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14. ABSTRACT
Objective: Dizziness and imbalance are common symptoms following head injury that can continue for months or years in some individuals. Multiple causes of post-concussive dizziness can present a challenge to diagnosis, and obstacle to treatment. The Departments of Veterans Affairs and Defense (VA/DoD) developed clinical practice guidelines that outline recommendations for managing individuals with post-concussive dizziness, but it is unclear how these recommendations impact treatment for post-concussion dizziness/imbalance. The purpose of this study is to determine factors that contribute to successful outcomes of patients with concussion/blast-related dizziness. *Methodology:* We used VA and DoD health databases to identify and examine characteristics of Veterans with specific (for example, inner ear balance dysfunction) and non-specific diagnoses of post-concussion dizziness. Then, we surveyed Veterans using questionnaires and access the VA electronic medical records to determine factors that impact long-term recovery of post-concussion dizziness. Specifically, we examined the impact of factors such as type of treatment, the presence or absence of health conditions such as headache and anxiety, the severity of head injury, as well as age and gender. *Findings:* This study revealed that access to specialty care was the best predictor of receipt of a dizziness and/or vestibular dysfunction diagnosis among those who report disruptive dizziness on the Comprehensive Traumatic Brain Injury Evaluation (CTBIE). Further, Black non-Hispanic veterans and those with substance use disorder diagnoses or treatment are significantly less likely to receive these diagnoses, potentially illuminating disparities or barriers in access to or utilization of specialty care for veterans with disruptive dizziness. We sent surveys to 4250 Veterans and received 1062 completed surveys (25% response rate), and chart abstraction were performed on the 1062 Veterans who completed the survey. Our findings revealed that post-concussive dizziness occurs in some individuals even a decade or more after the injury. Several factors present at or around the time of the initial clinical evaluation were associated with persistent dizziness, and these include increased age, high school education level, identification as a Black non-Hispanic veteran, TBI status, diagnoses of post-traumatic stress disorder or hearing loss, abnormal vestibular function, and severe self-reported dizziness at the initial evaluation. *Impact/Significance:* Our findings support the need to decrease disparities or barriers in access to or utilization of specialty care for veterans with disruptive dizziness. The use of telemedicine, patient education, provider cultural competency in health disparities, and the refinement of evidenced-based clinical pathways in the treatment of disruptive dizziness are possible mechanisms for improving long-term outcomes following deployment-related TBI among post-9/11 veterans. Further, these findings support the use of an interdisciplinary polytrauma team model to facilitate communication across providers and manage risk factors that may impact recovery from post-concussive dizziness.

15. SUBJECT TERMS
Vertigo, Dizziness, Vestibular, TBI, Patient Outcomes, Neurobehavioral Symptom Inventory

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1. INTRODUCTION:

Chronic dizziness or imbalance is a common symptom following head injury that can negatively impact quality of life. Injured Veterans of the recent wars typically enter the Veterans Health Administration (VHA) through the Polytrauma clinics and undergo the Comprehensive Traumatic Brain Injury Evaluation (CTBIE) which includes the Neurobehavioral Symptom Inventory (NSI). Although there are several clinical practice guidelines for post-concussive symptoms, there are no data on the effectiveness of clinical management pathways for reducing symptoms of dizziness. We examined long-term outcomes of post-concussive dizziness in Veterans with traumatic brain injury (TBI) to determine factors and clinical management strategies associated with successful outcomes. We used a chart review and Veteran survey (see Appendix A) to examine clinical referral patterns, diagnostic testing, and types of VA and non-VA care used to treat Veterans with post-concussive dizziness. This research effort is part of a long-term goal to establish a unique treatment platform to diagnose, localize, and treat dizziness and imbalance related to mild TBI.

2. KEYWORDS:

Vertigo, Dizziness, Vestibular, Traumatic Brain Injury, Patient Outcomes, Neurobehavioral Symptom Inventory

3. ACCOMPLISHMENTS:

What were the major goals of the project?

Major Task 1: Complete Regulatory Requirements for Study	**Timeline (Months)**	**Percentage Completed**
Prepare Regulatory Documents and Research Protocol		
Finalize consent, human subjects protocol chart abstraction tool / Survey	1	100%
Coordinate with Sites for MOU/ DTA completion, nondisclosure agreements	1-5	100%
Secondary site IRB protocol submission (expedited)	1-4	100%
Submit amendments, adverse events and protocol deviations as needed	1-36	N/A
Coordinate with Sites for annual IRB report for continuing review	Annually	N/A
Milestone Achieved: Local IRB and HRPO approval at Mountain Home Research and Education Corporation (MHREC) and Western Institute for Biomedical Research, Salt Lake City (WIBR)	3-6	100%
Major Task 2: Identify cohort who meet criteria for high NSI vestibular symptomology	**Timeline (Months)**	**Percentage Completed**

Subtask 1: Obtain VA data for Post-9/11 Veterans		
Complete data request documentation for VA and DoD data sources	4-6	100%
Obtain VA and DOD data, calculate NSI severity, identify comorbidities, including TBI and TBI characteristics, and other clinical characteristics	6-7	100%
Milestone Achieved: Raw Data obtained	7	100%
Subtask 2: Identify vestibular and non-specific dizziness diagnoses in FY02-FY15 cohort		
Compile data from VA and DoD data sources and identify vestibular and non-specific dizziness diagnoses	7	100%
Milestone Achieved: Cohort of Veterans with Dizziness identified	7-8	100%
Conduct/interpretation of logistic regression analyses on Post-9/11 VA cohort and complete manuscripts	8-12	100%
Milestone Achieved: Aim 1 completed	12	100%
Major Task 3: Conduct survey of Veteran with high vestibular symptomology	**Timeline (Months)**	**Percentage Completed**
Obtain survey supplies, develop REDCap and paper survey administration forms, and develop logistics for survey process. (*WIBR*)	1-7	100%
Identify sample with high vestibular symptomology (NSI vestibular scale score of ≥ 3) AND who received care in a vestibular relevant clinic AND who received a diagnosis vestibular-specific or non-specific dizziness. (*WIBR*)	7-8	100%
Verify contact information and prepare survey mailings for administration. (*WIBR*)	7-26	100%
Conduct survey administration via online, mail (and telephone if preferred by respondents) modalities. (*WIBR*)	7-26	100%
Treatment responders will be identified: improvement in an individual's vestibular symptom score of ≥ 2 points or 20% improvement in the NSI vestibular subscale score. (*WIBR*)	7-27	100%
Milestone Achieved: Study sample frame for Aim 2 identified and characterized; Survey data for Aim 2 collected	27	100%
Major Task 4: Identify Sample for Aim 2 and conduct chart abstraction	**Timeline (Months)**	**Percentage Completed**
Develop and finalize chart abstraction data elements. *(MHREC)*	1-6	100%
Develop chart abstraction form in REDCap. *(MHREC)*	7-8	100%
Conduct preliminary training for chart abstraction on test cases identified from administrative data with high vestibular symptomology (NSI vestibular scale score of ≥ 3) AND who received care in a vestibular relevant clinic AND who received a diagnosis vestibular-specific or non-specific dizziness. *(MHREC)*	8-10	100%

Perform chart abstraction from electronic medical record via VISTA web system to describe type of care received and sample characteristics, including TBI, comorbidities, demographics. *(MHREC)*	11-30	100%
Milestone Achieved: Study sample frame for Aim 2 identified and characterized	30	100%
Major Task 5: Conduct analyses comparing Veterans with and without vestibular specific diagnoses who Responded vs. Non-responders	**Timeline (Months)**	**Percentage Completed**
Conduct interim and final analyses/ interpretation for Aim 2. *(WIBR + MHREC)*	30-34	100%
Complete manuscripts for publication. *(WIBR + MHREC)*	30-36	100%
Milestone Achieved: Report findings comparing Veterans who Responded vs. Non-responders (Aim 2)	36	100%

What was accomplished under these goals?

Aim 1: Identify the proportion of Veterans evaluated in the CTBIE who report high vestibular symptomology on the NSI, the extent to which individuals with high NSI vestibular scores have a vestibular specific diagnosis based on ICD-9 codes, and the relationship between vestibular symptomology, vestibular specific diagnosis codes and TBI characteristics.

Using VHA data, we identified an initial cohort of 26,814 post-9/11 veterans who were included in the roster of individuals deployed to post-9/11 conflicts (VA Office of Public Health) and who also had high Vestibular symptoms using the following criteria: (1) completion of a CTBIE, (2) high NSI vestibular symptomology (NSI Vestibular subscale [NSI-V] score ≥6), (3) at least three years of VA care between fiscal years 2002 and 2016, and (4) two or more years of care after 2006. Within this sample, we reviewed International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9) diagnostic codes from VHA inpatient and outpatient data (FY02-2015) for vestibular and dizziness diagnoses, and we identified three subgroups with high NSI-V scores: veterans with (1) no vestibular or dizziness diagnosis, (2) general dizziness diagnosis, and (3) vestibular diagnosis. Inclusion criteria for vestibular or dizziness ICD-9 code grouping included at least one inpatient or two outpatient ICD-9 codes within a 7-day period (see Figure 1 in Appendix B: Swan et al., 2022, *J Head Trauma Rehabil*).

Results**:** We found that patients with high vestibular symptomology are a potentially undiagnosed but profoundly afflicted subpopulation. Approximately 85% who reported moderate or more severe disruption due to persistent vestibular symptoms on the NSI at the initial CTBIE had no vestibular or dizziness diagnosis. Using logistic regression, we evaluated socio-demographics, injury history, common post-concussive conditions, health service variables, and clinical perspectives to determine factors associated with the diagnosis status for Veterans who reported high vestibular symptomology on the CTBIE (see Table 3 in Appendix B: Swan et al., 2022, *J Head Trauma Rehabil*). Increased access to or utilization of specialty clinical care at the VA were significant predictors of dizziness and/or vestibular dysfunction diagnoses in the fully adjusted

model. Veterans that identified as Black non-Hispanic and those with substance use disorder diagnoses or care were substantially less likely to receive dizziness and vestibular dysfunction diagnoses (see Appendix B: Swan et al., 2022, *J Head Trauma Rehabil*).

Aim 2: Among Veterans with vestibular specific and non-specific dizziness diagnoses, identify those who experienced a clinically significant reduction of dizziness symptoms ("improvers" and "non-improvers") and factors associated with amelioration of symptoms.

We conducted an observational cohort study to examine the factors associated with long-term outcomes of post-concussive disruptive dizziness in veterans of the post-9/11 wars (see Appendix C: Akin et al., in press, *Am J Audiol*). The NSI-V score was used an outcome measure for dizziness in 987 post-9/11 veterans who indicated disruptive dizziness at an initial VHA CTBIE.

The NSI is a 22-item scale that is used routinely by the VHA to measure post-concussive symptoms at the CTBIE (Cicerone, 1995; Meterko et al., 2012; see Appendix A). The first three items of the NSI comprise the vestibular subscale (NSI-V) and were used as a measure for disruptive dizziness. Specific components of the NSI-V are (1) feeling dizzy, (2) loss of balance, and (3) poor coordination. Using a 5-point Likert scale, Veterans rated each item in terms of how much the symptom disrupted activities in the last two weeks, with 0 indicating no disruption (rarely if ever present; not a problem at all) and 4 indicating very severe disruption (almost always present and unable to perform at work, school or home due to this problem; probably cannot function without help). The total NSI-V score can range from 0 to 12. For this study, we defined disruptive dizziness as an NSI-V score ≥6, consistent with moderate or more severe disruption.

We used two NSI scores for each participant: the first obtained during the CTBIE (between fiscal years 2007 and 2016) and the second obtained via the survey (April 2019 through January 2021). To examine long-term outcomes of post-concussive dizziness, we calculated an NSI-V change score by subtracting the NSI-V score obtained at the CTBIE from the NSI-V score obtained through the survey. Negative scores indicated improvement over time, and positive scores indicated worsening symptoms over time.

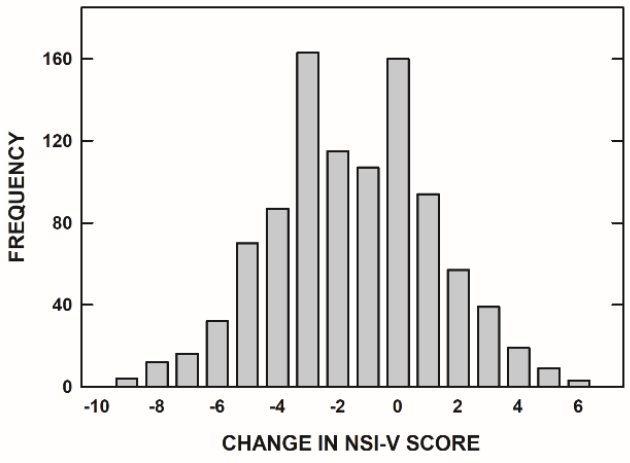

Figure 1. Histogram showing the frequency distribution for the change in the NSI-V score for the 987 post-9/11 Veterans with disruptive dizziness (NSI-V ≥6) at the CTBIE. The change in the NSI-V score was calculated as the difference in the NSI-V scores obtained at the CTBIE and the survey (Appendix C: Akin et al., in press, *Am J Audiol*).

Results: The majority of Veterans (61%) demonstrated a decrease in the NSI-V score suggesting less dizziness on the survey compared to the CTBIE, 16% showed no change, and 22% had a higher (worse) score.

Differences in the NSI-V change scores were examined for demographics, injury characteristics, comorbidities, and vestibular and balance function variables, and multiple linear regression analyses were used to explore associations among the variables and the NSI-V change score. Significant differences in the NSI-V change score were observed for TBI status, diagnoses of post-traumatic stress disorder (PTSD), headache and insomnia, and vestibular function (see Table 1 in Appendix C: Akin et al., in press, *Am J Audiol)*. Multivariate regressions revealed significant associations between the NSI-V change score and the initial CTBIE NSI-V score, education level, race/ethnicity, TBI status, diagnoses of PTSD and hearing loss, and vestibular function (see Table 2 in Appendix C: Akin et al., in press, *Am J Audiol)*.

Overall, these findings suggest that post-concussive dizziness can continue for years following an injury. In summary, factors associated with poor prognosis included TBI, diagnoses of PTSD or hearing loss, abnormal vestibular function, increased age, identification as a Black veteran, and a high school education level.

Hypothesis 2.1: Veterans who received treatment for dizziness in accord with the VA/DoD Clinical Practice Guideline for the Management of Concussion-mild TBI (February 2016), will be more likely to have significant reduction of symptoms.

To address specific Aim 2 hypotheses, additional analyses were performed.

Survey Administration. A total of 4250 Veterans evenly distributed among the three diagnostic groups (no vestibular or dizziness diagnosis, general dizziness diagnosis, vestibular diagnosis) were selected to receive an invitation to participate in the survey. The survey included multiple validated instruments and a treatment measure developed by the team to collect data on treatment types used by Veterans (see Appendix A). The survey was organized to reduce cognitive burden and psychological triggers that might occur from answering sensitive questions related to experiences during deployment or current psychological distress. All 4,250 Veterans in the sample were mailed invitation packets in a rolling basis over beginning in April 2019 through January 2021, using a modified Dillman approach, and a post-it survey method that has been shown to increase questionnaire response rates especially among Veterans with disabilities. Follow-up invitations were mailed to non-completers until a minimum number of surveys were received for each of the three groups (~350 each group, minimum 1050 completed surveys) to achieve an analytic power of 80% at $p<0.05$.

For the subsequent analyses, Veterans were categorized as “improvers” or “non-improvers” using the NSI-V scores obtained via initial CTBIE data from VHA and survey data. The total NSI-V score can range from 0 to 12. To examine whether a Veteran was an “improver” or not, we scored the difference between NSI-V scores recorded in VHA data from the initial CTBIE (between fiscal years 2007 and 2016) and the NSI-V reported in the survey (April 2019 through January 2021). Although no clinically important difference indices have been developed for the

NSI, various studies have attempted to determine reliable change indices – ranging from 15% to 50% depending on the score of interest and study focus. For our study, Veterans whose scores decreased by more than 20% were classified as "improvers" and those with less than or equal to 20% decrease or increased scores were classified as "non-improvers". We also calculated the numbers of years between the time of CTBIE and survey. We excluded 20 participants who skipped at least one of the NSI vestibular sub-score questions.

The research team developed treatment questions that were included in the survey to collect data on types of treatments used by Veterans to help improve their dizziness (Q9 in Appendix A). The questions listed 12 types of treatments and asked if Veterans had received the treatment, where treatment was received (type of facility), and whether the treatment resolved the dizziness or balance problem. For this analysis, we created a binary variable to account for a Veteran indicating they had any type of treatment, regardless of location, versus those who did not list any treatment. From the cohort of 1062 survey completers, we excluded 20 participants who were missing at least one NSI score needed to calculate the NSI-V, 32 who did not complete the Ohio State University Traumatic Brain Injury Identification Method (OSU TBI-ID), 33 missing treatment status, 26 missing the initial Dizziness Handicap Inventory (DHI) question asking if they are currently experiencing dizziness, and 4 missing education status in the survey. Finally, 15 participants were excluded as race was "unknown" in VHA data. The final sample included 932 participants.

Contrary to our hypothesis, our results showed that Veteran non-improvers were more likely to indicate they participated in treatment of any kind. Four treatment types included in the VA/DoD Clinical Practice Guideline for the Management of Concussion-mild TBI were assessed, along with a variety of other types of treatments that might have been sought. More non-improvers than improvers participated in balance training, counseling or mental health services, medication, and vestibular rehabilitation ($p<0.01$), and although vestibular rehabilitation is a recommended practice for Veterans with vestibular conditions, it was less frequently reported than other types of treatment (Table 1). Because of the observational nature of these data, we cannot say that those who received guideline concordant treatment had subsequent worse outcomes. Rather, it is likely that this finding indicates confounding by indication where those with the worst symptoms receive more guideline concordant therapy.

Table 1. Treatments reported by non-improvers versus improvers.

		Non-improver		Improver			
N = 932		n	%	n	%	Chi-square	*P*-value
Receiving treatment at all (any type)						5.06	0.02
	Yes	383	52.83	342	47.17		
	No	91	43.96	116	56.04		
VA/DoD Recommended Treatments							
Balance training						6.41	0.011
	Yes	179	56.65	137	43.35		
	No	295	47.89	321	52.11		

Counseling or other mental health service						11.85	0.001
	Yes	282	56.06	221	43.94		
	No	192	44.76	237	55.24		
Medication						6.45	0.011
	Yes	264	54.89	217	45.11		
	No	210	46.56	241	53.44		
Vestibular rehabilitation						6.23	0.01
	Yes	76	61.29	48	38.71		
	No	398	49.26	410	50.74		
Other treatment types							
Acupuncture						0.0023	0.96
	Yes	129	50.99	124	49.01		
	No	345	50.81	334	49.19		
Chiropractic procedures						0.016	0.9
	Yes	155	51.16	148	48.84		
	No	319	50.72	310	49.28		
Meditation or other relaxation						3.95	0.047
	Yes	173	55.45	139	44.55		
	No	301	48.55	319	51.45		
Surgery						0.83	0.36
	Yes	52	55.32	42	44.68		
	No	422	50.36	416	49.64		
Tai Chi						0.96	0.33
	Yes	47	55.95	37	44.05		
	No	427	50.35	421	49.65		
Yoga						0.5	0.48
	Yes	87	53.37	76	46.63		
	No	387	50.33	382	49.67		
Diet						6.83	0.009
	Yes	124	58.77	87	41.23		
	No	350	48.54	371	51.46		
Nutritional Supplement						1.24	0.27
	Yes	82	55.03	67	44.97		
	No	392	50.06	391	49.94		
Other						0.37	0.54
	Yes	47	47.96	51	52.04		
	No	427	51.2	407	48.8		

Hypothesis 2.2: Improvers will report a lower impact of dizziness on functional, emotional, and physical domains, and higher quality of life compared to non-improvers.

To test this hypothesis, we used survey data collected through multiple validated instruments including the DHI; Veterans-Rand 12 (VR-12) from which we calculated the Mental Health and Physical Health Subscores (MCS12 and PCS12); the Center for Epidemiologic Studies Depression (CESD) scale; the PTSD Checklist for Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (*DSM-5*) assessment scale (PCL5); the Migraine Disability Assessment test (MIDAS); and the Generalized Anxiety Disorder (GAD-7) assessment. Veterans who did not complete any of these items were excluded from analyses, resulting in a sample of 721 Veterans.

First, we calculated the DHI subscales to understand the impact of dizziness on functional, emotional, and physical domains and calculated VR-12 subscales to ascertain differences in quality of life for the improvers and non-improvers. We conducted t-tests between non-improvers versus improvers for each of the subscores (Table 2). Consistent with our hypothesis, non-improvers reported higher impact of dizziness (DHI; $p<0.00$) and improvers reported better scores. Improvers reported a significantly higher quality of life as measured by overall mental health (MCS12) and physical health (PCS12) scores ($p<0.00$).

Table 2. T-tests for dizziness and general physical and mental health quality of life measures for improvers versus non-improvers.

	Non improver		Improver			
N = 721	n	Mean	n	Mean	T-test	P-value
DHI physical	372	19.91	349	14.69	12.65	<0.001
DHI emotional	372	24.95	349	16.53	12.8	<0.001
DHI functional	372	26.06	349	17.38	13.82	<0.001
DHI total	372	70.92	349	48.6	14.66	<0.001
MCS12	372	28.91	349	35.66	-7.74	<0.001
PCS12	372	31.09	349	36.37	-7.49	<0.001

Hypothesis 2.3: Veterans with diagnoses of PTSD, anxiety, depression, or headache will experience poorer outcomes than Veterans without these comorbidities.

Using self-report for depression, PTSD symptoms, headache, and anxiety collected in the survey, we compared results between improvers and non-improvers (Table 3). More non-improvers reported depression, PTSD, severe headache, and moderate to severe anxiety than improvers ($p<0.001$).

Table 3. Improver status by self-reported conditions (depression, PTSD, headache, anxiety).

	Non-improver		Improver			
N = 721	n	%	n	%	Chi-square	P-value
CESD Depression					49.76	<0.001
Yes	355	56.71	271	43.29		
No	17	17.89	78	82.11		
PCL5 PTSD					24.97	<0.001
Yes	344	55.31	278	44.69		
No	28	28.28	71	71.72		
MIDAS headache					38.83	<0.001
little/no	25	27.17	67	72.83		
mild	10	34.48	19	65.52		
moderate	24	38.71	38	61.29		
severe	313	58.18	225	41.82		
GAD7 Anxiety					73.41	<0.001
little/no	7	11.29	55	88.71		
mild	62	40.26	92	59.74		
moderate	116	51.79	108	48.21		
severe	187	66.55	94	33.45		

We performed a series of analyses to distinguish self-report data from ICD-9 diagnoses available through the VHA and to compare self-report data for those with diagnoses of PTSD, headache, anxiety, and depression. Table 4 provides the counts of listed diagnoses for each of the mental health factors of interest.

Table 4. Frequency of ICD-9 diagnoses (VHA data) for 721 surveyed Veterans.

	Not diagnosed		Diagnosed	
N=721	n	%	n	%
PTSD	83	11.51	638	88.49
Headache	181	25.1	540	74.9
Anxiety	351	48.68	370	51.32
Depression	153	21.22	568	78.78

For each of the diagnostic criteria listed in Table 4, we then examined each of the self-report outcomes of interest from the survey (DHI subscales for impact of dizziness, VR12 subscales for quality of life), and each self-report item for PTSD, depression, anxiety, and headache. Survey outcomes were compared for Veterans with and without comorbidity diagnoses.

PTSD: Veterans diagnosed with PTSD reported higher impacts of dizziness on physical (p<0.05), emotional (p<0.001), and functional (p<0.001) domains; lower mental health quality of life (p<0.001) and lower physical quality of life (non-significant; Table 5). All Veterans with PTSD had self-report measures for depression, anxiety, headache, and PTSD that were significantly worse than Veterans with no PTSD diagnosis (p<0.001; Table 6).

Table 5. T-tests for dizziness and general physical and mental health quality of life measures for Veterans with and without a PTSD diagnosis.

	No PTSD		PTSD			
N = 721	n	Mean	n	Mean	T-test	P-value
DHI physical	83	16.17	638	17.54	-1.92	0.055
DHI emotional	83	16.82	638	21.4	-4.06	<0.001
DHI functional	83	18.82	638	22.26	-3.13	0.002
DHI total	83	51.81	638	61.19	-3.48	<0.001
MCS12	83	40.24	638	31.13	6.6	<0.001
PCS12	83	35.59	638	33.4	1.92	0.056

Table 6. PTSD diagnosis status by self-reported conditions (depression, PTSD, headache, anxiety).

	No PTSD		PTSD			
N = 721	n	%	n	%	Chi-square	P-value
CESD Depression					38.83	<0.001
Yes	54	8.63	572	91.37		
No	29	30.53	66	69.47		
PCL5 PTSD					39.78	<0.001
Yes	53	8.52	569	91.48		
No	30	30.3	69	69.7		
MIDAS headache					12.13	<0.001
little/no	19	20.65	73	79.35		
mild	6	20.69	23	79.31		
moderate	7	11.29	55	88.71		
severe	51	9.48	487	90.52		
GAD7 Anxiety					25.63	<0.001
little/no	17	27.42	45	72.58		
mild	25	16.23	129	83.77		
moderate	22	9.82	202	90.18		
severe	19	6.76	262	93.24		

Headache: Veterans diagnosed with headache reported higher impacts of dizziness on physical (p<0.02), emotional (p<0.001), and functional (p<0.01) domains; lower mental health quality of life (p<0.001) and lower physical quality of life (though not significant; Table 7). All Veterans diagnosed with headache had self-report measures for depression (p<0.001), PTSD (p<0.04), headache(p<0.00), and anxiety (p<0.05) that were significantly worse than Veterans with no headache diagnoses (Table 8).

Table 7. T-tests for dizziness and general physical and mental health quality of life measures for Veterans with and without a headache diagnosis.

	No headache		Headache			
N = 721	n	Mean	n	Mean	T-test	P-value
DHI physical	181	16.49	540	17.68	-2.28	0.02
DHI emotional	181	18.86	540	21.54	-3.22	0.001
DHI functional	181	20.27	540	22.4	-2.63	0.009
DHI total	181	55.61	540	61.62	-3.02	0.003
MCS12	181	35.15	540	31.18	3.83	<0.001
PCS12	181	34.46	540	33.38	1.28	0.2

Table 8. Headache diagnosis status by self-reported conditions (depression, PTSD, headache, anxiety).

	No headache		Headache			
N = 721	n	%	n	%	Chi-square	P-value
CESD Depression					18.97	<0.001
Yes	140	22.36	486	77.64		
No	41	43.16	54	56.84		
PCL5 PTSD					4.13	0.04
Yes	148	23.79	474	76.21		
No	33	33.33	66	66.67		
MIDAS headache					18.2	<0.001
little/no	36	39.13	56	60.87		
mild	12	41.38	17	58.62		
moderate	18	29.03	44	70.97		
severe	115	21.38	423	78.62		
GAD7 Anxiety					7.85	0.05
little/no	24	38.71	38	61.29		
mild	39	25.32	115	74.68		
moderate	57	25.45	167	74.55		
severe	61	21.71	220	78.29		

Anxiety: Veterans diagnosed with anxiety did not report significantly higher impacts of dizziness on physical, emotional, and functional domains compared to those without a diagnosis of anxiety; however, they did report lower mental health quality of life (p<0.001; Table 9). All Veterans diagnosed with anxiety had self-report measures for depression, anxiety, headache, and PTSD that were significantly worse than Veterans with no anxiety diagnoses (p<0.001; Table 10).

Table 9. T-tests for dizziness and general physical and mental health quality of life measures for Veterans with and without an anxiety diagnosis.

	No anxiety		Anxiety			
N = 721	n	Mean	n	Mean	T-test	P-value
DHI physical	351	17.32	370	17.44	-0.25	0.8
DHI emotional	351	20.78	370	20.96	-0.24	0.81
DHI functional	351	21.87	370	21.85	0.037	0.97
DHI total	351	59.98	370	60.24	-0.15	0.88
MCS12	351	33.72	370	30.71	3.34	<0.001
PCS12	351	34.02	370	33.29	1	0.32

Table 10. Anxiety diagnosis status by self-reported conditions (depression, PTSD, headache, anxiety).

	No anxiety		Anxiety			
N = 721	n	%	n	%	Chi-square	P-value
CESD Depression					5.61	0.02
Yes	294	46.96	332	53.04		
No	57	60	38	40		
PCL5 PTSD					6.53	0.01
Yes	291	46.78	331	53.22		
No	60	60.61	39	39.39		
MIDAS headache					2.59	0.46
little/no	51	55.43	41	44.57		
mild	15	51.72	14	48.28		
moderate	32	51.61	30	48.39		
severe	253	47.03	285	52.97		
GAD7 Anxiety					13.27	0.004
little/no	38	61.29	24	38.71		
mild	84	54.55	70	45.45		
moderate	114	50.89	110	49.11		
severe	115	40.93	166	59.07		

Depression: Veterans diagnosed with depression reported higher impacts of dizziness on physical (p<0.02), emotional (p<0.00), and functional (p<0.001) domains; lower mental health quality of life (p<0.001) and lower physical quality of life (p<0.001). All Veterans diagnosed with anxiety and 113 Veterans not diagnosed for depression self-reported depression on the survey (p<0.001; Table 11). Self-reported anxiety was significantly higher for Veterans diagnosed with depression versus those who were not (p<0.001; Table 12).

Table 11. T-tests for dizziness and general physical and mental health quality of life measures for Veterans with and without a depression diagnosis.

	No depression		Depression			
N = 721	n	Mean	n	Mean	T-test	P-value
DHI physical	153	16.31	568	17.67	-2.44	0.015
DHI emotional	153	18.67	568	21.46	-3.16	0.002
DHI functional	153	19.7	568	22.44	-3.2	0.001
DHI total	153	54.68	568	61.58	-3.28	0.001
MCS12	153	36.99	568	30.88	5.62	<0.001
PCS12	153	35.88	568	33.05	3.18	0.002

Table 12. Depression diagnosis status by self-reported conditions (depression, PTSD, headache, anxiety).

	No depression		Depression			
N = 721	n	%	n	%	Chi-square	P-value
CESD Depression					28.55	<0.001
Yes	113	18.05	513	81.95		
No	40	42.11	55	57.89		
PCL5 PTSD					3.42	0.06
Yes	125	20.1	497	79.9		
No	28	28.28	71	71.72		
MIDAS headache					3.48	0.32
little/no	25	27.17	67	72.83		
mild	6	20.69	23	79.31		
moderate	16	25.81	46	74.19		
severe	106	19.7	432	80.3		
GAD7 Anxiety					19.18	<0.001
little/no	23	37.1	39	62.9		
mild	38	24.68	116	75.32		
moderate	52	23.21	172	76.79		
severe	40	14.23	241	85.77		

What opportunities for training and professional development has the project provided?

The WIBR team provided survey administration and data cleaning training to junior staff. Mentoring junior research assistant to conduct national survey processes and research staff participating in VA cyberseminars related to TBI, mental health and sensory dysfunction. Drs. Pugh and Kalvesmaki mentored one of the graduate research assistants, John Doyle, who is also a

Veteran, to prepare a master's thesis manuscript using data analyses of dizziness on Veteran employment outcomes. Dr. Kalvesmaki served on his thesis committee.

Three audiology clinical doctoral students contributed to the chart abstraction at MHREC and a Ph.D. student contributed to processing of the chart review data for the preliminary analysis. Five physical therapy clinical doctoral students performed chart abstractions at MHREC under the supervision of Dr. Hall. The DPT students used the physical therapy clinic notes to abstract information regarding treatment for dizziness related to TBI. Their findings were presented at East Tennessee State University DPT capstone presentation day in December 2022.

How were the results disseminated to communities of interest?

In addition to a peer-reviewed publication, we completed a manuscript (see Appendix B: Swan et al., 2022, *J Head Trauma Rehabil*) described above which identifies and characterizes disruption due to dizziness symptoms following deployment-related TBI and factors associated with receiving diagnoses or care for these symptoms.

Dr. Pugh also presented findings from this paper as a guest lecturer for Clinical Epidemiology to doctoral students in Population Health Sciences program at the University of Utah.

Dr. Akin presented preliminary findings in her presentation entitled "Head Trauma and Imbalance" presented at the 10th biennial National Center for Rehabilitative Auditory Research (NCRAR) conference. The NCRAR is a Veterans Affairs Rehabilitation Research & Development-funded research center with the mission of improving the quality of life of Veterans and others with hearing and balance problems through clinical research, technology development, and education that leads to better patient care. The American Journal of Audiology is publishing a special issue in February 2023 with proceedings from this conference (Appendix C: Akin et al., in press, *Am J Audiol).*

What do you plan to do during the next reporting period to accomplish the goals?

Not applicable.

4. IMPACT:

What was the impact on the development of the principal discipline(s) of the project?

This study revealed that access to specialty care was the best predictor of receipt of a dizziness and/or vestibular dysfunction diagnosis among those who report disruptive dizziness on the CTBIE. Further, Black non-Hispanic veterans and those with substance use disorder diagnoses or treatment are significantly less likely to receive these diagnoses, potentially illuminating

disparities or barriers in access to or utilization of specialty care for veterans with disruptive dizziness.

In addition, this study revealed that post-concussive dizziness occurs in some individuals even a decade or more after the injury. Our findings reveal several factors present at or around the time of the initial clinical evaluation that are associated with persistent dizziness, and these include increased age, high school education level, identification as a Black non-Hispanic veteran, TBI status, diagnoses of PTSD or hearing loss, abnormal vestibular function, and severe self-reported dizziness at the initial evaluation. These findings support the use of an interdisciplinary polytrauma team model to facilitate communication across providers and manage risk factors that may impact recovery from post-concussive dizziness. Further, access to long-term interdisciplinary polytrauma care may be necessary for individuals with persistent dizziness.

What was the impact on other disciplines?

Not applicable as this is a multidisciplinary project. See response to the item above.

What was the impact on technology transfer?

Nothing to report.

What was the impact on society beyond science and technology?

Our findings support the need to decrease disparities or barriers in access to or utilization of specialty care for veterans with disruptive dizziness. Telemedicine, patient education, provider cultural competency in health disparities, and the refinement of evidenced-based clinical pathways in the treatment of disruptive dizziness are possible mechanisms for improving long-term outcomes following deployment-related TBI among post-9/11 veterans.

Further, our findings support the use of an interdisciplinary polytrauma team model to facilitate communication across providers and manage risk factors that may impact recovery from post-concussive dizziness.

5. CHANGES/PROBLEMS:

Changes in approach and reasons for change

Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them

This project was delayed for several reasons. Co-PI, Dr. Pugh, transferred to the VA Salt Lake City Health Care System (SLC) at the time of the project funding, which resulted in delays in start-up. Specifically, there were hiring and contracting delays at WIBR which led to reduced expenditures. In addition, there was a delay in completing the regulatory process at the Mountain Home site (MHREC) because the local IRB for MHREC requires approval of regulatory documents from all other study sites prior to granting local approval for MHREC. Due to COVID-19, our mailing schedule was delayed, and additional surveys and follow-up letters were mailed in FY21 to achieve our goal of 1050 completed surveys. Finally, MHREC was short-staffed May-August 2021 due to maternity and sick leave.

We requested and were approved for a 1-year no cost extension (NCE) and completed the study within that NCE.

Changes that had a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use of biohazards and/or select agents

Nothing to report.

6. PRODUCTS:

- **Publications, conference papers, and presentations**

Journal publications.

Akin, F. W., Swan, A. A., Kalvesmaki, A., Hall, C. D., Riska, K. M., Stressman, K. D., Nguyen, H., Amuan, M., & Pugh, M. J. (in press). Factors that impact the long-term outcome of post-concussive dizziness among post-9/11 Veterans. *American Journal of Audiology.*

Swan, A. A., Akin, F. W., Amuan, M. E., Riska, K. M., Hall, C. D., Kalvesmaki, A., Padilla, S., Crowsey, E., & Pugh, M. J. (2022). Disruptive Dizziness Among Post-9/11 Veterans With Deployment-Related Traumatic Brain Injury. *The Journal of Head Trauma Rehabilitation*, *37*(4), 199–212. https://doi.org/10.1097/HTR.0000000000000714

Swan, A. A., Nelson, J. T., Pogoda, T. K., Akin, F. W., Riska, K. M., Hall, C. D., Amuan, M. E., Yaffe, K., & Pugh, M. J. (2020). Association of Traumatic Brain Injury With Vestibular Dysfunction and Dizziness in Post-9/11 Veterans. *The Journal of Head Trauma Rehabilitation*, *35*(3), E253–E265. https://doi.org/10.1097/HTR.0000000000000513

Books or other non-periodical, one-time publications.

Nothing to report.

Other publications, conference papers and presentations.

Akin, F. W. (2022, March 11). *Factors Associated With Outcomes in Patients with Vestibular Symptoms Related to Traumatic Brain Injury* [Conference Presentation]. The 19th Annual World Congress of Society for Brain Mapping and Therapeutics, Los Angeles, CA.

Akin, F. W. (2021, September 29 – October 1). *Head Trauma and Imbalance* [Conference Presentation]. 2021 NCRAR 10th Biennial Conference, Portland, OR.

Pugh, M. J., Swan, A. A. (2020, January 7). *The Big Picture: The Scope of Sensory Deficits Associated with Traumatic Brain Injury* [Webinar]. VA TBI Cyberseminar. https://www.hsrd.research.va.gov/ for_researchers/cyber_seminars/archives/ video_archive.cfm?SessionID=3752

- **Website(s) or other Internet site(s)**

Nothing to report.

- **Technologies or techniques**

Nothing to report.

- **Inventions, patent applications, and/or licenses**

Nothing to report.

- **Other Products**

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name:	*Faith Akin*
Project Role:	*Principal Investigator*
Researcher Identifier (e.g. ORCID ID):	*0000-0001-9739-738X*
Contribution to Project:	*Dr. Akin has overseen project startup planning, chart abstraction at MHREC, and manuscript preparation.*

Name:	*Mary Jo Pugh*
Project Role:	*Co-Principal Investigator*
Researcher Identifier (e.g. ORCID ID):	*0000-0003-4196-7763*
Contribution to Project:	*Dr. Pugh has overseen project startup planning, survey development, health system data analyses, and survey administration at WIBR.*

Name:	*Courtney Hall*
Project Role:	*Co-Investigator*
Researcher Identifier (e.g. ORCID ID):	*0000-0001-9403-1980*
Contribution to Project:	*Dr. Hall has assisted with survey and chart abstraction development, startup planning and training at MHREC, and manuscript preparation.*

Name:	*Alicia Swan*
Project Role:	*Co-Investigator*
Researcher Identifier (e.g. ORCID ID):	*0000-0003-2412-0499*
Contribution to Project:	*Dr. Swan has assisted with regulatory requirements, survey and chart abstraction development, and manuscript preparation.*

Name:	*Kristal Riska*
Project Role:	*Co-Investigator*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Dr. Riska has assisted with survey and chart abstraction development and manuscript preparation.*

Name:	*Kara Stressman*
Project Role:	*Study Coordinator*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Dr. Stressman has assisted with chart abstraction at MHREC and manuscript preparation.*

Name:	*Erin Dula*
Project Role:	*Research Assistant*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Dr. Dula has assisted with chart abstraction at MHREC.*

Name:	*Silvia Padilla*
Project Role:	*Research Specialist*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Ms. Padilla was responsible for survey administration at WIBR.*

Name:	*Andrea Kalvesmaki, PhD*
Project Role:	*Research Associate*
Researcher Identifier (e.g. ORCID ID):	*0000-0002-4282-0619*
Contribution to Project:	*Dr. Kalvesmaki is responsible for overall project management, staff training, survey administration at WIBR, and manuscript preparation.*

Name:	*Megan Amuan*
Project Role:	*Data Scientist*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Ms. Amuan prepares and analyzes Health System data and assists with manuscript preparation.*

Name:	*Sarah Leonhart*
Project Role:	*Research Analyst*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Ms. Leonhart assists with survey administration and data processing at WIBR.*

Name:	*Eleanor Gonzales*
Project Role:	*Senior Research Analyst*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Ms. Gonzales assists with survey administration and data processing at WIBR.*

Name:	*Robert George*
Project Role:	*Research Analyst*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Mr. George assists with survey administration and data processing at WIBR.*

Name:	*John Doyle*
Project Role:	*Graduate Research Assistant*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Mr. Doyle assists with survey administration at WIBR.*

Name:	*Lindsey Gavin*
Project Role:	*Graduate Research Assistant*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Ms. Gavin assists with survey administration at WIBR.*

Name:	*Huong Nguyen*
Project Role:	*Data Scientist*
Researcher Identifier (e.g. ORCID ID):	
Contribution to Project:	*Dr. Nguyen prepares and analyzes survey and chart abstraction data and assists with manuscript preparation.*

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

No changes to report.

What other organizations were involved as partners?

Organization Name:	Location of Organization:	Organization Contributions:
Duke University	Durham, North Carolina	Collaboration
University of Texas San Antonio	San Antonio, Texas	Collaboration

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS:

Not applicable.

QUAD CHARTS:

Please see Appendix E for Quad Chart.

9. APPENDICES:

Appendix A: Surveys

Appendix B: Swan et al., 2022

Appendix C: Akin et al., (in press)

Appendix D: Swan et al., 2020

Appendix E: FY22 Quad Chart