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

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ABSTRACT

Objective: To investigate the contribution of dizziness to Post-Concussion Syndrome (PCS), 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 accounting for 23% each**.** Chi-square analysis indicated that individuals with dizziness and PCS had a 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:** Dizziness and PCS was predictive of poorer mental health than suffering from 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 the symptoms of 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 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 playing sports, road traffic accidents (RTA), falls, and assault 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, a leading cause of death and disability estimated to be sustained by 64 to 74 million civilians per year[6] and approximately 90% of these injuries are blunt force and categorised as mTBIs.[4]

The acute symptoms of mTBI typically resolve within 3 months but 15% to 30% of individuals develop symptoms that persist for longer, sometimes years post-injury, known as post-concussion syndrome (PCS).[7-9] This chronic condition is associated with a broad range of somatic, cognitive, and neuropsychiatric 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 in CT or MRI scans if individuals do seek medical attention.[11-12] Diagnosis of PCS is further complicated as the symptoms of PCS 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. Acute symptoms of dizziness have been shown to affect 84% of military blast related injuries for more than 30 days,[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 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 combinations of vestibular disorder[21]; BPPV was seen in 57% of these cases, cevicogenic 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 mixture highlights the need to carry out a full neuro-otological assessment to determine the most appropriate treatment.[14,22-23]

Behavioural difficulties from mTBI, PTSD and vestibular disorders often look similar and include short-term memory problems, attention, fear, depression and anxiety.[15,24-27] This similarity may be partly due to an overlap in pathophysiology from these comorbid conditions such as neuroinflammation, brain morphology changes, excitotoxicity, and oxidative changes.[28] There is a need to study these links, 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 (HPA) 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 aims of the current study were to retrospectively examine data from UK military personnel with mTBI seen via the mTBI service at Defence Medical Rehabilitation Centre (DMRC) Stanford Hall. The aims were to, firstly, characterise the natural history of the mTBI sample. Secondly, to determine if the combination of PCS and dizziness was predictive of poorer mental health outcomes than PCS alone. Thirdly, to evaluate if dizziness was directly influencing 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 Defence Medical Rehabilitation Centre Stanford Hall for assessment and treatment of PCS. Only data from patients classified as having ≥1 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 symptoms were categorised within 3months of injury and chronic ≥3. 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 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, 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 in the previous 2 weeks they've 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 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 persistent 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., BBQ 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 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 ANOVA was then performed on the two groups to compare differences in PCS symptoms (measured by the RPQ) pre- and post- treatment. Finally, in the PCS and dizziness group a mediation analysis was implemented. To establish whether the severity of dizziness (as measured by the DHI) directly influenced PCS (RPQ) symptoms 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 about here----

mTBI history can be seen in Table 2. The two most frequently reported mechanisms of mTBI were sports and falls, each equally accounting for 23% of the sample. More than half of the participants had suffered post-traumatic amnesia for <24 hours (60%) and/or a loss of consciousness for <30 minutes (53%). Altered consciousness was experienced by (39%) of the sample and 48% had a previous history of >1 mTBI. Two thirds of the sample had chronic PCS (65%) and 35% had acute PCS and were seen within 3 months of sustaining a mTBI.

----Table 2 about here----

GAD-7, PHQ-9, DHI, and RPQ scores were taken during the initial clinical assessment. As can be seen in Table 3, these showed that more than half of the participants (58%) showed symptoms of anxiety, two-thirds (67%) showed 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 about here----

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 dizziness and PCS group had significantly increased depression, dizziness, and PCS symptoms pre-treatment, than the PCS only group.

----Table 4 about here----

A Comparison of RPQ Scores Pre-and Post-Treatment

To compare participants' PCS symptoms before and after treatment, a 2 (PCS group: dizziness and PCS vs PCS only) x 2 (Time: pre-treatment vs post-treatment) Mixed ANOVA was performed on the 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 dizziness and PCS 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 (DHI) seen in participants with dizziness and PCS before treatment, had a direct effect on their pre-treatment PCS symptoms (RPQ) and any indirect effects on their anxiety (GAD-7) and depression (PHQ-9) scores.

----Figure 1 about here----

As can be seen from Figure 1, there was a direct effect of dizziness on PCS symptoms, $P=.001$. 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 symptoms (pathway b_1, $P=.165$), depression did have an indirect effect on PCS symptoms (pathway b_2, $P<.001$). Overall, dizziness, anxiety and depression were shown to be significantly associated with total effects of PCS symptoms ($P<.001$).

DISCUSSION

The main findings of this retrospective analysis indicate that dizziness both directly and in conjunction with the total effects of mental health influence 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 symptoms 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 symptoms 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 and 90% of all mTBI cases were blunt injuries, and 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[43] of 5869 UK military personnel deployed to Iraq attributed the symptoms of PCS to psychiatric disturbance, due 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 in many patients using 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 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 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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TABLES & FIGURES

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

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

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

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

*****Presence ≥ scores of 5[36-37]

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

Measure	Dizziness-PCS		PCS-only		t_{df}	*P* value	Cohen *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

[a]Significant when adjustments are made for multiple comparisons (*P*=.05/5=.01)

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.*