Vestibular Rehabilitation for Dizziness and Balance Disorders After Concussion

Bara A. Alsalaheen, PT, MS, Anne Mucha, PT, MS, NCS, Laura O. Morris, PT, NCS, Susan L. Whitney, PT, PhD, NCS, FAPTA, Joseph M. Furman, MD, PhD, Cara E. Camiolo-Reddy, MD, Michael W. Collins, PhD, Mark R. Lovell, PhD, and Patrick J. Sparto, PT, PhD

Background and Purpose: Management of dizziness and balance dysfunction is a major challenge after concussion. The purpose of this study was to examine the effect of vestibular rehabilitation in reducing dizziness and to improve gait and balance function in people after concussion.

Methods: A retrospective chart review of 114 patients (67 children aged 18 years and younger [mean, 16 years; range, 8–18 years]; 47 adults older than 18 years [mean, 41 years; range, 19–73 years]) referred for vestibular rehabilitation after concussion was performed. At the time of initial evaluation and discharge, recordings were made of outcome measures of self-report (eg, dizziness severity, Activities-specific Balance Confidence Scale, and Dizziness Handicap Inventory) and gait and balance performance (eg, Dynamic Gait Index, gait speed, and the Sensory Organization Test). A mixed-factor repeated-measures analysis of variance was used to test whether there was an effect of vestibular rehabilitation therapy and age on the outcome measures.

Results: The median length of time between concussion and initial evaluation was 61 days. Of the 114 patients who were referred, 84 returned for at least 1 visit. In these patients, improvements were observed in all self-report, gait, and balance performance measures at the time of discharge ($P < .05$). Children improved by a greater amount in dizziness severity ($P = .005$) and conditions 1 (eyes open, fixed support) and 2 (eyes closed, fixed support) of the Sensory Organization Test ($P < .025$).

Discussion: Vestibular rehabilitation may reduce dizziness and improve gait and balance function after concussion. For most measures, the improvement did not depend on age, indicating that vestibular rehabilitation may equally benefit both children and adults.

Conclusions: Vestibular rehabilitation should be considered in the management of individuals post concussion who have dizziness and gait and balance dysfunction that do not resolve with rest.

Departments of Physical Therapy (B.A.A., S.L.W., P.J.S.), Otolaryngology (J.M.F.), Physical Medicine, and Rehabilitation (C.E.C.-R.), and Orthopedic Surgery (M.W.C., M.R.L.), University Of Pittsburgh; Centers for Rehab Services (A.M., L.O.M.), University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania.

Correspondence: Patrick Sparto, E-mail: psparto@pitt.edu
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INTRODUCTION

Concussion is one of the most prevalently acquired neurologic conditions occurring in children and young adults.[1,2] According to the Centers for Disease Control and Prevention, concussion is synonymous with the term “mild TBI (traumatic brain injury).”[3] Using the definition proposed by the Centers for Disease Control and Prevention,[3] concussion is a complex pathophysiologic process induced by traumatic forces secondary to direct or indirect forces to the head that disrupts the function of the brain. This disturbance of brain function is typically associated with normal structural neuroimaging findings (ie, computed tomography scan, magnetic resonance imaging). It results in a constellation of physical, cognitive, emotional, and/or sleep-related symptoms and may or may not involve a loss of consciousness.

Duration of symptoms is highly variable and may last from several minutes to months or even longer in some cases. Some factors that may contribute to prolonged recovery include loss of consciousness, amnesia, and confusion[4]; however, our understanding regarding this issue is still very limited.

Dizziness is a frequent symptom of concussion and has been reported to occur in 23% to 81% of cases in the first days after injury. Estimates of the prevalence of persistent dizziness after mild TBI vary widely from 1.2% at 6 months to 32.5% at 5 years.[5–8] Poor balance and postural instability have been reported in many studies after concussion[9–11] and have been correlated with dysfunction in sensory integration.[12,13]

Despite the high incidence of dizziness and balance dysfunction in people who have had a concussion, reports of vestibular and balance rehabilitation in the management of concussion are sparse.[14–17] Part of the reason for the lack of information is that, in many cases, symptoms resolve relatively quickly before referrals to tertiary providers can be made. In 1 study, >75% of high school football players returned to play within 3 weeks of their concussion.[18] The use of vestibular rehabilitation in the treatment of concussion-related dizziness and balance dysfunction has been promising, although Shepard et al[17] commented that the duration of vestibular rehabilitation is longer in people with head injury compared with unilateral peripheral vestibular dysfunction.

It has not been established whether the dizziness severity and balance dysfunction are the same for children and adults after concussion. Furthermore, it is unknown whether the amount of recovery from dizziness and balance dysfunction differs between children and adults after concussion.[19–21] Children's tolerance to biochemical changes associated with concussion may be different from adults, and consequently the sequelae from impacts of the same magnitude may be different between children and adults.[19] Furthermore, the role that played by the continuous and rapid maturation in children's cognitive abilities and postural strategies in the recovery process is unknown.[19,20,22,23]

The purpose of this retrospective study was to examine the severity of dizziness symptoms and gait and balance dysfunction reported by people who were referred for vestibular rehabilitation after concussion. Furthermore, this study investigated the effect of vestibular rehabilitation on reducing dizziness and gait and balance dysfunction, and whether the amount of recovery during vestibular rehabilitation was different between adults and children.

METHODS

Subjects

A retrospective chart review was performed on the records of 114 consecutive patients including children, who were referred between 2006 and 2008 to a tertiary balance center for vestibular rehabilitation after being diagnosed of a concussion. For the purpose of this study, children were defined as 18 years and younger, and the adults were defined as older than 18 years. The median age for children (45 girls, 22 boys) was 16 years with a range of 8 to 18 years, and the median age for the adults (25 women, 22 men) was 41 years with a range of 19 to 73 years. Of the 114 patients who were examined, 84 had more than 1 visit and 30 had a single visit. The study was approved by the institutional review board at the University of Pittsburgh.

Intervention and Outcome Measures

The vestibular rehabilitation intervention consisted of a customized program that was tailored to each patient's impairments and functional limitations that related to dizziness, ocular motor function, and gait and balance function.[24] The categories of exercises most frequently provided in vestibular rehabilitation and in the home exercise program included gaze stabilization exercises (eg, VORx1 [in which the individual maintained a fixed gaze position while turning the head from side to side] in sitting and standing positions), standing balance (eg, standing with feet apart and feet together on foam with eyes open and closed), walking with balance challenge (eg, walking with head turns, tandem walking, and obstacle avoidance), and, in a few cases, canalith repositioning maneuvers. Exercises were prescribed to be done daily.

Self-report and performance measures were administered at the initial evaluation and at weekly and monthly intervals. The time points considered for this report include the initial evaluation and discharge scores. If a measure was not recorded at the time of initial evaluation or discharge, the assessment at the time point closest to the time of initial evaluation or discharge was used.

Self-Report Measures

Records related to self-report measures in which patients were asked to verbally rate their current dizziness severity on a scale from 0 to 100 (in which 0 indicates no dizziness and 100 indicates maximum dizziness). Verbal anchors relating to severity of dizziness (eg, slight, mild, moderate, and severe) were provided for the scale. In addition, patients were asked to describe their dizziness using any of the following nonexclusive terms: spinning, lightheadedness, off-balance, nausea, sensation of motion, and others.

The Activities-specific Balance Confidence (ABC) scale is a questionnaire used to assess the respondents' level of confidence that they would not lose their balance while performing 16 functional activities. The highest possible score of 100 suggests maximum confidence and a score of 0 suggests no confidence.[25] The Dizziness Handicap Inventory (DHI) is an instrument used to assess the individual's disability due to their dizziness in 25 items relating to physical, emotional, and functional domains. The highest overall score on the test is 100 and higher scores indicate greater disability resulting from dizziness.[26]

Gait and Balance Performance Measures

Observational Measures of Gait and Balance: The Dynamic Gait Index (DGI) is an 8-item instrument that assesses the ability to walk with head turns, changes of speed, and around obstacles. The score for each item ranges from 0 to 3, where 0 is severe impairment and 3 is normal. The highest possible score is 24.[27] The Functional Gait Assessment (FGA) is a 10-item test based on the DGI. The maximum score is 30, and higher scores indicate better performance.[28] Gait speed was timed with a stopwatch while patients walked at their comfortable speed over a 4-m course. The Timed Up and Go is a timed test during which the patient stands from a chair, walks 3 m at his/her normal walking speed, and returns to the chair.[29] The 5 times sit to stand (FTSTS) test requires patients to stand up and sit down on a chair of standard height 5 times as quickly as possible. The patients were asked to complete the task with their hands crossed on their chest.[30]

Dynamic Computerized Posturography: Patients performed the Sensory Organization Test (SOT, Neurocom, Inc., Clackamas, Oregon) under 6 different sensory conditions: (1) eyes open, fixed support; (2) eyes closed, fixed support; (3) sway-referenced vision, fixed support; (4) eyes open, sway-referenced support; (5) eyes closed, sway-referenced support; and (6) sway-referenced vision and support surface. Three 20-second trials were performed for each condition. The highest theoretical equilibrium score is 100 (indicating no sway), and losses of balance were graded as 0. Average scores for each condition were recorded, and the composite score was calculated using a weighted average of the individual trials.

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Statistical Analysis

The process of care, including time between the concussion and the initial evaluation for vestibular rehabilitation, number of visits, and duration of treatment was summarized by descriptive statistics.

Process of Care

The nonparametric Mann-Whitney *U* test was performed to examine whether there was a significant difference between patients who continued after their initial evaluation and those who did not, for the time between concussion onset and their initial evaluation for vestibular rehabilitation therapy. The Mann-Whitney *U* test was also performed to examine whether there was a significant difference in treatment duration and the number of visits between children and adults who received vestibular rehabilitation therapy.

Outcome Measures

Independent *t* tests were performed to determine whether there was a difference in outcome measures at their initial evaluation between patients who were referred for vestibular rehabilitation therapy but did not continue after their initial evaluation and those who continued their intervention. Independent *t* tests also were performed to determine whether there was a difference in outcome measures between children and adults at the time of the initial evaluation. For the independent *t* test, Levine's test of equality of variance was examined. In those outcome measures that did not have equal variance, the *P* value from the test that did not assume equal variances was used.

For the patients who had at least 2 visits, a mixed-factor repeated-measures analysis of variance was performed on each outcome measure to see whether there was an effect of treatment, age group, and interaction (treatment × age). The within-subjects factor was treatment with 2 levels (before and after treatment). The between-subjects factor was the age group with 2 levels (children and adults). For each outcome measure, only the patients who had data at both time points were included in the repeated-measures analysis of variance, and the sample size is reported for each. For all analyses, the level of significance was $\alpha = 0.05$.

RESULTS

The vestibular rehabilitation was provided by 8 physical therapists; 2 of the therapists treated approximately 44% and 27% of the cases, respectively. The most frequent description of dizziness was a symptom of being off-balance (68% of the patients), followed by lightheadedness (54%), spinning (46%), nausea (38%), and sensation of motion (23%). Off-balance was the most frequent description in both children and adults. Five patients had benign paroxysmal positional vertigo (BPPV). One of the patients with BPPV did not return after his initial visit. Three patients had pure BPPV, and a canalith repositioning maneuver was used as the only intervention. Finally, the fifth patient with BPPV also had other dizziness and balance dysfunction that was treated with a customized program in addition to the canalith repositioning maneuver.

Process of Care

Of the 114 patients, 30 received an initial evaluation without returning for a second visit. Reasons for not returning included the following: physical therapy was not indicated (n = 6), the patient lived far away (n = 8), and noncompliance (n = 16). The 2 groups of patients who came only for their initial evaluation and those who returned for more visits did not differ based on age ($t_{112} = 1.1$, $P = .31$), sex ($\chi^2 = 2.6$, $P = .11$), and duration of time between the concussion and referral to the vestibular rehabilitation clinic (median, 61 days; range, 6–2566 days; Mann-Whitney $U = 717$, $P = .07$; see Table 1).

Eighty-four patients returned for at least 1 additional visit, and the median number of visits was 4 visits (range, 2–13 visits), occurring over a median duration of 33 days (range, 7–181 days). There was no significant difference between children and adults in the number of visits (Mann-Whitney $U = 730$, $P = .323$) or the duration of treatment (Mann-Whitney $U = 723$, $P = .363$).

Outcome Measures at Initial Evaluation

Outcome measures obtained during the initial evaluation for all 114 patients are reported in Table 1. Patients who did not continue after their initial evaluation had significantly better scores on the dizziness severity, ABC, DHI, DGI, FGA, gait speed, and FTSTS ($P < .05$). The FTSTS was the only outcome measure that was significantly different between the children and the adults at the time of the initial evaluation, with children having faster performance (children, 9.7 ± 3.5 seconds; adults, 13.2 ± 5.4 seconds; $t_{49.8} = -3.3$, $P = .002$).

Change in Outcome Measures

For patients who had received vestibular rehabilitation therapy, there was a significant treatment effect for all the self-report and performance measures (Table 2).

The outcome measures in which there was a significant interaction between treatment and age are displayed in Table 3. There was a significant interaction between treatment and age for dizziness severity ($F_{1,62} = 8.6$, $P = .005$). Post hoc analysis revealed that after treatment, children's dizziness severity was reduced by mean of 19 points ($F_{1,40} = 31.0$, $P < .001$). However, there was no significant difference in dizziness severity for the adult group between pre- and post-treatment ($F_{1,22} = 0.06$, $P = .805$; Table 3). There were also significant interactions between treatment and age for conditions 1 and 2 of the SOT ($F_{1,19} = 6.7$, $P = .018$ and $F_{1,19} = 5.9$, $P = .025$, respectively, Table 3). In both conditions, children had significant improvement in their scores ($P < .01$). However, there was no significant improvement for adults.

Only 3 of the measures demonstrated a significant main effect of age (ie, collapsing across time). Children demonstrated significantly lower (better) DHI scores (36 ± 6) compared with adults (46 ± 20) ($F_{1,67} = 5.8$, $P = .019$). Children showed significantly higher scores on the FGA (25 ± 2) compared with adults (23 ± 3) ($F_{1,46} = 5.0$, $P = .030$). Children also had lower FTSTS (9.5 ± 2.6 s) compared with adults (13.8 ± 5.8 s) ($F_{1,34} = 8.7$, $P = .006$).

TABLE 1. Mean (SD) of Demographic and Outcome Measures at Initial Evaluation for Vestibular Rehabilitation According to Those Subjects Who had Evaluation Only and Those Who Returned for at Least 1 Additional Visit

Outcome Measure	Evaluation Only (n = 30)	Treatment (n = 84)	Statistic, *P* Value[a]
Sex	15 F, 15 M	56 F, 28 M	$\chi^2 = 2.6$, .106
Age (y)	28 (16)	25 (15)	$t_{112} = 1.1$, .314
Median (range) time from concussion to evaluation, d	96 (8–2566)	58 (6–1149)	$U = 717$, .07
Dizziness severity (63 children, 46 adults)	11 (20)	23 (21)	$t_{52.1} = -2.8$, .008[b]
ABC Scale (65 children, 46 adults)	78 (25)	65 (28)	$t_{109} = 2.2$, .028[b]
DHI (66 children, 46 adults)	37 (19)	48 (22)	$t_{110} = -2.5$, .014[b]
DGI (60 children, 36 adults)	22 (3)	21 (3)	$t_{94} = 2.3$, .027[b]
FGA (60 children, 36 adults)	27 (5)	24 (5)	$t_{94} = 2.5$, .013[b]
Gait speed (61 children, 38 adults)	1.21 (0.23)	1.07 (0.26)	$t_{97} = 2.2$, .033[b]
TUG (s) (51 children, 32 adults)	7.9 (1.5)	9.0 (2.3)	$t_{81} = -1.8$, .070
FTSTS (s) (50 children, 33 adults)	7.9 (2)	11.7 (5)	$t_{47.4} = -4.8$, <.001[b]
SOT (composite) (38 children, 21 adults)	70 (12)	55 (20)	$t_{57} = 1.7$, .083
SOT condition 1 (38 children, 20 adults)	83 (16)	88 (11)	$t_{5.5} = -1.1$, .482
SOT condition 2 (38 children, 20 adults)	85 (12)	80 (15)	$t_{56} = 0.71$, .478
SOT condition 3 (38 children, 20 adults)	86 (9)	75 (22)	$t_{56} = 1.2$, .251
SOT condition 4 (38 children, 20 adults)	74 (9)	53 (26)	$t_{18} = 4.1$, <.001[b]
SOT condition 5 (38 children, 20 adults)	52 (15)	37 (25)	$t_{8.7} = 2.2$, .057
SOT condition 6 (38 children, 20 adults)	59 (18)	41 (24)	$t_{56} = 1.8$, .074

Note that not all subjects had measures assessed at the initial evaluation.
[a] *t* is the independent sample *t* test, *U* is the Mann-Whitney *U* test.
[b] $P < .05$.
Abbreviations: SD, standard deviation; M, male; F, female; ABC, Activities-specific Balance Confidence Scale; DHI, Dizziness Handicap Inventory; DGI, Dynamic Gait Index; FGA, Functional Gait Assessment; TUG, Timed Up and Go; FTSTS, five times sit to stand; SOT, Sensory Organization Test.

TABLE 2. Mean (SD) of Outcome Measures at Times of Initial Evaluation and Discharge

Outcome Measure	Pretreatment	Posttreatment	*F* Test, *P* Value
Dizziness severity (41 children, 23 adults)	21 (22)	12 (18)	$F_{1,62} = 11.4$, <.001[a]
ABC Scale (41 children, 27 adults)	64 (27)	84 (17)	$F_{1,66} = 31.5$, <.001[a]
DHI (42 children, 27 adults)	49 (21)	30 (22)	$F_{1,67} = 45.5$, <.001[a]
DGI (30 children, 18 adults)	20 (3)	23 (1)	$F_{1,46} = 42.6$, <.001[a]
FGA (30 children, 18 adults)	22 (5)	28 (3)	$F_{1,46} = 62.9$, <.001[a]
Gait speed (29 children, 17 adults)	1.02 (0.28)	1.28 (0.23)	$F_{1,44} = 38.3$, <.001[a]
TUG (22 children, 16 adults)	9.7 (2.5)	7.8 (1.8)	$F_{1,36} = 27.8$, <.001[a]
FTSTS (20 children, 16 adults)	13.1 (6)	9.7 (5)	$F_{1,34} = 15.9$, <.001[a]
SOT (composite) (13 children, 9 adults)	48 (19)	71 (13)	$F_{1,20} = 36.8$, <.001[a]
SOT condition 1 (13 children, 8 adults)	83 (13)	92 (4)	$F_{1,19} = 7.2$, .015[a]
SOT condition 2 (13 children, 8 adults)	76 (18)	86 (9)	$F_{1,19} = 5.3$, .033[a]
SOT condition 3 (13 children, 8 adults)	71 (21)	87 (9)	$F_{1,19} = 7.8$, .012[a]
SOT condition 4 (13 children, 8 adults)	46 (28)	80 (9)	$F_{1,19} = 27.2$, <.001[a]
SOT condition 5 (13 children, 8 adults)	29 (24)	51 (15)	$F_{1,19} = 21.6$, <.001[a]
SOT condition 6 (13 children, 8 adults)	29 (21)	60 (15)	$F_{1,19} = 32.0$, <.001[a]

[a] $P < .05$.
Abbreviations: SD, standard deviation; ABC Scale, Activities-specific Balance Confidence Scale; DHI, Dizziness Handicap Inventory; DGI, Dynamic Gait Index; FGA, Functional Gait Assessment; TUG, Timed Up and Go; FTSTS, five times sit to stand; SOT, Sensory Organization Test.

DISCUSSION

The primary finding of this study is that people who had persistent dizziness and gait and balance dysfunction after having a concussion seem to have improved after vestibular rehabilitation. Although many postconcussive symptoms, including dizziness and imbalance, may resolve within the first few weeks after the concussion,[18,31] it is less likely that the patients in our sample fell in this category. Only 8 of 114 (7%) of the patients in our sample had an initial evaluation within 3 weeks of the concussion, and the median number of 61 days (range, 6–2566 days) between the most recent concussion and their referral to vestibular rehabilitation suggests that the symptoms did not resolve spontaneously and consequently required intervention. Five patients in our sample had BPPV. Although BPPV has been shown to be common after concussion, this did not seem to be the case in

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TABLE 3. Mean (SD) for the Significant Interaction Effect ($P < .05$) Between Age Group and Treatment on Dizziness Severity and SOT Scores

	Children		Adults	
Outcome Measure	**Pretreatment**	**Posttreatment**	**Pretreatment**	**Posttreatment**
Dizziness severity(41 children, 23 adults)	26 (22)	7 (11)	21 (20)	20 (25)
SOT condition 1(13 children, 8 adults)	79 (14)	92 (3)	91 (3)	91 (6)
SOT condition 2(13 children, 8 adults)	72 (21)	89 (5)	83 (11)	83 (13)

Abbreviations: SD, standard deviation; SOT, Sensory Organization Test.

our study sample and this may be attributable to the extended length of time between the concussion and initial evaluation for vestibular rehabilitation in this sample.

The intervention spanned a median of 4 visits and 33 days. The number of visits is comparable to other open-ended trials of vestibular rehabilitation for both peripheral and central causes of dizziness reported from the same clinic.[32–34] However, the duration of care in this report was shorter than in other studies. It is not clear whether the shorter duration of care truly represented faster recovery rates or rather a change in frequency of treatment visits that enabled the therapists to progress the exercise program more quickly. However, this improvement in outcomes in the same number of visits over a shorter time period may indicate that individuals referred for vestibular rehabilitation after concussion may benefit from more frequency of visits at the beginning of care.

The recovery observed in our sample occurred across multiple domains, ie, self-reports of dizziness severity, dizziness handicap (DHI), balance confidence (ABC scale), and functional balance performance. The magnitude of improvement compares well with other types of vestibular disorders.[32–36] Furthermore, the average magnitude of change was greater than the minimal clinically important difference established for the DHI[26] (18 points), gait speed[37] (0.1 m/s), and SOT composite score[38] (10 points). Although statistically derived minimal clinically important differences (MCIDs) have not been established for the other outcome measures, in our clinical experience, mean improvements of 20 for the ABC scale, 3 for the DGI, and 6 for the FGA, suggest clinically significant changes. Without a control group, it is not possible to know the relative contributions of the vestibular rehabilitation program, concurrent medical management, and natural recovery toward the improved outcomes. Furthermore, we were not able to determine how impaired the patients were immediately after concussion and therefore are unable to know how much improvement in outcomes may have already occurred before vestibular rehabilitation therapy. However, our findings are consistent with previous studies that have shown that vestibular rehabilitation may help to reduce dizziness and improve overall balance for individuals with concussion.[14–17]

The scores of dizziness severity and DHI at initial evaluation were similar to those of several other reports of persons with vestibular disorders, including central and peripheral dysfunction.[32–34] However, our subject sample had qualitatively better scores on several of the functional gait and balance measures, including the DGI, TUG, FTSTS, and self-reported ABC scale. It is possible that the better gait and balance scores in this study reflect the younger age distribution of this group. An age difference was found for several of the gait and balance measures, including FTSTS and FGA, so this explanation is plausible but not definitive because normative data for these measures in children are not available. In contrast, across all conditions, the SOT scores obtained by children during the initial evaluation (data not shown) were worse than the scores obtained by adults with vestibular disorders[39,40] and healthy children,[23,41] providing additional evidence of dysfunctional sensory integration with concussion in children.[12,42]

To assess whether age affected the amount of improvement, the interaction between treatment and age was examined. Only 3 of the measures demonstrated significant interactions: dizziness rating and conditions 1 and 2 of the SOT. The significant interaction for the dizziness severity revealed that children had a greater improvement in symptom severity despite having slightly worse ratings at the initial evaluation. Closer inspection of the dizziness severity data for the adult group showed that despite the improvement of dizziness in many patients, the large variability in the posttreatment scores may have contributed to the overall lack of treatment effect on dizziness for the adults.

The significant interaction effect in SOT conditions 1 and 2 indicates greater improvement in scores in children compared with adults. The adults had a narrow range of scores that were within normal limits for SOT condition 1, whereas the distribution of the scores for SOT condition 1 were more dispersed in children, which provided greater ability to measure recovery. In SOT condition 2, children again had greater room for improvement because of lower initial scores, but it is also surprising that the adults' scores did not increase to normal values. Overall, the results of posturography analyses should be interpreted cautiously because they were limited by the low number of patients (13 children/8 adults). However, the lack of interaction between treatment and age in the DGI, FGA, gait speed, FTSTS, and SOT suggests that these gait and balance measures could be used to track recovery after vestibular rehabilitation in both adults and children. It would be of great interest for future studies to investigate the responsiveness of gait and balance measures in individuals after concussion.

Another aim of the study was to examine whether age affected the overall level of symptoms and the amount of recovery. There were age-related differences in DHI, FGA, and FTSTS scores. The significantly lower scores on the DHI in children compared with adults may support the notion that the perception of a dizziness handicap is different between children and adults.[8,21] However, at the time of initial evaluation, the dizziness severity was not different between the 2 groups. This apparent contradiction may be explained by items in the DHI that are not applicable to children (eg, "Does your problem interfere with your job or household responsibilities?") and by lack of items that relate dizziness to the functional difficulties that the children are experiencing.[8] Although the DHI has not been validated for use with children, we used it because there were no other alternatives that assess the impact of dizziness on the functional activities of children, and we believed that most of the items would respond to changes that occurred during vestibular rehabilitation. The lower mean FTSTS scores in children (by 4 seconds) are probably not related to any concussion-related factors but rather explained by greater physical fitness and agility. In addition, significantly higher FGA scores in children (by 2 points) may reflect abilities that are not related to the concussion severity. Normative data has not been established for children. Furthermore, a difference of 2 points between groups may not be clinically meaningful.

Limitations and Future Directions

Although we believe that this study added to our understanding of the potential benefits of vestibular rehabilitation after concussion, the results of this study were limited by the retrospective nature of the data and the lack of control group. Without a control group, it is difficult to rule out the effect of time on the reported measures. First, we were not able to report the immediate markers of concussion severity, such as loss of consciousness, amnesia, and confusion, and we were not able to investigate whether the presence of these markers could predict poorer outcomes. Second, although a postconcussion symptom checklist is recommended as an essential tool in concussion management,[43–47] it was not implemented as a part of vestibular assessment. Third, because there was no complete vestibular function test battery, we were not able to classify our patients into 1 of the dizziness groups previously described by Hoffer et al.[14]

We endorse a multidisciplinary approach in which physicians, neuropsychologists, physical therapists, and athletic trainers work together to comprehensively manage concussion. Knowing that there are modifiers for concussion management,[48] we recommend having a profile for the patient with concussion in which all the tests for the different domains (symptoms, neurocognitive, and balance) at all evaluation points (baseline, immediately after concussion, and throughout recovery) are documented in a systematic manner and kept accessible to any member of the team. Inclusion of these items into standard vestibular rehabilitation evaluation of individuals after concussion should be implemented.

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