RESEARCH ARTICLE

Exercise Prescription Patterns in Patients Treated with Vestibular Rehabilitation After Concussion

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Abstract

Background and Purpose. Individuals with concussion often complain of persistent dizziness and imbalance, and these problems have been treated with vestibular rehabilitation exercises. The purpose of this study is to describe the vestibular rehabilitation exercise prescriptions provided to individuals after concussion. **Methods.** A retrospective chart review of vestibular rehabilitation home exercise programmes prescribed by physical therapists for 104 participants who were diagnosed with concussion was conducted. Each of the exercises was classified by exercise type, duration and frequency. Frequency counts of the most common exercise types were recorded. Exercise progression patterns were examined by determining how exercise types were modified from visit to visit. **Results.** Eye–head coordination exercises were the most commonly prescribed exercise type (in 95% of participants), followed by standing static balance exercises (in 88% of participants), and ambulation exercises (in 76% of participants). **Conclusions.** Understanding the prescription patterns of expert clinicians may elucidate the vestibular-related impairments of individuals after concussion and may provide a resource for therapists who may be starting vestibular rehabilitation programmes for management of individuals with concussion. To improve quality of care, future research should be directed to relate outcomes to the exercise prescription patterns. Copyright © 2012 John Wiley & Sons, Ltd.

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Keywords

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Introduction

Reports of dizziness and imbalance are prevalent in individuals who have had a concussion. Twenty-three to 81% of persons post concussion report dizziness in the first days post concussion. Estimates of the prevalence of persistent dizziness after mild traumatic brain injury varies widely from 16–18% at 3 months (Dischinger et al., 2009, Lannsjo et al., 2009), 1.2% at 6 months (Maskell et al., 2007) to 32.5% at 5 years (Masson et al., 1996). Persistent balance problems have also been reported three weeks after concussion (Lovell et al., 2006; Blinman et al., 2009).

Vestibular rehabilitation is a key component to the management of dizziness and balance disorders resulting from vestibular system dysfunction, either peripherally or centrally (Horak et al., 1992; Herdman et al., 1995; Yardley et al., 1998; Herdman et al., 2003; Krebs et al., 2003; Enticott et al., 2005). Despite the high incidence of dizziness and balance dysfunction in people who have had a concussion, reports of vestibular and balance rehabilitation in management of concussion are sparse (Herdman, 1990; Gizzi, 1995; Gurr and Moffat, 2001; Hoffer et al., 2004). Previous studies have shown that vestibular rehabilitation reduces dizziness and improves overall balance for individuals with head injury (Herdman, 1990; Gizzi, 1995; Gurr and Moffat, 2001; Hoffer et al., 2004; Alsalaheen et al., 2010).

The accepted standard of care for vestibular rehabilitation is to use a problem-oriented approach in which impairments and functional limitations are identified during the initial evaluation, and customized exercises are prescribed to address the individual's specific problems, while accounting for the pathology and other co-morbidities (Herdman and Whitney, 2007). General guidelines for exercise prescription and progression are available in Herdman et al. (Herdman and Whitney, 2007), and more specific programmes have been documented for prospective clinical trials (Herdman and Whitney, 2007). Outside of these descriptions of authoritative practice guidelines, there have been no reports of how vestibular rehabilitation therapists actually use these principles in practice. An understanding of what exercises have been prescribed for individuals with dizziness and imbalance after concussion may be useful for several reasons. Assuming that the physical therapists adhered to the problem-oriented approach described previously, the study can provide a detailed picture of the specific impairments and functional limitations encountered by the individuals with concussion and the path by which they returned to their pre-morbid status. Moreover, by understanding the prescription and progression patterns provided by expert clinicians, physical therapists new to prescribing vestibular rehabilitation exercises for patients with concussion can use this information to better understand how to start and then make the exercises more challenging. Additionally, therapists can use the framework of exercise categories, exercise groups and exercise modifiers to better document the detailed prescription pattern of vestibular rehabilitation exercises. Consequently, the purpose of this study is to describe exercise prescription patterns in patients treated with vestibular rehabilitation exercises.

Methods

Subjects

A retrospective chart review of 114 participants referred to a tertiary vestibular rehabilitation clinic for vestibular rehabilitation after being diagnosed with concussion was performed. Five patients did not have an indication for vestibular rehabilitation therapy, and four patients were diagnosed with benign positional paroxysmal vertigo and were successfully treated using the modified Epley canalith repositioning maneuver (Epley, 1992) without need for home exercises. One patient did not return for subsequent visits. A total of 104 participants (66, female/38, male, mean age 24 y, SD 19 y) received a computer-generated home exercise programme (HEP) of vestibular rehabilitation exercises after being diagnosed with concussion. Results of the intervention were previously reported (Alsalaheen et al., 2010). Participants were referred for a median of 58 (6–1,149) days after the concussion episode. The duration of the vestibular rehabilitation intervention was a median of 33 (range 7–181) days, encompassing a median of 4 (range 2–13) visits. The HEP was designed by eight physical therapists with at least three years experience in vestibular physical therapy.

Procedure

Each of the computer-generated exercise handouts (Visual Health Information, WA, USA) that was placed in the chart was reviewed by one of the authors (PS), and each exercise was classified according to general exercise categories that address common areas of dysfunction in individuals with vestibular and balance disorders. VHI software has a pre-determined set of exercises that allows therapists to make modifications for the initial exercise prescription. The software also allows therapists to create new exercises and to make changes to progress the different exercise prescriptions.

There are five main exercise categories: 1) eye–head coordination; 2) sitting balance; 3) standing static balance (i.e. feet-in-place), 4) standing dynamic balance (feet moving, but not walking); and 5) ambulation. Each one of these categories consisted of different exercise types.

A brief description of the exercise categories and types is included as follows.

1. Eye–head coordination exercises: This exercise category contains many exercise types that involve movement of head and/or eyes for the purpose of vestibulo–ocular reflex (VOR) gain adaptation, symptom habituation, or oculomotor re-education. The exercises include: VORx1, VORx2, VOR cancellation, convergence, smooth pursuits, anticipatory gaze shifts, imagined target, and saccades (Whitney and Herdman, 2007).
2. Sitting balance exercises: The patient maintains balance while sitting upright, weight shifting from side to side, or bouncing.
3. Standing static balance exercises: The patient stands with feet in place while upright or weight shifting. The patient can be asked to stand on one leg, stand on a rocker board or stand with one foot on a step. This category also includes the sit-to-stand exercise.
4. Standing dynamic balance exercises: The patient stands and moves without walking. The patient might march in place, step forward or backward, step to the side, step up or down, or turn around.
5. Ambulation exercises: The patient walks forward, backward, on stairs, with turns and practices braiding (i.e. side stepping in an over and under pattern), skipping, jogging and running.

For each type of exercise, a universal set of 10 modifiers was used to describe other characteristics of the exercise (Table 1): 1) the posture in which the exercise is performed; 2) the type of support surface; 3) the size of the base of support; 4) the positioning of the trunk; and 5) arms; 6) the direction of head movements; 7) the direction of whole body movements; 8) the visual input; 9) the presence or absence of a dual cognitive task; and 10) any other special circumstances, such as target distance (near or far) when performing VORx1 exercise. The frequency and duration of time prescribed per exercise were also recorded. Frequency is recorded in terms of the number of times it is performed per day, and the duration of the exercise is given by length of time or number of repetitions. Finally, the intensity of the exercise can be described in terms of speed of movement or change in symptom rating. Note that the intensity may not have relevance for some categories, for instance sitting or static standing balance.

Analysis

To provide an understanding about the patient's initial presentation and the progression for a specific exercise type, the visit during which each new exercise was prescribed was recorded. An exercise qualified as a new exercise if at least one modifier was different than the previous prescriptions. Progression was defined as performance of the same exercise type, but under more challenging conditions (e.g. progressing VORx1 from standing with feet apart to feet together or walking). Frequency counts of the most common exercise categories and most common exercise types within each category (constituting 95% of each category) were recorded. Exercises provided to the participants as a HEP were analysed, rather than the exercises performed during the clinic visit because the documentation was more uniform and presumably reflected the most important activities that each patient needed

Table 1. The exercise modifiers used for the vestibular rehabilitation exercises

Modifier	Choices
Posture	1: Sitting, 2: Standing, 3: Walking, Not applicable/Not specified (NA/NS)
Surface	1: Level, 2: Foam, 3: Uneven, 4: Obstacle, 5: Stairs, 6: Ramps, NA/NS
Base of support	1: Feet-apart, 2: Feet-together, 3: Semi-tandem, 4: Tandem, NA/NS
Trunk position	1: Upright, 2: Leaning, 3: Rotated, NA/NS
Arm position	1: Weight bearing, 2: Close to body, 3: Away from body, 4: Reaching, 5: Carrying, 6: Picking up objects, 7: Juggling, NA/NS
Head movement direction	1: Still, 2: Yaw, 3: Pitch, 4: Roll, NA/NS
Direction of whole body movements	1: Anterior–posterior, 2: Medial–lateral, 3: Multi-directional, NA/NS
Visual input	1: Eyes closed, 2: Eyes open, 3: Complex patterns, NA/NS
Cognitive dual task	1: Yes, 2: No
Special circumstances	For example, note if the VORx1 exercise was performed with a near or far target

to work on. Throughout the results, and unless specified otherwise, the percentages were relative to the overall number of participants who received a HEP (i.e. $n = 104$).

Results

A total of 104 participants had a HEP prescription. Out of the sum total of 411 patient visits, a printed HEP sheet was located for 335 visits (82%). It is not known in the remaining 18% of the visits, if the participants were given a new HEP without being placed in the chart, or if the therapist wanted the patient to continue with the same HEP. The 76 missing home exercise notes were distributed among 40 participants. There were no differences in age, gender and time between concussion and vestibular rehabilitation between this group with missing data and the group without missing data; however, the group with missing data had a longer treatment duration (48 ± 29 days v. 26 ± 16 days, $p < 0.001$).

Table 2 summarizes the frequencies for the most common exercise categories and exercise types, prescribed throughout the duration of the intervention as well as for the first visit only. Eye–head coordination exercises were the most commonly prescribed category, including 95% of the participants who had received a HEP. The VORx1, VOR cancellation, convergence and VORx2 were the four most common exercises in this category, respectively. The standing static balance category was the second most common category of exercises, prescribed in 88% of participants; the most frequent were standing upright on level and foam surfaces, single leg stance, weight-shifting exercises in various directions, and sit-to-stand. The ambulation category was the third most commonly prescribed category (76% of participants), with forward ambulation followed by backward ambulation, and walking with turns. To accompany these commonly prescribed exercises, we have detailed the most common frequency and duration as specified by the physical therapists.

Preferred prescription patterns

Even though the number of potential exercises is large due to the combination of modifiers that could be used, the physical therapists demonstrated preferred prescription patterns that contained a small subset of the potential combinations. For example, examination of these patterns revealed that the VORx1 exercise was usually prescribed in both the yaw and pitch planes. For each patient, it was further customized by

Table 2. Summary of the most common prescribed exercises throughout therapy and during the first visit in number of subjects (percentage of subjects). The total number of participants is 104. The most common frequency and duration of these exercises is also shown

Exercises	Exercises throughout therapy	First visit	Frequency (times/day)	Duration
Eye–head coordination	**99 (95%)**	**89 (86%)**		
VORx1	92 (88%)	75 (72%)	3	60 s
VOR cancellation	67 (64%)	31 (30%)	2	10 reps
Convergence	30 (29%)	21 (20%)	2	10 reps
VORx2	9 (9%)	1 (1%)	1	30 s
Standing static	92 (88%)	69 (66%)		
Standing upright	87 (84%)	67 (64%)	2	30 s
Single leg stance	29 (28%)	7 (7%)	4	30 s
Weight shift	15 (14%)	2 (2%)	1	10 reps
Sit to stand	14 (13%)	11 (11%)	1	10 reps
Ambulation	79 (76%)	43 (41%)		
Forward ambulation	76 (73%)	42 (40%)		
Feet apart, yaw head turns	64 (62%)	31(30%)	1	20 head turns
Feet apart, pitch head turns	29 (27%)	12(12%)	1	20 head turns
Tandem, head still	33 (32%)	9 (9%)	1	20 feet
Backward ambulation	44 (42%)	10 (9%)		
Feet apart, head still	18 (17%)	8(8%)	1	20 feet
Feet apart, yaw head turns	14 (13%)	0 (0%)	1	20 head turns
Tandem, head still	21 (20%)	3 (3%)	1	20 feet
Ambulation with turns	19 (18%)	2 (2%)	1	Every five steps

changing the posture, size of base of support and visual input. Therefore, the therapists usually did not alter the following modifiers during the VORx1 exercise: surface, trunk position, arm position, direction of whole body movement or involvement of cognitive dual task. The specific patterns for the VORx1 exercise will be presented in more detail in the section on progression.

The VOR cancellation exercise was customized primarily by changing the posture and/or the base of support (BOS). As with the VORx1, VOR cancellation was prescribed in both yaw and pitch planes. In 38% of the participants who received a HEP, VOR cancellation was prescribed in the standing position on a level surface (most with feet apart). While in the standing position, the target was either held in one hand while the arm was moving (e.g. a playing card) or tossed between hands (e.g. a ball). This exercise was also performed while walking (37% of participants), also with targets that were tossed or held in the hand. VOR cancellation was prescribed in the sitting position for 18% of participants, always while having the target held in hand.

For the standing static balance exercise category, the standing upright exercise was customized and/or progressed by changing the surface, BOS, direction of head movement and the visual input modifiers. The most common surface was a level one, which was prescribed in 74% of the participants receiving a HEP. Participants were instructed to stand with feet together (46%), followed by standing tandem and semi-tandem (34% and 31%, respectively). Across these three BOSs, the exercise was most commonly prescribed with head still and eyes closed. When the exercise was given with head movement in the yaw direction ($n = 45$), the eyes were open in most cases ($n = 41$). When performed on a foam surface (37%), the standing upright exercise was most commonly prescribed with feet apart followed by feet together (27% and 8%, respectively). When performed with feet apart, it was most commonly performed with head still and eyes closed.

The most common modifiers of the ambulation exercises were the BOS and direction of head movement. Forward ambulation was the most common prescribed exercise in 73% of the participants. The majority of the participants performed the exercise with feet apart (68%). Tandem ambulation was the second most common forward ambulation (34%). Across the different BOSs the exercise was prescribed with yaw head movement most frequently (62%), then with pitch head movement and no head movement (28% and 12%, respectively).

Progression

The VORx1 exercise can be used as an example of how exercises were progressed (Table 3). The initial exercise prescription was given most commonly in standing with feet apart (40 participants), followed by standing with feet together (29 participants) and sitting (21 participants). For the participants who were prescribed VORx1 in sitting, 11 participants were

Table 3. Progression patterns for the VORx1 exercise. The total number of participants who received the exercise is 92. The categories are not mutually exclusive, in that some participants may have been performing VORx1 in more than one posture

	Posture				
	Sitting	Standing feet apart	Standing feet together	Standing tandem/ST	
Initial prescription	21	40	29	1	1
Progression(s)					
Sitting		—	1	—	—
Standing feet apart	11		—	—	—
Standing feet together	6	19		—	—
Standing tandem/ST	—	2	7		2
Walking	2	10	17	3	
Standing other	—	2	2	—	—
Walking other	—	—	—	—	2
Final prescription	4	19	30	8	31

ST: Semi-tandem.

progressed to standing with feet apart, six participants to standing with feet together, two to walking and four participants did not progress any further. During the final prescription of VORx1, 31, 30 and 19 participants were instructed to perform the exercise during walking, standing with feet together and standing with feet apart, respectively. Fewer numbers of participants were given their last VORx1 progression in the semi-tandem and tandem position (six and two participants, respectively).

Discussion

Based on the exercises that were prescribed, we can infer that most of the impairments in these individuals with concussion were in three domains; Eye–head coordination, standing static balance, and ambulation. The exercises that were given to the participants in this study are consistent with those prescribed in other research studies involving vestibular rehabilitation (Smith-Wheelock et al., 1991; Horak et al., 1992; Herdman et al., 1995; Schubert et al., 2008). Moreover, although the previous studies of vestibular rehabilitation in patients with post concussion symptoms did not provide a detailed description about their vestibular rehabilitation programme, the use of VORx1 and 'positional exercises' has been reported (Hoffer et al., 2004).

Impairments in the eye–head coordination have been reported after brain injury, and may result from disruption in the VOR (Shumway-Cook, 2007) or reflect increased symptoms with head and eye movement (Scherer and Schubert, 2009). Vestibular adaptation exercises that improve VOR gain will consequently improve gaze stabilization during head movement. (Herdman and Whitney, 2007; Schubert et al., 2008) Eye–head coordination exercises can also be prescribed for habituation purposes if the patient is found to have symptom provocation independently of any reduction in VOR gain. In the current sample of participants, 95% were found to have impairments in eye–head coordination. Because most of the participants did not have formal vestibular function testing, it is not certain how many participants had reduced VOR gain. However, most of the participants had symptom provocation with eye and head movements.

Several studies have reported different balance and ambulation impairments in patients with post-concussion symptoms. Despite the evidence that impairments in static balance spontaneously resolve within the first 3–5 days after concussion (Guskiewicz et al., 1996; McCrea et al., 2003), 88% of the current participants were found to have impairments in standing static balance at least 6 days after the concussion. In addition, patients may exhibit slower gait velocity (Kaufman et al., 2006; Parker et al., 2008; Catena et al., 2009), shorter stride length (Parker et al., 2005), and wider step width (Catena et al., 2007). In the current sample of participants, ambulation impairments were found in 76% of the participants.

Ninety percent of participants who had difficulties in the domain of eye–head coordination received a HEP to address gaze stabilization during their first visit (Table 2). Of the participants who had standing static balance difficulties, 76% received a HEP in the standing static balance category during the first visit. However, only 54% of the participants who had difficulties during walking were given ambulation exercises during their first visit. These results suggest that the eye–head coordination category is the domain that is usually addressed first by the expert clinicians during vestibular rehabilitation for patients post concussion. Several factors may account for why ambulation exercises were not emphasized during the first visit. First, it is common for persons with vestibular disorders to become symptomatic before the ambulation evaluation is complete (Whitney and Herdman, 2007). Second, the therapist may have identified gait impairments but decided to address the eye–head coordination and standing static balance problems first to instill confidence and make sure the participant performed the exercises safely before addressing the more dynamic balance deficits (i.e. during ambulation). Others have suggested using a less aggressive pattern of progression for patients with post concussion symptoms during vestibular rehabilitation (Shumway-Cook, 2007). Although the reasons for prescription patterns have not been verified through the current data, these previously mentioned issues are frequently seen in the management of patients with vestibular disorders and warrant a frequent re-evaluation for patient's status to determine the current impairments and functional limitations throughout the course of vestibular rehabilitation (Whitney and Herdman, 2007).

The analysis revealed important observations about the exercise prescription and progression patterns. For eye–head coordination exercises, the most important modifiers were the posture and base of support. A typical pattern of progression for the VORx1 exercise would be from sitting to standing with feet apart, to standing with feet together, to walking. By varying the combinations of posture and the size of base of support, the patient must learn to adjust for natural body movements that occur while coordinating the eye and head movements during typical daily activities. VOR cancellation is needed to follow moving objects while the head is synchronously moving in the same direction. Posture was the most important modifier to be changed during VOR cancellation prescription. The exercise was mainly performed in postures that match the scenarios in which the suppression of VOR is needed in real life (i.e. standing and walking). For participants who were more symptomatic, the exercise was prescribed while sitting and progressed to standing and walking after the symptoms improved (data not shown).

Participants received the VORx2 exercise as part of the progression less frequently (9%) than is typically prescribed for people with unilateral vestibular hypofunction. Several reasons may exist to explain this. The participants may not have returned for enough visits to begin this exercise because their symptoms improved and they were discharged. In other cases, the participants may still have been highly symptomatic with the VORx1 exercise.

Because of the retrospective study design, we were not able to record the explicit rationale for the therapists' prescription. All of the therapists who prescribed the exercises were trained in the customized problem-oriented approach that is considered to be the standard intervention for vestibular rehabilitation (Herdman and Whitney, 2007). Therefore, we can assume that the general rationale for the exercise prescription in each case was developed using the same framework of the following: 1) identifying the impairments during the evaluation; 2) prescribing a specific initial exercise to address that impairment safely; and 3) progressing the exercise by increasing difficulty so that the activity can be done in a functional manner. Although the current design cannot specifically address 'why' the exercises were given, we believe knowing 'what' was prescribed by expert therapists is an important step in understanding the management of these individuals. Given the extreme shortcomings in the published literature about the vestibular rehabilitation exercises for individuals post concussion, we believe that this manuscript is useful for clinicians who are starting vestibular rehabilitation exercises because the exercise prescription and progression patterns included in this manuscript is more detailed from previous studies that have commented on the vestibular rehabilitation exercises post concussion (Gizzi, 1995; Gurr and Moffat, 2001; Hoffer et al., 2004). Consequently, if a therapist has a basic understanding of the general principles of vestibular rehabilitation, they can now see how other therapists initially began the programme and then progressed the participants. For example, the results of this study suggest that during the initial visit, a therapist may want to concentrate on assessing eye–head coordination exercises and standing static balance activities, and when indicated, prescribe exercises in these domains. Initially, the VORx1 exercise was prescribed most frequently in standing with feet apart. In later visits, the participants progressed to perform additional eye–head coordination exercises, in more destabilizing postures, and also perform more ambulation exercises. Future studies should incorporate a prospective design and determine both elements of prescription pattern (i.e. the 'what' and 'why').

Additionally, we were not able to report the intensity of the prescribed exercises; this is attributed in part to the retrospective nature of our study in which the intensity was not specified in the software that was used to generate the HEP sheets. In the case of eye–head coordination exercises, participants were generally instructed to move their head at a speed that caused their symptoms to increase slightly. Nonetheless, we believe intensity should be more formally quantified in the prescription of vestibular rehabilitation exercises, in cases where it applies. For instance, in the case of eye–head coordination exercises, the speed of head movements (or eye movements) is not well described, and is difficult to monitor. Perhaps wearable sensors could be developed to assist in this area in which the speed of head movement is recorded. Another potential way to prescribe the intensity, especially in the case of symptom provocation, is by having the subject perform the exercise until they reach a certain level of symptom severity on a visual or verbal analogue scale. For standing dynamic exercises, the intensity could be prescribed as the number of repetitions per minute, and increased to a higher intensity during the progression. For ambulation exercises, intensity could be prescribed as the gait speed, or speed of head movements performed during gait.

While the progression of aerobic and resistance exercises is typically based on increasing the intensity or volume of the same exercise type, vestibular rehabilitation exercises are often based on subtle variations of the exercise types that are not able to be classified using the frequency, intensity, time and type principle of the American College of Sports Medicine (ACSM). The current system was designed to facilitate the reporting of exercises commonly used during vestibular rehabilitation. (Herdman et al., 2001; Herdman and Whitney, 2007) The five main exercise categories and exercise types within each category were loosely based on general exercise categories that address common areas of dysfunction in individuals with vestibular and balance disorders. It is important to note that the patients with dizziness and balance disorders also may have been given range of motion and strengthening exercises as a part of their HEP. However, the prescription frequency of these exercise types was much lower than the vestibular rehabilitation exercises.

One of the limitations encountered in the study was having missing HEPs. The group with missing data did not differ from the group with complete data in age, gender, and time since concussion; therefore, systematic bias is less likely to have had occurred in prescriptions that may have been based according to age and gender. The group difference in treatment duration may indicate that there was greater opportunity to have data missing, or support the notion that the therapist may have asked the more impaired participants (i.e. longer treatment duration) to continue the same HEP without documenting that in the chart.

Conclusions

Individuals with dizziness and imbalance post concussion may exhibit impairments in the eye–head coordination, standing static balance and ambulation. The exercises prescribed by expert clinicians are comparable with the exercises prescribed for individuals with unilateral vestibular hypo-function. Even though the number of potential exercises is nearly limitless due to the number of modifiers, the physical therapists demonstrated preferred prescription patterns that limited the number of modifiers used. By knowing the preferred prescription and progression pattern of exercises employed by expert physical therapists, other clinicians initiating a vestibular rehabilitation treatment programme for individuals post-concussion may have a foundation to guide their intervention.

Ethical approval

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Conflict of interest

There are no conflicts of interest.

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