes, or if having all components of the comprehensive program available to patients are necessary to achieve successful outcomes. The exploratory nature of the current study sets the foundation for future investigations to determine the causal relationships between treatment regimens for patients with concussion and successful patient outcomes.

Conclusion

Following 6 months of participation in a supervised home exercise vestibular rehabilitation program with aerobic training, significant improvements were observed in participants' self-report of concussion related symptoms, function, and return to meaningful activities. Interestingly, these improvements were found to be independent of the age of the participant. A critical finding of the current study was the relationship between time of measurement and return to work, and a strong association between the time of measurement and return to physical activities. At the 6-month assessment, more individuals were able to participate in their premorbid physical activities than would have been predicted by chance. Further analysis showed that clinicians can have reasonable expectations to observe improvement in participation level measures early in the rehabilitation program, but should not be surprised by a slower recovery rate for concussion related symptoms and an individual's perceived balance confidence.

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Published online 1 Dec 2016.
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