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Dizziness Directly Influences Post-Concussion Symptoms and is Predictive of Poorer Mental Health in UK Military Personnel: A Retrospective Analysis

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ABSTRACT

Objective: To investigate the contribution of dizziness to post-concussion symptoms, depression, and anxiety symptoms. **Setting:** Mild Traumatic Brain Injury Service, Defence Medical Rehabilitation Centre, Stanford Hall. **Participants:** 283 UK military personnel from the Royal Navy, Royal Airforce, Royal Marines, and British Army. **Design:** A retrospective analysis of data from the Ministry of Defence (MoD) medical records database. **Main measures:** 16-item Rivermead Post Concussion Symptom Questionnaire, Generalized Anxiety Disorder 7-item scale, Patient Health Questionnaire-9, The Dizziness Handicap Inventory. **Results:** Injuries from sports or falls were the most common mechanism of mTBI (mild traumatic brain injury), accounting for 23% respectively**.** Chi-square analysis indicated that individuals with dizziness and post-concussion symptoms (PCS) had greater severity of PCS, depression, and anxiety than those with PCS alone**.** Mediation analysis showed dizziness directly and independently influenced the severity of PCS, despite the indirect effects of mediating depression and anxiety symptoms. **Conclusion:** Comorbid dizziness and PCS were predictive of poorer mental health compared with PCS alone. Additionally, dizziness directly influenced the severity of PCS irrespective of the indirect effects of mental health symptoms. These observations suggest that treating dizziness with vestibular rehabilitation may improve PCS and mental health.

Keywords: *Dizziness, mTBI, PCS, vestibular rehabilitation, UK military personnel.*

INTRODUCTION

During the conflicts in Iraq and Afghanistan, blast mild traumatic brain injury (mTBI) was characterized as a signature injury of the war and attributed to both increased exposure to explosive munitions, and higher survival rates due to advancements in battlefield medicine.[1-3] Currently, it is more likely that military personnel sustain blunt mTBI from civilian mechanisms such as sport, road traffic accidents (RTA), falls, and assaults whilst in garrison non-deployed settings, although published data to reflect this is sparse.[4-5] What is well-known is that TBI is a global public health concern and a leading cause of death and disability, estimated to be sustained by 64 to 74 million civilians per year.[6] Approximately 90% of these injuries are blunt-force and categorised as mild.[4]

Acute symptoms following mTBI typically resolve within three months, but 15% to 30% of individuals develop symptoms that persist for longer, sometimes years post-injury, known as post-concussion syndrome.[7-9] This chronic condition is associated with a broad range of somatic, cognitive, and emotional symptoms and can be difficult to diagnose.[10] This is partly because mTBIs frequently go unreported, but also because there are commonly no visible signs of anatomical damage from mTBI on computed tomography or magnetic resonance imaging scans when individuals do seek medical attention.[11-12] Diagnosis of post-concussion syndrome is further complicated as the symptoms overlap with those from post-traumatic stress disorder (PTSD) and vestibular disorders.[13-15]

Dizziness is one of the most common symptoms of mTBI and vestibular disorders. Dizziness complaints have been shown to affect 84% of patients evaluated more than 30 days following blast exposure,[16] with an enduring presence of postural instability evident up to 7 years post initial injury.[17] However, vestibular pathology is not exclusive to blast mTBI and is frequently seen in blunt injuries too.[18] These prevalences are especially concerning because dizziness at just 6 months post-onset is closely linked to psychological distress and a failure to return to work.[19-20]

Different regions of the vestibular system are vulnerable to injury after both blunt and blast, head, or neck injuries. A retrospective study of 63 patients suffering from vertigo following TBI revealed several types of vestibular disorder[21]; benign paroxysmal positional vertigo (BPPV) was seen in 57% of these cases, cervicogenic vertigo in 27%, otolith disorder in 25%, labyrinth concussion in 19%, secondary endolymphatic hydrops in 19%, perilymphatic fistulae in 5%, and central vestibular in 5%. This variety of presentations highlights the need to carry out a full neuro-otological assessment to determine the most appropriate treatment.[14,22-23]

Common difficulties that arise from mTBI, PTSD and vestibular dysfunction, all of which may occur simultaneously, encompass cognitive changes; such as memory and attention deficits, fatigue, anxiety, and depression.[15,24-27] This similarity between symptom presentations may be partially attributable to overlapping pathophysiological changes such as neuroinflammation, excitotoxicity and oxidative damage.[28] There is a need to study these links further, to better understand the nature of mTBI and develop future treatment approaches.

Neuromodulation of the vestibular nerves in animal models also show that vestibular pathways to the hypothalamus are involved in stress responses mediated by the hypothalamic-pituitary-adrenal axis, which may well regulate function of ion transporters and ionic homeostasis of the inner ear.[29] This relationship is, however, bidirectional as more severe PTSD symptoms in US veterans were associated with worse dizziness handicap and vertigo symptom severity scores.[30] In fact, mediation analysis of UK military veterans with mTBI showed that vestibular disturbance directly and independently influenced increased severity of PCS, headaches, and disability; irrespective of mediating PTSD, depression, and anxiety.[5] This, coupled with emerging evidence of the utility of vestibular rehabilitation therapies (VRT) in remediating PCS and PTSD as well as vestibular disorders, is indicative of the far-reaching influences of the vestibular system and the need to better understand them.[31-32]

The main objective of the current study was to retrospectively examine data from UK military personnel with PCS seen via the mTBI service at the Defence Medical Rehabilitation Centre (DMRC) Stanford Hall. The aims were as follows: Firstly, to characterise the natural history of the mTBI sample. Secondly, to determine whether a combination of PCS and dizziness was predictive of poorer mental health outcomes compared with PCS alone. Thirdly, to evaluate whether dizziness directly influences the severity of PCS, independent of mediating comorbid depression and anxiety. Lastly, to examine the potential utility of VRT in the remediation of PCS.

METHODS

Participants

This study retrospectively reviewed the MoD internal medical records database of serving military personnel, including the Royal Navy, Royal Airforce, Royal Marines, and British Army. The sample comprised patients who had been referred to the mTBI service at the Defence Medical Rehabilitation Centre Stanford Hall for assessment and treatment of PCS. Only data from patients classified as having 1 or more mTBI were included, those with moderate or severe TBI were excluded. mTBI was classified by a loss of consciousness (LoC) from 0 to 30 minutes and/or post traumatic amnesia (PTA) from 0 to 1 day and/or alteration of consciousness (AoC) up to 24hrs, with normal structural imaging.[33-34] Acute mTBI is within three months of sustaining injury, more than three months is a chronic condition. A favourable ethical opinion was granted prior to data collection from the University of Kent.

Data

Data review took place between March 2020 and October 2021. Records were looked at for patients who had been through the service between January 2016 and June 2021. Diagnosis of mTBI was confirmed by a Neurological Rehabilitation Consultant, Psychologist, Occupational Therapist, and Neuro Physiotherapist via a semi-structured clinical interview at the patient's first appointment with the DMRC Stanford Hall mTBI service. Prior to the

COVID-19 pandemic, these interviews were predominantly face-to-face, but from April 2020 onwards they were carried out via video conferencing platforms. The interviews determined the mechanism and severity of the brain injury, and assessed PCS presentation as well as comorbid depression and anxiety. Patients were diagnosed with PCS using a combination of the 16-item Rivermead Post Concussion Symptom Questionnaire (RPQ)[35] and clinical interview. Although $n = 8$ RPQ scores were not recorded in a way that we could access, all participants were diagnosed with PCS.

Upon entry to the mTBI service, most patients were additionally assessed for symptoms of anxiety using the Generalized Anxiety Disorder 7-item scale (GAD-7)[36], and depression, using the Patient Health Questionnaire-9 (PHQ-9).[37] The GAD-7[36] (anxiety) and PHQ-9[37] (depression) scales are 7-item and 9-item scales respectively, which ask participants to rate how often over the past two weeks they have experienced each symptom (item). Total possible scores range from 0-21 for the GAD-7 and 0-27 for the PHQ-9, with higher scores indicating more severe anxiety/depression.

Patients referred to the mTBI service with symptoms of dizziness and imbalance were also assessed to determine the severity of disability from dizziness using the Dizziness Handicap Inventory (DHI).[38] Where appropriate, patients' neuro-otological history was then assessed on an individual basis by a specialist neuro-physiotherapist, to determine the correct course and management of the specific balance and dizziness disorder.

Treatment

Following assessment, those patients who were considered to meet the clinical criteria for mTBI and who had ongoing symptoms were provided with education and support for managing their difficulties by a multi-disciplinary team encompassing neuropsychology, occupational therapy, and physiotherapy. Patients followed a tailored rehabilitation plan specific to their goals and symptoms, the aim being to help them manage any physical changes, cognitive difficulties, and psychological distress caused by the injury.

Treatment of dizziness symptoms consisted predominantly of a VRT program, which among other components encompassed gait training, balance and habituation exercises, gaze stability work and breathing techniques, and canalith repositioning manoeuvres (e.g., barbecue roll, Epley) for benign paroxysmal positional vertigo (BPPV). The rehabilitation exercises were performed within a range of indoor (e.g., gym, pool) and outdoor settings, as well as within a virtual reality environment, and BPPV treatment was repeated as often as necessary alongside other mTBI treatment. Patients who required more intensive input for persistent symptoms (vestibular and otherwise) were additionally invited to attend a group residential course which targeted areas such as fatigue management, relaxation training, and graded return to exercise.

Statistical Analysis

Summary statistics were calculated to show sample demographics, mTBI history, and comorbid symptoms. Two chi-square analyses were then performed to determine the relative frequency and severity of depression (PHQ-9) and anxiety (GAD-7). This included two groups: those with PCS and dizziness, and those with PCS only. Individuals suffering from dizziness and PCS were diagnosed by clinicians via a combination of objective (e.g., physical examination tests) and subjective (e.g., symptom questionnaire and clinical interview) assessments. Independent samples *t* tests were used to investigate differences in the severity of comorbid symptoms between those with and without dizziness, and a mixed Analysis of Variance (ANOVA) was then performed on the two groups to compare differences in PCS (as measured by the RPQ) pre- and post- treatment. Finally, in the PCS-dizziness group a mediation analysis was implemented to establish whether the severity of dizziness (as measured by the DHI) directly influenced PCS (RPQ) when depression (PHQ-9) and anxiety (GAD-7) were taken into account as mediators. This analysis also examined the combined total effects of dizziness in the mediation and outcome variables. All analyses were conducted using SPSS 26 and participants with missing data were excluded. Mediation analysis was conducted

utilising Hayes'[39] macro for SPSS with bias correction bootstrapping the sample to 10,000 with 95% confidence intervals. Coefficients were considered statistically significant at $P < .05$.

RESULTS

Overview of Sample Characteristics

As can be seen from the demographics in Table 1, the majority of the sample were male (86%) non-commissioned officers (89%), who predominantly served in the British Army (72%). Ages ranged from 18-62, with mean age 32.2 (*SD* 8.8).

Table 1. *Sample demographics (N=283)*

		n			***n***
Gender	Male	243	**Military service branch**	Army	203
	Female	40		Airforce	42
Rank	Non-Commissioned officers	251		Navy	29
	Commissioned officers	32		Royal Marines	9

mTBI history can be seen in Table 2. The two most frequently reported mechanisms of injury were sports and falls, each equally accounting for 23% of the sample. More than half of the participants had suffered post-traumatic amnesia for less than 24 hours (60%) and/or a loss of consciousness for less than 30 minutes (53%). Altered consciousness was experienced by (39%) of the sample and 48% had a previous history of more than 1 mTBI. Two thirds of the sample had chronic PCS (65%) and 35% had acute PCS and were seen within three months of sustaining their injury.

Table 2. *Overview of mTBI history (N=283)*

		n			***n***
Mechanism of Injury	Fall	64	**mTBI History**	>1 mTBI	135
	Sports-related	64	**Level of Consciousness**	Loss of consciousness	149
	Road traffic accident	52		Altered consciousness	109

	Assault	45		Post-traumatic amnesia	169
	Blast	28	**PCS Symptoms**	Chronic	185
	Other	30		Acute	98

Abbreviations: mTBI, mild traumatic brain injury; PCS, postconcussion symptoms

GAD-7, PHQ-9, DHI, and RPQ scores were captured during initial clinical assessment. As can be seen in Table 3, these showed that more than half of the participants (58%) reported symptoms of anxiety, two-thirds (67%) reported symptoms of depression, and 45% of the sample reported symptoms of dizziness. Overall, 60% of the sample were diagnosed with PCS only and 40% were diagnosed with dizziness and PCS.

Table 3: *Frequency of co-morbid symptoms (N=283)*

			Missing			**Missing**
		n	**cases (*n*)**		***n***	**cases (*n*)**
GAD-7[a]	Anxiety present	165	36	**Diagnosis/ PCS Group**		
PHQ-9[a]	Depression present	189	35	PCS only	171	0
DHI[b]	Dizziness present	127	143	Dizziness/ PCS	112	0

Abbreviations: DHI, Dizziness Handicap Inventory; GAD-7, Generalized Anxiety Disorder 7-item scale; PCS, postconcussion symptoms; PHQ-9, Patient Health Questionnaire-9.
[a]Presence scores of 5 or more[36-37]
[b]Presence scores of more than 0

The Influence of Dizziness on GAD-7, PHQ-9, and RPQ Scores

Exploratory chi-square analyses indicated that there was a significant association between severity of depression (PHQ-9) in relation to PCS group, χ^2_2=15.759, P<.001. Specifically, those with dizziness and PCS were more likely to have moderate to severe levels of depression than those with PCS only. There was also a significant association between PCS group and anxiety (GAD-7), χ^2_1=5.610, P=.018; individuals with PCS only were more likely to have no or mild anxiety, whereas those with dizziness and PCS were more likely to have moderate to severe levels of anxiety.

The Effect of Dizziness on Comorbid Symptoms

As can be seen in Table 4, independent samples *t* tests revealed that the PCS-dizziness group had significantly worse symptoms of depression, dizziness, and PCS pre-treatment, compared with the PCS-only group.

Table 4. *Comparison of comorbid symptom severity in those with and those without dizziness*

Measure	Dizziness-PCS		PCS-only		t_{df}	*P*	Cohen's *d*
	Mean	SD	Mean	SD			
Depression (PHQ-9)	11.8	6.4	8.4	6.3	4.1_{246}	<.001[a]	0.5
Anxiety (GAD-7)	9.2	5.8	7.5	5.8	2.3_{245}	.025	0.3
Dizziness (DHI)	36.9	23.3	18.7	19.1	4.3_{138}	<.001[a]	0.9
Pre-treatment PCS (RPQ)	31.2	14.3	25.0	13.8	3.6_{273}	<.001[a]	0.4
Post-treatment PCS (RPQ)	18.3	14.9	15.7	13.7	1.2_{174}	.232	0.2

Abbreviations: DHI, Dizziness Handicap Inventory; GAD-7, Generalized Anxiety Disorder 7-item scale; PCS, postconcussion symptoms;
PHQ-9, Patient Health Questionnaire-9; RPQ, Rivermead Post Concussion Symptoms Questionnaire.
[a]Significant when adjustments are made for multiple comparisons (*P*=.05/5=.01)

A Comparison of RPQ Scores Pre-and Post-Treatment

To compare PCS scores before and after treatment, a 2 (PCS group: PCS-dizziness vs. PCS-only) x 2 (Time: pre-treatment vs. post-treatment) mixed ANOVA was performed on RPQ scores. This showed a significant main effect of PCS group, $F_{1,170}$=4.3, *P*=.040, η_p^2=.025, observed power=0.5, with the PCS-dizziness group having significantly higher RPQ scores (mean 25.1, SE 1.3) than the PCS-only group (mean 21.3, SE 1.3). There was also a significant main effect of Time, $F_{1,170}$=131.4, *P*< .001, η_p^2=.436, observed power=1.0, with participants having significantly lower RPQ scores post-treatment (mean 17.2, SE 1.1) compared with before (mean 29.1, SE 1.0). There was no Group x Time interaction effect, $F_{1,170}$=1.0, *P*=.317, η_p^2=.006, observed power=0.2.

The Influence of Dizziness on RPQ Scores

Prior to mediation analysis a multiple linear regression was conducted to identify the variables that were significantly associated with the DHI scores. DHI, PHQ-9, GAD-7, and RPQ scores were all significantly associated with each other (all $P<.001$ with coefficient scores ranging from $r=0.554$ to $r=0.726$). A mediation analysis was then performed to determine whether the degree of dizziness seen in participants with dizziness and PCS before treatment had a direct effect on their pre-treatment RPQ scores and any indirect effects on their anxiety (GAD-7) and depression (PHQ-9) scores.

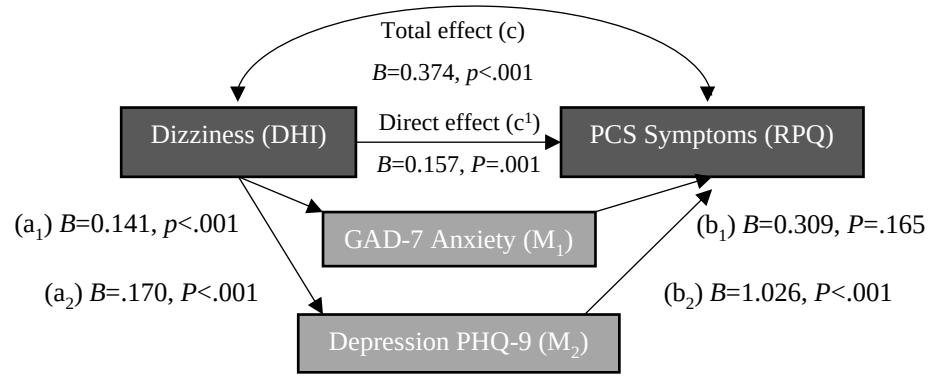

Figure 1. Mediation Analysis. RPQ (N = 132). DHI indicates Dizziness Handicap Inventory; GAD-7, Generalized Anxiety Disorder 7-item scale; PCS, postconcussion symptoms; PHQ-9, Patient Health Questionnaire-9; RPQ, Rivermead Post Concussion Symptoms Questionnaire.

As can be seen from Figure 1, there was a direct effect of dizziness on pre-treatment PCS scores, $P=.001$. A significant association in pathway a_1 was seen ($P<.001$), with dizziness influencing anxiety and depression in pathway a_2 ($P<.001$). Although there was no indirect effect of anxiety on PCS (pathway b_1, $P=.165$), depression did have an indirect effect (pathway b_2, $P<.001$). Overall, dizziness, anxiety and depression were shown to be significantly associated with the total effects of PCS ($P<.001$).

DISCUSSION

The main findings of this retrospective analysis indicate that dizziness both directly and in conjunction with the total effects of mental health influences the severity of PCS. The strength of these directional associations are supported by chi-square analyses, ANOVAs and t-tests, which illustrate that dizziness and PCS combined are associated with a greater severity of PCS, comorbid depression, and anxiety. Examination of pre-and-post treatment PCS scores showed that both groups improved with treatment.

The treatment protocol used by the mTBI service did remediate PCS in both groups and emerging research indicates that VRT may be effective in reducing PCS and comorbid neuropsychiatric sequalae.[31-32] However, it is difficult to determine to what extent VRT may have affected PCS in the current study, as retrospective analyses cannot provide as robust a research design as that of an RCT with comparative treatment groups and controls. Whilst there were no significant post-treatment differences between those with dizziness and PCS and those with PCS only, it is noteworthy that these groups had comparable post-treatment scores, despite the dizziness and PCS group having much worse symptoms pre-treatment.

In light of the current study's findings, it is suggested that neuro-otological assessments be carried out in all patients with PCS. Forty percent of the current sample were referred to the mTBI service with dizziness complaints and 90% of all mTBI cases were blunt injuries sustained most frequently from falls and playing sports (45% combined). The links between blast-related mTBI and over-pressure trauma to the inner ear are well-established,[40-41] but secondary blunt injuries from blasts and other blunt mTBI mechanisms can also result in vestibular pathology.[42] Previous research looking at 5869 UK military personnel deployed to Iraq[43] attributed symptoms of post-concussion syndrome to psychiatric disturbance, owing to symptoms being non-specific and there being overlap between presentations. It may not always be practical or possible to provide neuro-otological testing on deployment, however, the possible contribution of vestibular factors to a patient's presentation post-mTBI should be

considered. Indeed, other research from UK military personnel with mTBI has shown an association with dizziness and loss of concentration 7 years post-deployment[44]. It is therefore suggested that there is the potential for inadvertently misattributing vestibular dysfunction and PCS to psychiatric disturbance, thereby overlooking an alternate, more appropriate diagnosis and treatment. Moreover, concussion rehabilitation providers may benefit from engaging the services of VRT specialists sooner so that they can assist with alleviating and treating the myriad of symptoms related to concussion, potentially leading to a faster recovery.

There are some limitations to this retrospective analysis and the use of clinical records. Firstly, we were unable to analyse post-treatment mental health scores, as they were not collected for many of the patients seen through the mTBI service. The analysis also did not account for differences in acute or chronic mTBI presentations which may differ. It was also not possible to account for the potential extent of PTSD and symptom exaggeration influencing PCS and vestibular disorder severity.[45-46] Lastly, we were not able to determine the effects of VRT on reducing dizziness symptoms, using retrospective study design. Despite this, there is indication of an intrinsic relationship between the vestibular system, PCS and mental health. Previously, this relationship has shown with co-occurring PTSD to induce devastating long-term functional effects in UK military veterans, where World Health Organisation Disability Assessment Schedule (WHODAS) scores had greater levels of disability than 90% of the general world population.[5] These conditions have also been linked to a number of pathophysiological and neurodegenerative conditions[28,47] so should be considered holistically in the context of lifetime adverse health conditions.[48-50] Future research should investigate vestibular influences in PCS further and the efficacy of VRT in an RCT that examines both behaviour and biomarkers to establish whether treatment has any long-term effects in remediating PCS sequalae.

In conclusion, dizziness is linked to poorer mental health and greater severity of PCS. However, there are bidirectional links that potentially suggest the vestibular system can both

exacerbate and remediate PCS sequalae. Future research should investigate these relationships holistically in a lifetime context.

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